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A Cointegration Approach to Modelling Inflation in a Small Open Economy

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Cointegration theory and the error correction mechanism are used to model inflation in a small open economy. The empirical results for Barbados indicate that wages, productivity, unemployment and the price of traded gods are significant explanatory variables of the inflationary process.

I. Introduction

The purpose of this paper is to estimate a model which is theory-consistent and capable of explaining the process generating the observed data on inflation in a small open economy. The main feature of the empirical analysis is the use of cointegration theory to separate the "long run" information in the data from the "short run" dynamics of the inflationary process.

Studies of inflation in small, open economies have emphasized the highly significant role which foreign (that is, import) prices play in fuelling the domestic rate of inflation in the long run (see for example, Downes (1985), Bourne (1977), Chung (1982)). However, it is important to identify other major determinants of the inflationary process, especially those which the economic authorities can control to some degree, since

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these factors can form the basis of anti-inflationary policies in a particular country.

This paper integrates the main domestic and foreign factors that influence the inflationary process, and utilizes recent developments in econometric modelling techniques to estimate an inflation function for Barbados. In section 2, the basic theoretical features of the inflationary process in a small open economy are presented. The econometric modelling procedure is outlined in section 3. An empirical analysis of the inflationary experience in the small open economy of Barbados is undertaken in section 4. The adequacy of the modelling design is examined through the use of various diagnostic tests. Finally, a discussion of some of the policy implications of the research findings is undertaken with special reference to Barbados.

II. Theoretical Analysis

A small open economy is generally characterized by a high incidence of foreign trade, an inability to influence either export or import prices by varying the supply of and the demand for goods, a fixed exchange rate and an endogenous money stock. These features condition the nature of the inflationary process by their effect on the main determinants of inflation in such an economy. It is expected that the ratio of traded goods to nontraded goods is relatively high in the small open economy, so that changes in foreign prices would have a significant effect on the economy.

Using the traded — nontraded sector framework, the aggregate price level (P) can be specified as a function of prices in the traded (PT) and nontraded goods (PNT) sectors; that is,

$$(1) \qquad P = f(PT, PNT)$$

Given that the limited economic power of small open economies in the international markets results in their being largely price takers, the prices of traded goods are assumed to be exogenously determined on the international market.

Assuming that prices in the nontraded goods sector — construction, internal transport, public utilities, business and professional services, distribution and government — are based on the average or "full" cost principle, then taxes, wages, import prices, productivity and an interest rate (that is, the cost of credit or working capital) may represent important cost factors (see McClean (1981), Gafar (1982)). Import prices affect the

nontraded goods sectors both directly as in the case of the distributive trades and indirectly in the other subsectors via the purchase of imported inputs. Demand factors may also affect prices in the nontraded sector in the "short run." At the aggregate level, the unemployment rate reflects market conditions in the commodity and labor markets, that is the degree of monopoly and monopsony power (see Choudhry et al. (1972, p. 38)). The joint effect of these conditions depends on the nature of the shift of the demand curves facing firms and the slope of the supply curve of labor. Therefore, the joint effect of the market conditions on prices has an indeterminate sign. Whilst changes in market conditions are likely to affect prices in the long run, we expect that, in the short run, such changes would not be significant. The price function for the nontraded goods sector is therefore given as:

$$(2) \qquad \underset{+}{PNT} = g(\underset{+}{W}, \underset{+}{PM}, \underset{+}{R}, \underset{-}{PROD}, \underset{+}{T}, \underset{\pm}{U})$$

where W represents wages, PM improt prices, R the cost of credit or interest rae, PROD productivity, T a vector of tax rates, and U the unemployment rate. The signs under the variables represent the direction of change or effect of these variables on the prices in the nontraded goods sector.

For a fixed exchange rate regime, the substitution of equation (2) into (1) yields the aggregate price function:

$$(3) \qquad \underset{+}{P} = h(\underset{+}{PT}, \underset{+}{W}, \underset{+}{PM}, \underset{+}{R}, \underset{-}{PROD}, \underset{+}{T}, \underset{\pm}{U})$$

This specification of the price formation process in the small open economy suggests that domestic prices, external prices, wages, productivity, the interest rate, tax rates and the unemployment rate could form a "long-run" equilibrium relationship. In order to establish this assertion and also to identify the "short-run" dynamics of the inflationary process, conintegration theory is utilized.

III. Econometric Methodology

Conventional econometric theory has been developed on the assumption that the underlying data processes are stationary. Most economic variables that are used in econometric modelling do not exhibit constancy in mean and variance, and therefore classical inference is not generally

valid under these conditions. However, recent developments in econometric theory have shown that valid estimation and inference is possible when a set of nonstationary variables is cointegrated. Broadly speaking, a set of nonstationary variables is cointegrated if there exists a linear combination of these variables that is stationary. This stationary linear combination can be interpreted as a "long-run" equilibrium relationship. The series are thus expected to move so that over time they do not tend to drift too far apart. Cointegration theory therefore permits the separation of the "long-run" information contained in the daa from the "short-run" dynamics about which economic theory is generally silent.

The methodology employed is based on the Granger Representation theorem (see Granger (1981), Granger and Weiss (1983), Engle and Granger (1987)) which states that, if a set of variables is cointegrated, then there exists a corresponding error correction representation of these variables. Formally, the components of a vector z_t are cointegrated of order d,b, that is $z_t \sim CI(d,b)$, if each of the components is I(d), and there exists a cointegrating vector $x \neq 0$ such that

$$(4) \qquad e_t = x'z_t \sim I(d-b),\ b>0$$

where I(d) implies that the series needs to be differenced d times to achieve stationarity. When the dimension of z_t is greater than 2, x may not be unique as there may be more than one cointegrating vector, some of which may be linearly dependent. For r linearly independent cointegrating vectors and $d = b = 1$, an error correction representation of r stationary random variables exists, such that

$$(5) \qquad A(B)\ z_t = D(B)(I-B)\ z_t = b\ e_{t-1} + c(B)\ u_t$$

where $A(B) = D(B)(I-B)$ is a lag polynomial with $D(0) = I_n$, n being the dimensionality of z_t and c(B) a finite scalar polynomial in the lag operator B. In general, we can conceive of error correction models (ECM) as a class of model reparameterizations observationally equivalent to unrestricted autoregressive distributed lag (ADL) systems written in terms of current and lagged changes in the endogenous and exogenous variables and lagged level variables. Since the test for cointegration requires the series to be integrated of order $d>0$, we proceed in the following manner:

(a) formulate the static "long-run" theoretical relationship of interest;
(b) investigate the temporal properties of the identified variables;
(c) test for a vector of cointegrated variables;
(d) estimate an error correction representation; and

(e) test the adequacy of the resulting equation.

To the extent that a significant error correction term in (d) implies that the set of variables are cointegrated, both (c) and (d) may not be required. In fact, e_t in (4) can be tested for stationarity independently of the error correction representation (see Dickey and Fuller (1979, 1981)). However, steps (c) and (d) may be used jointly to investigate the potential omission of variables in the "long-run" formulation (that is, obtaining a larger cointegrating set of variables. See Hall and Henry (1987)). The modelling approach used in this paper follows the above theoretical developments and emphasizes the desirability of formulating models that are theoretically consistent and capable of adequately explaining the data generation process. Standard econometric theory indicates that the error term is a "catch all" variable that includes all influences not directly used in the modelling process. In this regard, the error term will exhibit classical properties only if the classical regression assumptions are upheld. As a corollary, the assumption of classical properties in the error term implicitly accepts "the axiom of correct specification" (Leamer (1978)). Thus the modelling process can be viewed as a design problem, the criteria for which, if jointly satisfied, will prove necessary but not sufficient for generating an adequate model. Consequently, we use design criteria as evaluative tools to obtain a tentatively adequate model. Thus diagnostic tests feature strongly in our approach.

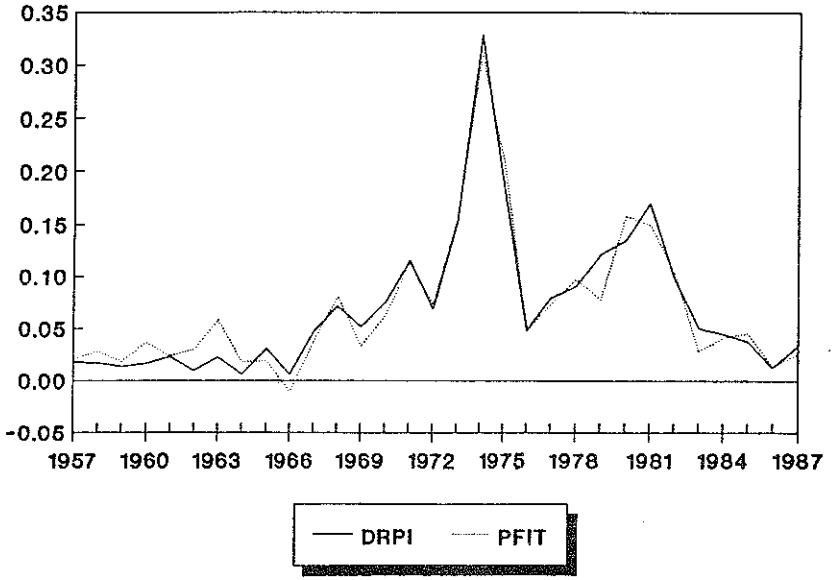
IV. Empirical Analysis

In this section, we examine the determinants of the inflationary process in Barbados over the period 1955-1987. An examination of the time path of the inflation rate over the period indicates that between 1955 and 1966 relatively low rates of inflation were recorded (see figure). With the devaluation of the British pound sterling in November 1967, there was an effective devaluation of the Eastern Caribbean dollar (the currency used in Barbados at that time) which was freely convertible with and pegged to the pound sterling. This devaluation resulted in a significant increase in the rate of inflation in the late 1960s as the prices of imported goods rose significantly.

The period 1970-1977 was marked by double digit-inflation rates due primarily to the significant increases in world export prices of food and manufactured goods, the quadrupling of the cost of petroleum and related products occasioned by the increase in oil prices by the international oil cartel OPEC in 1973, and the high growth of international li-

Figure

ACTUAL AND FITTED VALUES OF DRPI



quidity between 1970 and 1974. These factors resulted in a significant increase in foreign prices and hence the domestic rate of inflation. Whilst there was a sharp decline in the inflation rate in 1975 and 1976 from its peak in 1974, there was another spurt of high inflation rates between 1978 and 1982. The increase in oil prices was a major contributor to the high rates during this period. Between 1983 and 1987, inflation rates were relatively low.

Although external factors have been dominant in determining the inflationary process in Barbados, we also need to examine other factors such as wage rates which may influence the rate of inflation in both the short and long run. The factors specified in equation (3) form the basis of our econometric investigaton.

The variables forming our "long-run" cointegrating set are obtained by simplifying the variables of equation (3) to reflect the fact that the traded goods sector consists of exports, imports and import-competing goods and services. Thus, the import price index and the vector of taxes are components of the price index of the traded goods sector.

Previously, Downes (1985) and Holder and Worrell (1985), using different specifications, found the loan rate to be a significant explanatory

variable in the inflationary process in Barbados but not in Jamaica and Trinidad and Tabago. In this paper, we take the view that the cost of credit (loan rate) is likely to be more important, in the long run, to investment decisions, whereas productivity is more likely to influence the pricing process. A fall in the cost of credit will, ceteris paribus, lead to an increase in investment and productivity, given technical progress, and subsequently to a fall in prices. The positive loan rate effect found in previous studies, although consistent with the inverst price-productivity relationship postulated, does not identify the transmission mechanism as above. Thus, our maintained "long-run" equilibrium relationship hypothesizes that the price level is a function of the wage rate, productivity, the price of traded goods and the unemployment rate.[1]

An investigation of the temporal properties of the series in the equilibrium relationship showed that, using the Dickey and Fuller (1978, 1981) and Bhargava (1986) tests for unit roots, the series are integrable of order one with the possibility of drift terms. Thus, the identified vector of variables will be cointegrated if the error term of a suitably normalised static regression is stationary. In this paper, we assume that the normalization is on prices, and suppress issues relating to the possibility of a cointegrating matrix with rank greater than one.

Using annual Barbadian data for the period 1955-1987,[2] we obtain the following regression equation using ordinary least squares estimation:

$$
\begin{aligned}
(6)\qquad & lp = 0.23 + 0.81\ lw - 0.58\ lprod + 0.49\ lpt + 0.01\ ur \\
& \quad (2.57)\ (23.73)\ (14.71)\ \ (12.67)\ \ (4.54) \\
& \bar{R}^2 = 0.998\ \ s.e. = 0.036\ \ d.w. = 1.94\ \ DF(t) = -6.51 \\
& Arch((X^2(1)) = 0.13\ \ Norm(X^2(2)) = 0.35\ \ Sc(t) = -0.24 \\
& Acf\ Lags\ 1\text{-}10:\ -0.06\ -0.20\ -0.17\ -0.09\ -0.11 \\
& s.e. = 0.17\ \ 0.11\ \ 0.12\ \ -0.22\ \ -0.23\ \ 0.17
\end{aligned}
$$

where lp is the log of the retail price index; lw is log of wages; lprod is log of productivity defined as real GDP per person; lpt is log of the price of traded goods;[3] and ur is the unemployment rate. The t-values are the adjusted t-statistics for cointegrating regressions from REG-X (Hall,

[1] The test suggested by Hall and Henry (1987) was utilized to show that the interest rate variable was not a significant augmenting variable in the "long-run" static regression that included prices, wages, productivity, price of traded goods and unemployment.

[2] The data used in this paper are available on request.

[3] The traded goods sector refers to sugar, other agriculture, tourism and manufacturing.

1989). Sc and Arch test for first order serial correlation and autoregressive conditional heteroskedasticity (see Harvey (1981)). The Dickey-Fuller "t" test (DF(t)) on the residuals of equation (6) indicates stationarity. The partial and autocorrelation functions (Acf) of the residual vector also point to a stationary series — the Q statistic for 10 lags is 8.15. We can therefore conclude that the five variables constitute a cointegrating set, that is, a "long-run" equilibrium relationship.

Applying the two-step method of Engle and Granger (1987), an error correction representation was then estimated using instrumental variables to allow for simultaneity in wages and productivity. The resulting equation for the period 1957 to 1987 is:

$$
\begin{aligned}
(7) \qquad & dp = -0.008 + 0.64\ dw - 0.49\ dprod + 0.26\ dpt + 0.20\ dpm \\
& \qquad (0.59)\ \ (4.03)\ \ \ (6.35)\ \ \ \ \ (6.43)\ \ \ \ (3.70) \\
& + 0.004\ dur + 0.20\ dp_{t-1} - 0.76\ ec_{t-1} + 0.06\ drl_{t-1} \\
& \ \ (2.64)\ \ \ \ \ (3.25)\ \ \ \ (5.32)\ \ \ \ (2.12) \\
& \bar{R}^2 = 0.93\ \ s.e. = 0.019\ \ \ d.w. = 2.20\ \ \ Rmse = 0.016 \\
& Reset\ (F(4,\ 18)) = 1.24\ \ \ Chow(F(2,21)) = 0.12 \\
& Invr(X^2(7)) = 7.8\ \ \ Norm(X^2(2)) = 1.43\ \ \ Pc(X^2(2)) = 0.29 \\
& Sc(t) = -0.42\ \ \ Scnl(t) = -1.03\ \ \ Arch(X^2(1)) = 0.12^4
\end{aligned}
$$

where "d" signifies the first difference of the previously defined variables; dpm is the first difference of the log of import prices; drl is the first difference of the log of the loan rate; and ec is the residual from equation (6) (see also Granger, (1986)). The instrumental variables include lagged endogenous, current and lagged exogenous variables from equation (7), the error correction term (ec_{t-1}), current and lagged growth rates of real government expenditure, growth in domestic credit and the change in the loan rate. Rmse is the root mean square error; Reset is Ramsey's test for linearity; Invr is Sargan's test of the validity of the instrument set; Norm is the Jarque-Bera (1980) normality test computed with GIVE residuals; Pc is the chi-square test for predictive accuracy; Chow is Chow's test for structural change (stability); Scnl tests for first order non-linear serial correlation and follows the suggestion in Breusch and Godfrey (1981); (see Sargan (1976) and Pagan and Hall (1983)).

The correlation matrix shows that the regressors (except dpt and dpm) are not highly correlated, suggesting that multicollinearity is not a major

4 Normality is not assumed for this statistic. When this assumption is imposed, the Arch is 0.83.

problem. The estimated coefficients are all significant at the 5% level, and have plausible signs and magnitides. Recursive estimation of equation (7) indicates that the coefficients are stable. The diagnostic tests suggest that the residuals do not violate the classical assumptions. Furthermore, the error correction term in the dynamic model is also statistically significant, corroborating the previous conclusion that the variables are cointegrated. Thus the estimated equation adequately explains the observed changes in the price level over the estimated period.

The results indicate that wage increases impact positively on the rate of inflation, and that increases in productivity are passed on to consumers in the form of lower prices. External prices also influence the rate of inflation. In equation (7), dpm captures the total import component of price increase impulses originating from both the traded and nontraded sectors, and helps focus on the impact of import prices on domestic price inflation in the small open economy. The lagged inflation variable indicates that last period's inflation rate impacts positively on the current rate of inflation, suggesting some expectational adjustment mechanism in the "short-run." The positive coefficient on the change in the unemployment variable suggests that the pricing process is partly sensitive to overall market conditions in the commodity and labor markets. However, the small value of the coefficient indicatives that the sensitivity of the price changes to changes in labor market conditions may be offset by other demand influences. Changes in the loan rate have a delayed effect on inflation in the "short-run." Thus, the rate of inflation increases with costs which have significant labor and import components, but is dampened by productivity gains. The main policy implications of the results for a small open economy are therefore:

(a) the need to accommodate the effects of imported inflation (for example, through selected price controls in the short run);
(b) the encouragement of a wages policy which seeks to control the rate of growth of wages;
(c) the fostering of measures to boost productivity in the economy.

V. Conclusion

This paper has utilized conintegration theory and the error correction mechanism to model an inflation relationship for a small open economy. It is shown that the methodology can be applied gainfully to formulate a dynamic model that can be depicted as a tentatively adequate conditional characterization of the data generation process. The resulting error correc-

tion model shows wages, productivity, unemployment, price of tradeables and import prices to be significant explanatory variables of the inflationary process in Barbados.

CORRELATION MATRIX

dw	dprod	dpt	dpm	dur	dp_{t-1}	ec_{t-1}	drl_{t-1}
1.00							
0.06	1.00						
0.09	0.14	1.00					
0.21	0.17	0.48	1.00				
0.18	0.14	0.33	0.18	1.00			
0.30	–0.27	0.32	0.31	0.14	1.00		
0.37	–0.03	0.13	0.04	0.19	0.07	1.00	
0.04	–0.10	0.01	0.07	0.10	0.11	–0.11	1.00

References

Breusch, T.S. and L.G. Godfrey, "A Review of Recent Work on Testing for Autocorrelation in Dynamic Economic Models" in B. Currie, R. Nobay and D. Peel (eds) *Macroeconomic Analysis: Essays in Macroeconomics and Econometrics,* Croom Helm, London, 1981.

Choudhry, N.K. et al., *The Trace Econometric Model of the Canadian Economy,* University of Toronto Press, Toronto, 1972.

Chung, J.W., "Inflation in a Newly Industrialized Country: The Case of Korea," *World Development,* 10, 7, 1982, 531-539.

Dickey D.A. and W.A. Fuller, "Distribution of Estimates for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association,* 74, 366, 1979, 427-431.

_____, "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica,* 49, 4, 1981, 1057-1072.

Downes, A.S., "Inflation in Barbados: An Econometric Investigation," *Economic Development and Cultural Change,* 33, 3, 1985, 521-532.

_____and H. Leon, "Testing for Unit Roots: An Empirical Investigation," *Economics Letters,* 24, 1987, 231-235.

_____and A.W.A. Mcclean, "Wage Determination in a Small Open

Unionized Economy: The Case of Barbados," Research Paper, Department of Economics, *University of the West Indies,* Cave Hill Campus, Barbados, 1982.

Engle, R.F. and C.W. Granger, "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55, 3, 1987, 251-276.

Gafar, J., "The Effect of Inflation and High Interest Rate Policies in Developed Countries on the Less Developed Countries," *Indian Journal of Economics,* 62, 246, 1982, 405-415.

Granger, C.W.J., "Some Properties of Time Series Data and Their Use in Econometric Model Specification," *Journal of Econometrics,* 16, 1, 1981, 121-130.

———, "Developments in the Study of Cointegrated Economic Variables," *Oxford Bulletin of Economics and Statistics,* 48, 3, 1986, 213-228.

——— and A.A. Weiss, "Time Series Analysis of Error Correction Models," in Karlin, S, T. Amemiya and L.A. Goodman (ed) *Studies in Econometrics, Time Series and Multivariate Statistics,* 255-278, Academic Press, New York, 1983.

Hall, S.G., *REG-X, Computer Software and Manual,* 1989.

——— and S.G.B. Henry, "Wage Models," *National Institute Economic Review,* 119, 1987, 70-75.

Harvey, A.G., *The Econometric Analysis of Time Series,* Philip Allan, Oxford, 1981.

Holder, C., H.L. Leon and C.J. Wood, "Testing for Nonstationarities in Macroeconomic Time Series," *Social and Economic Studies,* 39, 4, 1990.

Holder, C. and D. Worrell, "A Model of Price Formation for Small Economies: Three Caribbean Examples" *Journal of Development Economics,* 18, 2/3, 1985, 411-428.

Jarque, C.J. and A.K. Bera, "Efficient Tests for Normality, Homoskedasticity and Serial Independence of Regression Residuals," *Economics Letters,* 6, 3, 1980, 255-259.

Leamer, E.E., *Specification Searches: Ad Hoc Inference with Nonexperimental Data,* Wiley, New York, 1978.

Mc Clean, A.W.A, "Pricing Policy in the Distributive Sector of Barbados," *Social and Economic Studies,* 30, 3, 1981, 63-75.

Pagan, A.R. and A.D. Hall, "Diagnostic Tests as Residual Analysis," *Econometric Reviews,* 2, 2, 1984, 159-218.

Phillips, P.C.B., "Time Series Regression with a Unit Root," *Econometrica,* 55, 2, 1987, 277-301.

Sargan, J.D., "Testing for Misspecification after Estimating Using Instrumental Variables," mimeo, *London School of Economics,* 1976.