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Dynamics”

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A THEORETICAL MODEL OF DEVELOPING COUNTRY INFLATIONARY DYNAMICS

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Abstract

One of the most difficult policy issues confronting monetary authorities in many developing economies is the management of a stable price environment. Unstable prices create uncertainty, lower investment, and raise costs of doing business, thus lowering rates of growth. As a result, there exists a widespread need for understanding inflationary dynamics in any country of interest. This paper develops a standard monetary inflation model and augments it to include import and labor cost of production factors in a theoretically plausible manner. Implications for implementing an empirical version of the model are also discussed.

Introduction

Almost every economy in the world must deal with the impacts of inflation in one manner or another. In general, inducing a stable price environment is regarded as a key step to improving economic welfare by enabling any given economy to operate more efficiently. This argument applies equally well to advanced economies such as the United States (Motley, 1993) as well as developing nations (Zind, 1993). Although the magnitude of disinflationary goals set by monetary authorities may differ, short-run price stabilization is frequently a center piece of government policy efforts worldwide. In cases where inflation is fairly low, maintenance of a stable price environment generally becomes one of the primary goals of central bank policy efforts.

In both situations, it is essential to understand the dynamics of price movements if these goals are to be attained.

This paper presents a theoretical modeling framework for the purpose of analyzing developing country inflationary dynamics. A standard monetary model is adapted to incorporate factor costs of production, labor and imported inputs, in a mathematically consistent manner. Subsequent material in the study offers a review of the literature, theoretical model, and implications for empirical implementation. Suggestions for future research are summarized in the conclusion.

Literature Review

The seminal research on inflationary dynamics in developing countries was conducted by Harberger (1963). That early paper analyzes Chilean data and interestingly points out that analyzing nominal data in level form could result in spurious correlations in equations estimated for highly inflationary economies. To circumvent this problem, percentage rates of change of both right-hand side and left-hand side variables are utilized in a linear regression framework based on the quantity theory of money. What became known as the "Harberger" framework incorporates real income, current and lagged values of the money supply, and the opportunity cost of holding cash balances. The success of this initial effort conducted on Chilean data spurred a series of replicated studies for other developing countries (for example, see Vogel, 1974). Results generally confirm the overall usefulness of the Harberger model.

Following numerous applied econometric studies utilizing this approach, it became apparent that exclusive reliance on domestic variables alone often provides unsatisfactory results. Bomberger and Makinen (1979) provide a thorough examination of the Harberger model using quarterly data for Korea, Taiwan, and Vietnam. Rather than extend the model in a new direction,

extensive testing is conducted in order to establish whether a suitable characterization of inflation is provided. While, parameter estimates do not appear sensitive to the time period selected, the elasticities of consumer prices with respect to money and real income are not always unitary as hypothesized. Also, the coefficient signs for the cost of holding money variables are sometimes negative.

Hanson (1985) extends the Harberger framework in a systematic fashion to incorporate an important missing component, import costs. An implicit cost function is utilized to derive an aggregate supply curve which includes local prices of imported inputs. When the underlying production function is homogeneous of degree one, inflation becomes a weighted sum of percentage changes in the money supply and imported good prices. This is important because it implies that, in line with the Bomberger and Makinen (1979) evidence, the elasticity of inflation with respect to money growth is less than one. Empirical results in the Hanson article strongly support the inclusion of import prices in models of inflation.

Subsequent research has provided additional evidence in favor of the augmented Harberger-Hanson approach wherein the effect of import prices on inflation is considered. Koch, Rosensweig, and Witt (1988) and Fullerton, Hirth, and Smith (1991) both report positive linkages between the trade-weighted exchange value of the dollar and consumer prices in the United States. These empirical studies indicate the existence of a unidirectional channel of influence from the exchange rate to domestic prices in the United States economy. As will be discussed below, causality direction has important implications for both model form and estimation technique.

Developing country studies have also confirmed the usefulness of an augmented modeling treatment of inflationary dynamics. Sheehey (1976) reports some of the early econometric

work along these lines. Sheehey (1980) reaches additional conclusions on the basis of empirical tests that indicate that accurate assessment of austerity policy efforts will likely require explanatory variables representing cost push factors. More recently, Brajer (1992) provides evidence that the latter category of models may offer better specifications than those which rely solely on domestic economic factors. Similarly, Fullerton (1993a,b) successfully imbeds a variant of this approach in large-scale macroeconomic forecasting models for Colombia and Ecuador using annual data.

There have been relatively few dynamic models estimated on the basis of monthly data for developing economies. Given that most business decisions in highly inflationary countries are reached within a short-range context, this is an area which needs to be addressed. Fullerton (1993c) empirically examines Colombian anti-inflationary efforts utilizing monthly data with an autoregressive-moving average (ARMA) transfer function. Separately, Fullerton (1995) develops an econometric model, based in large part on the augmented Harberger-Hanson framework, to examine price stabilization efforts in Ecuador. The estimated models for both economies are found to generate realistic simulation scenarios for policy analysis. Results reported in both articles also support the hypothesis of inflation rate inelasticity with respect to money supply growth.

Theoretical Model

Harberger's (1963) model is based on the traditional quantity theory of money equation:

1. $MV = PQ,$

where M represents some measure of the money stock, V is the velocity of circulation, P is the price level, and Q is real output. The realism of the model is enhanced by allowing velocity to vary

instead of arbitrarily forcing it to be constant. Velocity is assumed to be a predictable function of other macroeconomic variables that reflect the cost of holding cash balances.

To utilize percentage changes, the variables can be transformed by natural logarithms and first differenced. Introduction of a time subscript, and rearrangement of the terms, yields the basic Harberger equation:

$$2. \quad DP_t = DM_t - DQ_t + D(DP_{t-1}),$$

where the last term results from substituting for velocity and D represents a difference or backshift lag operator. Harberger directly substitutes for velocity, using the lagged change in the inflation rate to proxy for the implicit cost of holding money. This approach is useful when modeling inflation in countries where government banking system regulations have occasionally caused savings and loan rates to become fixed in nominal terms and temporarily negative in real terms. Unadjusted interest rates from these periods would obviously not provide accurate estimates for the cost of holding idle cash. In economies where financial markets have been allowed to operate more freely, and where appropriate data have been recorded, an interest rate series may also be used to define the last explanatory variable in Equation 2.

Equation 2 implies that inflation will vary positively with the money supply and inversely with respect to real output. A statistically significant intercept term will enter the estimated equation if there is a trend in the velocity of circulation. If only contemporaneous lags of M and Q enter in the equation, the parameters for both variables are hypothesized to be unitary. This can be tested empirically with the following specification:

$$3. \quad DP_t = a_0 + a_1DM_t - a_2DQ_t + a_3D(DP_{t-1}) + u_3,$$

where a_1 and a_3 are hypothesized to be positive, and the absolute values of a_1 and a_2 should both be statistically indistinguishable from one. The last argument in the expression represents the disturbance term.

Hanson (1985) proposes an implicit cost function dual of an aggregate production function which is homogeneous of degree one. Derived output supply functions from this framework will be homogeneous of degree zero in input and output prices. Equation 4 expresses this relationship using logarithmic first differences:

$$4. \quad DQ_t = b_0 + b_1DP_t - b_2DPI_t + u_4,$$

where PI represents imported input prices. When the relative prices of imported inputs increase, output is assumed to decline. The standard homogeneity assumptions for production and derived supply relations imply that $b_1 - b_2 = 0$.

The vector of input prices utilized in the derivation of Equation 4 can be extended to include factor prices beyond those represented by imported materials, equipment, and services. Perhaps the most obvious candidate to further improve the relevance of the framework is labor costs. Doing so yields the following theoretical expression:

$$5. \quad DQ_t = b_0 + b_1DP_t - b_2DPI_t - b_3DW_t + u_5,$$

where W represents wage and labor costs. In this case, the standard microeconomic assumptions for production and derived supply functions imply that $b_1 - b_2 - b_3 = 0$.

Equation 5 can be substituted into Equation 3 to eliminate the output term from the expression to be estimated. This step is exceedingly useful for avoiding interpolation bias in empirical studies of monthly inflation for countries where national income and product accounts are published at quarterly and/or annual

frequencies (for a discussion of interpolation bias, see Bomberger and Makinen, 1979). The resulting equation can be written as follows:

$$6. \quad (1 + a_2b_1)DP_t = a_0 - a_2b_0 + a_1DM_t + a_2b_2DPI_t + a_2b_3DPW_t + a_3D(DP_{t-1}) + u_6.$$

Equation 6 can be further simplified prior to estimation. Dividing through by the left-hand side constant term and rearranging terms such that the price series remains as the dependent variable generates the following relation:

$$7. \quad DP_t = c_0 + c_1DM_t + c_2DPI_t + c_3DPW_t + c_4D(DP_{t-1}) + u_7,$$

which also has testable properties. Note that as a result of expanding the channels of influence on aggregate price trends, the coefficient on the monetary variable, c_1 , is hypothesized to be significantly less than one. With the possible exception of the intercept, all of the regression parameters in Equation 7 are expected to be positive. During periods such as the 1960s and 1970s in developing countries when inflation is accelerating, c_0 is likely to be greater than zero (Clavijo, 1987). Disinflationary episodes such as those observed under the structural adjustment efforts of the 1980s and 1990s (Fullerton and Sprinkle, 1997) may have negative constant terms associated with them.

As indicated in the literature review, this general approach has provided a useful framework for analyzing quarterly and annual inflation rates. But because the implied lag structure is fairly short, it may require additional modification prior to estimation. This possibility does not reflect any deficiencies in the theoretical model as such, but arises due to the fact that data are published at different frequencies. As a result, if the inflationary impact of a change in the money supply is felt over the course of one calendar year, the implied lag structure for a model estimated with monthly data would potentially range up to 12 months in

length. Equation 8 takes into account this empirical issue which has confronted and confounded researchers for many years (see Laidler, 1993):

$$8. \quad DP_t = c_0 + \text{Sum}(c_{1i}DM_{t-i}) + \text{Sum}(c_{2j}DPI_{t-j}) + \text{Sum}(c_{3k}DPW_{t-k}) + \text{Sum}(c_{4m}D(DP_{t-1-m})) + u_8,$$

where $i,j,k,m = 1,2,\dots,M$.

The above model provides an attractive starting point for examining inflationary trends in an economy. It is not, however, without potential problems for analyzing price movements. The principal concern with this theoretical construct arises from the fact that Equation 8 treats all of the regressors as exogenous or pre-determined. In doing so, it does not allow for the possibility of statistical feedback or endogeneity between the left-hand and right-hand side variables.

If a central bank yields to political pressures and engages in accommodative monetary policy in the face of inflation shocks, this assumption would be violated. Research conducted using higher frequency data for Colombia indicates that the causality paths are unidirectional as implied by Equation 8 (see Fullerton, 1993c, and Leiderman, 1984). This was not an assumption to be taken lightly, however, as domestic prices, monetary aggregates, and import prices are modeled simultaneously in the Colombian macroeconomic model estimated using annual data by Fullerton (1993a). It would not be surprising if the feedback relations encountered in the latter paper also emerge in higher-frequency data samples, especially in cases where monetary authorities are forced to yield to political pressures. Empirical evidence of the latter situation is reported for Mexico during the 1980s (Leiderman, 1984). This likelihood is even greater in economies where wages and prices are linked via formal indexing rules and other types of cost-of-living escalator clauses in labor agreements (Dornbusch and Fischer, 1993).

A second possible concern arises from utilizing first differenced, log-transformed time series data in the equation to be estimated. If the resulting series are stationary, the equation can be estimated without risk of obtaining spurious correlations in the results. As shown in many studies of hyperinflationary economies, however, higher order differencing may be required to induce stationarity during periods in which prices increase rapidly (see Engsted, 1993). Because most developing countries have never experienced any hyperinflationary episodes, regular first differencing should adequately remove nonstationary trends in the first moments of any variables selected for analysis. It is still important, however, to formally test the latter assumption when empirical versions of Equation 8 are estimated.

Empirical Issues

In order to examine whether the working series included in Equation 8 are stationary, a variety of unit root tests may be utilized. For some developing economies where data limitations are severe, applying unit root tests to relatively short time spans may be risky. The latter consideration is due to the fact that these tests typically have low power unless long-run data sets are employed (Hakkio and Rush, 1991). Monthly time series data for consumer prices and exchange rates generally date back to 1957 and do not pose any problems of this nature. For other series such as money supply aggregates or wages, there may be little that can be done to circumvent this potential problem. In such cases, chi-square tests calculated for autocorrelation functions (Greene, 1993) may provide corroborative evidence to support the results obtained from the unit root tests.

As specified above, the model is explicitly built around a set of unidirectional causality relations from movements in the regressors to consumer prices. To examine whether the absence of simultaneity in the model is plausible, Granger causality tests

may be calculated for the stationary components of the series of interest. If the resulting F-tests fail to reject the feedback hypothesis, then the reduced form model appearing in Equation 8 is inadequate. Potential alternative candidate approaches include structural model systems of equations (Beltrán del Río, 1991, and Fullerton and Araki, 1996) as well as vector autoregression equation systems (Arellano and Gonzalez, 1993).

The model developed above accounts for more potential sources of inflation than do previous versions of the Harberger-Hanson theoretical framework. Its scope still may not be wideranging enough to explain all systematic variations in aggregate price levels for particular economies. If this is the case, the shortcoming will be manifested in the form of serially correlated residuals. If it is not possible to identify and extend the model to resolve the nonrandom component of the residuals, then the autocorrelation should be corrected in order to minimize the possibility of spurious estimation results (Hamilton, 1994). Even when valid theoretical respecifications can be identified, developing country data constraints may preclude expansion of the model to account for the omitted regressors (Sawyer and Sprinkle, 1987). In such instances, Pagan's (1974) nonlinear ARMAX procedure offers an attractive correction technique because of its capacity to handle autoregressive, moving average, and mixed error generating processes.

Expansion of the input price vector to include more than just import prices raises the risk of multicollinearity. Such an eventuality would, of course, make it difficult to correctly attribute the relative contributions of each variable to the overall inflationary process. In addition to the traditional recommendations for dealing with this problem (Pindyck and Rubinfeld, 1991), it may be helpful to experiment with alternative estimators. One candidate methodology is offered by ridge regression (for discussion, see Vinod, 1978). Because ridge regression has the undesirable side-effect of introducing a small

level of bias in the resulting parameter estimates, it is mandatory that extensive simulation experiments be conducted with any model designed for usage in either policy analytic and/or forecasting exercises.

The lag structure in Equation 8 is arbitrary by design. In estimation, however, specific lag lengths must be selected. Ultimately, this question is an empirical one. Experimentation with the lag structure generally cannot be avoided in any modeling process involving dynamic specifications. Fortunately, several decision rules are available. A formal statistical approach is provided by likelihood ratio model specification tests (Hamilton, 1994). Software packages frequently include automated versions of the Akaike and Schwarz criteria for dependent and independent variable lag inclusion (for descriptions, see Amemiya, 1980, and Hsiao, 1979).

Cognizant of the exploratory characteristics of the model developed herein, a variety of simulation exercises will be mandatory in evaluating empirical versions of Equation 8. The goal of the simulation tests is to provide insights with respect to the policy analytic and extrapolation accuracy validity of the underlying theoretical model. Usage of out-of-sample data not employed in parameter estimation provides the only means by which the simulation experiments can satisfy the Klein (1984) and Christ (1993) criteria for forecast and model evaluation.

Conclusion

An inflationary model is developed that includes both monetary and factor costs effects in a theoretically plausible manner. Specification and simulation of the model are relatively easy to accomplish. Because the model does not pose stringent data requirements, it is likely to be applicable to most developing economies where inflation remains a problem. Given its dynamic specification, the model may be useful in cases where monetary

officials continue to grapple with short-term price stabilization goals.

As presented above, the theoretical model underlying the reduced form model in Equation 8 represents an extension of Harberger-Hanson framework to include labor costs. Further expansion of the input price vector utilized in deriving Equation 5 and the subsequent expressions is easy to accomplish. Doing so will result in the inclusion of additional right-hand side variables in Equation 8, but not alter the basic form of the model. Logical candidates that are generally monitored by inflation analysts include domestic energy price measures and intermediate industrial good and material prices. The latter tend to rise very rapidly during periods in which industrial capacity utilization is relatively high (Emery and Chang, 1997, and Price and Dockery, 1991). Extending the input price vector along these lines, however, will raise the likelihood of encountering the aforementioned feedback and multicollinearity problems.

No matter what version of the dynamic framework is selected, numerous econometric issues may arise in estimation. With the exception of higher order first moment nonstationarity, the model can be adapted to handle most departures from standard statistical assumptions. It may be useful to expand the scope of the model to include additional equations that allow for potential endogeneity between inflation, money, wages, and exchange rates. Even if the latter are not required for parameter estimation consistency, they could enrich subsequent policy simulation analyses. The model itself can be imbedded in structural model systems to accomplish this goal. Empirical research utilizing this approach may help to unravel many of the questions remaining with respect to price trends in developing economies.

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