

Economic & Business Review

Volume 39, Number 2, 1997, pages 1-18

A Theoretical Model of Industrial Economy Inflationary Dynamics

JEL Category E31, Prices, Business Fluctuations, and Cycles

Thomas M. Fullerton, Jr.
Department of Economics & Finance and
Texas Center for Border Economic Development
University of Texas at El Paso
El Paso, TX 79968-0543
Telephone: 915-747-7747
Facsimile: 915-747-6282
Email: tomf@utep.edu

Eiichi Araki
Department of Economics
St. Andrews University
Osaka, Japan
Email: araki@andrew.ac.jp

Abstract

One of the ongoing policy issues confronting monetary authorities around the world 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, labor, energy, and intermediate goods and materials cost of production factors in a theoretically plausible manner. Implications for implementing an empirical version of the model are also discussed with a view toward the various econometric difficulties that may surface in estimation.

Acknowledgements

Partial funding support for this research was provided by the University Research Institute at the University of Texas at El Paso and by the Center for the Study of Western Hemispheric Trade at the University of Texas at El Paso.

A Theoretical Model of Industrial Economy Inflationary Dynamics

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 industrial economy 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

A seminal paper in the research on inflationary dynamics was actually conducted for developing countries by Harberger (1963). That early paper 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 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. Encouragingly, the parameter estimates do not appear sensitive to the time period selected. However, the elasticities 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 money supply changes and import prices. This is important because it implies that 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 on inflationary dynamics in the United States 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. These empirical studies indicate a unidirectional channel of influence from the exchange rate to domestic prices exists in the United States economy. As will be discussed below, causality direction has important implications for both model form and estimation technique.

Given the usefulness of the Harberger-Hanson framework, a natural question to ask is whether it can be further extended to systematically incorporate other variables that also impact upon price movements. Examples include labor, energy, and both intermediate and raw material prices (similar arguments are also presented in a different context by Dornbusch and Fischer, 1993). The models developed below are directed to this end. They are primarily intended to help model inflationary processes in industrial economies where data constraints are generally not binding. In principle, the augmented Harberger-Hanson approach can also be applied to developing economies, but data availability may preclude full implementation of the complete modeling system (for discussion, see Fullerton and Araki, 1996, and Sawyer and Sprinkle, 1987).

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. Unlike simple textbook examples of the quantity theory, Harberger enhances the realism of the model 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 then first differenced. Introduction of a time subscript, and rearrangement of the terms, yields the basic Harberger equation:

2. $DP_t = DM_t - DQ_t + DR_{t-1}$,

where the last term results from substituting for velocity and D represents a difference or backshift lag operator. In contrast to the original version of this model, Equation 2 utilizes a one period lagged change in a representative interest rate series to proxy for the implicit cost of holding money. This approach can only be applied to modeling inflation in countries where government banking system regulations have allowed savings and loan rates to vary in both nominal terms and real terms. Unadjusted interest rates from economies in which this is not the case would obviously not provide accurate estimates for the cost of holding idle cash. In economies where financial markets have not been permitted to operate flexibly, the lagged rate of change in an inflation index can be used to define the last explanatory variable in Equation 2 (Fullerton and Araki, 1996). The latter approach is not adopted here, thus yielding a slightly different specification than that appearing in Harberger (1963).

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 discernible 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:

$$3. \quad DP_t = a_0 + a_1DM_t - a_2DQ_t + a_3DR_{t-1} + u_3,$$

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 imports of 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:

$$6. \quad (1 + a_2b_1)DP_t = a_0 - a_2b_0 + a_1DM_t + a_2b_2DPI_t + a_2b_3DPW_t + a_3DR_{t-1} + u_6.$$

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:

$$7. \quad DP_t = c_0 + c_1DM_t + c_2DPI_t + c_3DPW_t + c_4DR_{t-1} + u_7,$$

which also has testable properties. Note that 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 which inflation is accelerating, c_0 is likely to be greater than zero (Clavijo, 1987). Disinflationary episodes such as those observed in many economies during the 1980s and 1990s may have negative intercept 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):

$$8. \quad DP_t = c_0 + c_1DM_{t-i} + c_2DPI_{t-j} + c_3DPW_{t-k} + c_4DR_{t-1-m} + u_8,$$

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

Further modification to the framework yields an even more realistic reduced form specification. Essentially, all that is required is to expand the input price vector used in Equation 5 prior to substituting for the DQ_t variable in Equation 4. It is generally agreed, for example, that domestic energy price measures and intermediate industrial good and material prices play important roles in the inflationary process. 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). Let E stand for energy prices and I represent intermediate industrial good and raw material prices. Solving the modified specification of the model and allowing for an arbitrary lag structure results in the following reduced form:

$$9. \quad DP_t = c_0 + c_1DM_{t-i} + c_2DPI_{t-j} + c_3DPW_{t-k} + c_4DE_{t-m} + c_5DI_{t-n} + c_6R_{t-1-s} + u_9,$$

where $i,j,k,m,n,s = 1,2,\dots,M$. As before, all of the estimated slope parameters are expected to be smaller than one. The constant term may be positive or negative.

Equation 9 provides an attractive starting point for examining inflationary trends in any given 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 9 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. Koch, Rosensweig, and Witt (1988), as well as Fullerton, Hirth, and Smith (1991), report evidence that this is not the case in the United States. It would not be surprising, however, if feedback were encountered in at least some instances since it has been in recent years that monetary policy in countries such as Canada and New Zealand has been freed to focus exclusively on price stability (Dornbusch and Fischer, 1993). Ultimately, the issue can only be resolved empirically. Careful testing should be utilized prior to selecting the methodology that will be employed in parameter estimation for Equation 9.

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, if not all, industrial economies have not experienced any hyperinflationary episodes during the post-war period, 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 9 are analyzed.

Empirical Analysis

In order to examine whether the working series included in Equation 9 are stationary, a variety of unit root tests may be utilized. For rare cases in which 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 9 is inadequate. Potential alternative candidate approaches include structural model systems of equations (Fullerton and Araki, 1996) as well as vector autoregression equation systems (Hamilton, 1994).

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/or extend the model to resolve the nonrandom component of the residuals, then the autocorrelation problem should be corrected in order to minimize the possibility of spurious estimation results (Hamilton, 1994). Even when valid theoretical respecifications can be identified, data constraints may preclude expansion of the model to account for the omitted regressors. 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 underlying Equation 4 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 9 is arbitrary by design. In estimation, however, specific lag lengths must be selected. Because 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).

Given the exploratory characteristics of the model developed herein, a variety of simulation

exercises will be mandatory in examining empirical versions of Equation 9. The goal of the simulation tests is to provide insights with respect to the policy analytic and extrapolation accuracy 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 above that includes both monetary and cost of production factor 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 virtually any industrial economy of interest. Given its dynamic specification, the model may be useful in cases where monetary officials continue to grapple with short-term price stabilization goals.

As developed above, the theoretical model underlying the reduced form presented in Equation 9 represents an extension of Harberger-Hanson framework to include domestically produced factor costs. Further expansion of the input price vector utilized in deriving Equation 5 and the subsequent expressions is easy to accomplish. In cases where this is necessary, doing so will result in the inclusion of additional right-hand side variables in Equation 9, but will not alter the basic form of the model. Extending the input price vector along these lines, however, will raise the likelihood of encountering the aforementioned simultaneity 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 modeling approach may help to unravel many of the questions remaining with respect to price trends in economies facing monetary policy decisions.

References

Takeshi Amemiya, 1980, "Selection of Regressors," **International Economic Review** 21, 331-354.

William A. Bomberger and Gail E. Makinen, 1979, "Some Further Tests of the Harberger Inflation Model using Quarterly Data," **Economic Development and Cultural Change** 27, 629-644.

Carl Christ, 1993, "Assessing Applied Econometric Results," Federal Reserve Bank of St. Louis **Review** 75 (March/April), 71-94.

Sergio Clavijo, 1987, "Hacia una Caracterización del Comportamiento de la Velocidad de Circulación del Dinero: El Caso Colombiano 1959-1986," **Ensayos Sobre Política Económica** 12, 59-79.

Rudiger Dornbusch and Stanley Fischer, 1993, "Moderate Inflation," **World Bank Economic Review** 7, 1-44.

Kenneth M. Emery and Chih-Ping Chang, 1997, "Is there a Stable Relationship between Capacity Utilization and Inflation?," Federal Reserve Bank of Dallas **Economic Review**, 14-20.

Tom Engsted, 1993, "Cointegration and Cagan's Model of Hyperinflation under Rational Expectations," **Journal of Money, Credit and Banking** 25, 350-360.

Thomas M. Fullerton, Jr. and Eiichi Araki, 1996, "New Directions in Latin American Macroeconometrics," **Economic & Business Review** 38, 49-73.

Thomas M. Fullerton, Jr., Richard Hirth, and Mark Smith, 1991, "Inflationary Dynamics and the Angell-Johnson Proposals," **Atlantic Economic Journal** 19, 1-14.

William H. Greene, 1993, **Econometric Analysis**, New York, NY: Macmillan Publishing.

Craig Hakkio and Mark Rush, 1991, "Cointegration: How Short is the Long-Run?," **Journal of International Money and Finance** 10, 571-581.

James D. Hamilton, 1994, **Time Series Analysis**, Princeton, NJ: Princeton University Press.

James A. Hanson, 1985, "Inflation and Imported Input Prices in some Inflationary Latin American Economies," **Journal of Development Economics** 18, 395-410.

Arnold Harberger, 1963, "The Dynamics of Inflation in Chile," Chapter 2 in **Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld**, edited by Carl F. Christ, Stanford, CA: Stanford University Press.

Chen Hsiao, 1979, "Autoregressive Modeling of Canadian Money and Income Data," **Journal of the American Statistical Association** 74, 553-560.

David Laidler, 1993, "Commentary on Assessing Applied Econometric Results," Federal Reserve Bank of St. Louis **Review** 75 (March/April), 101-102.

Lawrence R. Klein, 1984, "The Importance of the Forecast," **Journal of Forecasting** 3, 1-9.

Paul D. Koch, Jeffrey A. Rosensweig, and Joseph A. Witt, 1988, "The Dynamic Relationship between the Dollar and U.S. Prices," **Journal of International Money and Finance** 7, 181-204.

Brian Motley, 1993, "Inflation and Growth," **FRBSF Weekly Letter**, 93-44 (December 31), 1-3.

Adrian Pagan, 1974, "A Generalised Approach to the Treatment of Autocorrelation," **Australian Economic Papers** 13, 260-280.

Robert S. Pindyck and Daniel L. Rubinfeld, 1991, **Econometric Models and Economic Forecasts**, Third Edition, New York, NY: McGraw Hill.

Frantz Price and Karen Dockery, 1991, "Inflation," The WEFA Group **U.S. Economic Outlook** (April), 4.45-4.50.

Hrishikesh D. Vinod, 1978, "A Survey of Ridge Regression and Related Techniques for Improvement over Ordinary Least Squares," **Review of Economics and Statistics** 60, 121-131.

Richard C. Vogel, 1974, "The Dynamics of Inflation in Latin America, 1950-1969," **American Economic Review** 64, 102-114.

Richard G. Zind, 1993, "On Inflation and Growth in the LDCs," **Economic Studies Quarterly** 44, 108-116.