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The Search for a Natural Rate of Price Inflation: U.S. 1948-1995

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In the past two years, the nonacademic financial sector has expressed concern that substantial inflation rates loom on the horizon. The Federal Reserve's increasing of interest rates was intended to preempt possible inflationary waves. Academic economists on the other hand, have charged that Federal Reserve policy has shown no consistent economic plan, that its latest increases in interest rates, have been unnecessary and detrimental (Galbraith, 1994; Papdimitriou & Wray, 1994) and that it has even shifted its control focus toward maintaining the unemployment rate rather than controlling price inflation (Davidson, 1995).

In light of the recent qualified evidence for a natural rate of unemployment (Guastello, 1995a; Mitchell, 1993;), and the inverse (but somewhat obtuse) relationship between inflation and unemployment (Keynes, 1965), this study was undertaken to determine whether there existed a natural rate of inflation. Such a natural rate would represent an equilibrium between inflationary and deflationary economic effects. The goal of nonlinear dynamical analysis, therefore, is to determine whether asymptotic stability can be identified in inflation data, or barring that, to determine whether chaotic attractors, saddles, or other dynamics are evident.

Practical Basis for the Search

It would be helpful, therefore, to review some of the reasons why prices of commodities could rise or fall. At the producer's level of experience, prices of commodities sold are related to the producer's cost of materials, labor, and overhead. Materials costs would include import tariffs, rarity, and supply-demand dynamics associated with the materials. Labor costs include wages, benefits, special compensation packages for management. Overhead would include the maintenance of physical facilities, research and development, staff support, lots of corporate lawyers, advertising, and other "costs of doing business." Costs of doing business would include the interest rates on business loans.

At the point of product sales, prices could rise because of supply-demand dynamics again, and because of inelasticities of demand and supply. Changes in product design where more value is put into the product could result in a product price increase. For instance, the compact disk has replaced the phonograph record as a medium for recorded music. The compact disk offered a better signal to noise ratio, promised better durability, and offered longer playing times for new music programs, and hit the market at twice the price of the long playing phonograph record. Currently, the cost of manufacturing a compact disk is no greater than the cost of manufacturing a phonograph record in 1987, but the retail prices have only dropped about 10%. The introduction of a new higher-priced product, the compact disk again, allowed the price of a less sophisticated product, the cassette tape, to increase, thus closing the gap somewhat with the price of the high-priced product.

An echo of the same principle can be seen on the stock market. The price of a stock may increase because the value of the company, in terms of its assets and expected profits, is increasing; in this case we would observe increased prices with constant price-equity ratios. A speculative bubble, on the other hand, would occur when prices rise, often sharply, with little change in the organization's profits or promises (Guastello, 1993; Weintraub, 1983).

In response to rising costs of production, producers might substitute cheaper materials. Other options include automation to increase production and decrease labor input, deskilling work through automation so as to utilize cheaper labor sources, or exporting the jobs to lower wage countries. They might also substitute the occasional use of consultants to replace professional level employees, and invent new bonuses to give to top management for their strides in cutting costs.

From the consumer's experience, prices rise whenever the profit margins and cost structures are increased at any point when the product changes hands from producer to wholesaler to retailer to consumer. The cost of products rises invisibly with the cost of consumer credit and sales taxes. Consumer's might respond, however, by favoring vendors with more direct links to producers ("cutting out the middle man"), withholding purchases until a "special sale" or coupon gimmick is introduced. Needless to say, old fashioned supply, demand, elasticity and substitutability concepts are shrouded in a morass of marketing gimmicks.

Ultimately, consumers might respond to rising with an upward pressure on wages, either through job seeking or through labor organization. On the one hand the wage push may be reactionary to costs of living. On the other, a wage push may reflect a demand to share in the profits associated with highly demanded products. Increases in excess demand lead to high profit margins, and increased wage demands; the latter result in narrowed profit margins.

They might also curb their more elastic demands by saving their money in spite of low bank interest rates. As a historical note, there was a sudden lack of "consumer confidence" following the onset of the Gulf War. After the lack of spending was registered, credit care interest rates fell to nearly half their pre-Gulf levels.

Theoretical Basis of Equilibria and Stability

There are two perverse consequence of the money-interest dynamics (Keynes, 1965). One is runaway inflation, in which expectations of the lower future value of money are countered with programmatically high interest rates and prices of goods. The second is rigid deflation, characteristic of the U.S. depression of the 1930s, whereby cash was hoarded by both individual economic agents who avoided any spending, and by lending institutions who were averse to making loans, presumably because of a high perceived risk of default. Both extremes suggest the presence of attractor structure, at least in the sense of a stable set of system-wide economic policies that reinforce these self-fulfilling prophesies.

One might argue, however, that the economic outcomes of runaway inflation and rigid deflation represent anything but stability. In the case of runaway inflation, economic agents (individual and institutions) are constantly receipting to dramatic price and interest shifts. In the case of rampant unemployment and deflation, the individuals are prone to resort to political mechanisms for social change (such as the uprising of the American Communist Party), or balkanized economies that are somewhat insulated from the macroeconomic conditions.

One might surmise that healthy economies revolve around an equilibria of some sort, which are positioned between the two extreme conditions just described. Indeed, Keynes wrote, "In a static society or in a society in which for any other reason no one feels any uncertainty about the future rates of interest, the ... propensity to hoard ... will always be zero in equilibrium" (1965, p. 208-209). Today we might examine the true dynamical structure of "equilibrium" inasmuch as several structural possibilities could exist, with different implications. Keynes also noted in the same chapter that even if lending institutions chose to generate zero profit, they would still require non-zero interest rates to cover their operations costs. Thus the very existence of a banking system contributes a small amount to rising prices, which begins with the cost of money.

The bulk of the arguments presented thus far concerning money and interest appear to be predicated on supply and demand dynamics that affect the value of money. In the classical economics of the era pre-dating Keynes, the supply of money was the sole and simple explanation for inflation and deflation. Keynes noted, however, that the monetarist theory was flawed in that it did not separate the impact of the money supply from changes in the wage unit. Classical monetarist and Keynesian explanations for inflation coexist only in the untenable condition of full employment and zero tendency to save or hoard cash.

The Contribution of System Complexity

Although it is convenient to think of "money," "interest," "demand," "goods" and so forth as single variables, the economics realities are that the economy is net result of interactions among industrial sectors (e.g. agriculture, mining and mineral, construction, manufacturing, services, and so forth), each with its own local topographies of supply, demand, and wages. Post Keynesian economists have examined (among other things) such interrelationships, with an eye toward separating the contributions to inflation. Schultze (1959) advised that any statistical relationships that might be isolated among economic variables should not be taken to imply cause and effect in the conventional sense. Rather, the "causation mechanisms" that could be taking place vary from one time frame to another; thus any models one might extract are nonergodic.

In addition to the monetarist explanation for inflation, Schultze (1959) identified two others: the demand-pull explanation, where the demand for a product induces the supplier to raise prices, and the wage-push explanation, whereby the demand for wages induces prices to rise. The product of one economic sector may be a resource or supply for another. Thus the sequence of excess demand, increased prices, high profits, and upward wage push may operate in one sector, but a sequence of increased supply cost, flat demand, decreased profit margin, and downward wage push could exist in another sector.

Excess demand is not expected to drive prices up in times of high unemployment or excess capacity, however.

Another element of complexity is that not all labor within an industrial sector shares the same experience with wage trends. Specifically it is necessary to separate wage trends for production and managerial groups. During the 1948-1957 epoch, labor costs in manufacturing increased 17% for wage earners, but 63% for salaried personnel. Roughly the opposite was true in the 1939-1948 epoch in which wages increased 93%, but salaries only 53% (Schultze, 1959, p. 25). "Similarly, in manufacturing almost the entire reduction in employment takes place among production workers -- nonproduction worker employment [referring to management and salaried personnel] declines very slightly" (p. 56).

Schultze made an important observation that supports the view that there might exist a non-zero natural rate of inflation. The economy is less sensitive to downward price pressure than it is to upward pressure. Across most industries there is a "widespread downward price rigidity," suggesting that prices will show a net increase in the long run, except during the 1930s when unemployment was very high. Given that global price indices are the net result of exchanges throughout a complex system, it would be reasonable to predict that a stabilized positive rate of growth in prices would take the form of a chaotic attractor.

Method

Data consisted of monthly annualized producer price indices (PPI) and consumer price indices (CPI) for the period January, 1948, through February, 1995. The analysis method was the nonlinear regression technique for identifying a chaotic or nonchaotic attractor and its fractal (Lyapunov) dimension (Guastello, 1993, 1994, 1995b). The Lyapunov dimension (D_L) provides a test of chaos. In the mathematical model, we aim to estimate a from a time series of a dependent variable (order parameter) y such that

(1) $y = \| e^{at} \|.$

If a is positive, then the function is chaotic, expanding, and sensitive to initial conditions. If a is negative, then the function is a fixed point or periodic attractor, contracting, and insensitive to initial conditions. D_L is then calculated as

(2) $D_L = e^{a}.$

At present, the only workable statistical method for calculating D_L utilizes nonlinear regression coupled with structural modeling (Guastello, 1993, 1994a, 1994b, 1995; Johnson & Dooley, 1994). The process begins by modeling the simplest structure:

(3) $z_2 = e^{\theta_1 z_1 t} + \theta_2$

where θ_1 is the critical exponent, θ_2 is a constant (of little consequence), and z_2 and z_1 are consecutive values of our dependent measure in a time series that has been corrected for location (λ) and scale (σ_s).

(4) $z = (y - \lambda_s)/\sigma_s.$

Also, t = time; because all time lapses are equal intervals, t is set to the trivial value of 1. The resulting measure of dimension is then, following Eq. 2, $D_L = e^{\theta_1}$.

The second model in the series is the case where we have an unknown bifurcation variable. Here we test for the structure, but since we have neither an hypothesis as to what it could be or data to test it, we estimate the bifurcation variable θ_1 as a regression parameter:

(5) $z_2 = \theta_1 z_1 e^{\theta_2 z_1} + \theta_3$

In this case dimension is calculated as:

(6) $D_L = e^{\theta_2} + 1.$

The next step in the assessment of nonlinear trends it to compare the nonlinear functions with linear alternative explanations. In other circumstances where the data contains, N objects measured at two points in time, the following linear model is a good comparison:

(7) $z_2 = b_1 z_1 + b_2 x_1 + b_3 x_2 + b_n x_n.$

In Eq. 7, z is the dependent measure at two points in time as before, b_i are ordinary regression weights, and xi are other independent variables which we do not have in this application. The task is then to compare R^2 values for the linear and nonlinear models.

The sampling frequency will effect the size of the linear model's R^2 relative to the R^2 of the nonlinear model. For short lag lengths, the trajectory between two points in time is well-approximated by a linear model. It is only when the global picture is taken into account do we see the nonlinear structure that could be taking shape. Eq. 7, when applied to locally smooth trends, can produce an accurate forecasting model (or retrocasting model) that says that z_2 is a linear function of z_1; fresh observations of z_1 need to be made (almost) every time the forecast is to be moved ahead one time interval.

Another alternative comparison model is to regress z against time:

(8) $z_1 = bt + C.$

Eq. 8 says that z is a linear function of time and is not further dependent on its previous value. This is probably a more fair comparison from a modeling standpoint. Eq. 7, may have some value from the viewpoint of local prediction, however.

Results

Producer Price Index

For reference purposes, the PPI for the 1948-1995 time series appear in Figure 1. To simplify the diagram, each point represented in Figure 1 is an average of the 12 monthly observations for each year (except 1995 which contains two observations).

For this problem, λ was estimated as 0.00, and σ_s was estimated by the ordinary standard deviation, 5.08.

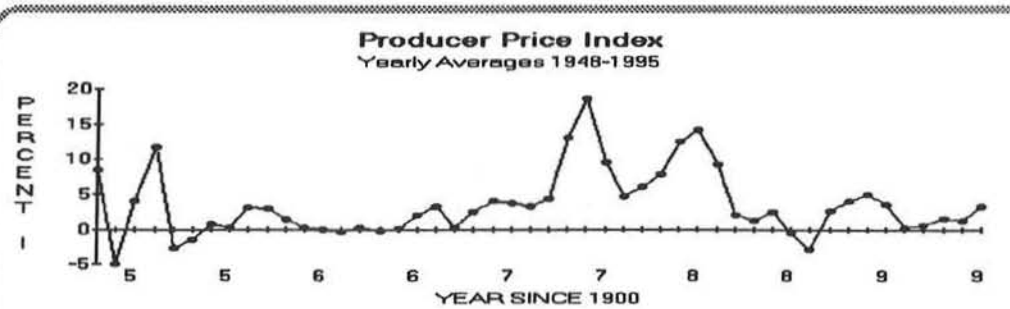

Figure 1: Annual average PPI inflaction rates for the U.S. 1948 - 1995

A chaotic attractor was isolated for the PPI ($R^2 = .75$) with $D_L = 1.51$ at a three-month lag interval. There were 554 observations in this time series. The resulting function was:

(9) $z_2 = e^{(0.411)z1} - 0.789.$

The attempt to test a bifurcation model resulted in a nonsignificant exponent, such that the null hypothesis of linearity was upheld. The time series was well-approximated, however, by the linear autoregressive function, whereby fluctuations were dampened from quarter to quarter and a small increase in inflation was added ($R^2 = .84$). The test for the linear effect over time showed a poor level of fit, by contrast ($R^2 = .02$).

The next procedure was to explore the function obtained for the PPI, forecast outcomes based on plausible initial conditions, and reverse-forecast the function to determine plausible initial conditions that might have produced it. Because D_L is evaluated at the norm of the time series, the constant θ2 can be interpreted as a further correction for location. Thus iterations would proceed without the constant, after which the constant would be added to zi before multiplying by the scale parameter to obtain real values, $y_{i.}$

Depending on the specifics of the problem under study, however, q2 may represent more than a location correction. It may, alternatively, represent the norm of an opposing function. The inflation problem may be such an example inasmuch as the sources of price increase at the producer level would trigger feedback to the producer to engage in cost cutting measures. Thus iterative series were explored with and without the constant.

Figure 2 shows the forecasts for the PPI based on Eq. 9 without the constant, with initial conditions of 3%, 6%, and 12% inflation. As expected, inflation rates rise in a nearly linear fashion until they hit a critical value and zoom off the graph into rampant inflation. Figure 3 shows forecasts for the PPI based on Eq. 9 with the constant included, the same three conditions of inflation, plus initial conditions of 3%, 6%, and 12% deflation. In all cases, iterates reached asymptotic stability at 0.38 moments, which correspond to an inflation rate of 1.93%.

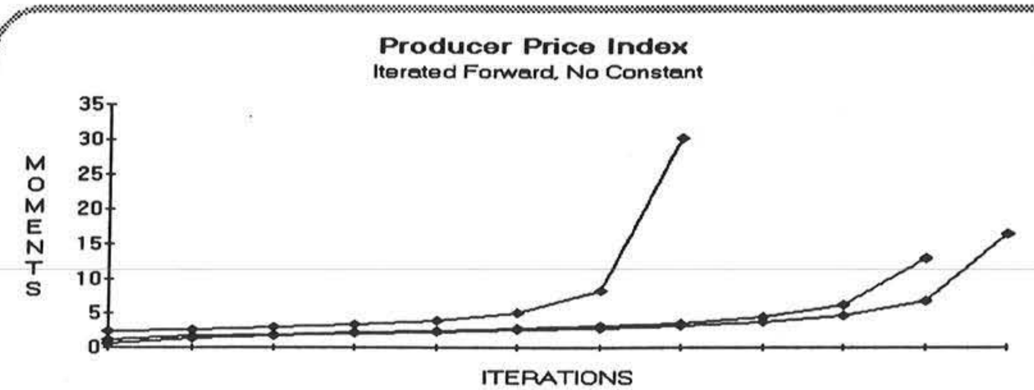

Figure 2: Chaotic function for PPI iterated forward in time without constant

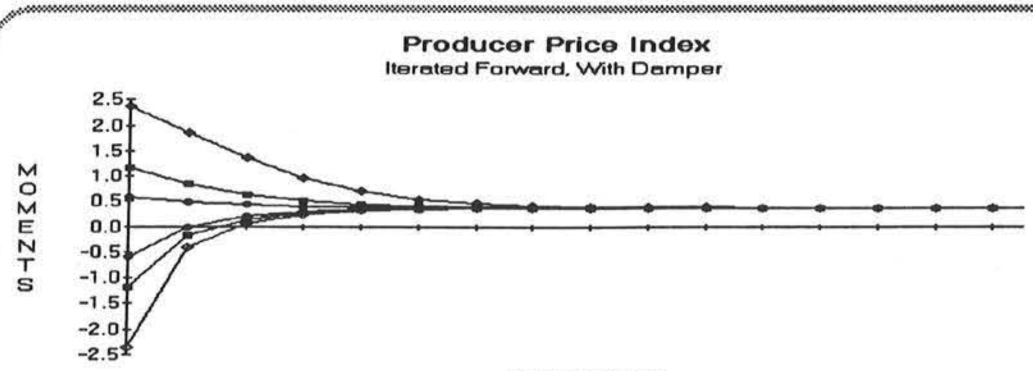

Figure 3: Chaotic function for PPI iterated forward in time with damping constant

Next, a backward iteration was performed to identify a plausible initial condition that could have produced the attractor that was obtained. Here, all six starting conditions converged to an epicenter of 0.74 moments (Figure 4). After subtracting the $\theta 2$ constant, the epicenter corresponded to -0.26%. This value represents a near-balance of forces affecting price increases and decreases, with a slight tendency toward price decreases.

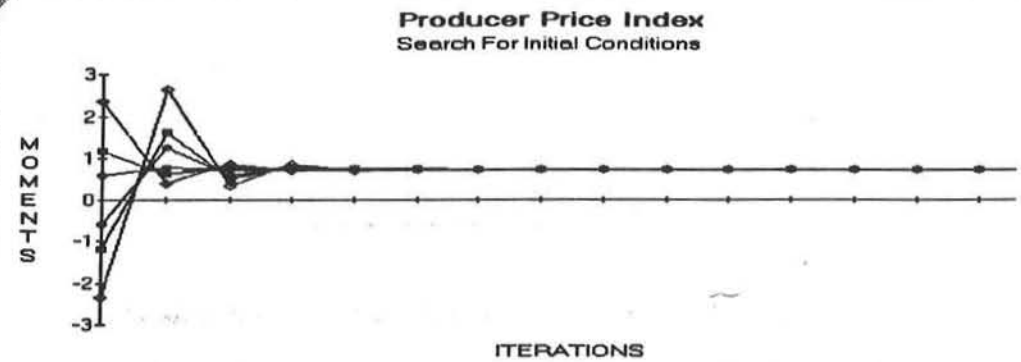

Figure4: Chaotic function for PPI iterated backward in time to determine its epicenter

Consumer Price Index

Estimates of λ and ss were 0.00 and 3.31, respectively; the latter was the ordinary standard deviation. For reference purposes, the CPI for the 1948-1995 time series appear in Figure 5. To simplify the diagram, each point represented in Figure 5 is an average of the 12 monthly observations for each year (except 1995 which contains two observations).

A chaotic attractor was isolated for the CPI ($R^2 = .85$) with $D_L = 1.49$ at a three-month lag interval (554 observations). The resulting function was:

(10) $z_2 = e^{(0.398)z1} - 0.555.$

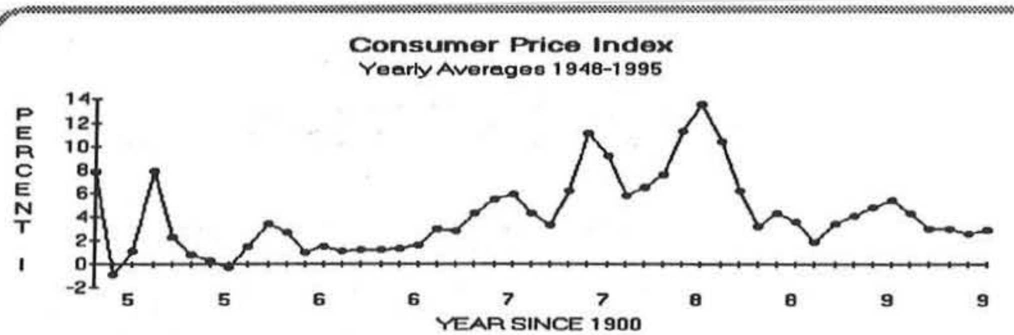

Figure 5: Annual average CPI inflation rates for the U.S. 1948 - 1995

The attempt to test a bifurcation model resulted in a nonsignificant exponent, such that the null hypothesis of linearity was upheld. The time series was well-approximated, however, by the linear autoregressive function, whereby fluctuations were dampened from quarter to quarter and a small increase in inflation was added ($R^2 = .90$). The test for the linear effect over time showed a poor level of fit, by contrast ($R^2 = .40$).

To explore the implications of the nonlinear function, Eq. 10 was iterated backwards without the constant to identify the epicenter of the chaotic attractor. Asymptotic stability was obtained at z = 0.324 moments, which, after subtracting the constant and multiplying by the scale parameter, resulting in an epicenter value of -0.76%. This value represented a small downward push on prices. The results are shown in Figure 6 for initial conditions of 3%, 6%, and 12% inflation.

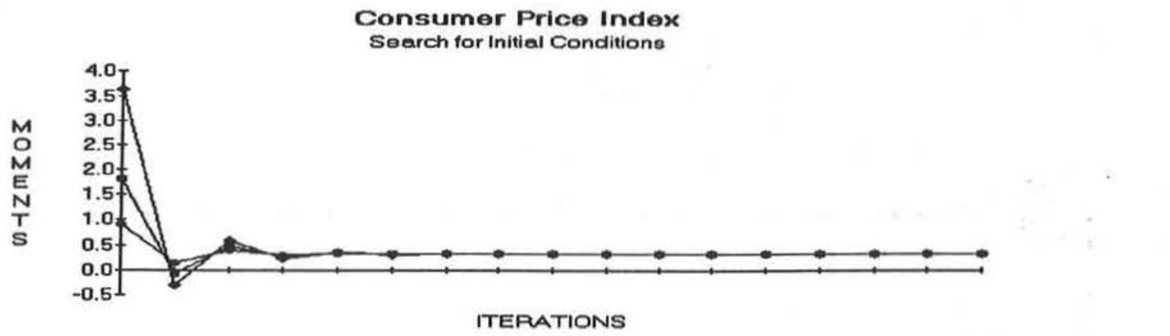

Figure 6: Chaotic function for CPI iterated backward in time to determine its epicenter

Eq. 10 was then iterated forward in time with the constant, using the same set of initial conditions. For initial conditions of 3% and 6%, the function converged asymptotically to 0.84 moments, corresponding to 2.78% inflation. For initial conditions of 12% inflation, however, there was a surprise -- inflation grew slowly, then took off at runaway proportions. Figure 7 shows a bit a surfing that was undertaken to determine the critical initial condition that would be responsible for inflation containment and runaway conditions. The critical value was between 3.55 and 3.56 moments, corresponding to initial conditions of 11.75% and 11.78% inflation, respectively.

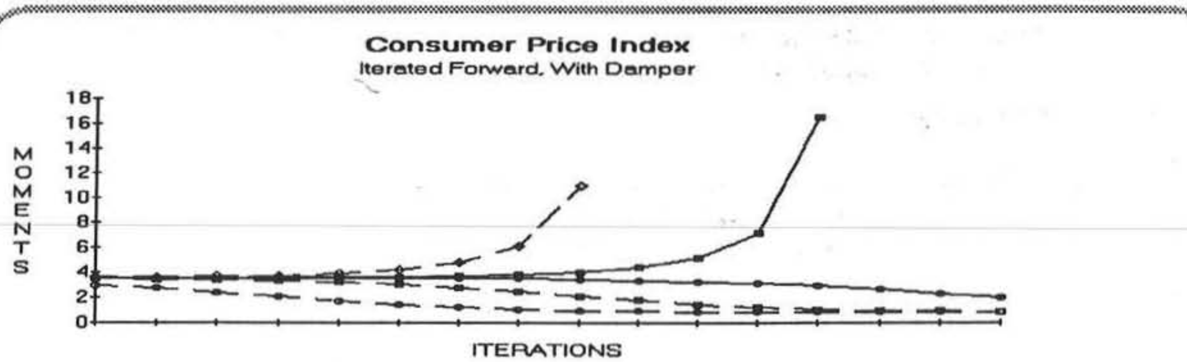

Figure 7: Chaotic function for CPi iterated forward in time, showing critical point, natural rates of inflation, and conditions for runaway inflation

Discussion

The results of the study showed low-dimensional chaos for U.S. inflation rates during the 1948-1995 era, with a Lyapunov dimensionality of approximately 1.5. Although there was short timer linear prediction of inflation rates, the global picture was, nonetheless, chaotic. The effect held up for both the PPI and CPI, and the effect was somewhat stronger for the CPI.

The chaotic function was explored to determine critical points of stability and bifurcation. In the case of the PPI, Keynes' theoretical claim that the equilibrium for price change was 0.0% was reasonably well supported. The epicenter of the chaotic attractor was actually -0.25%, indicating a slight tendency to hoard cash. Forward iteration showed asymptotic stability for a variety of initial conditions at 1.93% inflation. This value is taken as a natural rate for the PPI.

In the case of the CPI, the epicenter was located at -0.76% indicating a somewhat stronger bias toward savings compared to the PPI. This bias may reflect uncertainties of employment, but the data set analyzed here did not contain sufficient information to confirm this explanation. Forward iteration, however isolated a bifurcation point at 11.75% inflation, below which asymptotic convergence to 2.78% inflation was obtained. This value was taken as a natural rate for the CPI. Inflation skyrockets for initial conditions above the theoretical critical point.

The forward iterations for the PPI and CPU with and without the constant indicate that the constant is doing more work than adjusting the location parameter. Rather, it appears to represent an agglomeration of counterforces that work to damped inflation, such an unemployment levels, Federal monetary policy, and agricultural subsidies to contain food prices, and so on.

Future research on inflation dynamics should interlock data for unemployment trends, wage trends, and prices on critical imported products such as foodstuffs and oil. Schultze (1959) explicitly noted that his analyses did not pay any special attention to import prices, which he just regarded as just another commodity cost. Although that assumption may have been realistic for the U.S. in the 1950s, the economy of the 1990s is clearly globalized, and the U.S. has a negative balance of trade with the world. It is unclear how global economic dynamics may induce a bifurcating effect on the natural rate attractors described here. Strong bifurcation effects could promote chaotic instability throughout the economy, which would be eventually followed by self-organization into a very different economic picture.

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