

PRECURSORS OF THE P-STAR MODEL

Thomas M. Humphrey

Because the price level rises by a lesser extent than required for long-run equilibrium during the initial period of higher money growth, the price level has some catching up to do to reflect the higher rate of money growth. The rate of price change—the inflation rate—will therefore be above the long-run rate during this phase of the adjustment.

William Poole, *Money and the Economy: A Monetarist View*, p. 95.

Introduction

The preceding quotation states what economists have long observed: Prices, due to their initial lag in adjusting to unanticipated monetary changes, must temporarily rise at a faster-than-equilibrium pace if they are to reach their new equilibrium level consistent with the monetary change. Recently, analysts at the Board of Governors of the Federal Reserve System have embodied this insight into their latest inflation forecasting schema, the P-Star model—so-called because it refers to the equilibrium level P^* to which actual prices P tend to adjust.¹ From the gap or discrepancy between equilibrium and actual prices, $P^* - P$, the P-Star model predicts the direction of movement of the inflation rate. More precisely, it predicts that inflation will rise, fall, or stay unchanged as actual prices are below, above, or at their equilibrium level. Here is an inherently plausible inflation forecasting model that anyone can understand. Small wonder that it has caught the attention of the popular press, including the *New York Times*, *Business Week*, *The Wall Street Journal*, and the *American Banker*.²

The *New York Times* has hailed P-Star as a “new theory.”³ In fact, however, P-Star is neither new nor is it solely a theory. Instead it combines the

quantity theory of money with the observed empirical fact of lagged price adjustment into a predictive model whose major components have existed for at least 230 years. Every economist who ever believed (1) that the long-term trend of prices is roughly determined by money per unit of full-capacity real output, (2) that actual prices adjust to this trend with a lag, and (3) that during the process of adjustment such prices will be rising faster (or slower) than their trend rate of change qualifies as a P-Star proponent. Besides giving these ideas a catchy name, the Board has condensed them into an econometric equation that tracks inflation well. But the ideas themselves have a long tradition in mainstream monetary theory. To provide some needed historical perspective, this article documents the preceding assertions by showing that quantity theorists from David Hume to Milton Friedman would have recognized the P-Star model as a formalization of their own views on inflation. Before doing so, however, it is necessary to spell out the essentials of the P-Star model itself so that one can specify what earlier monetary theorists had to say about it.

The P-Star Model

The P-Star model is simple and straightforward. From the quantity theory equation of exchange $MV = PQ$, it defines equilibrium prices P^* as the product of the relevant money stock $M2$ per unit of potential output ($M2/Q^*$) and $M2$'s equilibrium circulation velocity V^* . In symbols, $P^* = M2V^*/Q^*$ with the asterisks referring to equilibrium magnitudes of the attached variables. Then the model predicts that inflation (1) will rise when actual prices P fall short of equilibrium prices P^* , (2) will fall when P exceeds P^* , and (3) will remain unchanged at a steady rate determined by the differential growth rates of money and real output when P equals P^* . In short,

¹ Jeffrey J. Hallman, Richard D. Porter and David H. Small, “M2 per Unit of Potential GNP as an Anchor for the Price Level,” April 1989, Staff Study 157, Board of Governors of the Federal Reserve System.

² Peter T. Kilborn, “Federal Reserve Sees a Way to Gauge Long-Run Inflation,” *New York Times*, June 13, 1989, sec. A, p. A1. “Putting Keynes’s Head on Milton Friedman’s Body,” *Business Week*, July 31, 1989, p. 66. Lindley H. Clark, Jr., “The Difficulties of Doing In the Dollar,” *The Wall Street Journal*, June 16, 1989, p. 6. H. Erich Heinemann, “Cure for Greenspan’s Dilemma Is Not to Be Found in Formula,” *American Banker*, June 19, 1989, p. 4.

³ Kilborn, “Federal Reserve,” p. A1.

$\Delta I = f(P^* - P)$ where ΔI denotes a change in the inflation rate and f is an empirical function relating that inflation change to the price gap which causes it. In other words, if no price gap exists then inflation remains unchanged at its given inherited rate sufficient to keep actual and equilibrium prices growing along the same path. But if actual prices fall short of equilibrium prices, inflation must rise to bring P up to P^* thus restoring equality between the two. That is, actual prices must temporarily climb a steeper path to reach equilibrium. Conversely, if actual prices exceed equilibrium prices, inflation must fall to bring actual into line with equilibrium prices. In short, the price gap $P^* - P$ predicts the direction of movement of the inflation rate.

Figure 1 illustrates how a price gap produces a rise in the inflation rate that lasts until the gap disappears. Depicted on the diagram are hypothetical time paths of equilibrium (dashed line) and actual (solid line) prices. The slopes or rates of change of these lines represent inflation rates. Up to time t_0 actual and equilibrium prices are the same. At time t_0 , however, a presumed rise in the rate of monetary expansion raises the equilibrium rate of inflation and opens a gap between equilibrium and actual prices. After a lag, actual prices start to rise. To reach equilibrium, however, they must grow at a rate in excess of the equilibrium inflation rate (slope $CD >$ slope BE) before stabilizing at that latter rate. During the interval of adjustment, the actual inflation rate temporarily rises above the equilibrium or steady-state rate. It also rises above its initial (preexisting) rate (slope $CD >$ slope AC). Here is the model's prediction that an emerging price gap augurs a temporary rise in inflation.

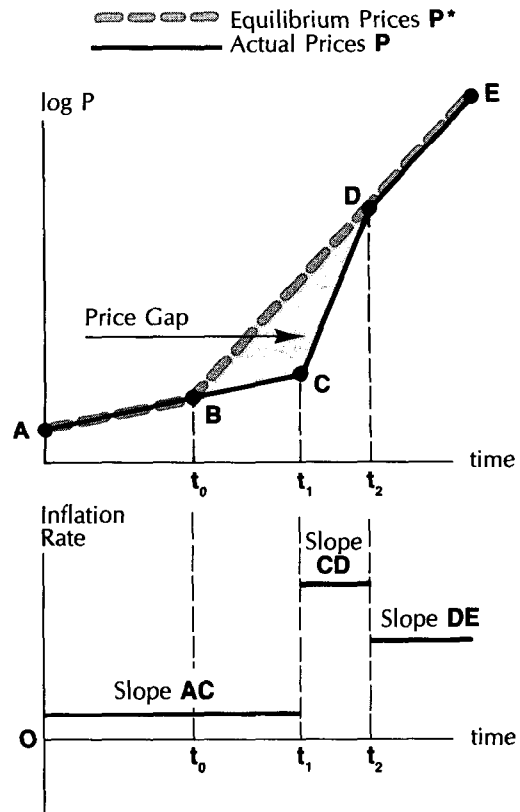
The price gap also implies the existence of corresponding output and velocity gaps—a result dictated by the equation-of-exchange identity $MV = PQ$. To preserve the identity, changes in the money stock M not absorbed by changes in prices P must be absorbed by changes in real output Q and velocity V . Accordingly, one or both of those variables must deviate from their long-run equilibrium values until P converges on its equilibrium level P^* dictated by the monetary change. In this way, an emerging price gap presaging changes in inflation ΔI also presages temporary movements in output and velocity about their long-run equilibrium levels. Thus for a given realized equilibrium money stock the price gap is equivalent to the sum of the velocity and output gaps.

Historical Roots

The ideas underlying the P-Star model have a rich heritage. They were endorsed by virtually every

Figure 1

P-STAR DIAGRAMMED: Price Gap Presages Rise in Inflation



At time t_0 a rise in money's growth rate steepens the path of equilibrium prices and opens a gap between them and actual prices. Actual prices, because they adjust with a lag, must subsequently accelerate to reach their equilibrium level at point D . The inflation rate therefore rises before stabilizing at its steady-state rate.

Conclusion: The price gap heralds a rise in inflation.

quantity theorist who ever believed that prices respond to money with a lag. To these analysts such a lagged price response implied at least two things. First, a money-induced jump in the equilibrium price level (or a steepening of its time path) would open a gap between equilibrium and actual prices that would last until the latter fully adjusted to the former. Correspondingly, real output would exhibit a temporary rise and velocity perhaps a temporary fall before returning to their pre-existing equilibrium levels. Second, during the interval of adjustment, actual prices would have to rise at a faster-than-

equilibrium rate if they were to reach their equilibrium level. In this way an emerging price gap ($P^* > P$) would herald a rise in the inflation rate just as a reverse gap ($P^* < P$) would herald its fall.

David Hume

Among early quantity theorists, David Hume (1711-76) expressed the foregoing view most succinctly. In his 1752 essays "Of Interest" and "Of Money" he argued four points. First, increases in the money stock produce equiproportional increases in the equilibrium price level consistent with output and velocity being at their long-run equilibrium levels. That is, $\Delta P^* = (V^*/Q^*)\Delta M$. Second, owing to initial distribution effects, imperfect information, sluggish nominal wages, and price perception errors, actual prices temporarily lag behind equilibrium prices. Third, their incomplete adjustment is, assuming no velocity gap, completely offset by compensating transitory rises in real economic activity above its equilibrium level. Fourth, the same process works for falls in the equilibrium price level. Such falls induce a temporary depression of real activity during the deflationary convergence of actual to equilibrium prices.

In Hume's own words:

Augmentation [in the quantity of money] has no other effect than to heighten the price of labour and commodities. . . . In the progress toward these changes, the augmentation may have some influence, by exciting industry; but after the prices are settled, suitably to the new abundance of gold and silver, it has no manner of influence.⁴

Though the high price of commodities be a necessary consequence of the encrease of gold and silver, yet it follows not immediately upon that encrease; but some time is required before the money circulates through the whole state, and makes its effect be felt on all ranks of people. At first, no alteration is perceived; by degrees the price rises, first of one commodity, then of another; till the whole at last reaches a just proportion with the new quantity of specie which is in the kingdom. In my opinion, it is only in this interval or intermediate situation, between the acquisition of money and rise of prices, that the encreasing quantity of gold and silver is favourable to industry. When any quantity of money is imported into a nation, it is not at first dispersed into many hands, but is confined to the coffers of a few persons, who immediately seek to employ it to advantage. . . . They are thereby enabled to employ more workmen than formerly, who never dream of demanding higher wages, but are glad of employment from such good paymasters. If workmen become scarce, the manufacturer gives higher wages, but at first requires an encrease of labour; and this is willingly submitted to by the artisan, who can now eat and drink better, to compensate his additional toil and fatigue. . . . It is easy to trace the money in its progress through the whole commonwealth;

⁴ David Hume, *Writings on Economics*, ed. Eugene Rotwein (Madison: University of Wisconsin Press, 1955), p. 48.

where we shall find, that it must first quicken the diligence of every individual, before it encrease the price of labour. . . . There is always an interval before matters be adjusted to their new situation; and this interval is as pernicious to industry, when gold and silver are diminishing, as it is advantageous when those metals are encreasing.⁵

Here then, is Hume's anticipation of the P-Star model: During transition periods actual prices deviate from equilibrium ones as do output and employment from their normal levels. Those deviations are corrected either by inflation (when $P^* > P$) or by deflation (when $P^* < P$). Either case requires a temporary change in the inflation rate from its zero steady-state level assumed by Hume. The price gap predicts the direction, positive or negative, of changes in the inflation rate.

Hume's Case Diagrammed

As the prototypal P-Star model, Hume's analysis warrants diagrammatic treatment (see Figure 2). The top diagram shows the time paths of actual (solid line) and equilibrium (dashed line) prices. The bottom line shows the time path of the inflation rate which is the same as the slope or rate of change of the path of actual prices. Up to time t_0 actual and equilibrium prices coincide at a zero rate of inflation. At time t_0 a one-time jump in the money stock raises equilibrium prices as shown by the corresponding jump or step increase of the P^* path from B to C. Were actual prices P to adjust instantaneously they too would rise from B to C without, however, affecting the inflation rate (slope of CD equals the slope of AB). Instead, they adjust with a lag over the path BD. During the adjustment period (t_0 to t_1) the rate of inflation (slope of BD) will be higher than its steady-state rate of zero. Consistent with the P-Star model, the price gap produces a rise in the inflation rate. This rise, however, vanishes when the price gap disappears. Using this same technique, one can also show how a step fall in P^* , by creating a negative price gap, produces a temporary fall in the inflation rate below its zero steady-state level as actual prices traverse a descending path to equilibrium.

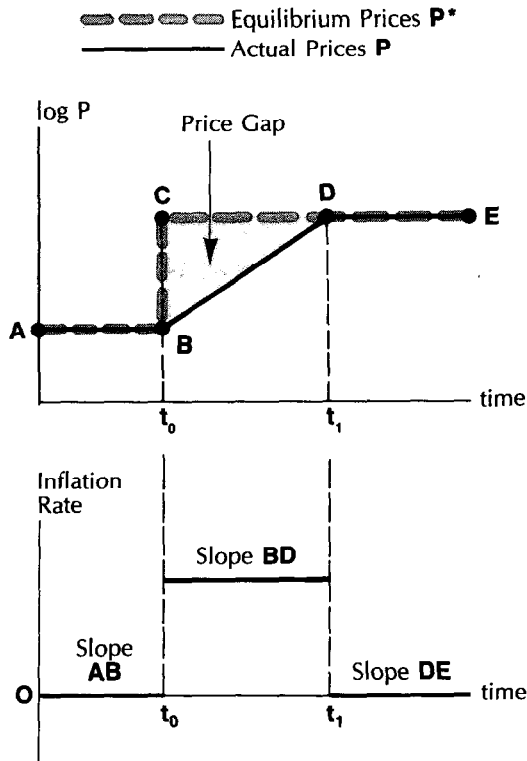
Henry Thornton

After Hume, Henry Thornton (1760-1815) also enunciated the essentials of the P-Star model. In his classic *The Paper Credit of Great Britain* (1802), Thornton explicitly stated (1) that changes in the money stock produce equiproportionate changes in equi-

⁵ *Ibid.*, pp. 37-8, 40.

Figure 2

HUME'S ANALYSIS



At time t_0 a one-time jump in the money stock raises equilibrium prices and opens a gap between them and actual prices. Inflation closes the gap by raising actual prices via the path BD to their equilibrium level. Inflation then drops back to its zero steady-state rate.

Conclusion: The price gap produces a temporary rise in inflation that ends when the gap disappears.

librium prices⁶ as implied by the equation $\Delta P^* = (V^*/Q^*)\Delta M$, (2) that, due to incomplete information, sluggish nominal wages, and price perception errors, actual prices temporarily lag behind equilibrium prices, (3) that the resulting price gap is, in the absence of a velocity gap, matched by compensating deviations of output and employment from

⁶ An increased money stock, wrote Thornton, will "be occupied in carrying on the sales of the same, or nearly the same, quantity of articles as before, at an advanced price the cost of goods being made to bear the same, or nearly the same, proportion to their former cost, which the total quantity of paper at the one period bears to the total quantity at the other." Henry Thornton, *An Enquiry into the Nature and Effects of the Paper Credit of Great Britain* (1802), ed. F.A. von Hayek (New York: Rinehart and Company, Inc., 1939), p. 241.

their natural equilibrium levels,⁷ and (4) that such deviations eventually vanish when actual prices converge on equilibrium ones.⁸ Since actual prices must rise (or fall) at a faster pace if they are to reach equilibrium, these propositions imply that the price gap $P^* - P$ is a good indicator of forthcoming changes in the inflation rate.

Thomas Attwood

Thornton focused on how P-Star price gaps presage changes in inflation. By contrast, Thomas Attwood (1783-1856), an inflationist proponent of full employment at any cost and leader of the so-called Birmingham School, focused on the output and employment implications of the price gaps. Like Thornton, Attwood acknowledged (1) that prices lag behind monetary changes, (2) that the resulting gap between actual and equilibrium prices requires a rise in inflation to bring the former into line with the latter, and (3) that the logic of the equation of exchange dictates that price gaps must be matched by compensating gaps in output and employment as those variables deviate from their equilibrium magnitudes. But whereas Thornton held that such gaps were of temporary duration only and could not be exploited for policy purposes, Attwood thought that they could be sustained by a continuous succession of monetary injections. According to him, such injections would keep equilibrium prices forever marching ahead of actual prices, perpetually frustrating the latter's attempts to catch up. Output and employment would in this way be given a permanent stimulus. To this end he advocated inflationary monetary policy to achieve absolute full employment. Said he,

I beg to be understood as . . . recommending that the Bank . . . be obligated or otherwise be induced, to increase the circulation of their notes as far as the national interests may require, that is to say, until all the labourers in the kingdom are again in full employment at ample wages.⁹

⁷ ". . . additional industry will be one effect of an extraordinary emission of paper, a rise in the cost of articles will be another.

Probably no small part of that industry which is excited by new paper is produced through the very means of the enhancement of the cost of commodities." *Ibid.*, p. 237.

⁸ With the closure of the price gap, money has no effect other than to "set to work labourers, of whom a part will be drawn from other, and, perhaps, no less useful occupations" such that aggregate real activity remains unchanged. *Ibid.*, p. 236.

⁹ Thomas Attwood, Postscript to *A Letter to the Earl of Liverpool* (1814), p. 44, in *Selected Economic Writings of Thomas Attwood*, ed. Frank W. Fetter (London: The London School of Economics and Political Science, 1964).

Elsewhere he reiterated this sentiment when he declared that prosperity has occurred whenever the government has

filled the Country with what is called *Money*; and this *plenty of Money* has necessarily produced a general elevation of prices; and this general elevation of prices has necessarily produced a general increase of *profit* in all occupations; and this general increase of *profits* has, as a matter of course, given activity to every trade in the kingdom; and whilst the workmen, in one branch of trade, are *producing* one set of articles, they are inevitably *consuming* an equal amount of all other articles. This is the *prosperity of the Country*, and there is no other prosperity which ever has been enjoyed, or ever can be enjoyed.¹⁰

In short, Attwood's version of the P-Star model allowed monetary changes to exert permanent non-neutral effects on real variables. By contrast, Thornton's version allowed for temporary nonneutrality only. So too did the version enunciated by John Stuart Mill (1806-73) in his celebrated 1833 critique of Attwood's inflationist schemes.¹¹ There Mill argued that, once information and price-perception lags are inevitably overcome, equilibrium prices dictated by money per unit of capacity output are realized promptly such that output and employment gaps disappear. It follows, said Mill, that such gaps are at best transitory phenomena that cannot be sustained by expansionary policy.

Other Classical Economists

Of course, not *all* classical quantity theorists accepted the P-Star model with its presumption of the short-run nonneutrality of money. David Ricardo (1772-1823) and John Wheatley (1772-1830), for example, believed that prices and inflation rates were *always* at their equilibrium levels such that no price gaps or associated nonneutralities could emerge. While agreeing that money determines the price level and money's growth the rate of inflation, these theorists rejected the notion of lagged price adjustment and the resulting transitory output and employment effects stemming from it. But their view was not universally held. For the most part, classical and neoclassical quantity theorists took the position of Hume, Thornton, Attwood, and Mill: they believed in lagged price adjustment and the temporary nonneutrality of monetary shocks. Except for Attwood and his fellow Birmingham inflationists, however, all agreed that price gaps eventually vanished and hence money was neutral in the long run.

¹⁰ Thomas Attwood, *The Late Prosperity, and the Present Adversity of the Country Explained* (1826), pp. 11-12, in *Selected Economic Writings of Thomas Attwood*.

¹¹ John Stuart Mill, "The Currency Juggle," *Tait's Edinburgh Magazine* (1833), reprinted in Vol. I. of *Mill's Dissertations and Discussions* (Boston, 1865), pp. 68-81.

Irving Fisher

Irving Fisher (1867-1947) endorsed the elements of the P-Star model in his *Purchasing Power of Money* (1912). On the distinction between equilibrium prices that vary equiproportionally with money according to the P-Star equation $\Delta P^* = (V^*/Q^*)\Delta M$ and those actually prevailing during transition adjustment periods, Fisher remarked: "The strictly proportional effect on prices of an increase in M is only the *normal* or *ultimate* effect after transition periods are over."¹²

Regarding the delayed response of prices to monetary shocks such that other variables in the equation of exchange absorb part of the shocks, he used a train analogy. "Normally the caboose [P] keeps exact pace with the locomotive [M], but when the train is starting or stopping this relationship is modified by the gradual transmission of effects through the intervening cars [V and Q]."¹³

Again, on the transition period when the economy adjusts to monetary shocks partly through temporary movements in velocity and output and partly through prices, he observed: "As to the periods of transition, we have seen that an increase in M produces effects not only on the p's, but on all the magnitudes in the equation of exchange. . . . We have seen, for instance, that a sudden change in the quantity of money and deposits will temporarily affect the velocities of circulation and the volume of trade."¹⁴ These velocity and output gaps, he noted, vanish once actual prices P converge on equilibrium prices P*.

Finally, on actual prices rising or falling to equilibrium at a faster-than-steady-state pace (assumed zero by Fisher), he wrote: "*Rising* [actual] prices must be clearly distinguished from *high* [equilibrium] prices, and *falling* from *low*. . . . Rising prices mark the transition between a low and a high [equilibrium] level of prices, just as a hill marks the transition between flat lowlands and flat highlands."¹⁵ Fisher's analysis, like the Board's P-Star model, predicts a rise in inflation when equilibrium prices P* exceed actual prices P. Conversely it predicts a fall in inflation when P exceeds P*.

Holbrook Working

The 1920s saw variants of the P-Star model employed in statistical tests of the quantity theory

¹² Irving Fisher, *The Purchasing Power of Money*, 2nd revised ed., 1922. (New York: Kelley, 1963), p. 159.

¹³ *Ibid.*, p. 161.

¹⁴ *Ibid.*, p. 159.

¹⁵ *Ibid.*, p. 56.

of money. For example, Holbrook Working (1895-1985) in his 1923 *Quarterly Journal of Economics* article "Prices and the Quantity of Circulating Medium, 1890-1921" used the model to show that money stock changes cause price level changes, albeit with a lag. Similar to Fisher and his predecessors, Working argued (1) that equilibrium prices are determined by velocity-adjusted money per unit of real transactions with the transactions and velocity variables being at their long-run normal or trend levels, (2) that actual prices adjust to equilibrium prices with a lag, (3) that during the adjustment period velocity and real transactions deviate from their long-run normal values, and (4) that such deviations vanish when actual prices converge on equilibrium ones.

To demonstrate these points, Working presented time series charts comparing actual and equilibrium prices for the period 1890-1921. The equilibrium price series he derived by multiplying each year's average money stock by the normal or trend value of the velocity-to-real-transactions ratio.

By substituting in the equation $MV/T = P$ the values of the index number of circulating medium (M) and of the index number of normal values of V/T it is possible to obtain what may be called normal values of P.¹⁶

Upon comparing these computed equilibrium prices with the corresponding series of actual prices Working found that the latter tended to adjust to the former with a six- to nine-month lag. This lag itself affected the time path of prices. To reach equilibrium, actual prices had to rise at a faster- or slower-than-equilibrium pace depending upon whether they were initially below or above their equilibrium level. In other words, inflation temporarily rose or fell to eliminate price gaps and the associated deviations-from-equilibrium of the velocity-to-transactions ratio. For just as

the departure of the actual price level from the [normal] price level . . . is associated with a corresponding departure of the actual value of V/T from the normal value of V/T ¹⁷

it follows that the

actual value of V/T being thus reduced below its normal value, as determined by the habits, business custom and productive power of the population, V/T tends to be restored to normal by an increase in P [as the latter variable eventually fully adjusts to the prior monetary change].¹⁸

¹⁶ Holbrook Working, "Prices and the Quantity of Circulating Medium, 1890-1921," *Quarterly Journal of Economics* 37 (February 1923): 242.

¹⁷ *Ibid.*, p. 250.

¹⁸ *Ibid.*, p. 233.

In short, velocity and output gaps disappear when actual prices converge to their equilibrium level. Here are all the components of the P-Star model, the statistical findings on which Working interpreted as confirming the quantity theory hypothesis of money-to-price causality.

Carl Snyder

Working was not the only analyst in the 1920s to publish time series charts comparing actual and equilibrium prices. Carl Snyder (1869-1943), an economist with the Federal Reserve Bank of New York, also published such charts.¹⁹ Like Working, Snyder derived his equilibrium price series by multiplying each period's average level of bank deposits (M) by the normal or trend value of the ratio of velocity to trade, and substituting the results into the equation $P = MV/T$. For actual prices he computed his own index of the general price level. Unlike Working, however, he attributed differences in the two price series to measurement error and not to temporary deviations in the velocity-to-trade ratio from its long-run normal or trend value. He argued that velocity and trade moved in unison in the short run, exhibiting identical and offsetting deviations from equilibrium such that the ratio V/T never varied from its trend value.²⁰ Thus, except for measurement error, equilibrium and actual prices should always be the same. Strictly speaking, Snyder's denial of the existence of price gaps $P^* - P$ and of the resulting need for inflation changes ΔI to close them disqualifies him as a P-Star proponent. Nevertheless, he did anticipate the empirical charts employed by Board P-Star economists today. His charts and their use by the New York Fed in the 1920s invalidate the *New York Times* statement that "The Fed has never had such a tool."²¹

Milton Friedman

Among modern quantity theorists, Milton Friedman stands as the foremost anticipator of the P-Star model. All the model's elements—long-run prices determined by velocity-adjusted M2 per unit of output, lagged price response, transitory velocity and output gaps, price gaps and the resulting changes in inflation—are to be found in his monetarist analysis of the inflationary process.

¹⁹ See his "New Measures in the Equation of Exchange," *American Economic Review* 14 (December 1924): 699-713.

²⁰ He further argued that velocity was trendless such that it played no role in price level movements.

²¹ Kilborn, "Federal Reserve," p. A1.

According to Friedman, a permanent increase in growth rate of money per unit of output steepens the associated time path of equilibrium prices. Actual prices, however, do not immediately adjust. Instead, velocity at first falls and then output rises to absorb the burden of adjusting to the monetary change. Prices eventually respond, converging on their equilibrium level as velocity and output return to their long-run natural magnitudes. Prices, because they lagged behind, must for a time grow at a faster-than-equilibrium pace if they are to reach their higher equilibrium level. Thus the emergence of a gap between equilibrium and actual prices signifies a temporary rise of inflation above its steady-state rate. In this connection, Friedman presents in his 1969 essay "The Optimum Quantity of Money" a diagram showing inflation rising above its steady-state rate before stabilizing at that rate as prices P move to their equilibrium level P^* .²²

Monetarist Textbooks

The preceding has focused on the scholarly literature. But the essentials of the P-Star model also found expression more than ten years ago in at least two monetarist textbooks. Thus Michael Darby on page 160 of his 1976 text *Macroeconomics* presents a diagram showing (1) lagged adjustment of actual to equilibrium prices, (2) the resulting price gap $P^* - P$, (3) the corresponding output gap $Q - Q^*$, and (4) the resulting changes in the inflation rate.

Darby assumes a permanent steepening of the time path of equilibrium prices owing to a permanent increase in the growth rate of money. Sticky nominal wages, however, cause actual prices to lag equilibrium prices, opening a gap between P^* and P . Output immediately adjusts in lieu of prices by rising temporarily above its equilibrium path. Inflation then rises

²²See Milton Friedman, *The Optimum Quantity of Money and Other Essays*. (Chicago: Aldine, 1969), p. 13.

to bring P into line with P^* as output returns to its natural equilibrium level. With the closing of the price and output gaps, inflation stabilizes at its long-run steady-state rate. This much is consistent with the P-Star model.

Similarly, William Poole on page 96 of his 1978 text *Money and the Economy: A Monetarist View* presents a diagram depicting hypothetical time paths of the price level, the unemployment rate (a proxy for real output), and the money stock. Poole's diagram shows how a rise in the growth rate of the money stock steepens the steady-state path of equilibrium prices and implicitly opens a gap between equilibrium and actual prices. To reach equilibrium, actual prices must for a time rise at a faster-than-equilibrium pace. That is, inflation must rise before stabilizing at its steady-state rate. During the adjustment process, unemployment moves in lieu of prices before returning to its long-run natural level. Here again is the essence of the P-Star model.

Conclusion

The P-Star model is hardly new; its essential components have been in use for a long time. Employing these components the Board has estimated the short-run dynamics of the relationship between the price gap $P^* - P$ and changes in inflation ΔI and has shown that the relationship accurately predicts inflation's behavior over the last decade or so.

To be sure, the model is based on an observed empirical regularity—namely prices' lagged response to monetary shocks—that may not hold across all policy regimes. Nevertheless, as a practical forecasting tool the model has much to recommend it. Besides tracking recent inflation well, it has over a longer period survived the test of time, having been used successfully by quantity theorists as far back as David Hume. Equally important, it focuses on the price level, the one variable with which the Fed should be most concerned.

THE U.S. PRODUCTIVITY SLOWDOWN: WHAT THE EXPERTS SAY

William E. Cullison

U.S. productivity growth has slowed significantly since 1973; moreover, U.S. productivity continues to grow at a slower rate than that of our major trading partners. What caused these things to happen? The answer to this question is still unsettled, although a number of potential explanations are being debated in the economics literature. These include energy prices, labor quality, measurement error, adequacy of mineral resources, governmental regulations, investment opportunities, managerial practices, and governmental trade policies. These explanations will be discussed in this article.

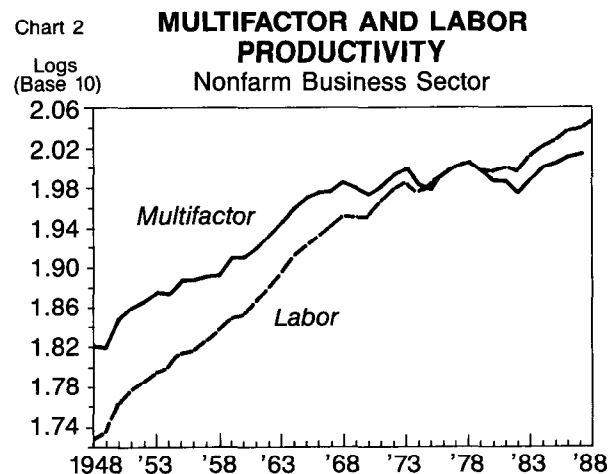
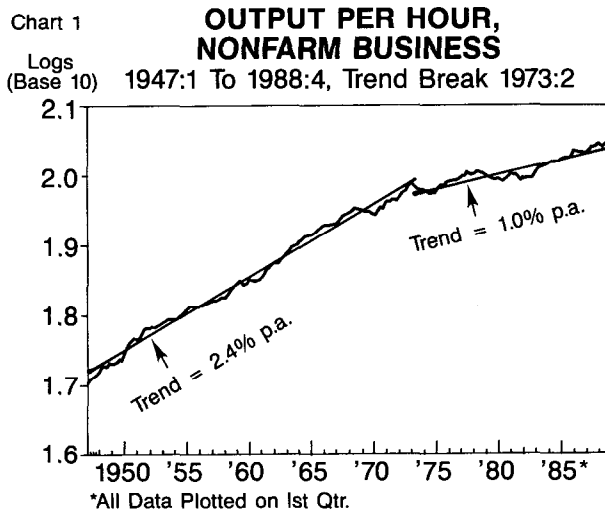
Two measures of productivity are commonly used. Labor productivity, or output per hour, is the simpler of the two to construct. To measure output per hour in the nonfarm business sector, one must first measure nominal output, defined as the market value of final goods and services produced in that sector. Then one must deflate the nominal output by the relevant price index to obtain real output. The final step requires dividing the estimate of real output by the number of hours worked in the nonfarm business sector to get per hour output.

Quarterly labor productivity data for the U.S. nonfarm private business sector from 1947 to 1987 are plotted on Chart 1. The chart shows actual labor pro-

ductivity plotted relative to the 2.4 percent per year trend that it averaged in 1947-73 and the 1 percent per year trend that it averaged in 1973-88.

Total factor productivity (TFP) is another way of measuring productivity. The TFP measure is popular among growth analysts because it provides information on the sources of economic growth. More precisely, TFP specifies the relative contributions to growth attributable to labor inputs, capital inputs, land inputs (occasionally), and productivity—the latter being the name given to the residual component of growth not attributable to the other three inputs. The productivity residual thus measures how efficiently the inputs of labor, capital and land are used in producing output. The actual estimation of TFP is complicated. Readers interested in studying total factor productivity in more detail might begin by reading the BLS publication, "Trends in Multifactor Productivity, 1948-81" [23], which contains references to other important works.

Chart 2 illustrates the different time paths of labor productivity (output per hour) and multifactor productivity (the BLS name for its measure of total factor productivity) over the 1948-88 time period. The chart illustrates that multifactor productivity growth after 1973 slowed by about the same amount as labor



productivity growth. In 1948-73 multifactor productivity averaged 1.7 percent growth per year, but the rate slowed to 0.2 percent in 1973-88.

Table I shows the growth in average U.S. labor productivity in the pre- and post-1973 periods in comparison to the productivity growth of selected other countries. The table shows that productivity growth worldwide has declined since 1973, but it also illustrates the second part of the productivity puzzle, that U.S. productivity growth, at 0.6 percent per year, remains well below that of a number of other countries.

I. THE DECLINE IN U.S. PRODUCTIVITY GROWTH SINCE 1973

In 1985, Edward Denison [10] published an exhaustive study of the U.S. productivity slowdown. He concluded that four factors clearly contributed to the post-1973 slowdown, two modestly and two substantially. The modest contributors were: 1) a decline in investment per worker and 2) more intensive environmental and worker protection regulations. The major contributors to the slowdown were: 1) the end of the population shift from low productivity farm and self-employed jobs to higher productivity jobs (15 percent of the slowdown), and 2) the effects of the 1973-75 and 1980-82 recessions on economic growth (16 percent of the slowdown).

In all, the Denison study attributed 40 percent of the post-1973 productivity slowdown to identifiable

sources. The study largely ignored the energy crisis, however, and dismissed declining labor quality as a source of slower productivity growth. This article will accept Denison's estimates of the effects of population shifts and the recessions on productivity, which together account for almost one-third of the 1.5 percentage point growth slowdown. Thus, only one percentage point per year remains to be explained.

Other possible sources of declining productivity growth include:

- Measurement error
- Declining labor quality
- Rising energy prices
- Environmental protection regulations
- Depletion of mineral resources
- Depletion of investment opportunities

Measurement Error¹

In a 1988 article [4], Martin Baily and Robert Gordon investigated whether a portion of the productivity slowdown could be attributed to measurement error. They found that there were serious

¹ This section relies heavily on the article by Martin Baily and Robert J. Gordon [4]. As the reader will observe, the section is somewhat longer than the relative importance of measurement error would seem to justify. The length of the section is justified, however, because the examples of measurement error found by Baily and Gordon are interesting in and of themselves, especially so to the financial services industries. Additionally, the examples should provide the casual reader with a necessary, but healthy, skepticism of economic data aggregates.

Table I

PRODUCTIVITY GROWTH IN THE BUSINESS AND MANUFACTURING SECTORS^a

(Average percentage changes at annual rates, selected countries)

	1960s ^b to 1973		1973-79		1979-86	
	Business	Mfg.	Business	Mfg.	Business	Mfg.
Belgium	5.0	7.2	3.0	5.0	2.4	4.1
Canada	2.9	4.1	2.0	1.2	1.3	1.4
France	5.9	6.4	3.5	4.0	2.4	2.5
Germany	4.9	4.8	3.4	3.3	2.0	2.4
Japan	8.6	10.3	3.2	5.2	2.8	6.3
Sweden	3.1	5.0	1.9	1.1	1.4	3.0
United Kingdom	3.3	4.1	1.2	0.6	1.9	3.4
United States	2.2	3.4	0.3	1.0	0.6	3.4

^a Output is value added in the business (GDP at factor cost excluding general government) and manufacturing sectors at constant prices. Productivity is labor productivity (output per employed person).

^b The starting years are as follows: Belgium 1962, Canada 1962, France 1964, Germany 1961, Japan 1967, Sweden 1964, United Kingdom 1960, and United States 1960.

Source: *OECD Economic Studies*, Spring 1988, p. 20.

problems with the way output and productivity were measured, but that, paradoxically, the problems did not help to explain much of the slowdown, basically for two reasons. First, some of the industries subject to measurement error sell much of their output to other businesses, so that measurement errors in those industries have less effect on aggregate productivity statistics. Second, there were measurement problems in earlier periods also—growth is understated now, but it was also understated before.

Baily and Gordon concluded that measurement error would account for 0.2 percentage points of the unexplained one percentage point per year slowdown in productivity growth since 1973.² They argued persuasively that although the official statistics had been underestimating productivity for years prior to 1973, measurement error had been getting worse since 1973, especially in the service sector.

Baily and Gordon observed that there was a fundamental paradox in the U.S. productivity data, namely, that the slow productivity growth has been accompanied by rapid, perhaps even accelerating, technological change. They cited a number of technological advances in the services sector, many of them emanating from the increased use of computers, which have revolutionized the processing of forms, payments, billings, and inventory control.

The finance industry, for example, offers all-in-one cash management accounts, automatic telephone machines for credit card approval, fast bill-paying by phone or personal computer, and 24-hour money machines. The airline industry offers preassigned seats and boarding passes, no-stop check-ins, frequent flyer plans, and flyer discounts aimed to the nonbusiness flyer. As a result of better inventory control, retailers can stock a larger variety of items with the same floor space. Drugstore chains have computerized prescription records. Hotel chains have frequent-stayer services, preprinted registration forms, and no-stop checkout. Restaurants, supermarkets, and hospitals provide itemized bills.

Despite these technological advances, measured productivity growth in the finance, insurance, and real estate sector is estimated to have declined at an average rate of 0.41 percent per year in the 1973-87 period after having risen an average of 1.41 percent

per year in the 1948-73 period. Productivity growth in retail trade averaged only one percent per year in 1972-86. Measured productivity in the air transportation industry also fell by 0.2 percent per year in 1972-86. This last statistic might not seem so strange, given some of the problems airlines have been facing. What makes it strange, however, is that a physical measure of productivity—scheduled airline passenger miles per employee—was rising substantially at a rate of 3.6 percent per year at the same time that conventionally-measured productivity was falling.

Baily and Gordon concluded that there is a basic problem in measuring the productivity of services. They also found problems in the measurement of productivity in air transportation and construction and found the productivity measurements in trucking and railroad transportation to be suspicious.

As noted above, labor productivity measures are calculated by first finding nominal output, then deflating that quantity by some price index. The resulting measure of real output is then divided by the number of labor units. Problems with measuring productivity almost invariably stem from problems in determining the right price index to use to get real output. This problem is particularly difficult when rapid technological changes have occurred.

For example, the personal computer used to write this article is 8-10 times faster and has twice the memory and four times the hard disk space of the 1983 model that it replaced. The total package for the old computer cost almost \$6000 in 1983, while the new computer package cost almost \$5000 in 1988. If a computer price index merely compared the prices of the two machines, it would show that computer prices in 1988 were 82 percent of what they were in 1983. In actuality, however, the new personal computer is a quite different product. As a result, such a price index would understate the actual decline in computer prices since 1983. A more appropriate measure would compare the price of the old computer to current prices of computers similar to the old one, which sell for approximately \$1500. An index based upon equivalent quality computers, therefore, would conclude that prices in 1988 were only 25 percent of what they were in 1983. The lesson is clear: an appropriate price index must take quality improvements into account.

In order to account for quality changes in the computer industry, the official price deflators for computers are derived in terms of price per computer “calculation” rather than price per computer “box.” Using this measure, the Bureau of Economic Analysis (BEA) estimated that computer prices fell during 1969-87 at a 14 percent annual rate.

² Baily and Gordon actually attributed 0.5 percentage points per year to measurement error (0.3 percentage points per year to declining labor quality) because they used a definition of total factor productivity that put changes in labor quality into the labor input. In their framework, overlooking a decline in the quality of labor would show up as a measurement error. For this article, however, declining labor quality is discussed as a distinct source of productivity decline.

Whether computer prices are measured appropriately by this index is open to debate. Edward Denison [9] argues that the current treatment of computers results in an *overstatement* of productivity growth in manufacturing, particularly in nonelectric machinery (which includes computers) since 1979. He observes that productivity measures that use GNP as the measure of output result in a double counting of the effects of computers—once as investment in nonelectric machinery and second as intermediate input embodied in final product. He also thinks the quality-adjusted computer prices used by the BEA tend to overstate the industry's real output.³

The problems in estimating the output of computers in times of rapid technological advance illustrate the difficulties involved in making productivity estimates for the manufacturing sector, where productivity is measured more accurately than elsewhere. The difficulties are multiplied when services need to be adjusted for quality changes. Baily and Gordon found a wide variety of specific measurement problems in service industries such as banking and insurance.

Consider the banking industry. It had no measured productivity growth in the 1948-73 period and only 0.05 percent growth per year in 1973-87. There are reasons to believe, however, that actual productivity in banking has increased fairly substantially since 1973. Improvements in handling paper checks and the increasing usage of electronic payments, for example, have resulted in substantial increases in real physical productivity in making payments. Loan processing has also become more efficient through the use of credit cards and lines of credit. The sustained growth in check and loan-processing productivity did not boost measured productivity in banking, however, because individual activities are weighted by their labor input shares. Thus, the more efficient activities such as credit card loans are considered to contribute less to bank output than conventional loans precisely because they utilize less labor.

Banks also have been providing customer conveniences through branching and 24-hour money machines. As a result, bank services in 1989 are a

³ Denison shows that output per hour in the total business sector—which averaged growth rates of 2.9 percent in 1948-73, 0.6 percent in 1973-79, 0.2 percent in 1979-82, and 2.2 percent in 1982-86—would have risen more slowly in 1979-82 (0.1 percent) and 1982-86 (1.8 percent) if it had not been for the exceptional productivity improvement in computer production. The slower productivity growth, of course, lies entirely within the manufacturing sector in which growth rates of 1.5 percent and 5.0 percent in 1979-82 and 1982-86 are reduced to 1.0 percent and 3.5 percent, respectively.

different (and considerably improved) product from bank services in 1970. Conventional productivity measures, however, do not consider convenience as a quality improvement, and branching is thought to reduce efficiency—it reduces the average population served by a bank office.

As another example, consider the insurance industry. The price indexes used to deflate the estimated value added in particular sectors of this industry are typically only loosely related to the true insurance "output." For example, the auto repair cost index is used to deflate value added by auto insurance, and the medical cost index is used to deflate the value added by health insurance. But these procedures lead to distortions. For example, because medical costs are rising so rapidly, the practice of deflating total value added in the health insurance sector almost certainly leads to an understating of the true growth of "output" in this industry and therefore the growth of productivity in the industry. Baily and Gordon argue "... given that the insurance industry has been able to benefit not only from computerization, but also from group policies, it is implausible that insurance costs should have risen faster than the price level for GNP" [4, p. 396].

As a result of the measurement error in banking and insurance and some questionable practices in measuring the deflator for commercial rental income in determining output in real estate, Baily and Gordon concluded that the growth of productivity in the finance, insurance, and real estate sector was probably understated by about 1.1 percent per year before 1973 and 2.3 percent per year after 1973.

Productivity growth in retail trade averaged 1.39 percent per year in 1958-72 and 1.0 percent per year in 1972-86. Baily and Gordon conclude that productivity in this sector is mismeasured because the BEA trade deflators do not consider consumer convenience to be a quality improvement, yet convenience has been one of the more important trends in retailing in the past two decades. Examples of the trend toward consumer convenience include the proliferation of sales catalogs, fast food establishments, automatic teller machines, 24-hour convenience stores, liberal store opening and closing times, laser scanners in supermarkets, and supermarkets that stock more varieties of items.

There are rather large differences between productivity in the transportation industries as measured by the Bureau of Economic Analysis and productivity measured in physical terms. The BEA estimates, for example, that productivity in the transportation industry grew at an average rate of 3.5 percent per year in 1948-73 but only 0.21 percent per year in

1973-86. In contrast, productivity measured in miles per employee rose at a fairly steady 3.3 percent per year rate over the entire 1948-86 time period, showing no significant decline after 1972. BEA-measured productivity in railroads rose only 2.2 percent per year in 1973-86, but railroad freight ton-miles per employee rose 5.5 percent per year. BEA-measured trucking productivity fell 0.3 percent per year over the 1973-86 period, while intercity trucking ton-miles per employee rose 2.3 percent per year over the same period. Airline productivity, as measured by the BEA, fell 0.4 percent per year over the 1973-86 period, but scheduled airline passenger miles per employee rose at a 3.8 percent rate.

Although Baily and Gordon did not determine the cause of the discrepancies in railroads and trucking, they found that airline productivity was mismeasured because the official statistics did not take account of airline discounts. The official BEA price deflator showed fares almost tripling between 1972 and 1986, but actual revenue collected per passenger mile increased only about 60 percent. A correction of that statistic will result in a marked increase in measured airline productivity.

Baily and Gordon concluded that productivity has probably been understated in the construction industry. The official data indicate that construction value added per hour fell 4.7 percent per year between 1967 and 1972, and fell again at a 2.2 percent per year rate between 1977 and 1986. Thus, between 1967 and 1986 measured real value added in construction fell by 12 percent despite a 40 percent rise in hours worked.

Baily and Gordon argued that real value added in construction has probably been mismeasured because the price indexes used to deflate nominal value added by construction allowed for virtually no increase in quality of output per square foot, either for residential or for nonresidential construction. In fact, the price deflators for construction have assumed no increase in quality per square foot since 1929.

As Baily and Gordon noted, price indexes based upon square footages can be biased if new features are included in houses of a particular size. Features new to residential construction since 1929 include central air conditioning, double-glazed windows, wall insulation, customized features, built-in dishwashers, and more attention to landscaping. Features new to nonresidential construction include faster elevators, more sophisticated heating and air conditioning systems, and intermediate layers between floors to allow more flexibility and access for electric lines and cooling ducts.

Labor Quality

Baily and Gordon attributed 0.3 percentage points per year of the slowdown in U.S. productivity growth since 1973 to mismeasurement of labor quality. The study of productivity and U.S. economic growth by Jorgenson, Gollop, and Fraumeni [17] concluded, as shown in Table II, that deteriorating labor quality had accounted for an even greater decline of 0.63 percentage points per year in the growth of U.S. productivity in 1973-79. Edward Denison, on the other hand, concluded that changes in the quality of the labor force contributed only a tiny amount to the productivity slowdown [10].

The Jorgenson, Gollop, and Fraumeni study decomposed labor quality by source (age, sex, education, employment class, and occupation; and various interaction measures) by industry. This decomposition enabled them to estimate the effects of these factors on labor quality (using compensation received as a proxy for quality). They found that

the age and sex factors are . . . the dominant causes of slowing growth of the quality index, [but] . . . the interaction effects of age and sex with each other and other factors are generally positive and consequently reduce the negative effect of . . . [-0.62] percent that would be inferred from summing the main effects of sex and age, . . . [-0.35] percent and . . . [-0.27] percent, respectively Yet even when all interaction effects are taken into account, the conclusion remains that the changing sex-age composition of the employed labor force has had a negative impact on labor input per hour worked. The increasing entry of women and young workers into low-paying jobs increases hours worked proportionately more than it increases labor input [17, p. 291].

Table II
ESTIMATES OF LABOR QUALITY
(Average annual rates of growth)

Source of Quality	1948-73	1973-79	Difference
	Percent	Percent	Col. 2 - Col. 1
Overall quality	0.61	-0.02	-0.63
Sex	-0.19	-0.54	-0.35
Age	-0.07	-0.34	-0.27
Education	0.66	0.36	-0.30
Employment class	0.17	-0.22	-0.39
Occupation	0.37	0.00	-0.37
Industry	0.28	0.08	-0.20

Source: Derived from Jorgenson, Gollop, and Fraumeni [17, p. 273].

Their study also showed that a considerable portion of the decline in labor quality after 1973 resulted from a diminished return to education.

There has been an ongoing discussion in the economics literature of the likelihood that the decline in the return to education stems from a decline in the quality of schooling—for example, as evidenced by the decline in the SAT scores that began in the 1960s. Baily's 1981 study [1] of the SAT score decline concluded that it could not have contributed to the post-1973 U.S. productivity slowdown because the decline was not large enough and the new entrants to the labor force did not make up a large enough fraction of the work force. A 1987 study by John Bishop [6] using not only the SAT scores but a variety of measures of general intellectual achievement (GIA) concluded that although the decline in the scores after 1967 could not explain the post-1973 slowdown, it probably did contribute to weak growth in the 1980s. That study estimated that the reduction in GIA reduced productivity growth by about 0.09 percent per year in 1973-80 and 0.24 percent per year during 1980-87 [6, p. 16].

Richard J. Murnane [18] agreed with Baily that a decline in educational quality was not responsible for the productivity decline. He stated that

both private and public reports have sounded the alarm that the nation is at risk because of the inadequacies of American education. These studies, in turn, have prompted observers to conclude that deterioration in America's schools has been a significant cause of the drop in the productivity growth rate over the past fifteen years. That conclusion is almost certainly not true. The productivity decline, especially the dramatic drop beginning in 1973, was too precipitous to blame on relatively slow-moving changes such as a possible reduction in the quality of the work force. There were some declines in scores on tests administered to elementary and secondary school students during the late 1960s and 1970s that are not well understood, but a large part of the decline in the SAT scores, the measures of educational performance given the most attention in the media is due to an increase in the number of students with relatively low ability who are taking the test. Perhaps most important, the rate of labor productivity growth has also fallen in other countries, including France, Germany, Britain, and Japan, since 1973 [18, pp. 215-16].

Murnane also noted the importance of workplace organization to productivity. He observed that the productivity of American workers in the recent General Motors-Toyota NUMMI automobile project rivaled the productivity of workers in Toyota plants in Japan after two years, mainly because of the use of the Japanese management system. This management system included such things as worker teams responsible for quality control, a just-in-time inventory system, and team standardization of tasks. This

increase in productivity was particularly significant as GM had previously closed down the plant and eighty percent of the labor force used in the joint venture consisted of workers previously laid off. This example also calls into question the assertion that the U.S. worker is of a relatively low quality.

Murnane is, however, concerned about the effects of education on future productivity. He observed that the skills that seem particularly important to worker productivity are

... the ability to understand directions (even when the manuals are poorly written), to ask questions, to assimilate and synthesize unfamiliar information, and to identify and solve problems that occur during the normal working day; in short, literacy and problem-solving skills in specific contexts [18, p. 223].

He cited studies that show Americans may not be acquiring these basic skills, in particular, the 1986 study for the National Assessment of Educational Progress (NAEP), which found that while 90 percent of 21-25 year old American adults could follow simple directions and solve single step problems, more than 30 percent had difficulty with nonroutine or multistep problems. The item scores indicated, moreover, that the problem was not basic reading skills but an inability to use reading to solve multistep problems. The 1986 NAEP mathematics assessment concluded about American students' math skills, a proxy for their problem-solving skills, that

the fact that nearly half of the 17-year-olds do not have mathematical skills beyond basic computation with whole numbers has serious implications. With such limited mathematical abilities, these students nearing graduation are unlikely to be able to match mathematical tools to the demands of various problem situations that permeate life and work [18, p. 225].

Murnane had several suggestions for improving the U.S. educational system. One of the more interesting was that since the types of achievement tests most often used by districts and states create incentives for teachers to focus instruction on arithmetic computation skills and word recognition skills rather than on the more difficult to assess problem-solving and literacy skills, the achievement tests should either be modified or given less weight in teacher evaluation.

Higher Energy Prices after 1973

The effect of the higher energy prices on productivity growth is one of the more hotly debated topics in the economics literature. A number of economists think that increases in such prices after 1973 had a major effect on worldwide productivity growth, while others think energy played a relatively minor role.

Dale Jorgenson [15] concluded that higher energy prices after 1973 were important determinants of the productivity slowdown. Jorgenson's study disaggregated the economy into sectors and then further broke down sectoral output growth into separate source components, namely, labor inputs, capital inputs, intermediate materials inputs, and productivity. These steps enabled him to study the characteristics of productivity growth by industry.

In an earlier study [16], Jorgenson and Fraumeni had classified productivity-growth in 35 major U.S. industries as capital saving or using, labor saving or using, energy saving or using, or materials saving or using. These classifications are useful for determining the effects of relative price increases of the various factor inputs on productivity growth. If, for example, an industry's productivity growth was capital using, an increase in the price of capital would lead to a slowdown in productivity growth, but if the industry's productivity growth was capital saving, increased capital prices would increase productivity growth in that industry.

Jorgenson and Fraumeni found the most common type of productivity growth, in 19 of the 35 industries, to have been capital using, labor using, energy using, and materials saving. They also found that productivity growth was *energy using* in 29 of the 35 industries studied. This last finding implied that increases in energy prices cause reductions in aggregate productivity growth.

Jorgenson [15] argued that the most striking change in the relative prices of capital, labor, energy, and materials inputs after 1973 was the substantial increase in the price of energy. He pointed out that real energy prices rose 23 percent in 1973-75 and 34 percent in the two years following the Iranian revolution in 1978. He concluded that

this evidence provides part of the solution to the problem of disappointing U.S. economic growth since 1973. Higher energy prices are associated with a decline in sectoral productivity growth for 29 of the 35 industries [studied]. . . . The resulting slowdown in sectoral productivity growth is more than sufficient to explain the decline in U.S. economic growth [15, p. 34].

Zvi Griliches [14] also agreed that energy is the prime suspect as a cause of the post-1973 productivity slowdown. He stated that

it is not just that many industries had to face new prices, change the way they used their factors of production, and scrap much of their now unprofitable capacity, but there was also a long worldwide recession induced by the fall in real wealth caused by OPEC, by the fall in aggregate demand caused by governments trying to control the resulting inflation, and the subsequent fall in U.S. exports and the increase in import competition in the early 1980s as

the result of rising dollar exchange rates. These factors combined together to produce one of the longest worldwide recessions and growth slowdowns from which the world may not yet have emerged [14, p. 19].

Some economists argue that energy played a smaller role in the productivity slowdown. Those economists point to discrepancies between the timing of the oil price increases and the productivity slowdowns in oil-related industries. As Baily and Gordon put it,

at first glance, industry productivity data suggest that the increase in energy prices in 1973 had an effect on productivity. Mining and utilities, two of the industries most heavily affected by the energy crisis, had the biggest post-1973 slowdowns. Transportation, too, had a major slowdown. On closer inspection, however, the impact of energy is not so clear. Both mining and utilities had begun to slow down before 1973. The depletion of easily available oil reserves in oil extraction, health and safety regulations in coal mining, and the depletion of innovation and returns to scale opportunities in electric power, together with the effect of environmental regulations, were reducing growth before the energy crisis hit. In the transportation sector, too, the timing seems a little off. This sector slowed less after 1973 than it did after 1979, a period when energy prices began to come down [4, pp. 362-63].

Mancur Olson [20] disputes this point. Although he agrees that the productivity growth began to slow slightly before the first oil shock (1973), he argues that all studies show the dramatic drop in productivity growth in 1973. As a result, he dismisses arguments about modest timing discrepancies.

Englander and Mittelstadt [12], writing for *OECD Economic Studies*, however, also dismiss energy as a prime cause of the worldwide productivity slowdown. They find a high elasticity of substitution between energy and other factors of production in OECD countries, excepting Japan where there was evidence of complementarity between energy and capital in the seventies and early eighties.

In sum, there is debate about the effects of the sharp run-up in oil prices on productivity growth. The Griliches-Jorgenson arguments seem most compelling, however, and the rise in oil prices seems to have almost certainly played some role in the productivity slowdown.

Environmental Protection Regulations

Governmental regulations, environmental and otherwise, have also been thought to contribute to the U.S. productivity slowdown,⁴ although as with

⁴ Discussion here is based upon output as normally defined. Some economists argue that clean air and clean water are themselves goods that should be included in output. If so, the discussion in this section should be made part of the section on measurement error.

oil prices, the extent of their contribution is under debate.

A 1986 study by Anthony Barbera and Virginia McConnell [5] found that estimates of the aggregate productivity decline in the 1970s resulting from environmental regulations ranged from 0.1 to 0.35 percentage points annually. The study found the largest effects of pollution abatement regulations in the chemicals; stone, clay and glass; and primary metals industries. Along the same lines, a 1983 study by Frank Gollop and Mark Roberts [13] estimated the 1970 Clean Air Act to have reduced the productivity growth of fossil-fueled electric utilities by 0.59 percentage points per year in 1973-79 period.

A recent study by Klaus Conrad and Catherine J. Morrison [8] examined the effects of mandated pollution abatement investment on productivity in the United States, Canada, and Japan. They found that pollution abatement expenses reduced U.S. productivity growth by 0.223 percentage points in 1973-80. Their results are shown in more detail in Table III.

Depletion of Mineral Resources and Investment Opportunities

William Nordhaus stated in 1982 [19] that about 65 percent of the U.S. productivity slowdown in 1973-79 could be attributed to depletion of mineral resources and investment opportunities. With respect to the depletion of mineral resources, he observed that total factor productivity in mining (principally oil and gas) in the U.S. grew at 2.6 percent annually during 1948-73, then declined at a 2.8 percent annual rate from 1973-79. He also noted that there

had been a break in the trend rate of finding oil and gas after 1973. With respect to a depletion of investment opportunities, Nordhaus cited a dearth of great inventions (telephone, automobile, rayon, airplane, computer, transistor, etc.) in recent years and a decline in patent applications in the seventies.

Whether there has been a depletion in mineral resources seems debatable from the perspective of 1989, although it may have seemed plausible in 1982. The idea of a depletion of investment opportunities, however, seems quite implausible today. As noted earlier, Baily and Gordon observed quite rapid technological progress in the U.S., mainly resulting from the continuing computer revolution.

It is true that patent applications declined in the seventies. In 1970, there were 76,000 patent applications in the U.S. while there were only 59,000 in 1983. This decline does not necessarily indicate an exhaustion of new invention opportunities, however. As Zvi Griliches pointed out,

. . . [patent applications] are heavily influenced by economic conditions and prospects. . . . Patent applications, for example, fell sharply in the 1930s, recovered in the late 1940s, and were essentially flat from the early 1950s through the early 1960s. They rose sharply in the late 1960s and then basically flattened out throughout the 1970s, starting to rise a bit in the 1980s. Most of the rise in patent applications in the late 1960s and early 1970s came from a major rise in applications from abroad which effectively crowded out a significant number of U.S. patents, given the relatively fixed resource level available to the U.S. Patent Office for processing such applications [14, p. 16].

Griliches added that the data on R&D expenditures and the technological news in the daily newspapers do not support the exhaustion hypothesis.

Summary

As is obvious, there are a number of potential explanations for the post-1973 productivity slowdown, and the experts differ on the relative contributions of each explanation. The views of the experts on the contributions are summarized in Table IV.

II.

U.S. PRODUCTIVITY COMPARED TO JAPAN AND GERMANY

The slowdown in productivity growth since 1973, as noted at the outset, has been worldwide. But productivity growth in the United States has also been relatively slower since 1973 than it has been in Germany, Japan, and selected other developed countries, as Table I shows. U.S. productivity growth has been

Table III

	PRODUCTIVITY ^a GROWTH ADJUSTED FOR POLLUTION ABATEMENT EXPENSES	
	1967-73	1973-80
Canada		
Traditional measure		0.229
Adjusted		0.278
Germany		
Traditional measure		2.855
Adjusted		2.963
United States		
Traditional measure	2.661	1.565
Adjusted	2.743	1.788

^a Total factor productivity.

Source: Conrad and Morrison [8, p. 692].

Table IV

**SOURCES OF THE PRODUCTIVITY SLOWDOWN,
ACCORDING TO THE EXPERTS**

Percentage Points Per Year	Reason for Slowing, Name of Expert
0.22	End of shift from low productivity farm and self-employed jobs to higher productivity nonfarm jobs. Denison [10].
0.24	Effects of 1973-75 and 1980-82 recessions. Denison [10].
0.30	Declining labor quality. Baily and Gordon [4].
0.63	Declining labor quality. Jorgenson, Gollop, and Fraumeni [17].
0.20	Measurement error. Baily and Gordon [4].
0.22	Pollution abatement expenses. Conrad and Morrison [8].
1.00	Depletion of mineral resources and investment opportunities. Nordhaus [19].
NA	Rising energy prices. Substantial—Griliches [14], Jorgenson [15], Olson [20]. Modest—Baily and Gordon [4], Englander and Mittelstadt [12].

especially slow relative to Germany and Japan, which experienced trend growth rates in 1979-86 of 2.0 percent and 2.8 percent respectively.

Volumes have been written on the causes of the variances between productivity growth rates in the U.S. and those of Germany and Japan. It is widely recognized, for example, that Germany and Japan have different cultures and their citizens have work ethics that differ from those of American workers. The school systems are different and students are trained differently. The Japanese management style is also different and according to many observers relatively more efficient than the traditional American managerial style. All of these differences are likely to contribute to the variances in national productivity growth rates.

Baily and Blair [2] examined whether the relative slowness in U.S. productivity growth can be attributed to a relative inefficiency of American managers. They observed that when American managers have been able to implement the Japanese team management systems, as in the Toyota-GM NUMMI plant in California, American workers have been able to achieve productivity comparable to the Toyota plant in Japan. On the other hand, they noted that a

number of American managers have had substantial difficulty in implementing the Japanese model. Moreover, they show that criticisms of American management practices extend beyond the automobile industry.

Lester Thurow, the dean of the Sloan School of Management, argues that American managers have failed to commercialize new technologies, pointing to the fact that U.S. companies missed out entirely on the VCR revolution, even though the original technology was developed in the United States. More recently, many companies—in and out of the auto industry—have failed to adopt the Just-in-Time production system developed by Toyota, a system that is much more than a way of saving inventory; it is a cost-saving reorganization of the entire system of production that forces workers to become much more conscious of the quality of each component [2, p. 190].

Baily and Blair were careful to note that the foregoing criticisms of American management practices are not universally shared. Defenders of American management have pointed out that although U.S. exports in the 1980s suffered as a result of the overvalued dollar, export shares of American multinational companies have remained strong. The ability of U.S. owned enterprises to remain competitive throughout this period, the defenders argue, is a sign of healthy management. Also,

... the fact that some U.S. industries have had trouble competing in world markets does not necessarily mean that American managers are deficient overall. For example, there are many industries—including agriculture, chemicals, and package express delivery—in which productivity in Japan is lower than in the United States [2, p.191].

As a result, Baily and Blair concluded that "... the evidence is not definitive in showing either that management quality deteriorated or that management caused the slowdown in U.S. productivity growth" [2, p. 193]. They argued, however, that management practices in the United States still are a matter of concern, for the competitive and regulatory structure in U.S. industry does not provide proper incentives for innovation and productivity improvement. They cited, as a basic description of how American companies deal with competitors, a portion of Michael Porter's book, *Competitive Strategy*:

... in most industries a central characteristic of competition is that firms are mutually dependent. ... In this situation, ... the outcome of a competitive move by one firm depends at least to some extent on the reactions of its rivals. ... Thus success can be assured only if the competitors choose to or are influenced to respond in a non-destructive way [21, p. 88].

As a result of this view of competitors, Baily and Blair argued that American firms have been unwilling to engage in aggressive competition with their

rivals, while Japanese firms have often used aggressive price-cutting tactics. Indeed, they argued that such tactics are typical of Japan's strategy for moving into foreign markets. In contrast, Baily and Blair argued that "... U.S. companies ... have been unwilling to use price-cutting as a form of investment to forestall the entry of rivals" [2, p. 195], believing that "aggressive price competition in the markets for new products will ... sharply reduce the return to innovation by [rapidly] eliminating any return in excess of the cost of production" [2, p. 197]. Baily and Blair also observed, citing U.S. laws against predatory pricing and dumping, that "... opposition to aggressive competition is enshrined in U.S. law" [2, p. 195].

In the past, when Japanese firms relied heavily on technology from the U.S., they were able to avoid the aforementioned trade-off between competition and innovation. Now, when Japan spends heavily on research and development (R&D), Japan meets the challenge of combining competition with innovation by setting government limits on competition. As Baily and Blair put it,

the Ministry of Industry and Trade (MITI) encouraged companies to allocate opportunities for technology development. One company would develop technology aimed for one part of the market, while another firm aimed at another part. This process increased the overall efficiency of R&D by reducing the duplication of research efforts and by allowing innovators to gain at least a temporary monopoly. ... Equally significant, Japanese companies have been able to appropriate more of the return to their R&D by directing a greater share to the development of new processes than their U.S. counterparts—... it is easier to keep the details of a new process secret (and thus to keep technological developments from flowing back to the U.S.). ... Finally, in situations in which Japanese groups have successfully limited their domestic competition, perhaps with help from MITI, companies have been able to earn their target return on R&D at home. But then the government encourages Japanese companies to compete abroad [2, p. 199].

Baily and Blair concluded that the United States could learn important lessons from Japan's treatment of returns to innovation. They argued that U.S. anti-trust enforcers should learn that bigness is not in itself bad. They also observed that Japan has found that aggressive competition in world markets has greatly encouraged cost cutting and quality enhancement. On the other hand, they did not advocate that the U.S. government allocate research initiatives among competing companies, observing that the costs of a misdirected industrial policy can be very high indeed.

Rohlen [22] compared Japanese and American school systems and noted that a higher percentage of students in Japan graduate from high school and that scores on achievement tests indicate that Japanese students have higher language and math

skills than American students. And Murname observed that

recent studies comparing the mathematics skills of American middle-class children with middle-class children growing up in Japan and Taiwan indicate similar skill levels among first graders, but markedly lower performance by American fifth graders [18, p. 227].

Other sources of the United States' productivity lag might include the relatively higher rates of overall investment in Germany and Japan, the relatively more rapid growth of nondefense R&D investment in those countries, the effects of more stringent pollution controls in the United States, and relatively more measurement error in the U.S. data. Tables III and V provide information relevant to these possibilities.

Chart 3 shows private fixed investment as a percent of GNP in Japan, Germany, and the United States. The chart shows that the U.S. figure is persistently smaller. Table V shows that total U.S. R&D spending as a percent of gross domestic product⁵ (GDP) has been relatively high in comparison to other countries. The U.S.'s 2.83 percent in 1985 led all others shown. A more relevant statistic, however, may be the *nondefense* R&D spending as a percent of GDP. According to that statistic, the United States spends a substantially smaller percentage of its product on R&D than either Japan or Germany. As Table VI shows, Japan had almost four times the number of U.S. patent applications in 1983.

Table III provides estimates of productivity growth adjusted for mandated pollution abatement investment. The table shows that measured U.S. produc-

⁵ Gross domestic product is market value of output produced by factors of production *located* in a country. By comparison, gross national product (GNP) is the market value of output produced by factors of production *owned* by citizens of a country.

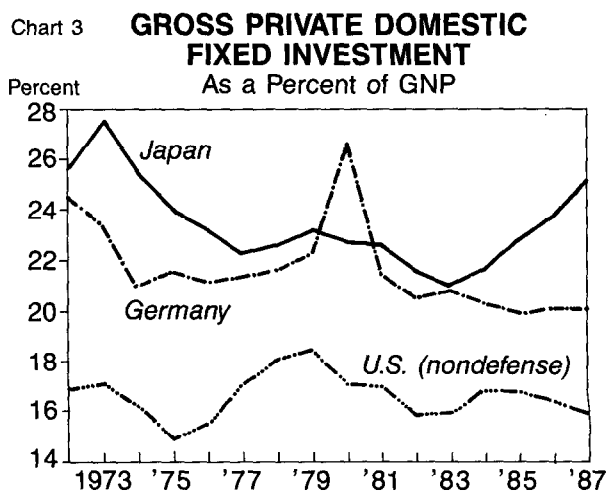


Table V
**RESEARCH AND DEVELOPMENT EXPENDITURES
 AS A PERCENT OF GDP**

(Selected countries, selected years)

TOTAL			
Country	1965	1975	1985
United States	2.76	2.32	2.83
Japan	1.55	2.01	2.61
Germany	1.60	2.24	2.66
France	2.03	1.80	2.31
United Kingdom	2.30	2.03	2.32

NONDEFENSE			
Country	1971	1975	1984
United States	1.68	1.72	1.82
Japan	1.84	2.00	2.64
Germany	2.03	2.10	2.47
France	1.46	1.46	1.79
United Kingdom	1.50	1.32	1.61

Source: *OECD Economic Studies*, Spring 1988, pp. 36-37.

tivity growth would have been 0.223 percentage points higher in 1973-80 had it not been for mandated pollution abatement investment. The table also shows that German productivity would have been only 0.108 percentage points higher per year. Thus,

Table VI
TOTAL PATENT APPLICATIONS

	1965	1975	1980	1983
United States	72,317	76,195	62,098	59,391
Japan	60,796	100,511	165,730	227,708
Germany	38,148	30,198	30,582	32,140
France	17,509	14,106	12,110	11,086
United Kingdom	24,274	20,842	19,710	20,011

Source: *OECD Economic Studies*, Autumn 1988.

the data imply that German pollution abatement regulations had a slightly smaller effect on productivity growth than U.S. regulations.

Finally, there is a possibility that productivity is measured more poorly in the U.S. than it is in Japan and Germany. The author has seen no study of Japanese and German data comparable to the Baily and Gordon study of productivity measurement in the U.S., but there is no reason to believe that the Japanese and Germans would ignore airline discounts, and allow for no quality improvements in construction. More significantly, the difficult measurement problems for productivity statistics stem from measurement of the productivity of services. Chart 4 shows construction, transportation, and services as a percent of GDP in the United States, Japan, and Germany. The chart shows that a substantially larger portion of U.S. GDP stems from those sectors—sectors in which productivity is more likely to be mismeasured. For this reason, U.S. productivity data probably contain relatively more measurement error.

III. CONCLUSION

The conclusion is that there is not any one cause of the U.S. productivity slowdown. Nor is there a single explanation of the slowness of U.S. productivity growth relative to other countries. Based on the research surveyed in this article, however, one can make educated guesses on the relative importance of some of the factors.

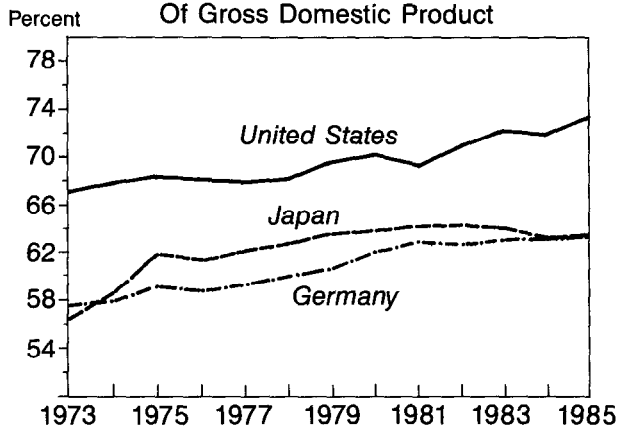
What contributed to the measured slowdown in U.S. productivity growth? Oil prices? Very likely. Mismeasurement? Very likely. Government regulations? Probably. A decline in labor quality? Perhaps.

Depletion of mineral resources? Doubtful. Depletion of investment opportunities? Doubtful.

What causes the U.S. to lag behind Japan and Germany in productivity growth? Cultural differences? Undoubtedly. Relatively less nondefense R&D spending? Probably. Relatively less capital spending? Probably. Differing governmental industrial policies? Possibly. Relatively poorer labor quality? Possibly. Relatively more measurement error? Possibly. Inferior management practices? Possibly. More stringent governmental environmental protection regulations? Maybe.

Chart 4

**CONSTRUCTION,
SERVICES & TRANSPORTATION**
As A Percent
Of Gross Domestic Product



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MACROECONOMIC PRICE INDEXES

Roy H. Webb and Rob Willemse*

Price indexes allow one to compare the average levels of prices at different times. By summarizing information on price trends, the indexes help people adjust for inflation when they choose how much to save, spend, work, and invest. Government officials, as well as voters, use price indexes to evaluate economic policies. In addition, both private contracts and government programs often use a particular price index to adjust payments for inflation.

EXAMPLES OF EARLY USES

One of the first uses of a price index in the United States arose from the substantial inflation of the Revolutionary War period. In order to maintain the real, or inflation-adjusted, pay of soldiers, officials in Massachusetts tracked the price of acquiring a market basket of the following goods: 5 bushels of corn, 68 $\frac{1}{4}$ pounds of beef, 10 pounds of wool, and 16 pounds of leather. The basic idea was simple: the percentage increase in the price of the market basket would have to be matched by the same percentage increase in soldiers' wages to compensate for inflation.¹

The federal government began collecting national price statistics in the late nineteenth century to evaluate the effects of tariffs. A particularly notable achievement was the production of a 50-year historical series of wholesale prices by the federal Bureau of Labor. In 1902 the Bureau began to regularly publish a Wholesale Price Index that could be used to track recent data. That price index was the forerunner of the current Producer Price Index (PPI); the agency is now known as the Bureau of Labor Statistics (BLS) and remains the primary source for aggregate price data in the United States.

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¹ This and many other early uses are described in W. Erwin Diewert, "The Early History of Price Index Research," National Bureau of Economic Research Working Paper No. 2713, 1988.

During World War I the BLS collected data on the pattern of consumer expenditures and retail prices. The data were used in adjusting wages of workers for wartime inflation. After the war, the "cost-of-living" index² was regularly published; by one account, more than half the settlements in wage disputes in 1923 were based on that index. The cost-of-living index was the predecessor of the Consumer Price Index (CPI).

In short, the subject of price indexes was of great interest even before the sustained inflation of the last half century. That prolonged period of inflation has in turn stimulated more interest in the subject of price indexes. And that additional interest has in turn led to the use of economic and statistical theory to make the indexes more accurate and more relevant.

THE MAJOR INDEXES

Consumer Price Index

The CPI is the most widely used barometer of the average price level. The index is watched closely by workers, retirees, participants in financial markets, and government officials. The CPI's prominence as an inflation measure is reflected in its widespread use as an escalator for wages and benefit payments. Many collective bargaining agreements, other private contracts, social security benefits, and federal and state assistance programs allow for increases in wages and transfer payments tied to increases in the CPI. Elements of the federal income tax structure, including tax brackets and personal exemptions, are also adjusted to reflect movements in the CPI. In addition, the CPI is used to adjust other economic statistics, including hourly and weekly earnings and median family income, for price changes.

The CPI is expressed as the ratio of average prices currently paid by consumers to the average prices paid in a reference, or base, period. Since items vary in importance in personal budgets, both the numerator and denominator of the ratio are *weighted*

² The index was not a true measure of the cost of living, however. While it did measure the prices of goods and services, it did not include other outlays such as taxes and interest. In addition, there was no consideration of goods and services provided by government, nor of fringe benefits provided by employers.

averages. For example, since most people spend more on housing than on socks, the price of housing has a larger weight in the index than the price of socks. More precisely, the CPI is an estimate of the ratio of the current price of a fixed market basket of consumer goods and services of constant quality to the price of that market basket in a specific base period. (See the Appendix for algebraic formulae for the CPI and other price indexes discussed in this article; in addition, numerical examples are also presented.) This market basket is designed to represent the average expenditures of a certain segment of the population at a certain time. The CPI is expressed as an index number. In 1988 the value of the CPI was 118.3, which means that the market basket cost 18.3 percent more in 1988 than it did in 1982-84, the base period.

Two versions of the CPI are published monthly by the BLS. They are published with a lag of roughly three weeks following the end of the month covered by the index. One is the *CPI For Urban Wage Earners and Clerical Workers (CPI-W)*, which is based on expenditures by consumers who represent about 32 percent of the U.S. population. The other is the *CPI For All Urban Consumers (CPI-U)*, which represents the spending habits of 80 percent of the U.S. population. The CPI-U, introduced in 1978, extended coverage to self-employed, professional, managerial and technical workers, and also the unemployed, retirees, and others not in the labor force. People who live in rural areas are the largest population group whose expenditures are not explicitly represented in the CPI-U. In practice, the CPI-U and CPI-W data are similar. For example, the compounded annual inflation rate over the period 1972 through 1986 was measured by the CPI-U to be 7.12 percent, whereas the CPI-W rose 7.01 percent.

The quality of the CPI as a measure of price change can be affected by the representativeness of the market basket that is priced each month. A *Consumer Expenditure Survey* is used to identify and specify quantities of the goods and services that will make up the market basket of the CPI. It consists of two separate surveys: a quarterly Interview Survey, which is designed to obtain data on expensive items that are purchased relatively infrequently, and a Diary Survey to gather information on more frequently purchased items. The latest survey, conducted by the Census Bureau from 1982 through 1984, was used to modify expenditure weights in the CPI beginning in 1987.

The weights in the CPI remain unchanged for relatively long periods; the CPI is therefore often referred to as a *fixed-weight* price index. Strictly

speaking, however, the entire record is a set of several time series of fixed-weight indexes that are spliced together. Since one set of expenditure weights is not used to calculate the CPI for every date, it is possible that a user viewing different dates will use index numbers based on different market baskets. Calculating inflation from 1980 to 1988, for example, the 1980 index would be based on the 1972-73 Consumer Expenditure Survey and the 1988 index would be based on the 1982-84 survey.

Once the expenditure weights are determined, the computation of the CPI for each month requires data on the current prices of items in the market basket. To obtain the price data, the BLS sends agents to many retail establishments in different parts of the country to obtain prices for about 100,000 items each month. The BLS then uses the individual prices to calculate CPI statistics at the local, regional, and national levels. In addition to the index for all items, the BLS calculates price indexes for selected components of the market basket such as food or entertainment.

Chart 1 graphs the CPI over its first 32 years. One can see the impact of major events, such as wartime inflation in the two world wars and the beginning of the Great Depression. Otherwise there is no clear trend; only the level is affected by various events. That is also the case when looking farther back. Using one estimate of the producer price index before 1890³ and the official index afterward, the level of that index only increased by about 10 percent from 1785 to 1913.

The picture shown in Chart 2 is somewhat different. Due to substantial inflation from 1945 to 1988, with the CPI increasing sixfold, this chart contains *percentage changes* in the CPI rather than the *levels* shown in Chart 1. At first, high rates of inflation were associated with wars; during the late 1970s, however, sustained high rates of inflation occurred during peacetime. Unlike the prewar period, there was no tendency for inflationary periods to be offset by deflation at other times.

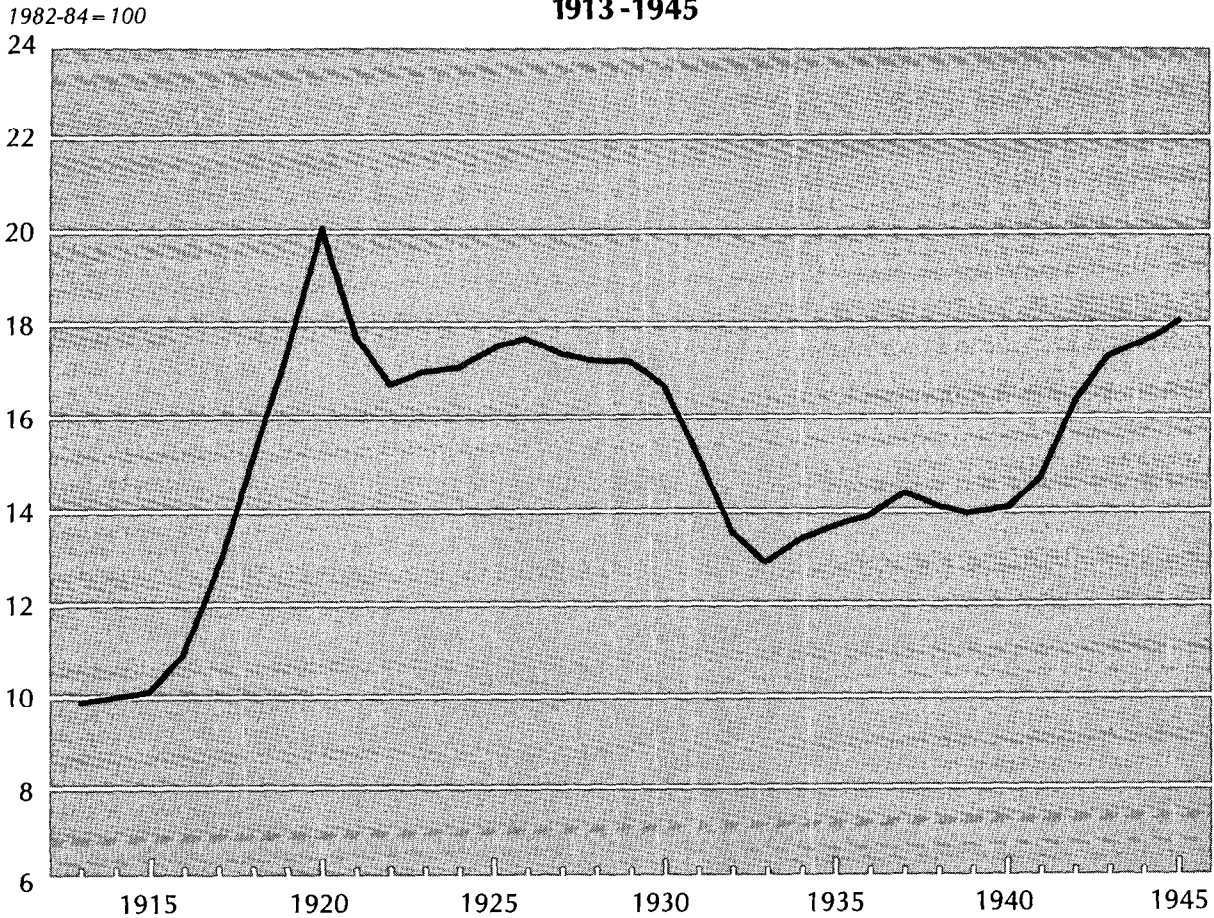
The Producer Price Indexes

The PPIs are used to estimate prices received by domestic producers of goods at various levels of processing. The PPI is largely composed of manufactured products, as shown in Table I. A notable omission from the PPI is the service sector, which

³ The series was estimated by G. F. Warren and F. A. Pearson, and is reprinted in U.S. Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1970, Bicentennial Edition, Part 1*, Washington, D.C., 1975, pp. 200-201.

Chart 1

**CONSUMER PRICE INDEX
1913-1945**



has grown rapidly in the United States during the twentieth century.⁴

Producer Price Indexes are presented in a number of ways based on different classifications of goods. The classification by *Stage of Processing* divides goods into three main categories: *crude*, *intermediate*, and *finished goods*. Crude goods are items that are entering the market for the first time, that have not been manufactured or fabricated, and that are not sold directly to consumers. They include items like grains, livestock, cotton, and crude oil. Items like lumber, fertilizer, machine belts, and yarn are intermediate goods. They have been processed but may require further processing, or may be complete but will be

⁴ The BLS is studying price indexes for services. It is possible that experimental indexes could be introduced for those services for which the quantity produced can be most accurately measured, such as transportation and communication. It would be much more difficult to produce meaningful indexes for services such as medical care, banking, and insurance where the quantity and quality produced is difficult to measure accurately.

used by businesses as material inputs. Finished goods will not undergo further processing; that category includes consumer goods as well as capital equipment.

Indexes are also calculated for special commodity groupings, organized by similarity of end-use or

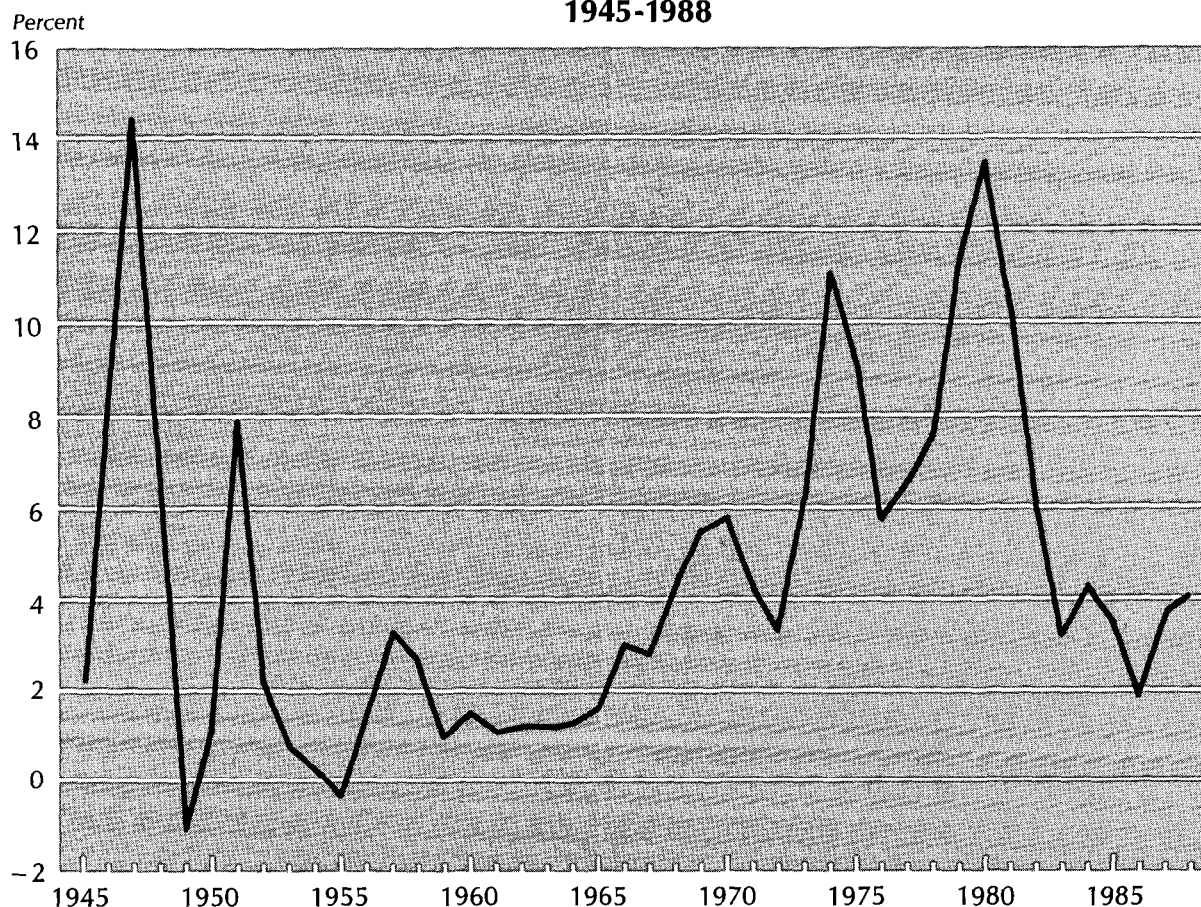
Table I
**COMPOSITION OF
PRODUCER PRICE INDEX
DECEMBER 1986**

Manufacturing	83.6 percent
Mining	7.2 percent
Agriculture	5.1 percent
Electric Power	3.4 percent
Other	0.7 percent

Source: *Monthly Labor Review*, August 1987, page 14.

Chart 2

CONSUMER PRICE INDEX CHANGES 1945-1988



material composition. Examples include the PPIs for industrial commodities and for farm products. Also, there are producer price indexes for the net output of different industries and their products.

The PPI is calculated from approximately 70,000 individual prices. Like the CPI, it is constructed using fixed weights for relatively long times. The weight for each individual component is the relative value of shipments of that item. Periodically, the Bureau of the Census conducts industry surveys that the BLS uses to update the value weights. Among the most important surveys are the Census of Manufactures, the Census of Agriculture, and the Census of Minerals, which includes oil and gas production. The latest surveys, conducted in 1982, have been incorporated in the PPI as of 1987. Previous value weights, which were used from 1976 through 1986, were based on Census results of 1972.

The PPI for all commodities in 1986 was 100.17. That is a concise way of saying that prices producers

received in primary markets for a group of items had increased 0.17 percent since 1982, with the prices of those items weighted by the relative values of 1982 shipments.

Price Measures from the National Income and Product Accounts

In the process of estimating GNP and its components, the Bureau of Economic Analysis (BEA) also estimates corresponding price measures, including fixed-weight price indexes, *implicit price deflators* and *chain price indexes*.

To calculate GNP and its components, the BEA estimates the dollar value of spending for current production. It then calculates what that spending would have been if current quantities had not been valued at current prices, but rather at prices paid during a reference (base) period. The ratio of the two spending totals, current dollar spending divided by constant dollar spending, is an *implicit price deflator*.

Implicit price deflators are computed for GNP, for broad expenditure categories such as consumer spending, and for more narrow categories such as consumer spending for stationery and writing supplies.

In the Appendix it is shown that an implicit deflator is unlike the indexes discussed above in two important respects. First, instead of using historic weights a deflator uses current quantities as weights. Second, an implicit deflator is not a pure price index, since changes in the index may reflect other factors than changes in prices. In fact, when two periods are compared (neither being the base period), the calculated change in the deflator depends both on the price change and also on any change in the relative quantities exchanged.

An implicit deflator can therefore behave differently from a fixed-weight index. For example, if people spend their money for different products, that by itself does not immediately affect the CPI or PPI, which are not affected unless individual prices change. The implicit deflators, however, can be very much affected when relative quantities change. To provide users with better data on price movements, the BEA also publishes fixed-weight price indexes for GNP and many of its components. The weights are the amounts produced in a particular base period, which at present is 1982.

Since the National Income and Product Accounts are used to study the economy over long periods of time, there is also a disadvantage to the fixed-weight price indexes: the farther from the base period, the less representative will be the base-period weights. The BEA therefore provides another alternative, a *chain price index*. It uses past prices for weights, but with the previous quarter as the base period. The change between two adjacent quarters is therefore determined solely by price changes. In that respect it is like the fixed-weight indexes. Unlike a fixed-weight index, however, shifting expenditure patterns will be incorporated in the chain index with only a one-quarter lag.

Although the differing measures of price levels may seem confusing, they usually tell similar stories over time. For example, between 1959 and 1988 the implicit price deflator for GNP and the GNP chain price index each grew at a 4.9 percent annual rate; the GNP fixed-weight price index grew at a 4.2 percent rate. Quarterly changes in the statistics, however, can diverge substantially; when they do, it is best to discount extreme movements in the implicit price

deflator, which can result from changes in relative quantities produced between two particular quarters.⁵

Chart 3 shows the GNP fixed-weight price index and the implicit price deflator for the last ten years. Note that they both reveal the decline in inflation in the early 1980s and the gradual rise since 1986. The implicit deflator is more volatile, however, as exemplified in 1986.

CAUTIONS

Price indexes are invaluable tools; however, no single index gives unambiguous answers to all questions. Some important cautions should be kept in mind.

Quality Change

Ideally, one can use price indexes for different dates to measure the average price change of goods and services of *constant quality*. Therefore if a price increase of an item is due solely to quality improvement, then that price increase should not affect the index.

To adjust for significant quality changes, statisticians sometimes use a practice known as linking. That procedure estimates a price change for a new product by the price change of a similar product for which quality did not change. In other instances statisticians estimate the amount of quality change by the cost of producing it. For example, car manufacturers routinely provide the BLS with cost data for new features or additional items that were once optional before becoming standard equipment. Thus if a new audio system added one percent to a car's cost of production and the new car price rose three percent, the quality-adjusted price increase would be two percent.

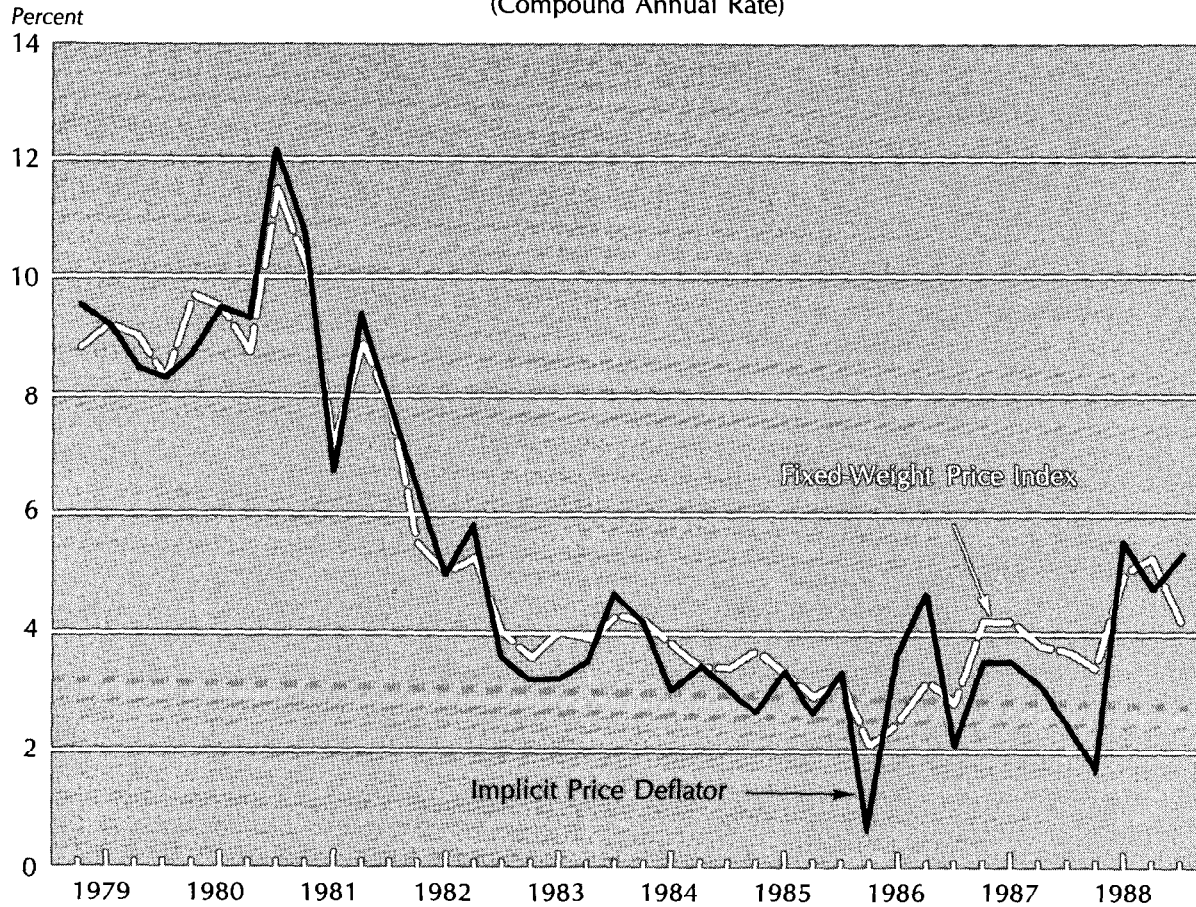
While those adjustments are clearly better than no adjustment for quality change, many observers believe they do not go far enough. As Robert J. Gordon has put it:

The typical product, whether automobiles in the 1920s, TV sets in the 1950s or electronic calculators in the 1970s, experiences after its invention an initial period of declining price, as its manufacturers spread the fixed cost of development over more and more units sold. Then, as the product becomes mature, there is less opportunity for

⁵ Although not regularly published, another type of index appeals to many economists. It is simply the geometric average—that is, the square root of the product—of an index based on historical fixed weights and an index based on current weights. For the case of GNP, one could use the average of the GNP fixed-weight price index and the implicit price deflator. This type of index was labeled an Ideal index by Irving Fisher, who was one of the first to note many of its advantages.

Chart 3

**PRICE MEASURES OF GROSS NATIONAL PRODUCT
QUARTERLY CHANGES: 1Q 1979-4Q 1988**
(Compound Annual Rate)



efficiency gains to cancel out increased wages and other costs, so prices begin to rise. Three aspects of the CPI cause it to understate quality improvements and to overstate price movements. First, the use of obsolete weights from decade-old expenditure surveys tends to place too little weight on modern products where price increases are relatively slow. Second, new models and products are typically introduced in the index much later than the date when their sales volume becomes important. And finally, the linking procedure, by far the most common quality-adjustment technique used by the BLS, tends both to treat new products as if they were mature products and to ignore performance improvements.⁶

For example, consider the difficulty in measuring the price of computers. For many years computer price changes were not included in the PPI, nor in the CPI's market basket, nor in the national income and product accounts; the price change was simply

assumed to be zero. Over the last few decades, however, the price of computing has fallen substantially; the price indexes therefore overstated the average inflation rate. Recently, the BEA has revised the national income and product accounts back to 1970 to account for computer prices, which they now estimate have been falling by 15 percent per year. In contrast, the CPI is not revised once it is published;⁷ it will therefore never be revised to account for the price declines found by the BEA for personal computers.

Other durable goods may also have higher quality levels that are not accurately reflected in price indexes. For example, Gordon has calculated that producers durable equipment prices grew by 66 percent from 1947 to 1983; in contrast, the BEA's official

⁶ Robert J. Gordon, "The Consumer Price Index: Measuring Inflation and Causing It." *The Public Interest* (Spring 1981), pp. 129-30.

⁷ Since the CPI is so frequently used to adjust contractual payments and government benefits, revising historical values could lead to complex revisions of liabilities and payments.

deflator for that category grew by 383 percent.⁸ The huge difference is accounted for by Gordon's detailed quality adjustments for many items using sources other than the BLS or BEA. In some cases his estimates were based on conventional methods such as linking; in other cases, however, he went beyond usual methods when new models performed much better than old ones.⁹

Problems in measuring quality change are especially severe for services, which are of growing importance in the economy. Traditional methods to correct for quality improvement are difficult to apply since by their very nature services leave little tangible product to examine once they have been rendered. For example, suppose that as a result of advances in medical knowledge a physician's effectiveness doubled, while the hourly fee increased by 50 percent. While only the fee could be accurately measured, it would dramatically overstate the price change for constant-quality physician's services.

Due to technical progress and increasing knowledge, many observers believe that the average quality of goods and services has risen over time, and that unmeasured quality change has caused inflation in the United States to be overstated by most price indexes.¹⁰ That belief, however, is extremely difficult to quantify. The examples above certainly indicate that the problem of measuring quality change is important and should be studied. Unfortunately, they do not provide the final word on the magnitude of unmeasured quality changes.

Homeownership

The CPI increased sharply in the late 1970s and early 1980s, with its annual rate of increase peaking at 15 percent in 1980. Some analysts have argued

⁸ Robert J. Gordon, *The Measurement of Durable Goods Prices*, Chicago: University of Chicago Press for the National Bureau of Economic Research, forthcoming. Part of the work is summarized in Martin N. Bailey and Robert J. Gordon, "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power," *Brookings Papers on Economic Activity 2* (1988): 347-431. The figures in the text are from the BPEA article, page 382.

⁹ Gordon's estimates are probably not universally accepted, however. As Jack Triplett put it (not referring to these particular estimates), "Just because an economist produces an index that differs from an official index, this does not necessarily imply that it is the official index that must be the incorrect one." ["Quality Bias in Price Indexes and New Methods of Quality Measurement," in Zvi Griliches, ed., *Price Indexes and Quality Change* (Cambridge: Harvard University Press, 1971), p. 212.]

¹⁰ On the other hand, it is of course possible to find products where quality has deteriorated. One example could be the growing use of graduate students for undergraduate instruction in many universities.

that flaws in the measurement of the cost of homeownership in the CPI contributed to its sharp increase.¹¹ At that time the CPI's cost of homeownership contained two main components, the house purchase price and the mortgage interest cost, as well as other expenses such as taxes, maintenance, and insurance. That method overweighted the cost of homeownership for two reasons. First, it treated the investment in a house much like the purchase of a nondurable good. Second, it confused the purchase price with the method of financing. That method therefore tended to overstate the CPI in the late 1970s as house prices and mortgage rates increased sharply.

Economists usually consider the purchase of a house to be an investment, and the use of a house to be consumption. The CPI, as a measure of the cost of consuming a bundle of goods and services, should therefore incorporate only the change in the current cost of housing services. One estimate of the current cost of using owner-occupied housing is the amount it would cost to rent a similar property. Starting in 1983 with the CPI-U and in 1985 with the CPI-W, the BLS adopted a *rental equivalence* approach to measure the cost of housing services. Rental equivalence approximates the change in the cost of services of homeownership with an index of rental prices.¹²

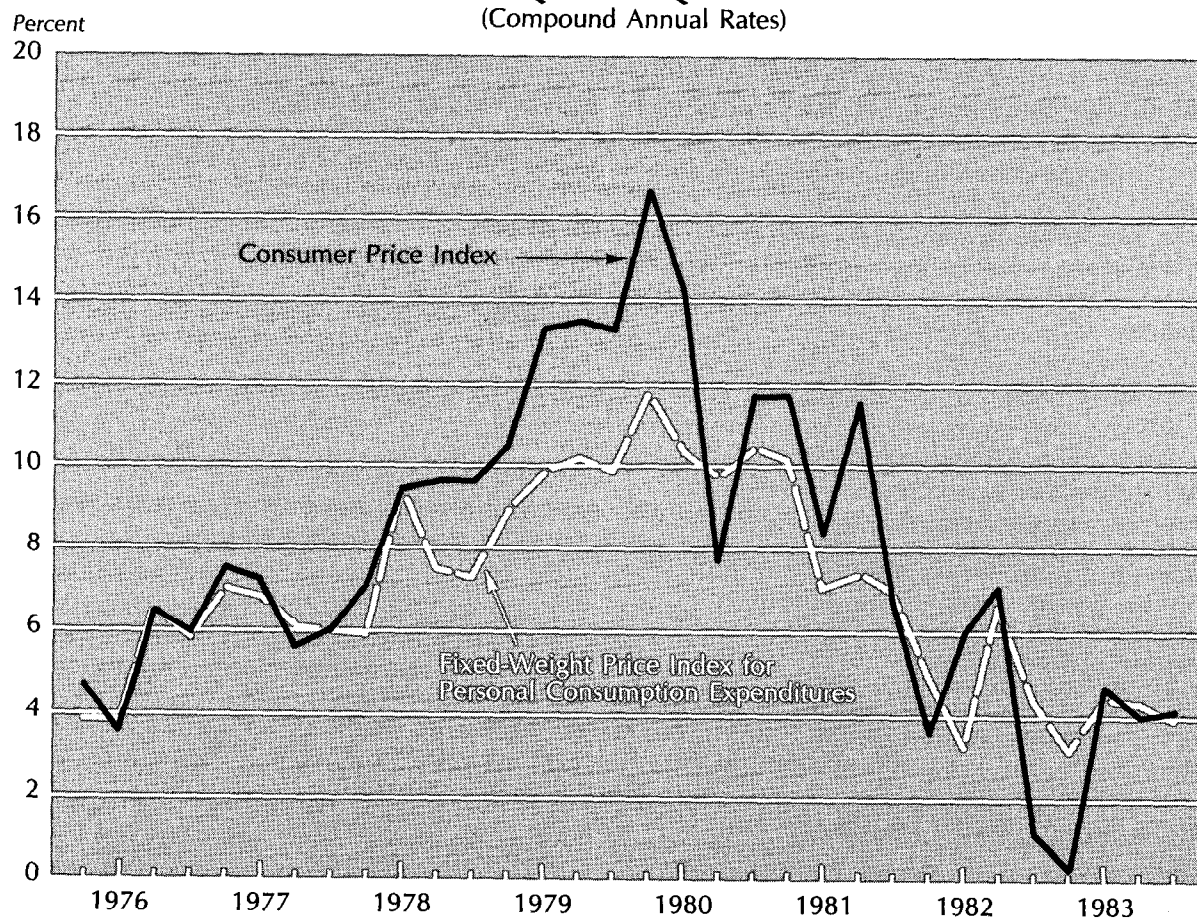
The rental equivalence approach was already used in another index of consumer prices, the personal consumption expenditure fixed-weight price index. Chart 4 shows the period in which the different measures diverged substantially: from 1978 to 1982, the CPI rose 10.7 percent whereas the fixed-weight price index for consumer spending rose 8.9 percent. The most important difference in the two statistics is their different methods of estimating prices for housing. Since the BLS does not revise CPI data once they are published, users of old CPI data should realize that the CPI-U data before 1983 (and the CPI-W before 1985) still use the old measurement of housing cost and thus overstate the actual price increases.

¹¹ For example, see Alan S. Blinder, "The Consumer Price Index and the Measurement of Recent Inflation," *Brookings Papers on Economic Activity 2* (1980).

¹² The same type of problem applies to other durable goods as well. The theoretically appropriate price to include is usually the price of obtaining the services of that good, not the purchase price of the durable itself. The normal approach in constructing the indexes, however, considers only the purchase price. Autos, therefore, are priced by the cost of buying a car, not the cost of driving a mile.

Chart 4

**CHANGES IN CONSUMER PRICE MEASURES
1Q 1976 - 4Q 1983**
(Compound Annual Rates)



Changing Quantities

People shift their buying habits over time due to changes in relative prices, real incomes, demographic characteristics, and tastes. The CPI, however, is based on a market basket that is fixed for long intervals. Table II provides a contrast between the major expenditure shares based on the 1972-73 and the 1982-84 consumer expenditure surveys.

The CPI's fixed expenditure weights become less representative over time as consumption patterns change. For example, consumers normally reduce consumption of items for which price increases are relatively large. This problem is often referred to as substitution bias. It is inherent in any price index whose weights are fixed and it becomes more serious when price movements are widely dispersed. In practice, substitution bias may not be very large. One

Table II

COMPOSITION OF CONSUMER SPENDING

Expenditure Group	Consumer Expenditure Survey	
	1972-73	1982-84
Food and Beverages	18.7	18.1
Food away from home	3.8	4.9
Housing	28.0	30.7
Apparel and Services	7.8	5.4
Transportation	18.7	19.7
Gasoline and motor oil	4.3	5.6
Medical Care	4.6	4.4
Other	22.2	21.7

Note: Relative importance of items, -stated as percentages of annual expenditure.

Source: *Monthly Labor Review*, June 1986, page 17.

recent study found substitution bias for the CPI from 1959 to 1985 was only about 0.18 percent per year.¹³

Lack of Good Data on Individual Prices

The BEA uses prices of individual items that were first collected for the CPI and PPI to estimate over 90 percent of the private sector prices in the National Income and Product Accounts. Since the accounts attempt to cover all current production, whereas the CPI and PPI cover limited areas, prices of some items remain to be estimated by the BEA. They may not have usable data for some of those remaining items, such as financial services like banking where both price and quantity may be difficult to define. In those cases the BEA may use the cost of production to estimate a product's price; the quantity produced is then estimated as total spending divided by that estimated price. If there are substantial productivity gains in those industries, however, then that procedure will overstate price change and correspondingly underestimate real output growth.

International Comparisons

As should now be apparent, compiling a price index involves many choices among imperfect alternatives. Not surprisingly, statistical agencies of different nations have made different choices. Thus one cannot assume that the price indexes of different nations are exactly comparable even if they have the same title. The CPI for Belgium, for example, does not include housing.

Miscellaneous Statistical Problems

The value weights now used to calculate the PPI are based on data from 1982, when the economy was in a severe recession. By contrast, during the previous survey year, 1972, the economy was rapidly expanding. The different phases of the business cycle in 1972 and 1982 would have led to substantial changes in the value weights in the PPI, whether or not there was any structural change in the economy. Thus the latest weights have fallen for industrial materials used in cyclically sensitive industries, such as construction and automobiles.

There is an inevitable lag between population movements, changes in regional weights of the indexes, and changes in expenditure patterns. For example, consider net population migration from cold to warm areas. If that migration did not promptly

¹³ Marilyn E. Manser, and Richard J. McDonald, "An Analysis of Substitution Bias in Measuring Inflation, 1959-85," *Econometrica* 56 (July 1988): 909-30.

affect the weights in the CPI's market basket, the index could overweight items such as snow blowers and underweight other items such as swimwear.

There has long been concern that the indexes may include list prices for some items rather than actual transaction prices. Since departures from list prices usually reflect sale items or negotiated discounts, any failure to use actual transaction prices would tend to overstate the price level.¹⁴ Moreover, if the number of sales or discounts increases when the economy is relatively weak, indexes calculated from list prices would overstate cyclical price rigidity.

Conclusion

These caveats indicate that price indexes do not answer all questions as well as we might wish. Despite their imperfections, however, the existing price indexes are invaluable. As Irving Fisher put it:

But, although in the science of optics we learn that a perfect lens is theoretically impossible, nevertheless, for all practical purposes lenses may be constructed so nearly perfect that it is well worth while to study and construct them. So, also, while it seems theoretically impossible to devise an index number, P, which shall satisfy all of the tests we should like to impose, it is, nevertheless, possible to construct index numbers which satisfy these tests so well for practical purposes that we may profitably devote serious attention to the study and construction of index numbers.¹⁵

SUGGESTIONS FOR FURTHER READING

The Bureau of Labor Statistics is the primary source for the CPI and the PPI and publications explaining their construction. The monthly publications *CPI Detailed Report* and *The Producer Price Indexes* present the actual data and contain brief introductions to the construction of the CPI and the PPI; they also announce and explain periodic revisions in the series. The *BLS Handbook of Methods, Part I and II*, describe in more detail the construction of the CPI and the PPI. The *Monthly Labor Review* contains recent data as well as articles on topics related to the CPI and PPI. The following were particularly valuable for this article: Jack E. Triplett, "Reconciling the CPI and the PCE Deflator," *Monthly Labor Review*, September 1981; and Andrew G. Clem and William D. Thomas, "New Weight Struc-

¹⁴ In countries with price controls, however, the actual transaction price is often higher than the list price. In that case the price index would understate the price level.

¹⁵ *The Purchasing Power of Money* (1911; reprint, New York: Augustus M. Kelley, 1963), p. 212.

ture Being Used in the PPI," *Monthly Labor Review*, August 1987.

The implicit PCE and GNP deflators are explained in most macroeconomic textbook discussions of the National Income and Product Accounts, such as in *Macroeconomics* by R. Dornbusch and S. Fischer (1984). The *Survey of Current Business*, published monthly by the Commerce Department, presents the data and regularly provides brief explanations of the deflators and price indexes.

Problems of quality adjustment in the price indexes are discussed in Robert J. Gordon's articles cited in footnotes 6 and 8 above. Other useful critiques of

official indexes include: Phillip Cagan and Geoffrey H. Moore, *The Consumer Price Index: Issues and Alternatives*, American Enterprise Institute, Washington, 1981; and Council on Wage and Price Stability, *The Wholesale Price Index: Review and Evaluation*, Washington, 1977.

On the relation of economic theory and index numbers, an accessible account is Peter Hill's "Recent Developments in Index Number Theory and Practice," *OECD Economic Studies* #10, Spring 1988. A classic comparison of many different price indexes is Irving Fisher, *The Making of Index Numbers*, Riverside Press, Cambridge, 1922.

APPENDIX

PRICE INDEXES AND IMPLICIT DEFLATORS

The CPI, PPI, and GNP fixed-weight price indexes all reflect weighted averages of prices relative to average prices in a base period. Since the weights on specific prices remain fixed for long periods of time, the indexes are often referred to as fixed-weight indexes. In symbols, a fixed-weight index can be represented as in equation (1a) or its possibly more intuitive form, (1b):

$$P_t = \frac{\sum p_t q_b}{\sum p_b q_b} \quad (1a)$$

$$= \sum \left(\frac{p_t}{p_b} \right) \left(\frac{p_b q_b}{\sum p_b q_b} \right) \quad (1b)$$

where P_t is the price index in period t , the summation signs represent summation over all commodities covered by the index, p_t is the price of a specific item in period t , q_b represents either the quantity of a specific item included in the market basket (CPI) or the quantity produced in the base period (PPI or GNP indexes), and p_b is the price of a specific item in the base period. In words, equation (1b) states that the price index is a weighted average of the relative price changes for specific items (the first term in parentheses), with the weights being the relative importance of the items in the base period (the second term in parentheses).

The deflators used in the National Income and Product Accounts are somewhat different since the weights of individual prices can vary over time. A deflator can be represented as in equation (2):

$$P_t = \frac{\sum p_t q_t}{\sum p_b q_t} \quad (2)$$

where P_t is the price index in period t , the summation signs represent summation over all commodities covered by the index, p_t is the price of a specific item in period t , q_t is the current quantity consumed of that specific item, and p_b is the price of a specific item in the base period. In words, equation (2) states that the price index is the ratio of current expenditure to current quantities times base period prices. When compared to the base period, an implicit deflator is a current-weight price index. That is, it is a weighted average of prices with the weights being current quantities. When two periods other than the base period are compared, however, the change in the deflator is a muddle of price and quantity changes that can be difficult to interpret.

The chain price indexes reported in the accounts are base-weighted, with the base period for any quarter being the previous quarter; a chain index can be constructed using equation (1a) or (1b) above. Since the base shifts over time the weights can more accurately represent current production than would a fixed-weight index based in a distant period. Moreover, it avoids much of the difficulty of interpretation of an implicit deflator for quarterly changes. On the down side, however, changes in the chain index over long periods of time may themselves be difficult to interpret, since the items produced can vary substantially.

A simple example may help clarify the types of indexes. Suppose that one wishes to construct a price index for fruit. There are two types of fruit, apples and oranges. Table III shows the prices of apples and oranges in April, May, June, and July and the amounts consumed. A fixed-weight Fruit Price Index (FPI)

Table III

NUMERICAL EXAMPLES OF PRICE STATISTICS

	APRIL	MAY	JUNE	JULY
Price per apple	12	20	20	20
Number of apples bought	6	3	2	2
Price per orange	4	4	4	2
Number of oranges bought	7	10	15	30
FPI: Level	100	148	148	134
Percentage change		48	0	-9
IFD: Level	100	132	119	69
Percentage change		32	-10	-42
CFI: Level	100	148	100	70
Percentage change		48	-32	-30
Avg.: Level	100	140	133	96
Percentage change		40	-5	-28

is calculated, using quantities consumed in April as the base; as is conventional, the index value in the base period is 100. An Implicit Fruit Deflator (IFD) is also calculated, as is a Chain Fruit Index (CFI). Finally, as suggested in footnote 4, the geometric average of the FPI and IFD is presented (Avg.).

For example, using equation (1a) to construct the FPI for May,

$$\text{FPI} = \frac{(20 \times 6) + (4 \times 7)}{(12 \times 6) + (4 \times 7)} = \frac{120 + 28}{72 + 28} = 148.$$

Similarly, using equation (2) to construct the IFD for June,

$$\text{IFD} = \frac{(20 \times 2) + (4 \times 15)}{(12 \times 2) + (4 \times 15)} = \frac{40 + 60}{24 + 60} = 119.$$

A few points are worth emphasizing. First, the monthly estimates of price change can differ substantially, depending only on how the index is con-

structed. The differences in this example are extreme since the relative price changes are also extreme.

Second, the implicit deflator is less than the fixed-weight index. That is often the case in the real world as well, since it results from the tendency to switch consumption toward relatively less expensive goods when relative prices change.

Third, although neither price changed in June, both the implicit deflator and the chain index changed substantially.

Fourth, in July there was a substantial decline in the price of oranges. The fixed-weight index put little weight on that decline due to the small relative importance of oranges in the base period, April.

Finally, note that the geometric average occupies the middle ground between the extremes. In this case it shows relatively little average price change over the summer; in contrast, the fixed-weight index shows substantial inflation and the implicit deflator and chain index both show substantial deflation.