JOURNAL OF INVESTMENT MANAGEMENT, Vol. 1, No. 1, (2003), pp. 19–44

www.joim.com

A THEORY OF INFLATION

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Inflation entails a loop running from prices to wages and back again from wages to prices. Change in inflation rates result from two types of intervention in that otherwise closed loop. Inflation surprise intervenes when the labor productivity of the marginal plant, hence the real wage, turns out different from what negotiators expected when they fixed the money wage. The second kind of intervention is quite predictable. Although changes in tradables prices affect money wages, changes in money wages do not affect tradables prices. The practical result is that the tradables inflation rate affects the home goods inflation rate, but not vice versa. *In small, open economies, the predictable tradables effect is more important. In large, closed economies, the effect of real wage surprise on home goods price, is more important. In the many countries somewhere between the extremes, both inflation mechanisms are too important to ignore.*

Introduction

In this paper, Section 1 describes an inflation mechanism for the closed economy, Section 2 describes a mechanism for the open economy, and Section 3 uses both mechanisms to explain inflation in some economies that are neither wholly closed nor wholly open.

Section 1 focuses on the US and Japan. Evidence in Section 2 suggests that the US and Japan are the worst possible cases for studying inflation behavior in open economies. Because of its simplicity, however, we think the closed economy model is a good place to start.

Perhaps there are some wholly open economies (Lichtenstein? Monaco?). Certainly, there are none in our small sample. Accordingly, Sections 2 and 3 deal instead with countries that are less than wholly closed. To avoid circumlocution in those sections, we call such countries "open".

By this standard, of course, the US and Japan are open. But the inflation model in Section 1 is for an idealized economy that is wholly closed. Readers may agree with us that the US and Japan are nevertheless the best tests for this model.

1 The Closed Economy

In some degree, large or small, with some sign, positive or negative, inflation will always be present in a closed economy for which the following hold:

1. the objective of wage negotiators is a certain real wage;

2. but wage contracts are expressed in terms of a money wage;
3. the real wage is determined in the aggregate, not by negotiators, but by the (real) marginal product of labor.

These considerations suggest that if wage negotiators try to influence the real wage by influencing the money wage, arguing for unusually large increases, for example, when labor markets are tight, they will experience endless frustration and disappointment, year after year.

Day-to-day changes in NYSE stock prices are random, even though some investors think they can profit from stale information. Similarly, is the level of real wages unaffected by the degree of ease or tightness in the labor market? A simple test is how inflation and inflation changes behave when wage negotiators are not striving for a result they cannot achieve collectively—when they are not committing a fallacy of composition. Samuelson defines a fallacy of composition as "a fallacy in which what is true of apart is, on that account, alone, alleged to be necessarily true of the whole" and proceeds to give some helpful examples; "If all farmers work hard . . . [and produce] a bumper crop, total farm income may fall . . ." (Paul A. Samuelson, *Economics* p. 14. McGraw Hill 1973.)

Suppose that, instead of attempting to influence the real wage, negotiators content themselves with trying to predict it. (There would then be no immediate link to unemployment or to the relative strength of the negotiators' bargaining positions.) Specifically, suppose they proceed by

predicting the real wage,
predicting the price level, and
computing the money wage that is consistent with their predictions.

We can focus on the essence of this "rational" inflation process if we break time up into discrete intervals, and assume all wage contracts are renegotiated at the beginning of each interval, based on

1. the same intentions regarding the real wage, and
2. the same expectations about money prices.

Letting

W = money wage
P = money prices
w = real wage

we have the "real wage" identity

$$w = \frac{W}{P}$$

$$\mathrm{d}w = \frac{P\,\mathrm{d}w - W\,\mathrm{d}P}{P^2}$$

Using the calculus formula for the total differential of a quotient and dividing by the original identity, we have what we will call our *basic identity*.

$$\frac{\mathrm{d}w}{w} = \frac{P\,\mathrm{d}W - W\,\mathrm{d}P}{PW} = \frac{\mathrm{d}W}{W} - \frac{\mathrm{d}P}{P}$$

which expresses the real wage identity in terms of rates of change.

It is clear from our basic identity that, when real wages are not changing, the rate of price inflation equals the rate of wage inflation. And if, when real wages are not changing, negotiators set the rate of change in money wages equal to last period's rate of change in money prices, then next period's price inflation will equal last period's price inflation. But what happens when real wages are changing?

Once negotiators have fixed the money wage by negotiation, the actual level of money prices will depend on the real wage. If the actual real wage turns out to be different from the expected real wage, negotiators will be surprised by the effect on money prices and the inflation rate.

In other words, in order to arrive at a money wage, negotiators have to make some assumption about the future real wage. But when the actual real wage turns out to be different, they are already locked into that money wage. The only variable in the identity that can reconcile that money wage with the actual real wage is the level of money prices. But if this level is different from what negotiators anticipated, so is the inflation rate.

As noted, wage negotiators do not know what either money prices or real wages will be for the period they are negotiating. Fortunately, the expectations operator is a linear operator. This means that the expectation of a sum is the sum of the expectations. So we can write

$$\mathrm{E}\left[\frac{\mathrm{d}w}{w}\right] \equiv \mathrm{E}\left[\frac{\mathrm{d}W}{W}\right] - E\left[\frac{\mathrm{d}P}{P}\right]$$

But negotiators have fixed the *actual* money wage for the period. Substituting the actual money wage for the expected money wage and transposing we have

$$\frac{\mathrm{d}W}{W} \equiv \mathrm{E}\left[\frac{\mathrm{d}w}{w}\right] + \mathrm{E}\left[\frac{\mathrm{d}P}{P}\right]$$

The actual inflation rate must satisfy our basic identity with the money wage previously fixed by negotiation and real wage negotiators can neither predict nor control. Substituting our expression for the money wage into the identity

$$\frac{\mathrm{d}P}{P} \equiv \frac{\mathrm{d}W}{W} - \frac{\mathrm{d}w}{w}$$

we have

$$\frac{\mathrm{d}P}{P} \equiv \mathrm{E}\left[\frac{\mathrm{d}P}{P}\right] + \mathrm{E}\left[\frac{\mathrm{d}w}{w}\right] - \frac{\mathrm{d}w}{w}$$

$$\frac{\mathrm{d}P}{P} - \mathrm{E}\left[\frac{\mathrm{d}P}{P}\right] = -\left\{\frac{\mathrm{d}\omega}{\omega} - \mathrm{E}\left[\frac{\mathrm{d}w}{w}\right]\right\}.$$

In this quite general result, a real phenomenon—surprise in the rate of change in the real wage—drives a monetary phenomenon—surprise in the rate of change in the money price level.

The model asserts that

1. surprises in the rate of inflation will be simultaneous with surprises in the real wage;
2. the effect on price inflation will be the same, whether the real wage surprise is due to an oil crisis, a currency change, or an employment surprise;
3. on average, a 1% surprise in the real wage will produce a 1% surprise in the inflation rate in the opposite direction, irrespective of the time dimension.[1]

This line of reasoning suggests that changes in the inflation rate can occur without any change in negotiators' relative bargaining positions, without any shifts from ease to tightness, or vice versa, in the labor market and without imputing to negotiators some mistaken notion that they can influence the real wage.

But are real wage changes

1. Big enough to explain changes in inflation?
2. Correlated with inflation changes?
3. Too predictable to explain inflation surprise?

Real Wage Surprise

Alas, it is not enough for a change in employment to generate change in the real wage. It has to generate real wage surprise. Because they are driven by demographics, for example, work force changes should be predictable. Is it nevertheless possible for the resulting changes in the real wage to be unpredictable?

The key to such questions is the economy's production function. It may take years to produce a capital good—four years for an oil refinery, six years for a fossil fuel electric generating plant, etc. How does the economy respond to sudden changes in current demand?

The economy has a stock of plant capacity. Over time, additions to that stock accumulate and, with them, a cumulative number of jobs $N(t)$ and a cumulative quantity of output $Y(t)$. At any real time t, $N(t)$ and $Y(t)$ are given, reflecting the history of capital investment and technology, and including three categories of plant: operating, idle, and scrapped.

At any given level of current demand, employers strive to use their newer, more efficient plant, idling the older, less efficient plant.[2] When plant built before time τ is idled, employment n and output y are, respectively,[3]

$$n = N(t) - N(\tau)$$
$$y = Y(t) - Y(\tau)$$

To vary output and employment at time t, policy makers vary τ. But different values of τ correspond to different vintages of marginal plant—hence different productivities for the marginal worker and different real wages. Other things equal, the higher are output and employment, the earlier is τ, the older is the marginal plant, and the lower is the resulting real wage.[4]

When employment n increases suddenly, how fast does output rate y increase? Holding t fixed and varying τ, we have

$$\Delta_n \approx \frac{\partial n}{\partial \tau}\Delta\tau = -\frac{\mathrm{d}N}{\mathrm{d}\tau}\Delta\tau$$
$$\Delta_y \approx \frac{\partial y}{\partial \tau}\Delta\tau = -\frac{\mathrm{d}Y}{\mathrm{d}\tau}\Delta\tau$$

At time t the rate of change of output y with respect to labor input n is

$$\frac{\Delta y}{\Delta n} = \frac{-(\mathrm{d}Y/\mathrm{d}\tau)\Delta\tau}{-(\mathrm{d}N/\mathrm{d}\tau)\Delta\tau} = \frac{\mathrm{d}Y/\mathrm{d}\tau}{\mathrm{d}N/\mathrm{d}\tau} = \frac{\mathrm{d}Y}{\mathrm{d}N}$$

where $\mathrm{d}Y/\mathrm{d}N$ is the labor productivity of plant built at time τ. We see that the marginal productivity of labor, hence the real wage, at time t depends on this ratio.[5]

When τ changes, $\mathrm{d}Y/\mathrm{d}N$ changes. So this number is the key to real wage surprise. When one undertakes to forecast the real wage, one has to answer three questions:

1. What is tomorrow's employment level?
2. How big a change in τ will it take to produce the new employment level? Consider the circumstances at time τ. Presumably, technology was advancing whether we were investing in it or not. But if not, then small changes in the current level of employment will correspond to big changes in τ, hence big changes in technology and big changes in the real wage. Such fallow investment periods correspond to "flat spots" on the $N(t)$ and $Y(t)$ curves—regions where jobs and output did not change when τ was changing. When a current decision to change the level of employment requires policy makers to traverse such a flat spot, the requisite change in τ, hence in technology and in the real wage, is abnormally big. But today's marginal plant is often 20–40 years old. Unless the precise location of these flat spots is still known, even predictable changes in n can cause big surprises in τ, hence in the real wage.
3. What is the productivity $\mathrm{d}Y/\mathrm{d}N$ of marginal plant corresponding to tomorrow's τ? Between today and tomorrow τ may not change at all. Or it may change suddenly if demand changes suddenly. (War? Financial panic?)

Although our theory of inflation is about surprise, we are obliged to use data on changes (or changes in rates of change, etc.). The difficulties posed by these three questions suggests there is plenty of uncertainty in real wage changes. But we cannot plausibly argue the changes we observe are entirely surprise.

Testing the Model

We have argued that the actual money wage is related to negotiators' expectations by

$$\frac{\mathrm{d}W}{W} = \mathrm{E}\left[\frac{\mathrm{d}w}{w}\right] + \mathrm{E}\left[\frac{\mathrm{d}P}{P}\right]$$

It is not obvious how negotiators form their expectations for the real wage. But they know they do not control money prices, and they find the macroeconomics mysterious. So, extrapolation has to be tempting. And, given that changes in the rate of price inflation are nearly random, last year's actual is an obvious basis for this year's expectation. This suggests a way to estimate the change in the real wage negotiators expect. Transposing and incorporating the extrapolation we have

$$E\left[\frac{\mathrm{d}w}{w}\right] = \frac{\mathrm{d}W}{W} - B\left[\frac{\mathrm{d}P}{P}\right]$$

where both right-hand terms are observable and B[ ] is the backshift operator.

But what if instead negotiators base their real wage expectation on extrapolation? Then, we would have two bases for our estimate of their real wage expectation. If our assumptions about extrapolation are valid, however, each should give the same estimate. Figure 1 tests the correlation between the two estimates.

If we combine the estimate that extrapolates price with our basic identity, we obtain

$$\frac{\mathrm{d}P}{P} - \mathrm{B}\left[\frac{\mathrm{d}P}{P}\right] = -\left\{\frac{\mathrm{d}w}{w} - \mathrm{E}\left[\frac{\mathrm{d}W}{W}\right]\right\}$$

If we combine the estimate that extrapolates the real wage with our basic identity, we obtain

$$\frac{\mathrm{d}P}{P} - \mathrm{B}\left[\frac{\mathrm{d}P}{P}\right] = -\left\{\frac{\mathrm{d}w}{w} - \mathrm{B}\left[\frac{\mathrm{d}W}{W}\right]\right\}$$

The first extrapolation suggests that changes in the inflation rate result from real wage surprise. The second suggests a way to predict changes in the inflation rate, using first differences to proxy real wage surprise. We think the second is both more heroic and more useful than the first.

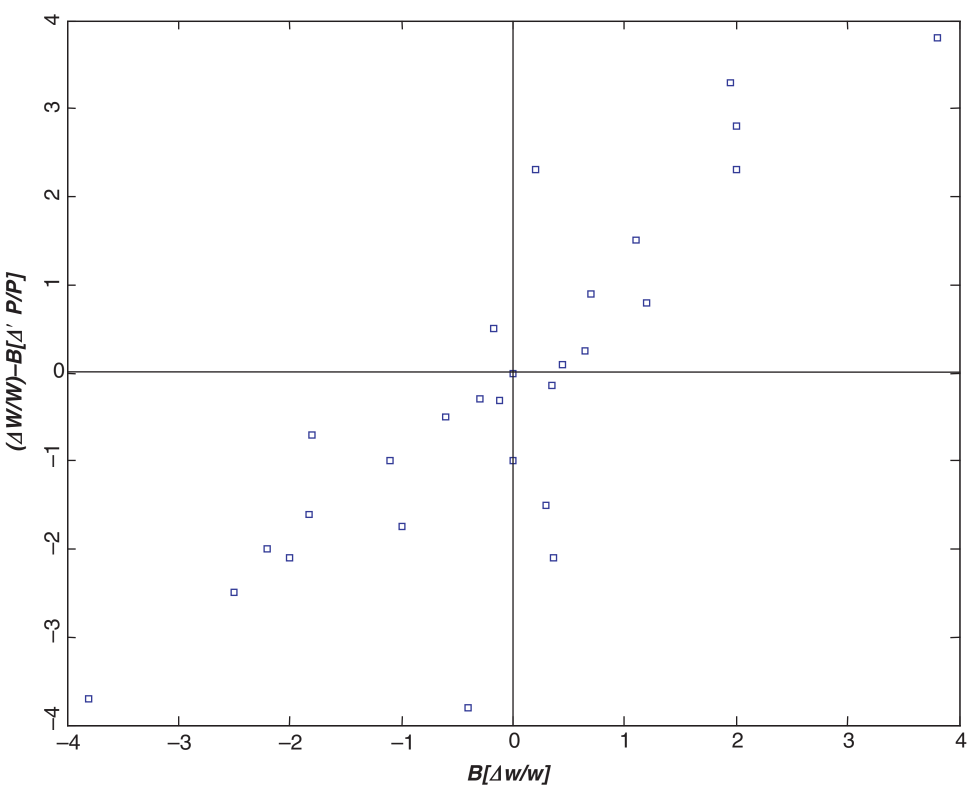


Figure 1 United States, 1972–1999.

The remaining figures make extensive use of some new symbols:

f = work force,
m = percentage unemployment $= (f - n)/f$,
Δm = change in percentage unemployment,
ω = inflation rate $= (\Delta P)/(P\Delta t)$,
$\Delta\omega$ = first difference in inflation rate ω,
$\Delta^2\omega$ = second difference in inflation rate ω,
Δw = first difference in real wage μr,
$\Delta w/w$ = fractional change in real wage,
$\Delta[dw/w]$ = first difference of $\Delta w/w$,
$\Delta^2[\Delta w/w]$ = second difference of $\Delta w/w$.

All data are annual.[6]

Appendix A explores the relation between employment and unemployment. Figures 2 and 3 show the power of unemployment to explain inflation change. The original Phillips curve plotted the inflation rate against the unemployment level. Because this paper is concerned with changes in inflation rates, Figure 2 displays first differences of these two variables for the US. (Appendix B discusses implications of our model for these curves.)

According to our model, a 1% real wage disappointment will raise the inflation rate 1%. But the model is about surprise. Some of the change in the real wage is surprise. Some is predictable. The surprising changes are our explanatory variable; the predictable changes are merely noise (see Appendix C). Because we cannot separate the former from the latter, we have an errors-in-variables problem. As in all such problems, our estimate of the coefficient is biased downward. Figure 4 shows the power of the real wage to explain change in the inflation rate in the US. But it also suggests that not all

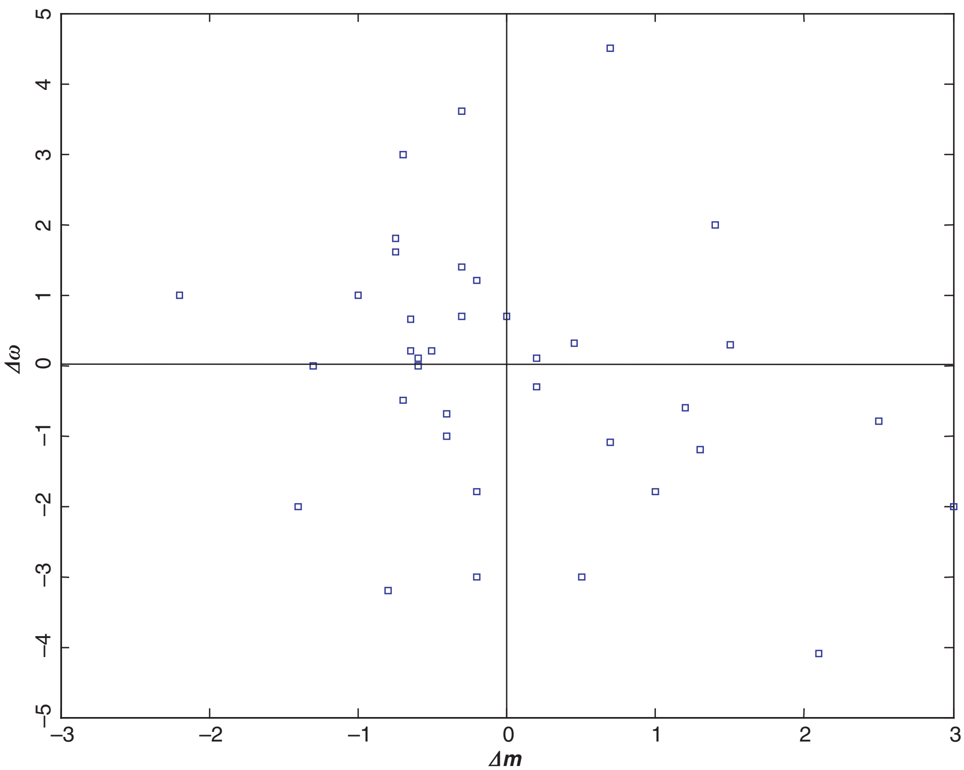


Figure 2 United States, 1958–1995.

real wage change is surprise, and that the real wage does not explain everything. Figure 5 plots second differences of these variables.

Figures 6 and 7 show Philips curve data for Japan. Figure 8 plots the change in price inflation for Japan against change in the real wage trend. The reader is cautioned against extrapolating from the data for the US and Japan. The evidence in Section 2 suggests that they are much less open than most countries, and that an entirely different inflation mechanism is operating in such countries.

Stagflation

Stagflation is the simultaneous occurrence of high unemployment and high inflation. It is a puzzle if one thinks labor scarcity is the key to inflation. But the puzzle disappears when one focuses on the real wage. We saw that

$$\tau = N^{-1}[N(t) - n]$$

Since the current real wage depends only on, it depends only on

$$N(t) - n.$$

Stagflation results when investment fails to create new, high productivity jobs, measured by $N(t)$, fast enough to keep up with employment n. Most productive work involves a partnership between man and machine (truck and driver, lathe and operator). It is quite true that, when output increases suddenly, workers get scarcer. But machines also get scarcer. The model in this section suggests that inflation is caused by a disappointing real wage—that is, by a disappointing marginal productivity of labor, due to "too many workers chasing too few jobs".

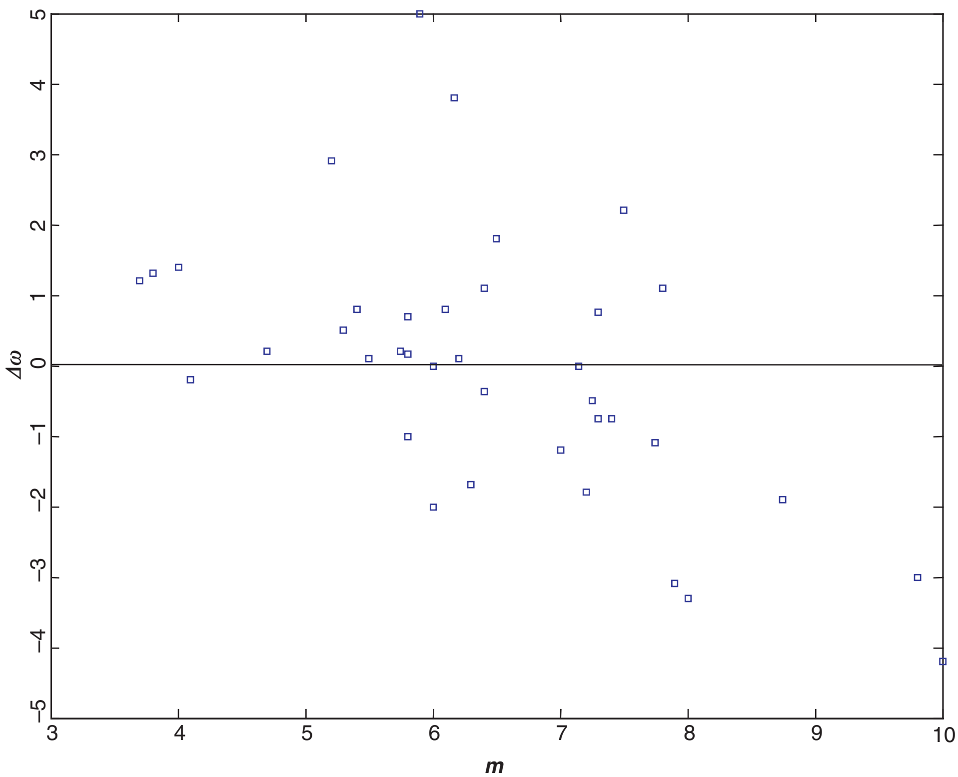


Figure 3 United States, 1958–1995.

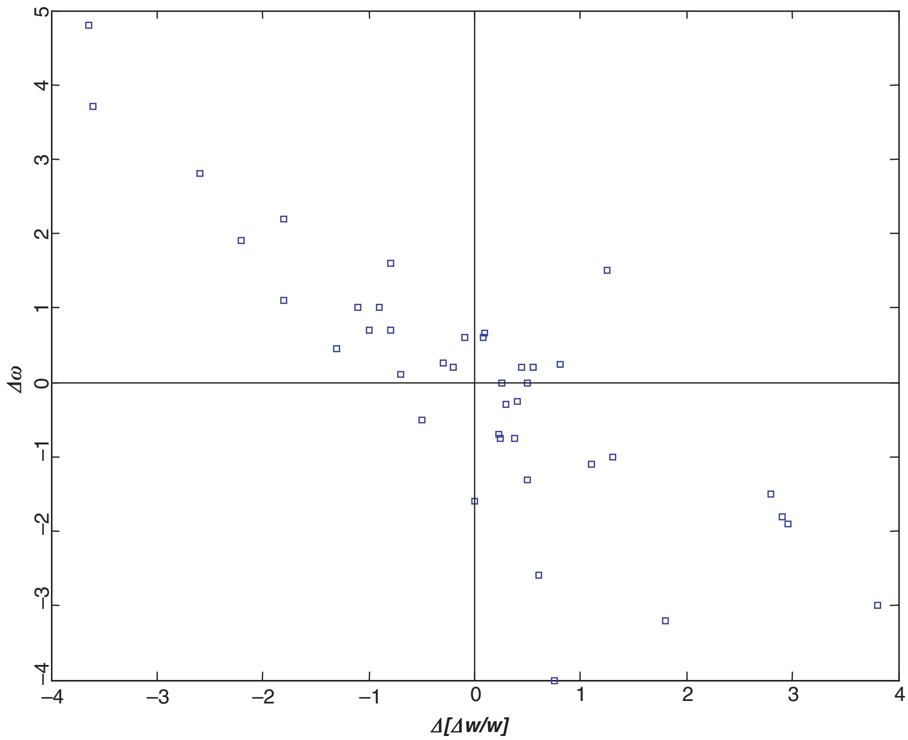


Figure 4 United States, 1959–1995.

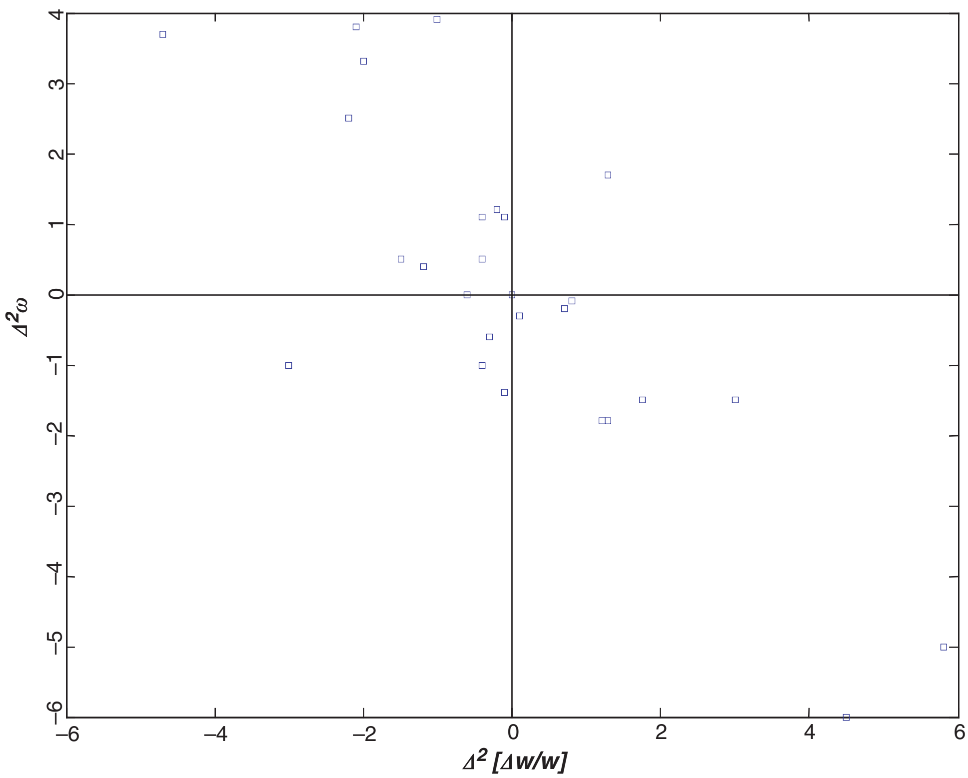


Figure 5 United States, 1973–1999.

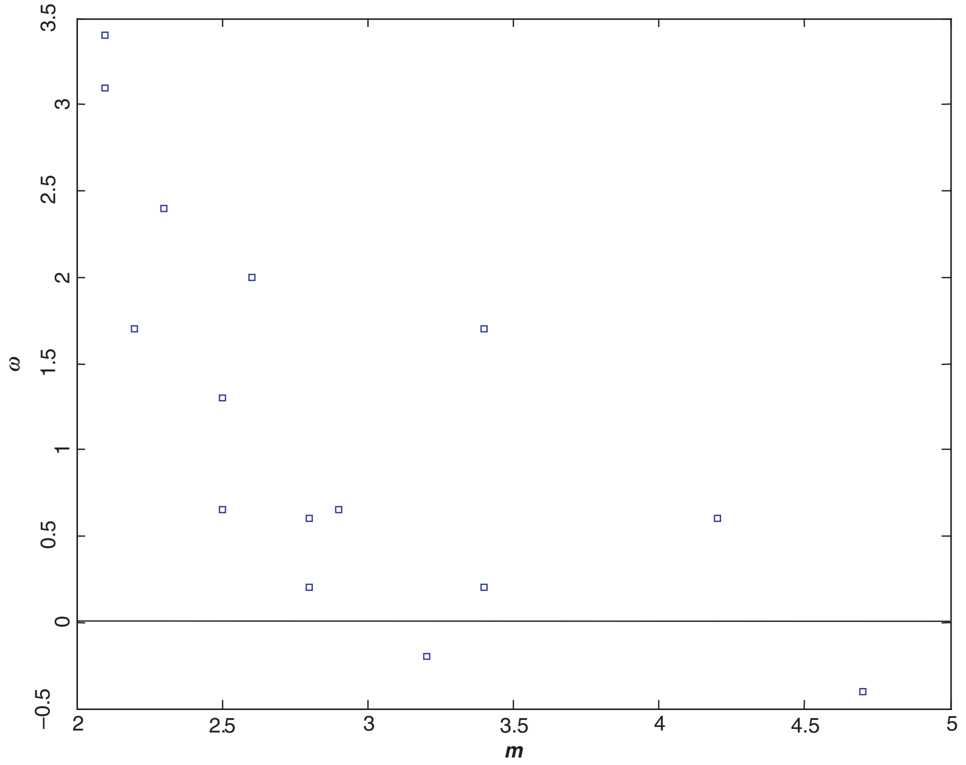


Figure 6 Japan, 1985–1999.

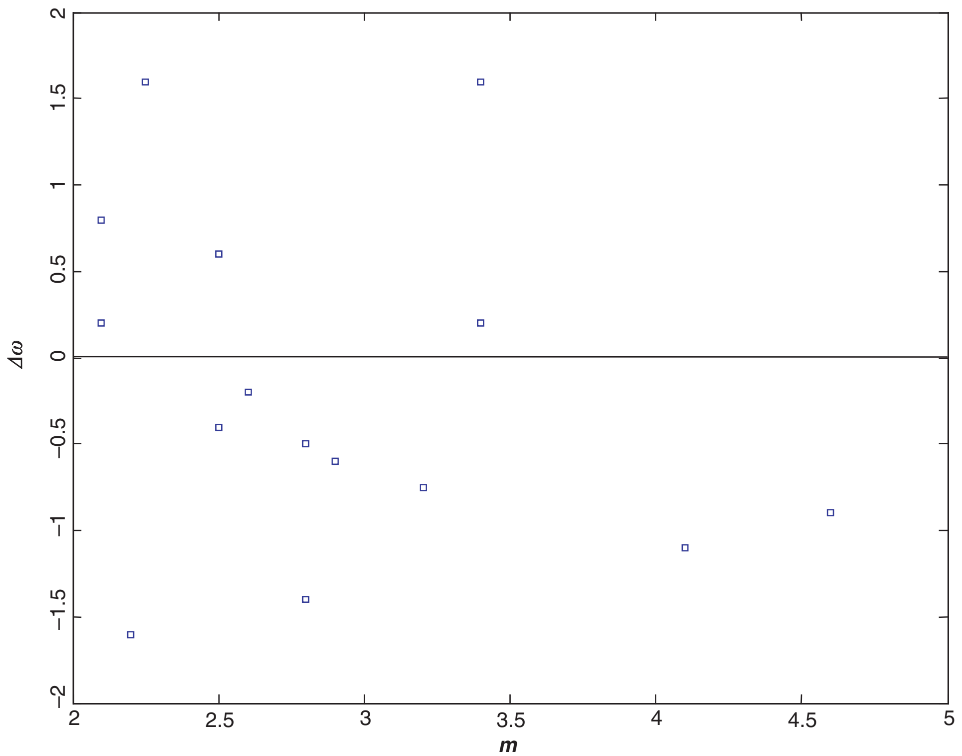


Figure 7 Japan, 1985–1999.

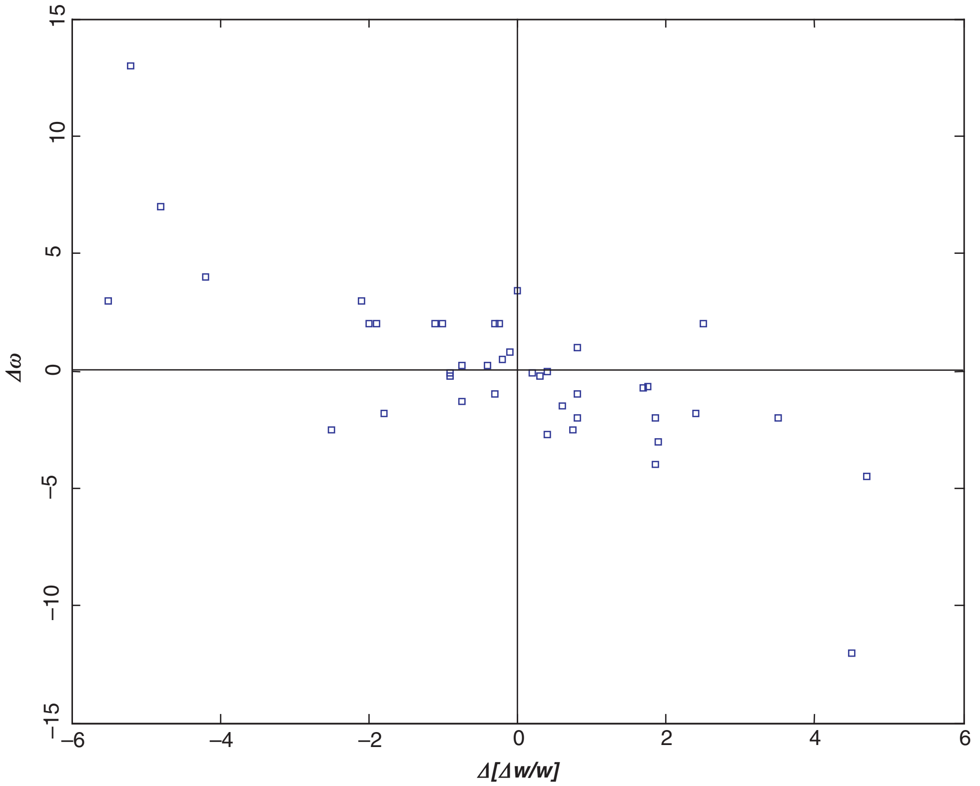


Figure 8 Japan, 1959–1999.

2 Inflation Momentum

When economists talk about inflation, what they have in mind is not mere price change, but rather momentum in price change. Momentum—the tendency for past price change to beget future price change—is a home goods phenomenon.

Barbers in Seville cannot meet the demands of shaggy New Yorkers. Haircuts are textbooks' favorite example of a home good (or service, as in this case). When the money wage in the US rises, the price of haircuts rises, along with the money prices of other home goods.

Steel is different. Manufacturers in Detroit can (and do) use steel made in Germany, Japan, and Korea. So the price of steel reconciles global supply with global demand (Detroit, Milan, Stuttgart, and Coventry). Steel is a tradable good (a "tradable"). When the money wage in the US rises, wages in Pittsburgh, Bethlehem, and Gary also rise. But, unless and until either the global price of steel rises or the value of the dollar falls, the price of steel in the US does not budge.

Economists' favorite examples of tradables are commodities—copper, pig iron, newsprint, petroleum, pulp, soy beans, sugar, and wheat. But today, automobiles and brown goods (radios, TVs, etc.) are also tradable goods.

With appropriate allowances for differences in transportation and other distribution costs, the price of tradables is everywhere the same. The local price is merely the global price translated into the country's local currency. Changes in local demand change the local price, hence local output, only when they change the global price. A country's home goods, on the other hand, do not have to compete with other countries' home goods. So there is no global price. Changes in local demand can be met only by changes in local output, induced by changes in local price.

The so-called "Australian model" contemplates a country so small that certain of its demand changes have no effect on global prices—hence no effect on local tradables prices and no effect on local tradables output. The late, great MIT economist, Rudiger Dornbusch, described it this way: "The country is assumed to be a price taker in the world market for importables and exportables alike . . . The distinction between importables and exportables becomes immaterial for most questions . . . With no need to distinguish . . . we can aggregate them into a composite commodity called tradable goods . . . [which] are then distinguished from non-traded goods or home goods."[7]

But can we apply the distinction to the US—the world's largest economy? Is US tradables demand so big that it dominates world tradables demand? Alas, we do not have data on tradables demand—either for individual countries or for the world as a whole.

It is easy to approximate the fraction of a country's GDP devoted to commerce with other countries. Although exports may not equal imports, their average gives us a rough measure. But we do not think this is the appropriate measure of the country's openness—of the relative importance of tradables. If local demand absorbs the entire output of a local tradables industry, it will contribute nothing to the host country's exports, while absorbing purchasing power that might otherwise be devoted to the country's imports. Are Harley-Davidsons more popular in the US than Yamahas? Are Yamahas more popular in Japan than Harley-Davidsons? Are Fiats more popular in Italy than Toyotas? Toyotas more popular in Japan than Fiats? Then, exports (or imports) are going to under estimate the importance of tradables to the overall price level of these countries.

Here's a simple way to get a very rough sense of the relative importance of US tradables to world tradables—hence, of the likely impact of US demand on global prices: assume that the ratio of tradables consumption to imports or exports is the same for the US as it is for the world. Then, the ratio of US tradables consumption to world tradables consumption equals the ratio of the US imports (exports) to world imports (exports).

Because it is less affected by year-to-year fluctuations in US prosperity, the export ratio is more stable. As Table 1 shows, over the last 30-years it has varied from 10.5 to 12.8%, with a average value of 11.9%.

If, when the US demand increases, home goods and tradables demand increase in the same proportion, then on average the percentage increase in home goods demand is $8.4 = 1/0.119$ times the per centage increase in global tradables demand. In understanding US inflation, we think the difference between tradables and home goods should be treated as a difference in kind. And if that is true for the US—the biggest economy in the world—it is surely true for every other country.

So fluctuations in the local money wage are going to have modest effects on global tradables prices, even if they have big effects on local home goods prices. So the closed loop connecting wage changes to prices and price changes to wages, which is so important for the home goods inflation model of Section 1, does not hold (or holds very weakly) for tradables. Whereas in a wholly closed economy, inflationary momentum continues until disturbed (e.g. by real wage surprise), in a wholly open economy, there is no home goods mechanism. We argue below that an economy that is neither wholly open nor wholly closed will exhibit inflation momentum, but the effect of a local disturbance will die out over time. And the more open the economy, the faster the disturbance will die out.

Table 1 Exports in $ billions

Year	World	US	Ratio
1972	4004	492	12.3
1973	5560	708	12.7
1974	8173	994	12.2
1975	8507	1089	12.8
1976	9602	1168	12.2
1977	10,881	1232	11.3
1978	12,596	1458	11.6
1979	16,300	1864	11.4
1980	19,459	2256	11.6
1981	19,497	2387	12.2
1982	18,006	2164	12.0
1983	17,568	2056	11.7
1984	18,642	2240	12.0
1985	18,878	2188	11.6
1986	20,580	2272	11.0
1987	24,312	2541	10.5
1988	27,795	3224	11.6
1989	30,241	3638	12.0
1990	34,386	3936	11.4
1991	35,303	4217	11.9
1992	37,577	4482	11.9
1993	37,616	4648	12.4
1994	42,818	5126	12.0
1995	51,232	5847	11.4
1996	53,436	6251	11.7
1997	55,300	6887	12.5
1998	54,360	6821	12.5
1999	56,358	7021	12.5
2000	63,405	7811	12.3
2001	61,148	7308	12.0
	1/11.9 = 8.4 times	3572/30 = 11.9	

The Theory

Define

- x real quantity of home goods
- z real quantity of tradables
- H money price of home goods
- T money price of tradables
- G money value of the open economy's real output of home goods (x) and tradables (z).

What do wage negotiators in an open economy look at, in order to judge what is happening to the price level? Consider first the money value of the gross domestic product:

$$G = xH + zT$$

Its total differential is

$$x\Delta H + z\Delta T + H\Delta x + T\Delta z$$

The first two terms reflect changes in money prices. We have argued that rational wage negotiators will allow only for inflation, focusing on the first two terms, and ignoring the last two, which reflect changes in the physical volume of output. We define ΔG as that part of the change in G due to price-level changes:

$$\Delta G = x\Delta H + x\Delta T$$

Inflation rates are fractional changes. Dividing by gross domestic product, we have a measure of the percentage, or fractional, impact of price changes on money GDP:

$$\frac{\Delta G}{G} = \frac{x\Delta H}{G} + \frac{z\Delta T}{G}$$
$$= \frac{xH}{G}\left(\frac{\Delta H}{H}\right) + \frac{zT}{G}\left(\frac{\Delta T}{T}\right)$$

It follows from the definition of G that

$$\frac{xH + zT}{G} = 1$$
$$\frac{zT}{G} = 1 - \frac{xH}{G}$$

Letting

$$\mathrm{C} = \frac{xH}{G}$$
$$1 - \mathrm{C} = \frac{zT}{G}$$

(C for "closed") we can write

$$\frac{\Delta G}{G} = \mathrm{C}\left(\frac{\Delta H}{H}\right) + (1 - \mathrm{C})\left(\frac{\Delta \mathrm{T}}{T}\right)$$

The measure of home goods inflation ΔH/H reflects both the real wage effects discussed in Section 1 and the effects of change in the hourly wage. In the absence of real wage surprise, the money price of home goods will change as fast (expressed as a percentage, or fractional change) as the money wage is changing. We have

$$H = Wh$$
$$\frac{\mathrm{d}H}{\mathrm{d}W} = h_0 = \frac{H}{W}$$
$$\frac{\mathrm{d}H}{H} = \frac{\mathrm{d}W}{W}$$

Substituting for the home goods inflation rate $\mathrm{d}H/H$ the contemporaneous money wage inflation rate $\mathrm{d}W/W$, we have

$$\frac{\Delta G}{G} = C\left(\frac{\Delta W}{W}\right) + (1 - C)\frac{\Delta T}{T}$$

where C is the fraction of the market basket's value consisting of home goods and $(1-C)$ is the fraction consisting of tradables.

Finally, assume that wage negotiators set next period's money wage W so that the resulting rate of wage inflation equals last period's rate of price inflation in G. We have

$$\left(\frac{\Delta W}{W}\right)_{t+1} = \frac{\Delta G}{G_t}$$

With this substitution, the expression for the total differential becomes

$$\left(\frac{\Delta W}{W}\right)_{t+1} = C\left(\frac{\Delta W}{W}\right)_t + (1 - C)\left(\frac{\Delta T}{T}\right)_t$$

For the change in the inflation rate, we have

$$\left(\frac{\Delta W}{W}\right)_{t+1} - \frac{\Delta W}{W_t}$$
$$= (C - 1)\left(\frac{\Delta W}{W}\right)_t + (1 - C)\left(\frac{\Delta T}{T}\right)_t$$
$$= (1 - C)\left\{\left(\frac{\Delta T}{T}\right)_t - \left(\frac{\Delta W}{W}\right)_t\right\}$$

Absent surprise, the local rate will move toward the global rate, traversing in each period a fraction of the remaining difference. We think this version of the total differential is the one best suited to estimating predictable change in countries' inflation rates. It is the one we use in the country regressions discussed below.

3 The Open Economy

In the closed economy, there is one inflation rate and one source of surprise. In the open economy, there are two inflation rates and three sources of surprise. In the absence of any surprise since time zero, the momentum in the home goods inflation rate X damps toward the tradables rate—which is to say, toward the global rate Z.[8]

Fortunately, the dynamics of *global* inflation are relatively simple. The reason is that the global economy is a closed economy. There is only one kind of surprise. And there is no damping because, for the global economy, there are no tradables: without tradables, there can be no tradables inflation rate to complicate the feedback loop between money wages and global money prices. For this reason, the model of Section 1 applies exactly to the global economy: the global inflation rate Z changes when, and only when, there are surprises in the real global price level (or equivalently, the real global wage level).

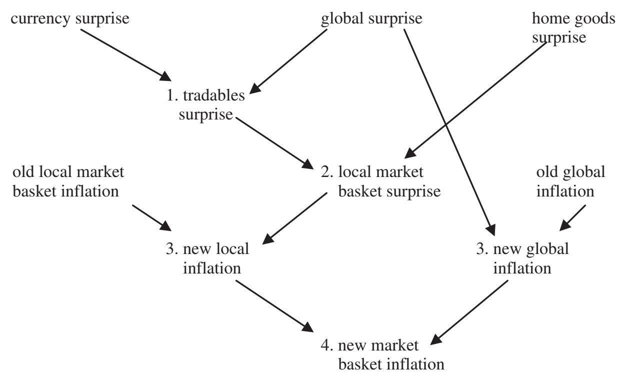
Real Wage Surprise

Surprise also affects the local inflation rate. The three sources are:

1. Home goods prices, which are driven by local demand and supply.
   "A mysterious occupational disease wipes out a country's population of barbers. The real price of haircuts skyrockets."
2. *Currency values*. Changes alter local money prices of tradables. We argue below that currency changes will tend to be a surprise. A one-time currency change will kick off inflation momentum in the money wages–home goods loop, subject to the usual damping in subsequent periods. Because the *global* inflation rate will not be affected, after the currency change, the local *tradables* inflation rate will not be affected either. So, in future periods, the only surviving momentum from the currency change will be in money *home goods* prices (and money wages).
   "Mozambique attempts to solve its trade deficit with a 50% devaluation of the meticai. Hunters respond with a sharp increase in money wage demands, which then raise the money price of bush meat, accelerating the already rapid home goods inflation. But, once repriced to reflect the new value of the meticai, the inflation rate for Land Rovers is essentially unchanged."
3. Global prices, which have two quite different effects. Because they change the global inflation rate, they also change the local tradables rate. But they also create surprise in the tradables portion of the worker's market basket. Negotiators' money-wage response kicks off momentum in the home goods loop. Like all home goods momentum, the latter effect damps out over time. But, because the global economy is closed, the momentum in global prices, hence in local tradables prices, does not damp out over time. Instead, it changes only when there are further global surprises.
   "An oil crisis creates global surprise and raises the *global* inflation rate. Local workers respond to the increase in local oil prices by increasing their wage demands, which then raise the money price of haircuts. So the *home goods* inflation rate also increases."

How Inflation Rates Change

A flow chart is the easiest way to see how the two inflation rates are affected by the three kinds of surprise.



The stage numbers in the flow chart refer to combinations of

1. global surprise and currency surprise;
2. tradables surprise and home goods surprise;
3. surprise and old inflation rate (global and local);
4. local inflation rate and global inflation rate.

The home goods-tradables combination discussed in Section 2 is an example of stages #2 and #4. It considered the price G of a "basket" of two goods with prices H and T and the respective quantities x and z. We had

$$\begin{aligned} G &= xH + zT \\ \mathrm{d}G &= x\mathrm{d}H + z\mathrm{d}T \\ &= xH\left(\frac{\mathrm{d}H}{H}\right) + zT\left(\frac{\mathrm{d}T}{T}\right) \end{aligned}$$

$$\frac{dG}{G} = \left(\frac{xH}{G}\right)\left(\frac{dH}{G}\right) + \left(\frac{zT}{G}\right)\left(\frac{dT}{T}\right)$$

The fractional change in the value of the basket was the sum of the fractional changes in the individual prices, weighted by the value of the corresponding terms (stage 4). But the same weights apply to the impact on market basket surprise of home goods surprise $\Delta h/h$ and tradables surprise, when we express these surprises as fractional changes in the respective prices (stage 2).

Section 1 provided an example of the sort of combination contemplated in stage #1. It expressed changes in the quotient $P = G/W$ in terms of a difference

$$\frac{\Delta p}{p} = \frac{\Delta G}{G} - \frac{\Delta W}{W}$$

involving fractional changes. Now we have another quotient.

$$\text{Local tradables price} = \frac{\text{Global price}}{\text{Currency value}}$$

Can we express the variables in this quotient as fractional changes? We can express local tradables surprise as price change divided by initial price—that is, as a fractional change. We can do the same with global inflation surprise ΔZ. And, if we define ΔV as the *ratio* of the change in currency value to its initial value, then we can write

$$\left\{\begin{array}{l}\text{Fractional}\\ \text{tradables}\\ \text{Price}\\ \text{surprise}\end{array}\right\} = \left\{\begin{array}{l}\text{Fractional}\\ \text{global}\\ \text{Price}\\ \text{surprise}\end{array}\right\} - \left\{\begin{array}{l}\text{Fractional}\\ \text{currency}\\ \text{surprise}\end{array}\right\}$$

$$= \Delta Z - \Delta V$$[9]

Finally, the closed-economy inflation model in Section 1 addresses the combination in Stage 3:

$$\text{New inflation} = \text{Old inflation rate} + \text{real price surprise}$$

(expressed as a fractional change ($\Delta h/h$)).

Using the appropriate rule for each combination we have[10]

$$\Delta Z - \Delta V$$

$$C\left(\frac{\Delta h}{h}\right) + (1 - C)(\Delta Z - \Delta V)$$

$$X + C\left(\frac{\Delta h}{h}\right) + (1 - C)(\Delta Z - \Delta V)$$

$$C\left[X + C\left(\frac{\Delta h}{h}\right) + (1 - C)(\Delta Z - \Delta V)\right] + (1 - C)(Z + \Delta V)$$

Consolidating terms, we have

$$CX + (1 - C)Z + C^2\left(\frac{\Delta h}{h}\right) + (1 - C^2)\Delta Z - C(1 - C)\Delta V$$

This is the new market basket inflation rate, expressed in terms of the old market basket rate X, the old global rate Z, and the three sources of surprise.

When we compute the first difference of a time series, convention dictates that we assign to values in the new series the later of the corresponding dates. For example, we have

$$Z_{t+1} - Z_t = \Delta Z_{t+1}$$

We write the effect on Z of all the global surprises between time t and time $t + 1$ as

$$Z_t + \Delta Z_{t+1}$$

On the other hand, all three sources of surprise can affect the local market basket inflation rate X between time t and time $t + 1$. Observing the same convention, we write our expression for the new market basket rate

$$X_{t+1} = CX_t + (1 - C)Z_t + C^2\left(\frac{\Delta h_{t+1}}{h_t}\right) + (1 - C^2)\Delta Z_{t+1} - C(1 - C)\Delta V_{t+1}$$

We have for the corresponding change in the local rate

$$X_{t+1} = (1 - C)(Z_t - X_t) + C^2\left(\frac{\Delta h_{t+1}}{h_t}\right) + (1 - C^2)\Delta Z_{t+1} - C(1 - \mathrm{C})\Delta V_{t+1}$$

In Box–Jenkins terms, the inflation model for the open economy is stationary, first-order autoregressive with no moving average component (because ΔH, ΔZ and ΔV are all current surprises). The right-hand side displays the four elements in the year-to-year change in an open economy's inflation rate:

1. regression of home goods momentum toward global momentum;
2. "home goods" surprise;
3. global surprise;
4. currency surprise.

Testing the Model

Ideally, we would like to test an open-economy inflation model that includes as explanatory variables global surprise, currency surprise, and home goods surprise. Alas, we do not have price data for the portion of the worker's market basket that is home goods. What we *can* measure is the CPI and the worker's money wage, hence the *combined* effect of home goods, currency, and global surprise on his real wage. So we can apply the model of Section 1.

On the other hand, we can incorporate the momentum effects of Section 2 if we can identify a suitable proxy for a "global" inflation rate. Although the IMF actually supplies such an index, we choose instead to use their index for "industrial" countries. Our thinking is that we want to give heavier emphasis to countries' most important potential trading partners.

But even with this crude data we can address two questions:

1. Does our proxy for surprise in the worker's market basket help explain change in the local inflation rate?
2. Does the local rate tend to regress toward the global rate?

The first is important for any economy that is not wholly open. The second is important for any economy that is not wholly closed. For the many real economies that are neither wholly open nor wholly closed, both questions are often important.

The regression model we propose has a constant term, a term for market basket, hence real wage, surprise, and a term for the difference between the home goods inflation rate and the global rate. Our dependent variable ΔX is change in (i.e. first difference of) the local inflation rate. Our proxy for real wage surprise is the first difference of the fractional change in the real wage. Our proxy for the "global" inflation rate is the IMF's CPI index for 23 industrial countries. Our time sample is 1968–1997.

The twelve countries in our sample, Australia, Netherlands, Canada, Spain, France, Sri Lanka, Italy, Sweden, Japan, the United Kingdom, Korea, and the United States, are the only countries that provided wage data to the IMF for our whole sample period. Table 2 suggests that this limited sample nevertheless spans a broad range of inflation behavior.

It is quite possible that France is not the only country for which our inflation model flops—that is, it just happened to be the only flop that supplied "wage" data for our entire time sample. (France calls the crucial IMF time series "labor cost", rather than "wage". Maybe the series is not intended to proxy the money wage.)

Table 2 Inflation behavior in the open economy 1968–1997

Country	Probability of null hypothesis	Coefficients of explanatory variables: Global–local	Δ^2 Real wage
United States	0.000	0.072	−1.060
Japan	0.000	0.122	−1.460
Korea	0.000	0.589	−0.476
Sweden	0.000	0.710	−0.204
United Kingdom	0.006	0.636	−0.403
Canada	0.007	0.586	−0.287
Spain	0.016	0.315	−0.236
Sri Lanka	0.029	0.537	−0.079
Australia	0.031	0.365	−0.234
Netherlands	0.044	0.158	−0.274
Italy	0.046	0.438	−0.076
France	0.145	0.430	−0.125

Conclusions

Sections 1 and 2 describe two radically different inflation mechanisms. Our evidence suggests that, in some countries, one mechanism or the other dominates. Unfortunately, most central bankers are home grown. When one kind of country (big, relatively closed, "hard currency") gives policy advice to the other kind (small, relatively open, "soft currency"), there is potential for frustration, misunderstanding, and failure. We think a formal model general enough to comprehend both experiences (Section 3) can make these dialogues more productive.

Do we now know the truth about inflation? Physicists are fond of saying that all physics is false. Surely, all economics is false in the physicists' sense, and this paper is no exception. The writer hopes some researchers will tackle the task of demonstrating the falsity of the ideas in this paper. If they do, Karl Popper would surely approve.

Appendix A: Devising Meaningful Tests

If the size of the work force were constant, changes in employment and unemployment would be perfect complements; one series would explain inflation exactly as well as the other. Even if labor shortages actually had nothing to do with inflation, unemployment could have impressive explanatory power. Figure A1 shows the strong association between unemployment and employment for the US.

Is there nevertheless a test that can distinguish between the "labor" model and the "machine" model? Of the two variables that determine unemployment—the level of employment and the size of the work force—the first reflects the degree of ease or shortage in both labor and machines. But the second has no direct effect on the demand for machines. So if the second—the size of the work force—explains inflation, then our model is wrong.

Assume f is the work force, n the level of employment, and m the unemployment expressed as a fraction of the work force.

Then, we have

$$m = \frac{f-n}{f} = 1 - \frac{n}{f}$$

$$\Delta m = -\left(\frac{f\,\Delta n - n\Delta f}{f^2}\right)$$

$$= \frac{n}{f}\left(\frac{\Delta f}{f} - \frac{\Delta n}{n}\right)$$

$$\frac{\Delta m}{1-m} = \left(\frac{\Delta f}{f} - \frac{\Delta n}{n}\right)$$

The expression $(1-m)$ is always positive and usually close to one. If unemployment (m) drives inflation, both the work force (f) and the level of employment (n) should have indirect effects on inflation through the unemployment variable. How much effect each

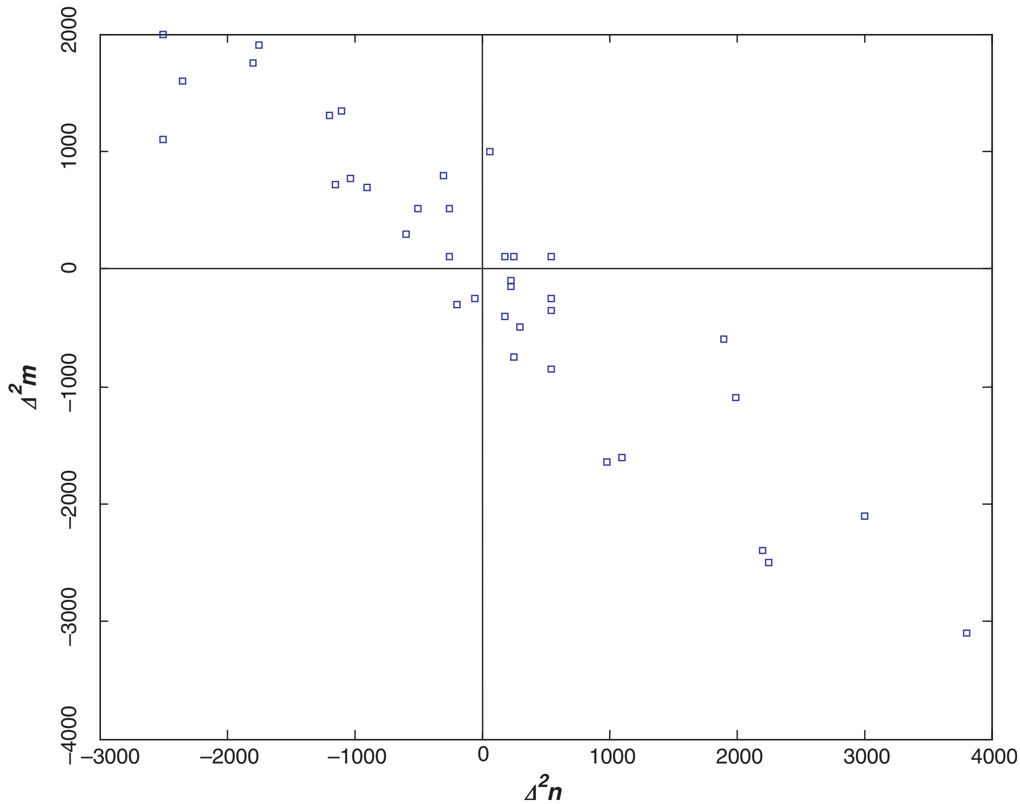


Figure A1 United States, 1959–1995.

has on inflation would depend on how much effect each has on unemployment.

If labor scarcity is the key to inflation, then work force increases should tend to lower the inflation rate. If, on the other hand, it is really employment rather than unemployment that is driving inflation, then work force changes should have no effect on inflation. So, in this naive view, work force data should provide a simple test.

But the US evidence is very disappointing. Figure A2 shows the (astonishing to us) lack of association between the work force and unemployment, expressed in second differences. How do we explain this, given the functional dependence of unemployment on the work force expressed in our identities? There are only two ways f could have no influence on m:

1. No excursion in f. As one would expect of an instrument of policy, n displays more excursion than f does. But f is not lacking in excursion.
2. Influence of n on m offsets the influence of f on m.

Given that f is driven by demographics and n is driven by economics, an accidental offset is improbable on its face. That fact that f has, on average, been completely offset by n has to be the result of deliberate policy on the part of the Fed. Evidently m changes, not when f changes, but only when the Fed *wants* m to change. Apparently, believing that the key to inflation is *un*employment, the Fed deliberately offsets work force changes with changes in the level of employment. It is hard to avoid the conclusion that the Fed thinks m is critical in controlling inflation.

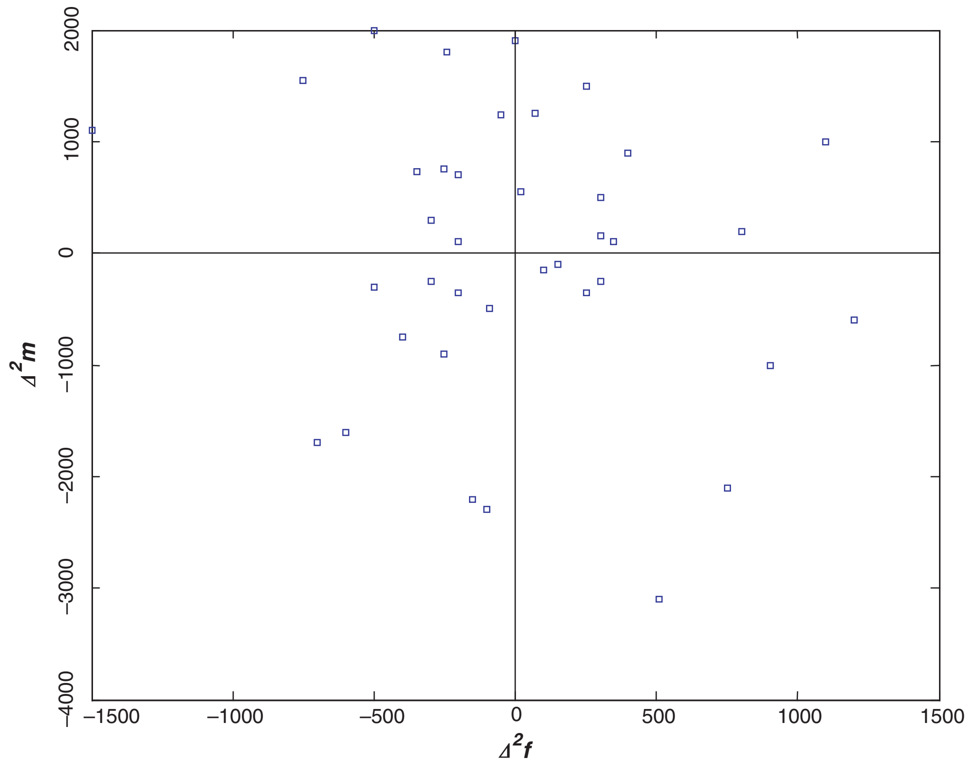


Figure A2 United States, 1958–1995.

Suppose, however, the key to inflation is employment, rather than unemployment. Because the Fed offsets them with employment increases, work force increases should be *in*flationary, not *de*flationary. Figure A3 regresses inflation against the work force (second differences in both variables). The association is weakly (but insignificantly) positive. Contrast the US experience with that for Japan (Figures A4 and A5).

Appendix B: The Phillips Curves

Our model has implications for both versions of the Phillips curve. Macroeconomic considerations determine what workers actually get: a lower level of unemployment corresponds to a higher level of demand, employment, and output. But higher real marginal costs (labor hours per unit of output) and real prices mean lower real wages (units of output per labor hour). So this year's real wage will be less than last year's. Suppose negotiators abandon their notions about what a job is worth and, instead, take last year's actual as their guide in choosing this year's real wage target; then they will be surprised. And the result will be an increase in price inflation proportional to the disappointment in real wage growth.

But if unemployment, hence the real wage, then holds constant at the new level, next year's real wage will equal last year's. The actual growth—zero—will accord with what negotiators expected. In the absence of real wage surprise, the rate of price inflation will not change. And any other fixed level of unemployment will have its own rate of inflation. This is the original Phillips model, with the level of unemployment determining the inflation rate (Phillips, 1958).

Now let us return to our original assumption that negotiators determine what they think jobs are worth in real terms. Consider a constant low level

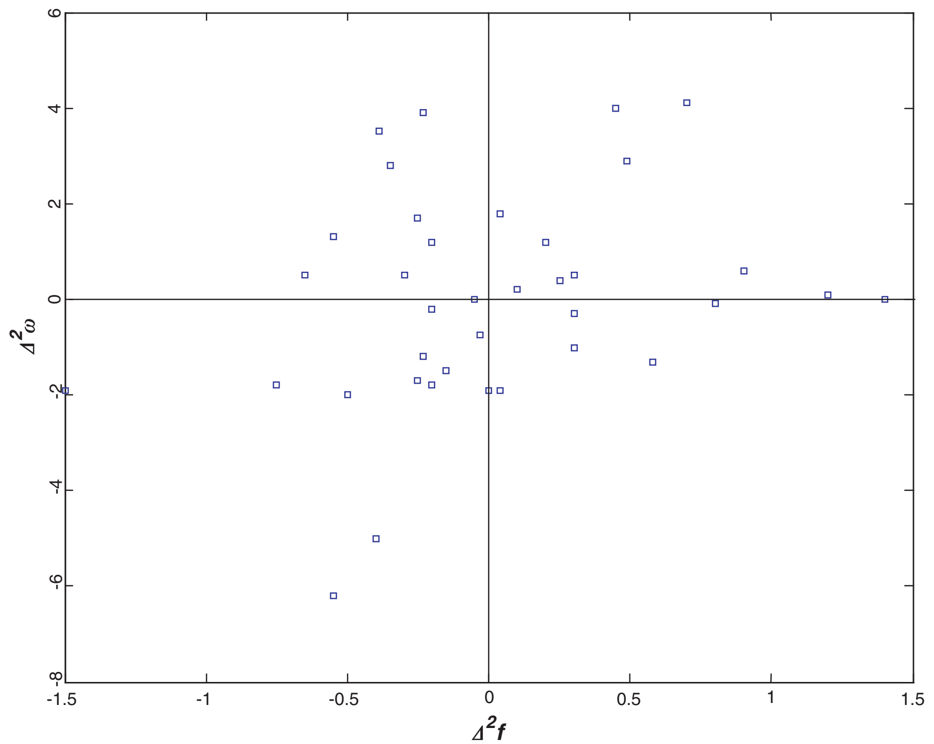


Figure A3 United States, 1959–1995.

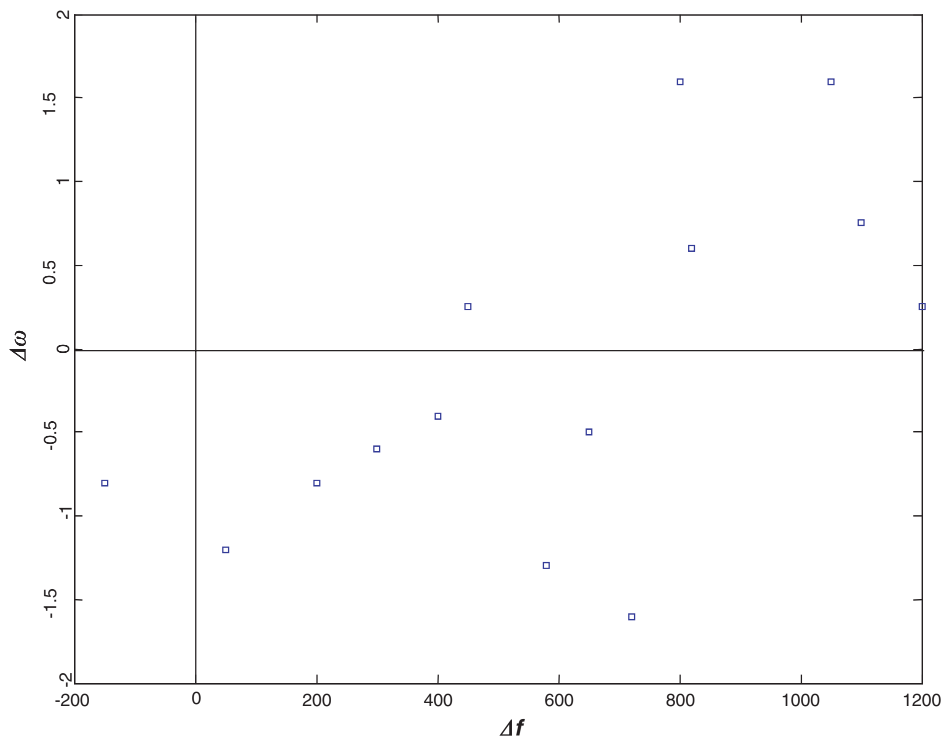


Figure A4 Japan, 1986–1999.

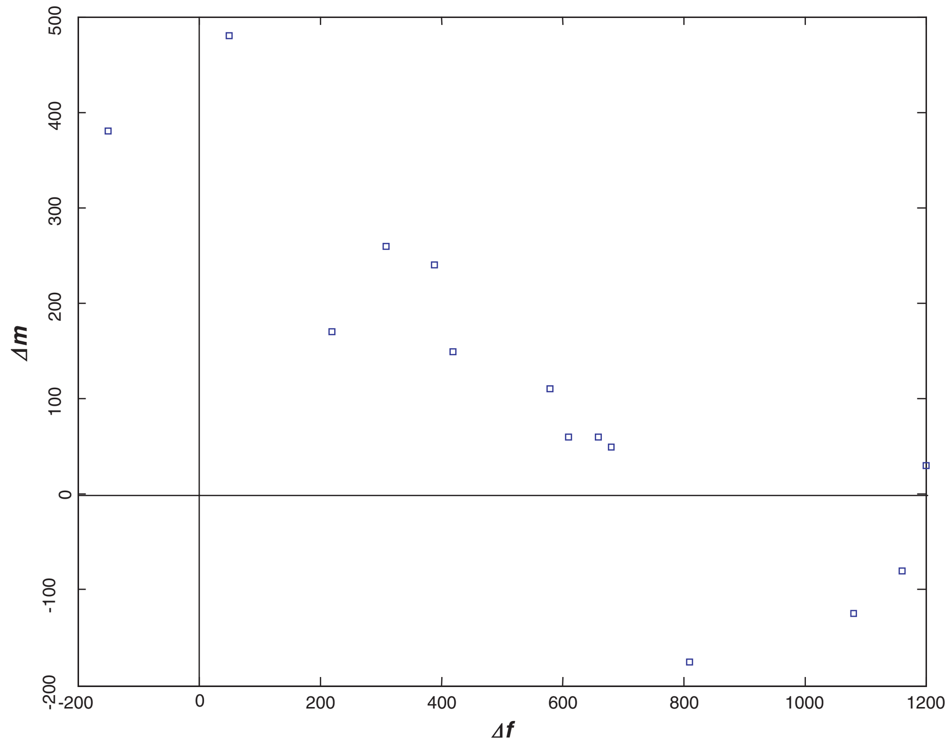


Figure A5 Japan, 1986–1999.

of unemployment with high marginal labor costs and real prices, and low real wages. If negotiators ignore the macroeconomic considerations year after year, then they will always come to the same conclusion about what jobs are worth—hence how much real wages need to grow from last year's actual—and experience the same surprise. But we have seen that the surprise in the rate of price inflation depends on the surprise in real wage growth (with a minus sign; it actually depends on the disappointment). Year after year, inflation will accelerate. This result is consistent with those inflation models in which the level of unemployment determines the time rate of change in the inflation rate (Friedman, 1977).

Presumably there is some level of unemployment, hence level of real wages, at which they accord with negotiators' conclusions about what jobs are worth. In the absence of a difference, negotiators do not expect change in real wages in the next period—and they are not surprised. So, at this level of unemployment, there is also no surprise in the rate of price inflation. This level is, of course, the NAIRU (non-accelerating inflation rate of unemployment).

Which Phillips Model?

Alas, our model is moot on the question which Phillips model applies. What do negotiators actually do with their expected change in the real wage? Do they use it to build a new expectation from scratch, using last period's actual? Or do they interpret "expected change" as "change in expectations"? The Phillips I negotiators take the former route. They observe last period's actual real wage, and estimate the change. But the Phillips II negotiators take the "expected change" and apply it to last period's expectation.

It is easy to demonstrate that Phillips I and Phillips II are equally defensible, if the expectation and backshift operators commute. We have

$$E[\Delta w] = E[(1 = B)w] = [E - EB]w$$
$$= [E - BE]w = \Delta[Ew].$$

$$\uparrow \qquad\qquad\qquad \uparrow$$

Phillips I Phillips II

But do E[ ] and B[ ] commute? The expectation held at time t is of the wage at $t+1$. But, applied to the current wage, the expectation operator E[ ] gives us last period's expectation of this period's backshift actual.

On the other hand, the operator B[ ] refers to last period's number. Applied to an expectation, it refers to the previous period's expectation of last period's actual. But this is what BE[ ] means. Applied instead to the wage, the backshift operator refers to last period's actual. So EB[ ] also means the previous period's expectation of last period's wage.

Wage negotiators really can exchange BE[ ] for EB[ ]!

Appendix C

Our model of the relation between real wage surprise and inflation surprise has a coefficient of one. The evidence in Figure 4 suggests a coefficient of 0.6. The difference is too big to be explained by estimation error. We think the discrepancy arises out of:

1. Our practice of using change as a surrogate for surprise.
2. The creation by the Fed of employment changes that offset the effect of work force changes on unemployment. One result is that unemployment changes are uncorrelated with work force changes. Another is that employment changes reflect work force, as well as policy, changes. (*Appendix A explains why Fed intervention causes work force (f) and unemployment (m) changes to be uncorrelated with each other.*)
3. The reflection in work force changes of certain demographic effects that are highly predictable, making these changes poor surrogates for surprise.

But if changes in f are mostly predictable, changes in m, reflecting Fed policy, are mostly surprise: the Fed's judgments are subject to error. Each period it corrects for the net difference between last period's judgment and this period's judgment. But implicitly last period's judgment was also a judgment about this period's judgment. So the period-to-period change is always surprise; the Fed's current steering input is usually dominated by the current surprise. As an explanatory variable, unemployment does not have the errors-in-variables problem employment has.

Is unemployment merely a convenient proxy for those changes in employment, hence those changes in the real wage, that are surprise?

Appendix D: Estimating Openness

What the closed-form model in Section 2 is clearly not is the best way to estimate the economy's degree of openness. There are two problems, either of which would probably be fatal.

Regression Bias

We noted, however, that the true values satisfy

$$\frac{xH}{P} + \frac{zT}{P} = 1$$

So the bias in the sum of our estimates for

$$C = \frac{xH}{P}$$

and

$$1 - C = \frac{zT}{P}$$

is equal to the amount by which it differs from one. This holds for every country.

The second problem relates to the frequency of wage negotiations. We have used annual data. But we cannot be certain that wages are renegotiated annually. If a country's effective frequency is 3 years, for example, then the true measure of openness is the cube of the number in the exhibit. We would like to think the ranking in the exhibit is meaningful, but it is possible that the effective negotiation frequency is different for different countries.

Table D1 displays regression estimates for a fairly wide range of countries. The statistical significance of our measure suggests that, for the more open countries, at least, the effect of global inflation is too important to ignore. Our "openness" number for the Netherlands is suspiciously low, however, ranking it between Japan and the United States. (See Table D2.)

Nomenclature

W	money wage
P	money price level
p	real price level
w	real wage
E[ ]	last period's expectation of this period's actual
t	real time
$N(t)$	jobs represented by the accumulated stock of capital
$Y(t)$	real output represented by the accumulated stock of capital
τ	the point in real time at which the marginal capacity was built
n	employment
y	output
Δ[ ]	the first time difference
B[ ]	last period's value
H	money price of home goods
T	money price of tradables
x	output of home goods

Table D1 Estimates of inflation change based on momentum model of Section 2 1968–1997

Country	Coefficient	Standard error	*P*
Sweden	0.730	0.185	0.001
Canada	0.687	0.223	0.005
United Kingdom	0.665	0.214	0.004
Korea	0.636	0.204	0.004
Sri Lanka	0.526	0.182	0.007
Australia	0.411	0.173	0.025
France	0.403	0.213	0.069
Italy	0.390	.0158	0.021
Spain	0.272	0.120	0.031
Japan	0.260	0.222	0.252
Netherlands	0.205	0.148	0.179
United States	0.017	0.342	0.961

Table D2 1997 Data

Country	Imports	Exports	Surplus/(deficit)	Coefficients from Table 2
Sweden	35.7	42.5	6.8	0.730
Canada	37.8	39.5	1.7	0.687
United Kingdom	28.5	28.5	—	0.665
Korea	33.5	34.6	1.1	0.636
Sri Lanka	43.6	36.5	7.1	0.526
Australia	20.1	20.5	0.4	0.411
France	22.7	26.0	3.3	0.403
Italy	22.4	26.5	4.1	0.390
Spain	27.2	28.4	1.2	0.272
Japan	10.2	11.4	1.2	0.260
Netherlands	53.8	60.6	6.8	0.205
United States	12.6	11.3	1.3	0.017

* As a percentage of GDP.

z output of tradables
h real price of home goods
C ratio of home goods output to total output
X local inflation rate
Z global, hence tradables, inflation rate
X_0 wage inflation rate at time zero
Z_0 global inflation rate at time zero
ΔZ (fractional) global surprise
V (fractional) currency surprise
Δh (fractional) surprise in real home goods prices
ΔX change in local inflation rate
f work force
m percentage unemployment $= (f - n)/f$
ω inflation rate
M money value of gross domestic product

Notes

1 Some people think falling wages are *de*flationary. They surely have in mind what we have termed the real-wage identity $w = W/P$. They are arguing that, if money prices do not change, then real and money wages must move up and down together. Are these the same people who argue that raising the minimum wage will raise the real wage? In these people's solar system, everything revolves around money prices. In our solar system, everything revolves around real wages (or equivalently, real prices). Whether this Copernican turn is justified depends, of course, on the evidence.

2 The only efficiency considered in this paper is *labor* efficiency. (Fuel efficiency is more important than labor efficiency, for example, for airliners.) If the only efficiency contemplated is labor efficiency, then the sole purpose of technology is to improve the labor productivity of plant. We also assume that newer technology is never used to improve the productivity of an old plant.

3 $N(t)$ and $Y(t)$ have to be measured from some arbitrary time datum. But the values of n and y do not depend on the choice of datum, as long as it precedes τ.

4 Why are not idle machines scrapped? Because they represent an option on the real price of output (with a strike price equal to their unit labor cost of producing). Idle machines are not scrapped until their option value falls below their scrap value.

5 We can express τ in terms of employment n. We have

$$N(t) = N(t) - n$$
$$\tau = N^{-1}\{N(t) - n\}$$

Substituting in our expression for y we have

$$y = Y(t) - Y\{N^{-1}[N(t) - n]\}$$

This production function expresses a closed economy's output y at time t as a function of its employment level n and its investment history, as contained in the monotonic, hence invertible functions $Y(\Delta)$ and $N(\Delta)$.

[6] With one exception, all the data used in this paper came from the *International Monetary Fund's International Financial Statistics Yearbook*. To lengthen our time sample for unemployment data, we used the *Bureau of Labor Statistics Handbook*.

[7] *Open Economy Macroeconomics*, Basic Books, 1980, p. 97.

[8] If it were actually true that

$$X_t = C^t(X_0 - Z_0) + Z_0$$

then we would also have

$$\begin{aligned} X_{t+1} &= C[C^t(X_0 - Z_0) + Z_0] + (1 - C)Z_0 \\ &= C^{t+1}(X_0 - Z_0) + CZ_0 - CZ_0 + Z_0 \\ X_{t+1} &= C^{t+1}(X_0 - Z_0) + Z_0 \end{aligned}$$

If the hypothetical relation held for time t, it would also hold for time $t + 1$. In fact, Section 2 demonstrated that we have for the first period

$$\begin{aligned} X_1 &= CX_0 + (1 - C)Z_0 \\ &= C(X_0 - Z_0) + Z_0 \end{aligned}$$

But if this result holds for $t = 1$, it holds for $t = 2$; if it holds for $t = 2$, it holds for $t = 3$. Mathematical induction shows that, relative to the old local rate X_0, the old global inflation rate Z_0 becomes steadily more important with time.

[9] In order to peg the value of its currency in the forward market, a central bank has to offset speculators' positions with a position of its own. When the speculators are right about the next move in the currency value, they win and the central bank loses. So central banks will strive to make their currency changes unpredictable. But wage negotiators will be just as surprised by these changes as currency speculators.

[10] Surprises also change the value of the home goods and tradables terms in the worker's market basket; if their *relative* value changes, C changes. We suppress this second-order effect.

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