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Credible Disinflation with Staggered Price-Setting

By LAURENCE BALL*

Although most macroeconomists agree that disinflations reduce output, there is no consensus about why. New classical economists argue that credibility problems are central—that disinflation would be costless if the public believed policy announcements. Many new Keynesians, by contrast, view credibility as less important. They blame the costs of disinflation on inflationary inertia arising from the frictions in wage- and price-setting, especially the staggered timing of price adjustment introduced by John Taylor (1979, 1980) and Olivier Blanchard (1983, 1986).

Does staggered price-setting imply that disinflation is costly, even with perfect credibility? The literature contains a confusing array of answers to this question. Some authors argue that staggering makes output losses inevitable during disinflation (e.g., Blanchard and Lawrence Summers, 1988). In Taylor (1983) and Stanley Fischer (1986 Ch. 7), disinflation can be costless, but only if it is slow: inflation must remain almost constant for several years after disinflation is announced. Output falls in these models if disinflation starts more quickly, as is usually the case in actual economies. Finally, a number of authors argue that *immediate* disinflation is costless; these papers use Guillermo Calvo's (1983) model of staggering, in which price adjustments occur stochastically (e.g., Willem Buiter and Marcus Miller, 1985).[1]

This paper seeks to clarify these issues. I derive the real effects of a credible disinflation in a simple continuous-time version of the Taylor-Blanchard model. The results support the view that staggered adjustment is *not* an important impediment to disinflation. With full credibility, disinflation can occur quite quickly (although not instantly) without reducing output. Indeed, the model yields a stronger, more surprising result: a quick disinflation causes not a recession but a *boom*.

Since this result is likely to appear counterintuitive, this paper tries to explain how one's intuition about disinflation can go wrong. The confusion about this issue arises largely from a misinterpretation of the original Taylor and Blanchard models. Taylor (1979, 1980) and Blanchard (1983, 1986) show that staggering produces inertia in the price level: prices adjust slowly to a fall in the money supply, and output falls substantially. Disinflation, however, is a change in the *growth rate* of money, not a one-time shock to the level. In informal discussions, analysts often assume that the inertia result carries over from levels to growth rates—that inflation adjusts slowly to a fall in money growth.[2] In fact, changes in money and changes in money growth have very different effects.

The paper contains four sections. Section I presents the basic model. To build intu-

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[1]Edmund Phelps (1978) presents yet another view on this issue. In his model, costless disinflation occurs if the money stock follows an odd path that oscillates and becomes stable only asymptotically.

[2]For example, Blanchard and Summers (1988 p. 182) argue that "on the...'Keynesian view,' even credible disinflation is likely to increase unemployment for some time, because of the inflationary momentum caused by overlapping price and wage decisions."

ition, Section II considers an example in which the *level* of money declines. This case produces the conventional result that output falls.

Section III considers disinflation. I assume that money growth and inflation start at a trend level that is expected to last forever. At some point, the Fed announces a new path for money growth that declines and eventually reaches zero. The public believes that the Fed will keep its promise, and it does. In this framework, fairly quick disinflations cause booms: output rises above the natural rate temporarily and never falls below it. For example, suppose that individual prices are adjusted once a year and inflation is initially 10 percent. A boom occurs if the Fed disinflates linearly over a year—if money growth is 5 percent after six months and zero after a year. Indeed, a boom occurs for any linear disinflation longer than 0.68 years.

Section IV presents a caveat to my results, which concerns the specification of price-setting. In my basic model, as in the original Taylor and Blanchard models, a firm's price is fixed between adjustment dates. An alternative assumption (Fischer, 1977) is that a firm chooses a predetermined but time-varying path of prices until the next adjustment. Costless disinflation is still possible in this case, but it must be slower than with fixed prices: time-variation generates considerable inflation inertia. I argue, however, that time-varying prices are not a convincing explanation for inertia, because they are uncommon in actual economies. In any case, the distinction between fixed and time-varying prices explains why my results differ from those of Taylor (1983) and Fischer (1986): those papers depart from Taylor's 1979 and 1980 papers by introducing time-variation.

Section V concludes. I do not take my finding of expansionary disinflations as a serious empirical prediction. Instead, it is a negative result: by itself, staggered adjustment does not explain why actual disinflations are costly. The explanation must include some additional factor, such as imperfect credibility.

I. The Model

The model is a simplification of the continuous-time Taylor-Blanchard model in Ball et al. (1988). The economy contains a continuum of imperfectly competitive firms indexed by i and distributed uniformly on $[0,1]$. Firm i's profit-maximizing nominal price is

$$p_i^* = m \tag{1}$$

where p_i is the firm's price and m is the money stock (all variables are in logs). That is, firms simply wish to keep their prices in line with nominal money.[3] Aggregate output is determined by a quantity equation:

$$y = m - p \qquad p = \int_{i=0}^{1} p_i \, di \tag{2}$$

where y is output and p is the aggregate price level. Equation (2) is the economy's aggregate demand curve.[4]

If firms adjusted prices continuously, each would set $p_i = p_i^* = m$ at every instant. The aggregate price level would equal the money

[3]The usual expression for profit-maximizing prices in models of staggering is a weighted average of the money stock and the aggregate price level: $p_i^* = vm + (1-v)p$. Equation (1) is a special case of this specification in which the parameter v equals 1. I focus on this case for simplicity; my working paper (Ball, 1990) shows that the results carry over to the general case. The general case can be derived from the quantity equation (2) and the assumption that firms face isoelastic cost and demand functions. Finally, the price-setting rule [equation (3)] can be derived by taking a second-order approximation to the profit function. See Ball and David Romer (1989) for details.

[4]One way to explain the costs of disinflation is to assume that aggregate output depends on expected inflation as well as real money, because expected inflation influences money demand. In this case, an announcement of disinflation reduces output by raising money demand. While this effect may be important at very high inflation, it does not appear to be central to the costs of disinflation in the United States. In any case, the effect becomes irrelevant if m is defined more broadly as nominal GNP, making (2) a tautology. With this approach, disinflation means that policymakers choose a declining path for nominal GNP growth, adjusting money growth to offset any shifts in money demand.

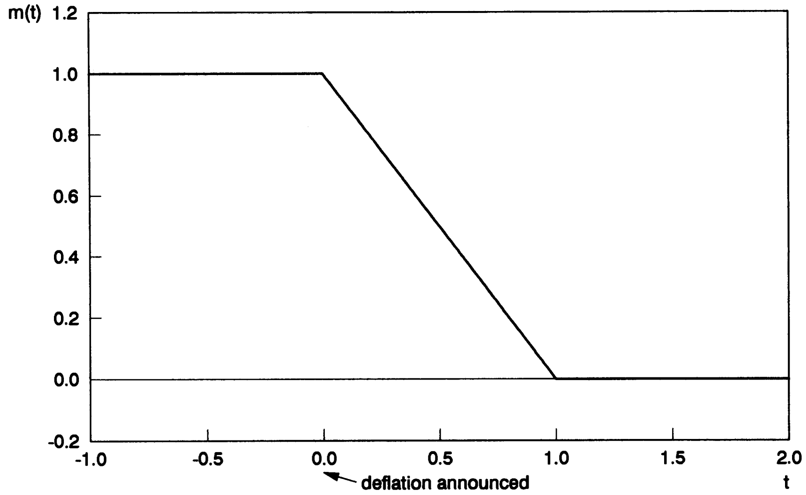

FIGURE 1. A DEFLATION

stock, and aggregate output would be zero. I assume, however, that a firm adjusts its price only at intervals of length 1 (a normalization). The price is fixed between adjustments. Let $x(t)$ be an individual price set at time t for the interval $[t, t+1)$ (I drop the i subscript because all firms acting at t choose the same price). A firm sets $x(t)$ equal to the average of its expected profit-maximizing prices over $[t, t+1)$:

$$x(t) = \int_{s=0}^{1} E_t p_i^*(t+s)\, ds = \int_{s=0}^{1} E_t m(t+s)\, ds. \tag{3}$$

Finally, I assume that price adjustment by different firms is staggered uniformly over time. This assumption and the definition of the price level imply

$$p(t) = \int_{s=0}^{1} x(t-s)\, ds. \tag{4}$$

The price level is the average of individual prices set over the last unit of time.

II. Deflation

To build intuition, this section briefly considers a deflation—a decrease in the *level* of money. This example sets the stage for the very different case of disinflation in Section III.

Assume that at all times $t < 0$ the money stock is constant at a level of 1:

$$m(t) = 1 \qquad t < 0. \tag{5}$$

At $t < 0$, price-setters believe that money will remain constant forever. At time zero, however, the Fed announces a new path for money:

$$m(t) = 1 - t \qquad 0 \le t < 1$$
$$= 0 \qquad t \ge 1. \tag{6}$$

Figure 1 plots this path. Money declines linearly, reaches zero after one unit of time, and then remains constant. The Fed's announcement of (6) is fully credible: price-setters believe the announcement, and it is carried out without further surprises.

Not surprisingly, one can show that this policy produces a recession: output falls below the natural rate of zero (see Ball [1990] for a proof). The intuition is familiar from previous work. Before time zero, prices are set equal to 1, because money is expected to remain at that level. These prices are too high once money begins to fall. With stag-

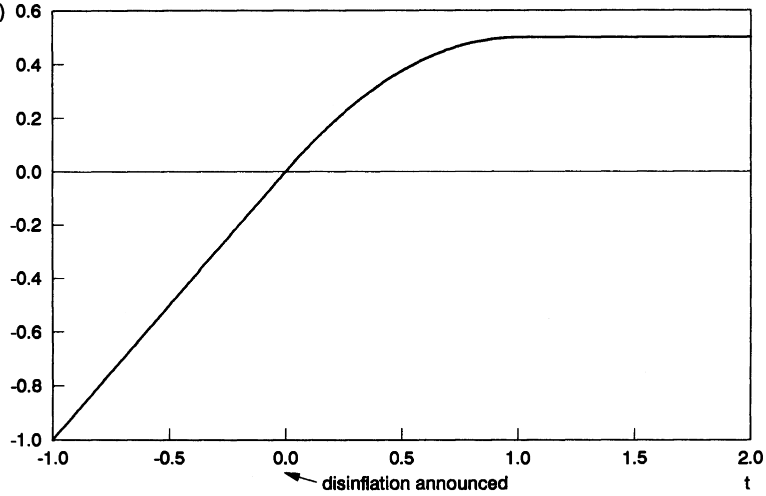

FIGURE 2. A DISINFLATION

gering, most prices cannot adjust quickly, and so the falling money stock reduces output.

III. Disinflation

In economies like the postwar United States, a monetary contraction means not a fall in the level of money, but a disinflation—a decline in money growth. This section shows that, contrary to intuition, fairly quick disinflations cause booms. I focus on a simple example and present a generalization at the end.

A. *The Example*

Here, it is the growth rate of money that is initially steady and then declines. For all $t<0$,

$$(7)\qquad m(t)=t$$

$$\dot{m}(t)=1\qquad t<0.$$

That is, money grows steadily at rate 1 (another normalization). This regime is expected to last forever, but at time zero the Fed announces

$$(8)\qquad \dot{m}(t)=1-t\qquad 0\le t<1$$

$$=0\qquad t\ge 1.$$

That is, $\dot{m}(t)$ follows the path assumed for $m(t)$ in the previous section. Equation (8) and the assumption that $m(0)=0$ determine the path of $m(t)$ in this example:

$$(9)\qquad m(t)=t-t^2/2\qquad 0\le t<1$$

$$=1/2\qquad t\ge 1.$$

Figure 2 plots $m(t)$. Since money growth is decreasing, the path of the money stock is concave. Once again, I assume that the Fed's announcement is fully credible.

To interpret this example, recall that a unit of time is the period for which an individual price is fixed. Suppose that prices are fixed for a year, the median in Alan Blinder's (1991) survey of firms. In this case, equation (9) implies that money growth is cut in half in six months and reaches zero in a year. This is a quick disinflation; it would surely cause a recession in many real-world economies.

B. *Steady Inflation*

In studying this example, a preliminary step is to determine the behavior of the economy before time zero, when disinflation is announced. At all $t<0$, money growth equals 1 and is expected to remain constant forever. Along with equations (2)–(4), this implies

$$(10)\qquad \begin{aligned} p(t) &= t \\ y(t) &= 0 \\ x(t) &= t+1/2 \qquad t<0. \end{aligned}$$

Not surprisingly, the price level grows at the same rate as money, and output is constant at the natural rate. An individual price $x(t)$ is the average of money over $[t, t+1)$, the interval when the price is in effect.

C. *A Boom*

I can now show that the disinflation path (8) implies a boom. A boom is defined as an output path that rises above the natural rate temporarily and never falls below the natural rate.

One way to show that a boom occurs is to derive the path of prices and compare it to the path of money (see Ball, 1990). This approach is tedious, however, and so I present an indirect but simpler proof. I first determine the path that individual prices $x(t)$ would have to follow for output to remain constant, given the path of money. I then show that firms in fact choose *lower* prices, which implies a boom.

Constant output requires

$$(11)\qquad m(t)-p(t)=0 \quad \forall t$$

and thus

$$(12)\qquad \dot{m}(t)-\dot{p}(t)=0 \quad \forall t.$$

Equation (8) gives $\dot{m}(t)$ for $t \geq 0$. Differentiating (4) yields $\dot{p}(t)=x(t)-x(t-1)$. Substituting these expressions into (12) yields

$$(13)\qquad \begin{aligned} 1-t-x(t)+x(t-1)&=0 \qquad 0\leq t<1 \\ -x(t)+x(t-1)&=0 \qquad t\geq 1. \end{aligned}$$

For $0 \leq t < 1$, $x(t-1)$ is set during the steady-inflation regime before time zero. Thus, using (10), $x(t-1)=t-1/2$ for $0 \leq t < 1$. Substituting this result into the first line of (13) and rearranging yields $x(t) = 1/2$, $0 \leq t < 1$. This result and the second line imply $x(t)=1/2$, $t \geq 1$. Thus, constant output requires

$$(14)\qquad x(t)=1/2 \qquad t\geq 0.$$

What prices do firms actually set? The actual $x(t)$ is given by equation (3); the expectations operator can be dropped for $t \geq 0$, because firms have perfect foresight after the Fed's announcement. Thus $x(t)$ is the average of actual money from t to $t+1$. Money is less than $1/2$ for $0 \leq t < 1$ and equals $1/2$ thereafter [see equation (9)]. Therefore, $x(t)$ is less than $1/2$ for $0 \leq t < 1$ and equals $1/2$ thereafter. For $0 \leq t < 1$, firms set prices below the level needed for constant output; thus there is a boom. More specifically, since prices set at $t=1$ last until $t=2$, the price level is too low, and there is a boom, until $t=2$:

$$(15)\qquad \begin{aligned} y(t)&>0 \qquad 0<t<2 \\ y(t)&=0 \qquad t\geq 2. \end{aligned}$$

D. *Discussion*

The result that disinflation causes a boom may appear counterintuitive, given the usual view that disinflations cause recessions. The source of confusion is that many papers on staggering, such as Blanchard (1983), study decreases in the *level* of money. As discussed above, such policies do reduce output. This result apparently guides many economists' intuition about the effects of "monetary contractions," even when the contractions are slowdowns in money *growth*. This paper shows that decreases in levels and decreases in growth rates have very different effects.

To understand the difference between deflation and disinflation, recall why the former reduces output: prices set before deflation is announced are too high once money begins to fall. In the case of disinflation, the overhang of preset prices is a less serious problem. Prices set before an announcement of disinflation are set higher than the current money stock in anticipation of further increases in money. If the level of money were stabilized instantly, these prices would be too high: cold-turkey disinflation would cause a recession. However, the overhang of high prices is easily overcome if money growth, while falling, remains positive for some time. The level of money quickly catches up to the highest preset price and can then be stabilized costlessly. This result contrasts with the case of deflation, in which prices set before time zero are stuck at a level that money has fallen below permanently.

Although this argument explains why disinflation need not cause a recession, it does not explain why output *rises*. The explanation for the boom is a bit subtle. Assume for simplicity that there is perfect foresight, even for $t<0$. In this case, equation (3) gives individual prices $x(t)$ in terms of future levels of money, and equation (4) gives $p(t)$ in terms of past $x(t)$'s. Combining these expressions yields

$$(16)\quad p(t)=\int_{s=0}^{1}(1-s)m(t-s)\,ds + \int_{s=0}^{1}(1-s)m(t+s)\,ds.$$

Here, $p(t)$ is a weighted average of $m(\cdot)$ from $t-1$ to $t+1$ (this is a version of Taylor's (1980) forward- and backward-looking solution). Crucially, since $\dot{m}(t)$ declines over $[0,1]$, $m(t)$ is concave (see Fig. 2); and since $m(t)$ is concave, an average of past and future m's is less than the current m, by Jensen's inequality. Thus $p(t)$ is less than $m(t)$, and output exceeds the natural rate. The concavity of $m(t)$ is the basic reason that disinflation causes a boom.

E. *A Generalization*

In the preceding example, money growth declines linearly and reaches zero in one unit of time. My working paper (Ball, 1990) considers a generalization in which money growth reaches zero in k units of time:

$$(17)\quad \dot{m}(t)=1-t/k \qquad 0\le t<k$$
$$=0 \qquad t\ge k.$$

For this case, I derive the minimum value of k for which a boom occurs; that is, I find the fastest linear disinflation that is expansionary. The minimum k is 0.68. Intuitively, if disinflation is too fast, then money does not grow enough to eliminate the overhang of prices set before time zero. At $k=0.68$, the contractionary effect of this overhang balances the expansionary effect arising from the concavity of $m(t)$.[5]

IV. Time-Varying Prices

This section considers a variant of my model in which, as in Fischer (1977), a firm chooses a time-varying path of prices rather than a single fixed price. The main examples of time-varying prices in actual economies are wages in three-year labor contracts. Time-varying prices slow disinflation considerably: to avoid a recession, money growth must remain constant from time 0 to time 1. The difference between fixed and time-varying prices explains most of the differences between my results and those of Taylor (1983).[6]

A. *The Result*

Assume now that a price-setter chooses a continuous path of prices over the next unit of time. Let $x(\tau,t)$ be a price set at τ for

[5]My working paper also derives the fastest boom-inducing path to zero money growth without imposing linearity. The fastest path is one in which money growth remains constant until $t=0.37$ and then drops discretely to zero. (This calculation assumes that money growth is nonincreasing. If this restriction is relaxed, then the fastest path is one in which the level of money jumps up at $t=0$ and then remains stable [Phelps, 1979].)

[6]The assumption of time-varying prices also explains why Fischer (1986) finds that costless disinflation is slow. The results of other studies are explained by other departures from my assumptions. In particular, Phelps (1978) derives an oscillating disinflation path because he restricts output to be constant; that is, he ignores disinflations that cause booms (see Ball, 1990). Buiter and Miller (1985) find that instant disinflation is costless because they assume stochastic intervals between price adjustments.

$t \in [\tau, \tau+1)$. The price level is the average of prices set for t over the last unit of time:

$$(18) \qquad p(t) = \int_{s=0}^{1} x(t-s,t)\,ds.$$

A firm sets its prices equal to expected optimal prices:

$$(19) \qquad x(\tau,t) = E_\tau p_i^*(t) = E_\tau m(t).$$

Otherwise, the model is unchanged.

I assume as before that $m(t) = t$ for $t < 0$ and consider an arbitrary path for money announced at time zero. For $\tau < 0$, $E_\tau m(t) = E_\tau p(t) = t$, since money growth is expected to remain steady. For $\tau \geq 0$, $E_\tau m(t) = m(t)$ and $E_\tau p(t) = p(t)$. Substituting these results and (19) into (18) yields

$$(20) \qquad \begin{aligned} p(t) &= (1-t)t + tm(t) && 0 \leq t < 1 \\ &= m(t) && t \geq 1. \end{aligned}$$

This price-level path and the quantity equation determine the path of output:

$$(21) \qquad \begin{aligned} y(t) &= [m(t)-t](1-t) && 0 \leq t < 1 \\ &= 0 && t \geq 1. \end{aligned}$$

For $t < 1$, output is zero if $m(t) = t$—if money growth remains at 1—and negative if money growth falls. For $t \geq 1$, output is zero regardless of $m(t)$. Thus the fastest disinflation without recession is one in which money growth remains constant until time 1 and then drops discretely to zero. Costless disinflation is considerably slower than with fixed prices, which permit linear disinflations that start immediately; and here, no disinflation causes a boom.

There are two reasons that disinflation is more difficult with time-varying prices than with fixed prices. First, there is greater inertia arising from prices set before time zero. There is an overhang not just of high prices, but of prices required to grow. Specifically, prices set just before time zero grow from 0 to 1 as $t \to 1$, because money was expected to follow that path. With fixed prices, by contrast, no price set before time zero exceeds $1/2$.

Second, with time-varying prices there is no expansionary effect of disinflation arising from Jensen's inequality. With time-variation, prices set for t depend only on expected money at t; firms need not average over money at different times. Thus the price level is no longer an average of past and future money, and the concavity of $m(t)$ does not raise output.

B. *Comparison to Taylor (1983)*

Taylor's 1983 paper studies disinflation in a model based on actual U.S. labor contracts. Taylor finds that, to avoid a recession, money growth must remain almost constant for several years and then can drop rapidly. The main sources of these results are the facts that most contracts last three years and wages are time-varying—firms set different wages for each year. Time-varying wages are a crucial departure from Taylor's 1979 and 1980 papers. As in my model, time-variation slows disinflation considerably.

Taylor's and my results with time-varying prices show that one can construct a model of staggered adjustment with considerable inflation inertia. In my view, however, these results are of limited practical importance, because time-variation is rare in actual economies. Output prices are almost always fixed between adjustments, and so are wages outside the North American union sector. More than 80 percent of U.S. wages are set for a year or less with no time-variation; thus, most wage-setting fits the assumptions under which disinflations cause booms. Conceivably one could argue that the union sector has a disproportionate effect on aggregate wages and prices in the United States. However, in many countries, such as the United Kingdom, virtually *all* wages are set for a year or less with no time-variation. If time-varying wages were central to the costs of disinflation, then Volcker would have caused a recession but Thatcher's disinflation would have been costless. Economists should aim for a theory of disinflation that is consistent with the prevalence of fixed prices.

V. Conclusion

New Keynesian macroeconomics explains the real effects of monetary policy with nominal price rigidity. A central result is that staggered price-setting slows the adjustment of prices to a fall in the money stock, so that output falls substantially. In postwar economies, however, monetary contractions have been slowdowns in money growth—disinflations—rather than changes in the level of money. This paper argues that staggered price-setting is not sufficient to explain the costs of disinflation. With credible policy and a realistic specification of staggering, quick disinflations cause *booms*.

This theoretical result does not fit the postwar experience of costly disinflations. Thus the next step is to ask whether modifications of the model produce more plausible results. A natural approach, following the new classical economists, is to relax the assumption of full credibility. In a sequel to this paper (Ball, 1992), I assume that the Fed announces a disinflation but credibility is imperfect: with a known probability, the Fed stops reducing money growth before its promise is completely fulfilled. I find that the interaction of this credibility problem with staggered adjustment generates plausible output behavior.

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