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The Zero Interest Rate Floor (ZIF) and its Implications for Monetary Policy in Japan

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Abstract

This paper uses the IMF's macroeconomic model MULTIMOD to examine the implications of the zero-interest-rate floor (ZIF) for the design of monetary policy in Japan. Similar to findings in other studies, targeting rates of inflation lower than 2.0 percent significantly increases the likelihood of the ZIF becoming binding. Systematic monetary policy strategies that respond strongly to stabilize output and inflation, or that incorporate some explicit price-level component, can help to mitigate the implications of the ZIF.

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I. INTRODUCTION

Summers (1991) predicted that the issue of the zero-interest-rate floor (ZIF) would become of central importance to monetary policy in an era of low inflation. He cautioned that the scope for adjusting the stance of monetary policy could become severely constrained if the monetary authorities pursued a very low inflation rate because such a choice would result in a low average level of nominal interest rates. Specifically, in a period where interest rates were already at low levels the ZIF might significantly reduce the monetary authority's scope to reduce real interest rates when its output and inflation stabilization objectives were threatened by adverse deflationary shocks to the economy.

Not surprisingly, given the events in Japan in the 1990s, considerable research effort has been devoted to the implications of the ZIF. This work has followed two different tracks. The first track has examined what other policy channels, besides the short-term nominal interest rate, are available to stimulate the economy once the ZIF becomes binding.[2] The second track has investigated how the design of the monetary policy framework (as summarized by policy rules and the choice of the target rate of inflation) can affect the probability that the ZIF will become a binding constraint on policy.[3] The work presented in this paper follows along both of these two tracks. One major difference, however, is that rather than using a closed-economy model to investigate this issue, this paper employs the Japan block of MULTIMOD, the IMF's multicountry macroeconomic model.[4]

Following along the research track that examines policy channels other than the short-term nominal interest rate, we consider one-off fiscal and monetary policy interventions designed to help stimulate the economy after persistent negative shocks have pushed interest rates down to the ZIF. We consider an increase in government spending because expansionary fiscal policy is often argued to be an effective means of stimulating the economy once monetary policy has become less effective as a result of the ZIF. The first monetary policy intervention that we consider is a credible commitment on the part of the monetary authority to restore any decline in the price level that has occurred because the short-term nominal interest rate has been constrained by ZIF. This monetary policy intervention can be thought of as a commitment to future inflation. This solution is suggested in Krugman (1998a,b) and is examined in Reifschnieder and Williams (1999). The second monetary policy intervention involves a sharp

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[2] See Krugman (1998a,b), Buiter and Panigirtzoglou (1999), Clouse and others (2000), and Svensson (2000).

[3] See Lebow (1993), Laxton and Prasad (1997, 2000), Fuhrer and Madigan (1997), Meredith (1999), Orphanides and Wieland (1998, 1999), and Reifschneider and Williams (1999).

[4] Most of the research in this area has either relied upon simple closed-economy models or models that have been approximately closed.

depreciation in the nominal exchange rate coupled with a credible commitment to achieve a specified price-level target over the medium term. This monetary policy approach to the problem of the ZIF is proposed in Svensson (2000). Finally, we consider a permanent increase in the target rate of inflation.

The one-off fiscal and monetary policy interventions that we consider are effective in stimulating the economy once the ZIF has become binding. These interventions reduce the length of time that the constraint binds and thereby reduce the output loss that is incurred. However, there are important differences that arise in the evolution of the government's debt-to-gdp ratio that make monetary-policy-based interventions more attractive; in both monetary-induced interventions the government's debt-to-gdp ratio is lower than in the scenario where the intervention is based on a fiscal expansion. This result arises because a monetary-policy-based intervention works through inflation expectations, thereby stimulating private demand by reducing expected real interest rates. In this case, revenue increases because of the increase in private demand and service costs on the existing stock of government debt fall because of the reduction in real interest rates.

Following along the second research track, we use the Japan block of MULTIMOD to investigate the implications of the ZIF for the design of systematic monetary policy in Japan. We first consider how the choice of the target rate of inflation influences the likelihood of the ZIF becoming binding and the magnitude of the deterioration in macroeconomic performance that results. For this initial step we use a base-case inflation-targeting policy rule that is similar to the Taylor rule.[5] We then consider how the base-case policy rule can be modified to mitigate the implications of the ZIF. The modifications include the strength of the policy response to deviations of forecasts of inflation from target and output from potential output as well as adding a price-level component to the rule. Incorporating a price-level component into the policy rule is in the spirit of the approaches suggested in Reifschnieder and Williams (1999) for compensating for the time that interest rates are constrained by the ZIF.

Consistent with the findings in other studies, the simulation analysis presented in the paper suggests that target rates of inflation below 2.0 percent significantly increase the probability that the zero constraint will become binding and that macroeconomic performance will suffer. For a given target rate of inflation, this probability increases further if the monetary authority's estimates of potential output embody persistent errors that are correlated with the

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[5] For this initial step we use a more forward-looking rule than the original Taylor (1993) rule. Under this policy rule, the short-term nominal interest rate is adjusted, relative to a forward-looking measure of the neutral short-term nominal interest rate, in response to the output gap and the gap between core inflation and the assumed target. The original Taylor (1993) rule is more backward looking than our base-case rule because the neutral nominal interest rate is not forward looking. Because of the structure of MULTIMOD (the existence of nonlinearities and multiple sources of shocks) the original Taylor rule is a relatively inefficient rule for generating low variability in both inflation and output.

business cycle.[6] The analysis suggests that there are modifications to the systematic component of monetary policy that help to mitigate the implications of the ZIF. Responding more aggressively to estimates of the output gap and forecasts of inflation, and incorporating an explicit price-level dimension into the base-case inflation-forecast-targeting rule all help to mitigate the implications of the ZIF. Of the modifications to the initial rule that are considered, we find that an asymmetric rule whereby the policymaker commits to restoring declines in the price level is the most effective. However, the results clearly suggest that the most important component in the monetary policy framework for combating the deleterious implications of the ZIF is a sufficiently high target rate of inflation. Taken together, the simulation analysis, the implications of potential output uncertainty and the possible biases in price indices suggest that, for Japan, an appropriate magnitude for the target rate of inflation could be as high as 2.5 percent.

The remainder of the paper is structured as follows. In section II, a brief overview of the structure of MULTIMOD is presented with particular focus on the inflation process and the transmission mechanism for monetary policy. Some simple stylized simulations are presented in section III to help develop some of the intuition for interpreting the results obtained from stochastic simulations. This section also presents the one-off policy interventions that have been designed to help stimulate the economy once the constraint has become binding. Section IV contains the results from stochastic simulations that illustrate the impact of different target rates of inflation and the design of the policy rule on the probability of the zero-interest-rate floor becoming binding and the associated impact on macroeconomic performance. Section V provides some concluding remarks.

II. MULTIMOD

MULTIMOD is a multi-regional macroeconomic model developed by the IMF staff for the primary purpose of analyzing alternative scenarios for the World Economic Outlook (WEO). As such, it is based on annual data and takes the WEO forecast as an "exogenous" baseline.[7] Its construction has gone through several stages. The simulations presented in this paper are based on the current Mark III version[8] and focus on the Japan block. Modern

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[6] There is a growing body of research that suggests errors about the level of potential output exhibiting these properties can arise from a wide variety of the estimation techniques used to identify unobservable supply-side concepts like potential output. See Drew and Hunt (2000), Gaiduch and Hunt (2000), Isard, Laxton and Eliasson (1998), and Orphanides and van Norden (1999).

[7] For the simulations presented in the paper, the equilibrium rates of inflation have been altered from that in the WEO baseline.

[8] Laxton and others (1998) describe the Mark III version of MULTIMOD; see also Isard (2000). The version used in this paper incorporates several major changes. These changes include: the

(continued...)

structural models like MULTIMOD have been designed to minimize first-order Lucas-critique problems and thereby provide insights on the key role of the monetary policy response in influencing the macroeconomic effects of various exogenous shocks.[9]

MULTIMOD analysis of the implications of the non-negativity constraint on nominal interest rates hinges critically on the nature of wage-price behavior. MULTIMOD, like most macroeconomic policy models, relies on a reduced-form Phillips curve to characterize the behavior of inflation in the industrial countries. Because MULTIMOD is used for addressing a wide range of policy questions, several versions of the model are maintained. A simple version of the model incorporates a linear Phillip's curve with parameter values that are constrained to be identical for all of the industrial country blocks. However, the version of the model used for the analysis presented in this paper incorporates a more detailed model of the inflation process that allows for nonlinearities and asymmetries to arise between demand conditions and inflation.[10] Further, the parameters in this formulation of the wage-price nexus are allowed to vary across the different industrial country blocks.

In this version of MULTIMOD, the modeling of inflation and inflation expectations distinguishes between CPI inflation and core inflation. Core inflation is defined as the rate of change in the GDP deflator excluding oil and is taken to be the measure on which monetary policy decisions are based. Although MULTIMOD does not include explicit wage rates, the dynamics of inflation and inflation expectations are characterized in a manner that implicitly recognizes important features of wage-setting behavior (in particular, contracting lags and wage-push elements).

The key equations in MULTIMOD's reduced-form wage-price structure are:

$$\pi_t^{CPI} = \delta_1 \pi_t^{M} + \delta_2 \pi_t^{C} + \delta_3 \pi_t^{POIL} + [1 - \delta_1 - \delta_2 - \delta_3]\pi_{t-1}^{CPI}; \qquad (1)$$

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incorporation of a Euro Area block; new base-case specifications of the behavior of monetary and fiscal policy; and a re-coding of the model that more easily permits solutions to the model in which countries choose different steady-state rates of inflation.

[9] Changes in policy rules will have effects on expectations in MULTIMOD because expectational variables are modeled explicitly and depend on the model's forecasts for these variables. However, MULTIMOD may not be completely immune to the Lucas Critique. The Phillips curve, for example, is a reduced-form equation, and there is always the possibility that a major change in the pattern of monetary policy behavior could lead to significant changes in the nature of wage and price contracts and the dynamics of inflation expectations.

[10] Allowing for nonlinearities and asymmetries in the inflation process means that large policy errors can have first-order welfare implications.

$$\pi_t^C = \psi \pi_{t+1}^e + [1-\psi]\pi_{t-1}^C + \gamma[(u_t^* - u_t)/(u_t - \phi_t)] + \alpha[\pi_{t-1}^{CPI} - \pi_{t-1}^C]; \quad (2)$$

$$\pi_{t+1}^e = \Omega[\lambda \pi_{t+1}^{CPI} + (1-\lambda)\pi_{t+1}^C] + [1-\Omega][\lambda \pi_{t-1}^{CPI} + (1-\lambda)\pi_{t-1}^C]; \quad (3)$$

where π^{CPI} is CPI inflation; π^M is the rate of inflation of the domestic-currency price of manufactured imports; π^{POIL} is the rate of inflation of the domestic-currency price of oil; π^C is core inflation (non-oil GDP deflator); π^e is a measure of expected inflation; u* is the non-accelerating-inflation rate of unemployment (the NAIRU); u is the unemployment rate; ϕ is the minimum absolute lower bound for the unemployment rate; and ψ, α, γ, Ω, λ, δ_1, δ_2, δ_3 are parameters.

Table 1 reports some of the parameter values from the model's wage-price block as well as some associated model properties that are helpful for understanding the inflation process in the model.[11] In particular, it reports estimates of the parameter values λ, α, ψ, Ω and γ for each country/block, as well as average values for these parameters across all of the industrial country blocks. The table also presents the unemployment sacrifice and benefit ratios that result from an artificial experiment where the rate of inflation is permanently increased by 1 percentage point (benefit ratio) and permanently decreased by 1 percentage point (sacrifice ratio). The sacrifice ratio of 0.8 for Japan implies that to reduce inflation permanently by one percentage point, the cumulative increase in annual unemployment above the NAIRU must be 0.8 percentage points.[12] Having the lowest sacrifice and benefit ratios implies that inflation is estimated to be more responsive to changes in unemployment in Japan than other industrialized countries. This arises primarily from the interaction of the slope parameter (γ) and the weight on the model-consistent lead of core inflation ($\Omega \bullet \psi \bullet (1-\lambda)$) in the Phillips curve.[13] All else equal, the larger

[11] Equation 2 has been estimated for each of MULTIMOD's major industrial countries/blocks as part of an unobserved components model that also includes equations for the deterministic NAIRU, the NAIRU, and an Okun's Law relationship between the output gap and the unemployment gap. The estimation is done using the Kalman filter and a constrained-maximum-likelihood procedure. Equations 1 and 3 were estimated with OLS.

[12] Comparing the sacrifice and benefit ratios in each country illustrates the direction of the asymmetry in MULTIMOD's inflation process; the cost incurred to reduce inflation is larger than the benefit that could be derived from increasing it. When the change in inflation is restricted to be only one percentage point, the difference between the sacrifice ratio and the benefit ratio is small. However, this relationship is nonlinear so that as the changes in inflation that are considered become larger, the degree of asymmetry increases.

[13] The degree of persistence in CPI inflation also contributes to the sacrifice and benefit ratios. For example, the difference between the sacrifice ratios for Canada and the United States is a result of a larger weight on lagged CPI inflation in the Canadian price block (0.13 for Canada versus 0.03 for the United States).

the slope coefficient (or the larger the weight on the lead of core inflation) the more responsive inflation will be to demand conditions. It is also worth noting that the magnitudes of α and λ imply that, in Japan, movements in the exchange rate and import prices do not have a large effect on core inflation.[14]

Table 1. MULTIMOD Key Inflation Parameters

	λ	α	Ω	ψ	$\Omega \cdot \psi \cdot (1-\lambda)$	Γ	Sacrifice Ratio[1]	Benefit Ratio[2]
Average	0.48	0.26	0.57	0.54	0.16	2.15	NA	NA
United States	0.48	0.35	0.53	0.51	0.14	2.22	1.25	-1.12
Euro Area	0.60	0.12	0.58	0.51	0.12	2.15	1.86	-1.61
Japan	**0.31**	**0.09**	**0.60**	**0.59**	**0.25**	**2.29**	**0.80**	**-0.74**
United Kingdom	0.34	0.42	0.60	0.58	0.23	2.38	1.02	-0.93
Canada	0.41	0.16	0.50	0.51	0.15	2.38	1.31	-1.15
Other Industrial	0.74	0.42	0.60	0.55	0.09	1.45	4.10	-3.22

[1] The sacrifice ratio is the cumulative *increase* in the annual unemployment rate that is required to *reduce* inflation permanently by 1 percentage point.

[2] The benefit ratio is the cumulative *decrease* in the annual unemployment rate that is required to *increase* inflation permanently by 1 percentage point.

The estimated sensitivity of inflation to demand conditions in Japan will play a key role in determining the implications of the ZIF. On the one hand, because of the high degree of responsiveness of inflation to demand conditions, negative shocks to aggregate demand can more easily push inflation below zero. In the face of the ZIF, this can quickly limit the monetary authority's ability to lower real interest rates, potentially leading to a deflationary spiral. On the other hand, because forward-looking expectations play a large role in determining the responsiveness of inflation to aggregate demand conditions, a well-designed monetary policy

[14] There are several possible factors that may be contributing to this property. First, imports represent a relatively small portion of the consumption bundle. Second, there is a large (albeit declining) number of regulated prices. Finally, the wage setting process in Japan is possibly more cooperative than in other industrial countries. Company profitability tends to be the most important factor underlying the variability in wages.

framework may also be able to exploit a potentially powerful transmission mechanism to overcome any deleterious implications of the ZIF.

MULTIMOD's base-case monetary policy reaction function is based on the familiar Taylor (1993) specifications. Specifically, the nominal short-term interest rate is adjusted—relative to a neutral nominal interest rate—in proportion to the deviation of current output from potential output and the deviation of inflation from target.[15]

In MULTIMOD, monetary policy stabilizes inflation through two main channels, direct price effects that operate through the exchange rate and import prices and indirect effects that operate via aggregate demand. When the monetary authority adjusts the short-term nominal interest rate, the real short-term interest rate moves because inflation is sticky. This movement in the real short-term interest rate affects the real exchange rate via uncovered interest parity. Because exchange-rate expectations also include backward and forward-looking components, the UIP condition implies that the real exchange rate will respond partially in the short run to the future cumulative gap between the real domestic and foreign short-term interest rates. Movements in the real exchange rate feed into domestic CPI inflation directly through import prices. CPI inflation, in turn, can feed into core inflation through expectations (λ) and the real-wage catch-up term (α). The movement in the real exchange rate also affects core inflation indirectly via aggregate demand because of its impact on the relative price of domestically- versus foreign-produced goods. The real interest rate affects core inflation indirectly by its influence on spending on private investment and consumption goods. This arises because movements in the real interest rate alter consumers' valuation of their human wealth, their marginal propensity to consume out of wealth, and the market value of capital relative to its replacement cost.

An important point to note is that because of the forward-looking structure of all of the channels through which real interest rates affect inflation, both current *and* future expected short-term real interest rates have an important role to play. This is an important feature when examining the implications of the ZIF. Once current nominal interest rates hit the ZIF, it is through future expected real interest rates that monetary policy must operate. The central role that this channel plays in MULTIMOD makes it a potentially useful framework for examining this issue.

The value of the equilibrium real interest rate is also an important variable that needs to be calibrated to study the implications of the ZIF. In the base-case version of MULTIMOD, the

[15] The base-case reaction function used here sets the short-term nominal interest rate equal to a neutral nominal interest rate plus 0.5 times the output gap plus 1.0 times the deviation from target of the current year's core inflation. In the simulations that incorporate uncertainty about potential output, this is in fact a forecast of core inflation that will generally turn out *ex-post* to be incorrect. The neutral nominal interest rate is defined as an equilibrium real interest rate plus the expected rate of inflation (as given by equation 3 above).

world equilibrium real interest rate is roughly 3 percent. However, an examination of the average real interest rate in Japan between 1970 and 2000 suggests a level closer to 2 percent would be more appropriate. For the simulations presented here, the equilibrium real interest rate in Japan has been set equal to 2.2 percent and the equilibrium real growth rate has been set equal to 2 percent. This level for the equilibrium real interest rate is consistent with that used for the United States in Fuhrer and Madigan (1997) and Reifschnieder and Williams (1999), although it is above the 1 percent level used in Orphanides and Wieland (1998).

III. Some Illustrative Simulation Experiments

This section presents some simple stylized simulations that will help develop some intuition that may be necessary to understand the results from the stochastic simulations presented in the next section. The simulation experiment consists of a persistent shock to domestic aggregate demand in Japan. We first examine how starting from different baseline solutions that assume different target rates of inflation influences the impact of the ZIF.[16] Using this stylized shock we also illustrate how errors about the level of potential output might influence the implications of the ZIF. Under an inflation target of zero percent, we examine the policy options for stimulating the economy once nominal interest rates have hit the ZIF. We also use the stylized shock to illustrate how a more aggressive policy rule (one with larger response coefficients on the output and inflation gaps) can alter the impact of the lower bound on nominal interest rates.

A. Calibrating the Stylized Shock

The shock that is used in this section of the paper was calibrated to increase in magnitude over the first three years and then to decay over the subsequent five years of the simulation horizon. It consists of negative exogenous impulses to the error terms in the investment and consumption functions.[17] Some details from the simulated response to the shock under an inflation target of 0.0 percent and the base-case policy rule are presented in Table 2. The shock was calibrated with an eye to the experience in Japan over the late 1990s presented in Table 3.[18] The declines in investment and consumption relative to potential output are broadly similar to the historical experience. However, the shock unfolds more slowly and the resulting output gap troughs at about 65 percent of the magnitude that is suggested by the historical data. In the simulation experiments, the policymaker is aware of the current period disturbances hitting the economy, but the policymaker and private agents assume that there will be no

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[16] In each baseline solution all variables are assumed to be equal to their equilibrium values.

[17] We do not attempt to identify the structural factors underlying this shock. Several interesting hypotheses that have attempted to account for the weakness in aggregate demand in Japan can be found in Ando (2000), Morck and Nakamura (1999), and Ramaswamy and Rendu (2000).

[18] This data is from the World Economic Outlook database.

additional disturbances in the future. In this sense, the policymaker and private agents are surprised by the shocks that arrive for each of the first 8 years of the simulation horizon.

Table 2: Simple Stylized Shock
(With an Inflation Target of Zero)

	0	1	2	3
Consumption as a percent of Potential Output	70.1	69.5	68.7	68.1
Change since year 0		-0.6	-1.4	-2.0
Investment as a percent of Potential Output	15.1	14.4	13.8	13.1
Change since year 0		-0.7	-1.3	-2.0
The Output Gap	0.0	-1.0	-1.9	-2.6
Core Inflation	0.0	-0.1	-0.4	-0.9

Table 3: Japan Over the Late 1990s

	1997	1998	1999	2000
Consumption as a Percent of Potential Output	65.2	63.1	62.6	62.7
Change since 1997		-2.1	-2.6	-2.5
Investment as a share of Potential Output	16.5	14.4	13.6	14.3
Change since 1997		-2.1	-2.9	-2.2
The Output Gap	0.0	-3.4	-4.5	-4.0
Core Inflation	0.3	0.3	-0.9	-1.1

The shock-minus-control paths of key macro variables that result from the exogenous disturbances to consumption and investment under the base-case policy rule and four values for the target rate of inflation are presented in Figure 1.[19] The ZIF becomes binding when the target rate of inflation is 1.0 percent or less. The constraint binds for 3, 4, and 7 years when the inflation targets are 1.0, 0.5 and 0.0 percent. The short-term nominal interest rate troughs at roughly 50 basis points under the 2.0 percent inflation target. The impact of the constraint on

[19] To conduct this experiment we have generated four different baseline solutions corresponding to the four different target rates of inflation under consideration, 2.0 percent, 1.0 percent, 0.5 percent and 0.0 percent. The equilibrium nominal interest rate in each of the baselines will be equal to the equilibrium real interest rate (2.2 percent) plus the target rate of inflation.

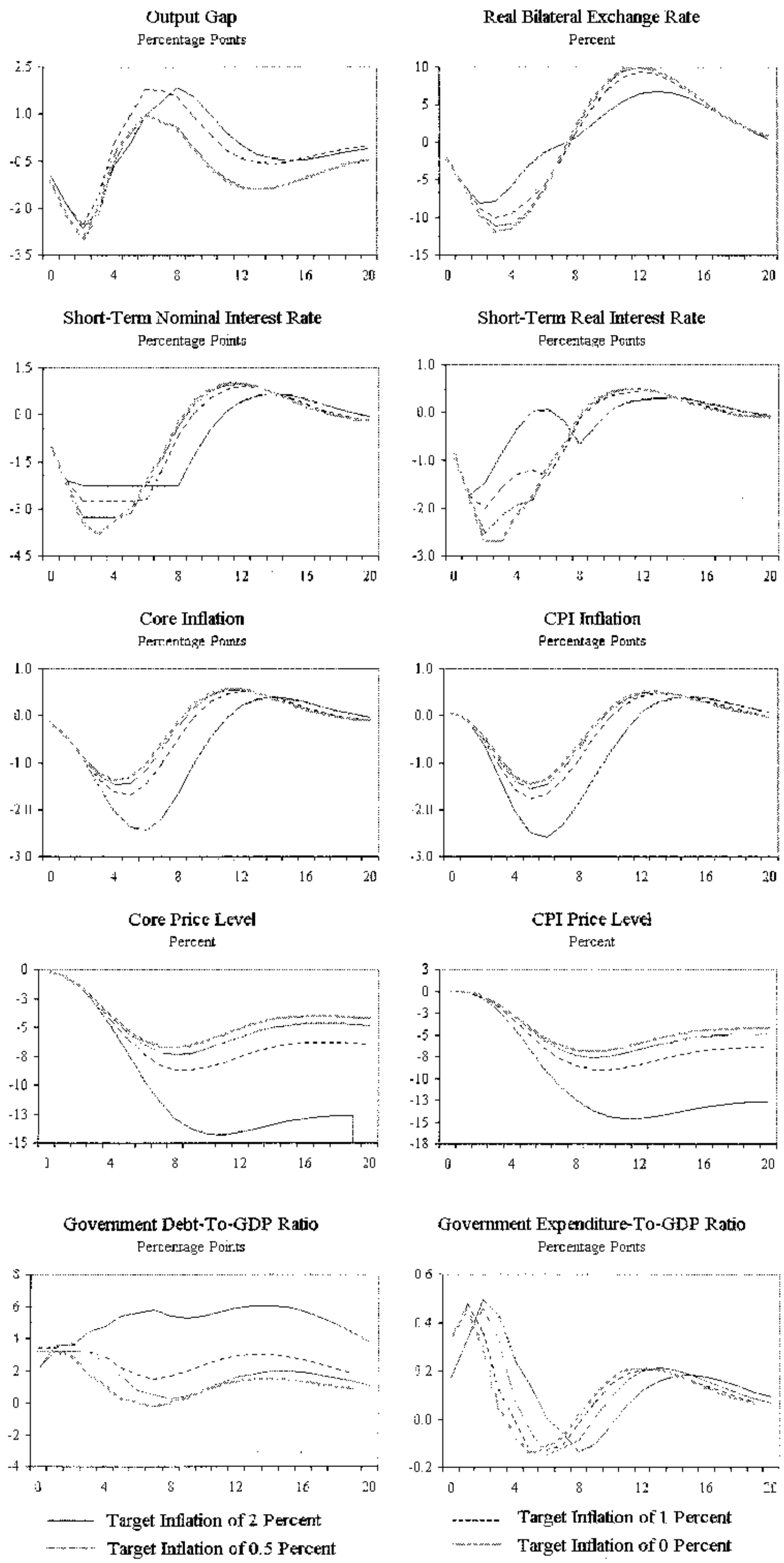
real interest rates is striking. Under the 2.0 percent inflation target, the real short-term rate falls by 270 basis points over the first three years. The real rate then remains at that level in the fourth year, after which time it slowly returns towards control. When the zero bound binds on the nominal interest rate, the real interest rate troughs at 250 basis points below control with the 1.0 percent inflation target, 200 basis points with the 0.5 percent inflation target, and 175 basis points with the 0.0 percent inflation target.

The higher real interest rates that result when the constraint on nominal interest rates binds mean that real output recovers more slowly from the shock, leading to larger and longer lived excess supply gaps. After 20 years, the cumulative loss in output is roughly 2.1 percent, 2.2 percent, 2.5 percent and 3.4 percent under inflation targets from 2.0 to 0.0 percent. The additional excess supply in the economy results in larger declines in inflation and the price level. Under inflation targets of 1.0 and 2.0 percent, the decline in the price level relative to its control path is about 5 percent. However, the price level falls by 7 percent under the 0.5 percent inflation target and by 13 percent when the target rate of inflation is 0.0 percent. These results illustrate, as has other research, that the negative impact of the zero bound increases greatly as the inflation target is lowered towards 0.0 percent.

In these simulations, fiscal tax rates are held fixed at their initial equilibrium rates for the first 11 years. Starting in the 12th year, the aggregate tax rate is allowed to adjust slowly to eventually restore the government's debt-to-gdp ratio to the values in the baseline.[20] As a result of tax rates being held fixed for the first 11 years, the effects on the government debt-to-gdp ratio increase as the target rate of inflation declines. With lower target rates of inflation, the deterioration in the fiscal position is greater because monetary policy's ability to reduce real interest rates declines. In the cases where the ZIF is most binding, the government debt-to-GDP ratio increases significantly because economic activity and the tax base are lower and the higher real interest rates directly increase the servicing costs on the outstanding stock of government debt.

[20] In some cases this convergence process in the government-debt-to-GDP ratio takes longer than 20 years.

Figure 1. The Target Rate of Inflation
Deviations from Control



B. Uncertainty about Potential Output

An important source of uncertainty facing policymakers is the underlying level of an economy's productive capacity. The significant lags between policy actions and their subsequent impact on prices mean that, to achieve their inflation objectives, policymakers must base their actions on indicators of future inflation pressure. One indicator of future inflationary pressure that is often relied on is the output gap, defined here as the difference between current output and productive capacity. However, an economy's productive capacity is unobservable and estimates of its level must be extracted from observable data. A common feature of all methods designed to measure potential output is that there is considerable uncertainty in the derived estimates and this uncertainty is generally the greatest at the end of the sample where the estimates are the most crucial for policymakers.[21] This uncertainty often leads to errors about the level of potential output that are serially correlated and, at times, correlated with the business cycle.[22] To illustrate some possible implications of relying on incorrect measures of potential output, we use the simple stylized simulation from the previous section to show how such errors about the level of potential output affect the impact of the ZIF.

The simulations presented here include the identical exogenous disturbances to investment and consumption as used in the previous simulations. However, now the policymaker also makes errors about the true level of potential output. The errors are assumed to be proportional to the decline in aggregate demand. As output declines relative to its expected level, the policymaker cannot fully determine how much of the decline is due to aggregate demand and how much is due to aggregate supply. The policymaker here is assumed to attribute too much of the decline in output to aggregate supply. This error not only affects the output gap that appears in the policy rule, but it also affects the policymaker's forecast of current inflation. In the next period, the policymaker realizes that an inflation-forecast error was made in the previous period, but cannot determine its source. Consequently, the policymaker's estimate of potential output is not revised in light of the error.[23] Once the aggregate demand shock has fully dissipated, the policymaker's estimate of potential output converges to the true level. Private agents on the other hand perceive the true level of potential output and are aware that the policymaker is making an error. The inflation process is driven by the true output gap and future policy settings that, for a period of time, are based on an incorrect estimate of the true level of potential output.

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[21] For a discussion of the uncertainty associated with output gap estimates see Laxton and Tetlow (1992), Kuttner (1994), Staiger, Stock and Watson (1997), and Orphanides (1997).

[22] For a discussion of the properties of real-time errors associated with estimates of potential output see Drew and Hunt (2000), Gaiduch and Hunt (2000), Isard, Laxton and Eliasson (1998), and Orphanides and van Norden (1999).

[23] This is a strong assumption and most multivariate techniques for estimating potential output would lead to a partial revision in the light of forecast errors.

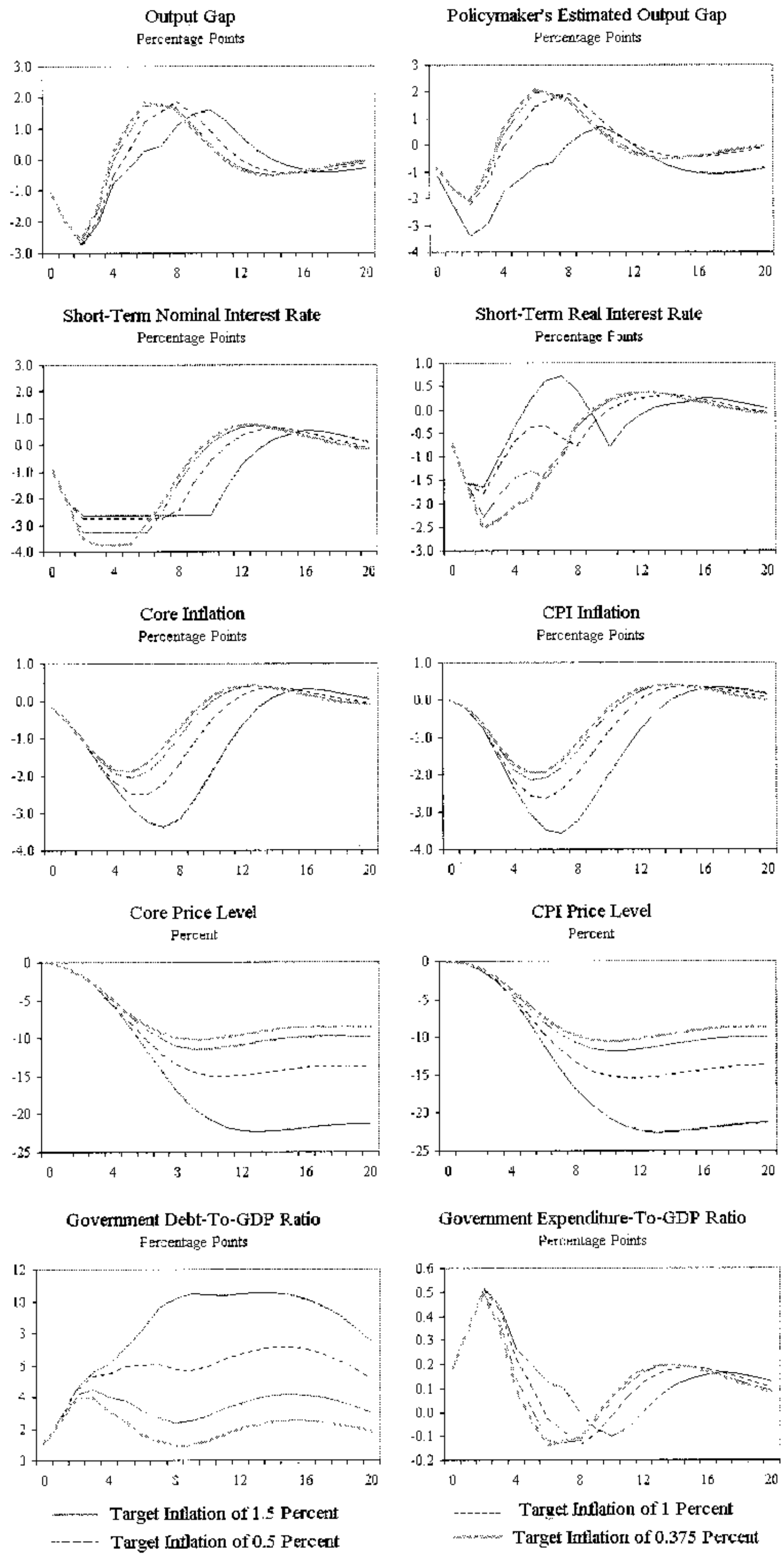
The results from this simulation are presented in Figure 2. The actual output gap and the policymaker's estimate of the output gap are contained in Table 4. If the time-series properties of the policy errors about potential output are similar to the properties of the errors considered here, potential output uncertainty could exacerbate the problem posed by the ZIF. The ZIF binds at a higher level of target inflation and binds for longer at a given target rate of inflation. The ZIF becomes binding when the inflation target is as high as 1.5 percent. The constraint binds for 5 years versus 3 under the 1.0 percent target and 6 years versus 4 when the inflation target is 0.5 percent. When the inflation target is 0.0 percent, the economy gets tipped into a deflationary spiral and the algorithm can only find solutions that violate the ZIF. The lowest inflation target for which the algorithm can find a solution that does not violate the non-negativity constraint is 0.375 percent. Under this inflation target, the constraint binds for 9 years and the cumulative loss in output essentially doubles relative to the case where the inflation target is 2.0 percent—the case where the constraint does not become binding. It is worth noting that this additional loss in output and the behavior of the real interest rate causes the government debt-to-gdp ratio to increase further.

In these simulations, the impact of the constraint is worse because the errors about potential output lead the policymaker to ease less aggressively as the shock is unfolding. This leads to more deflationary pressure becoming entrenched in inflation expectations. This greater deflationary pressure requires a larger future reduction in the short-term nominal interest rate to be unwound. At each point in time, private agents understand the policymaker's underestimation of the magnitude of the excess supply gap, which further magnifies the extent of deflationary pressure in expectations.

Table 4: Actual and Perceived Output Gaps ($\pi^* = 0.0$)

Year	Actual Output Gap	Estimated Gap	Error
0	0.0	0.0	0.0
1	-1.04	-0.84	0.20
2	-1.97	-1.61	0.26
3	-2.73	-2.22	0.51
4	-2.05	-1.52	0.53
5	-0.77	-0.36	0.41
6	-0.25	0.08	0.33
7	0.28	0.52	0.24
8	0.45	0.61	0.16
9	1.09	1.17	0.08
10	1.45	1.49	0.04

Figure 2. Uncertainty About Potential Output
Deviations from Control



C. One-Off Policy Interventions

Using the stylized shock under an inflation target of 0.0 percent, we now turn to consider the effectiveness of policy options designed to stimulate the economy once nominal interest rates have hit the ZIF. The policy interventions occur in the fourth year of the simulation when interest rates have been at the lower bound for a year. Three alternative interventions are considered: an increase in government expenditure; a credible commitment by the monetary authority to unwind the effect on the price level of the deflation; and a sharp depreciation in the currency combined with a credible commitment to a temporary price-level target. The results from these three interventions are presented in Figure 3 along with the outcome in the absence of any intervention.

The fiscal intervention consists of an increase in government expenditure of roughly one percent of gdp for four years. In each of the four years, the fiscal expansion is not expected to last beyond the current year; however, as new negative surprises to aggregate demand arrive, fiscal policy remains loose. Under the first intervention by monetary policy, the policymaker commits in the fourth year to restore all the declines in the price level that have occurred and will occur in the near future due to the negative shock and the constraint on nominal interest rates. Private agents believe the policymaker will achieve this objective and the policymaker does. Under the second monetary policy intervention, the monetary policymaker commits to achieving a price level target that is 5 percent above where the price level was in the year preceding the commencement of the shock. However, to increase the credibility of such an announcement the policymaker is assumed to engineer a 15 percent depreciation in the value of the nominal exchange rate (13 percent in the real exchange rate).[24]

The interventions all prove to be successful. The fiscal intervention eliminates the additional loss in output that arises when the inflation target is zero. After 20 years, the cumulative output loss is 2.2 percent, virtually identical to the cumulative loss of 2.1 percent under the 2.0 percent inflation target. The nominal interest rate becomes positive after four years at zero and the decline in the price level is cut roughly in half. When the policymaker commits to restoring the price level, the cumulative loss in output is reduced marginally from 3.4 to 3.0 percent. Interest rates remain at zero for 5 years (versus 7 years without the intervention) and the decline in the price level is fully reversed. When the exchange rate is depreciated and the medium-term price-level target is achieved, the cumulative loss in output is more than recovered as the loss is reduced to 1.6 percent. Interest rates also remain at zero for 5 rather than 7 years.

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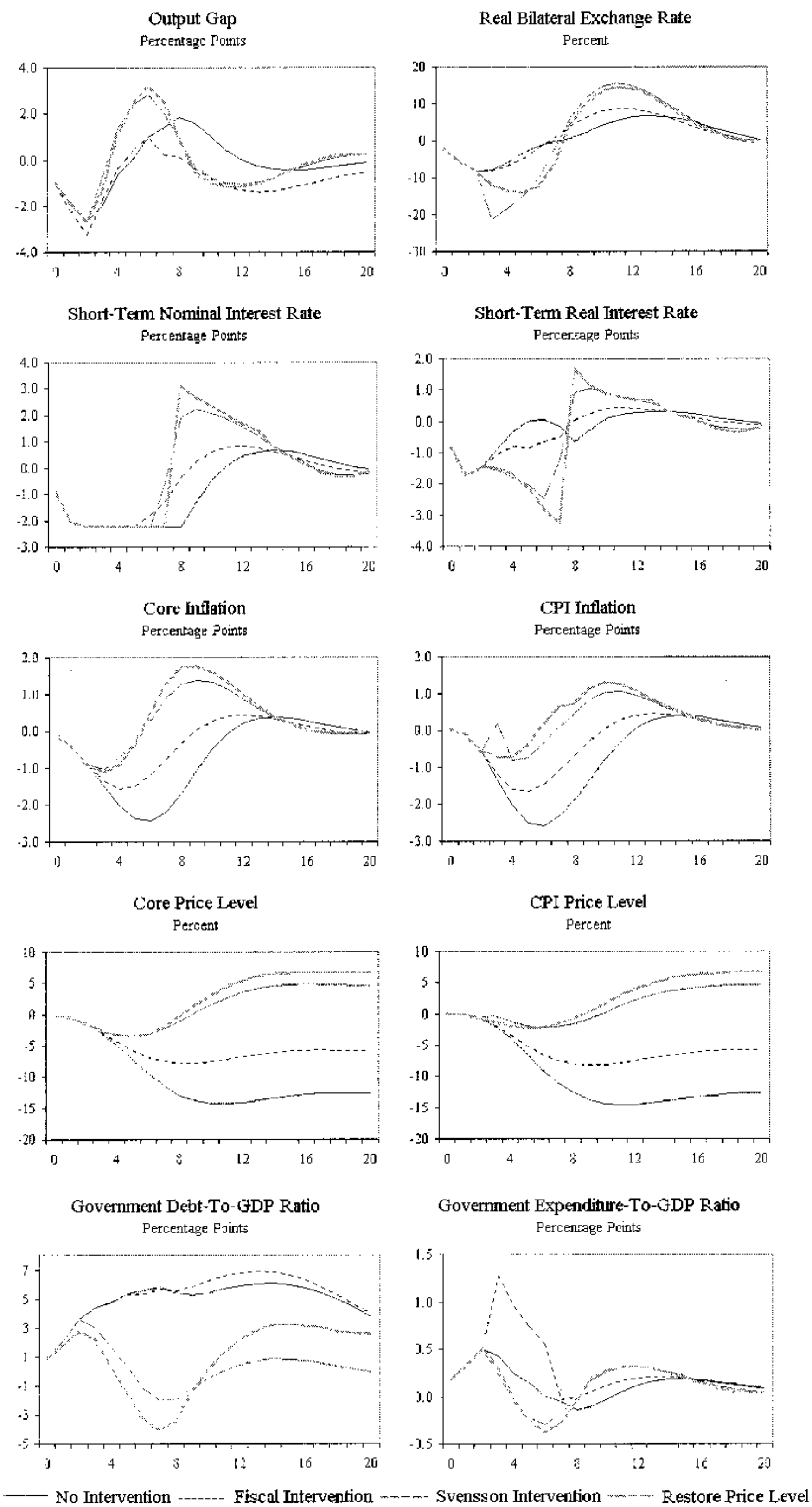
[24] The simulations assume that the monetary authority can achieve the depreciation that is desired. Svensson (2000) and McCallum (2001) argue that because the monetary authority can print money, it can announce a rate of exchange below the previously prevailing market rate and simply stand ready to sell the quantity of yen demanded at that price. Svensson argues that the value of the exchange rate would have to immediately converge to that rate for any market exchanges to occur. No one would pay a higher price than necessary for yen.

Figure 3. One-Off Policy Interventions
Deviations from Control



Although each of the strategies helps to mitigate the implications of the non-negativity constraint, there is an interesting difference that arises in the level of government debt during the period over which tax rates are fixed. In the fiscal intervention case, the government debt-to-GDP ratio has increased 6 percentage points by the tenth year of the simulation—versus a 5-percentage point increase in the absence of an intervention. By contrast, under the monetary policy interventions, the government debt-to-GDP ratio has declined back to control after ten years without any change in tax rates. The additional inflation results in lower real interest rates that stimulate aggregate demand. Consequently, tax revenues rise and the cost of servicing the existing stock of government debt falls. It is interesting to note that the lower real interest rates and the reduction in the real value of the debt do not arise because inflation surprises private agents. On the contrary, they occur because the policymaker successfully convinces private agents that it is going to generate some future inflation.

The large difference between the cumulative loss under the Svensson intervention and the other monetary policy intervention arises because of the level for prices that the policymaker commits to achieving. If the policymaker commits to achieving a price level that is 5 percent above the level when the shock initially hits and does not engineer a depreciation in the exchange rate, then the loss in output is also reduced to roughly the same as that achieved under the Svensson intervention.[25] Because of their effectiveness in these simulations at offsetting the negative macroeconomic implications of the ZIF, an important question becomes whether the policymaker can credibly commit to achieving its price-level objective. MULTIMOD's structure for expected inflation implicitly assumes that a significant proportion of private agents believe the policymaker's announced target for the price level. However, with nominal short-term interest rates constrained at zero at the time of the announcement, private agents may question the policymaker's *ability* to achieve the announced target. Further, the inflation fighting record of the Bank of Japan may also lead private agents to question the policymaker's *commitment* to achieve the announced target once the immediate deflationary danger diminishes.

MULTIMOD's structure does not allow for an explicit examination of the types of non–interest rate policy actions considered in Clouse and others (2000) designed to enhance the credibility of the policymaker's commitment to keep interest rates low in the future. The more confident are private agents that the policymaker will deliver low nominal interest rates in the future, the more credible is the commitment to the future inflation necessary to lower expectations of real interest rates. However, one could interpret the depreciation of the exchange rate in the Svensson intervention as a non-interest rate policy action designed to enhance the credibility of the policymaker's announced price-level objective. In the simulation presented here, the depreciation does not play an important role; however, in practice it could be key to generating the required expected inflation.

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[25] For other industrial countries the difference between these two interventions could be greater because of the larger impact of movements in the prices of imported goods on core inflation.

The one-off monetary policy interventions presented in Figure 3 consisted of a commitment to temporarily increase inflation above the assumed long-run target of 0.0. Another monetary policy option would be to announce a permanent increase in the target rate of inflation. Figure 4 presents the simulation results when the policymaker announces, in the fourth year, that the target rate of inflation will be increased from 0.0 to 2.0 percent.[26] As occurs under the temporary increases in target inflation, real interest rates decline significantly relative to the case of no intervention. Lower real interest rates stimulate private demand and the output gap is rapidly closed. Again, the increase in the government debt-to-gdp ratio is quickly reversed and the government debt ratio approaches its target level from below once the aggregate tax rate is allowed to adjust.

[26] In practice it may be more practical to announce an upward sloping path for the target rate of inflation that converges to the long run value (2.0 percent in this example). This would be similar in spirit to the disinflation paths announce by several central banks when they initially adopted formal inflation targets.

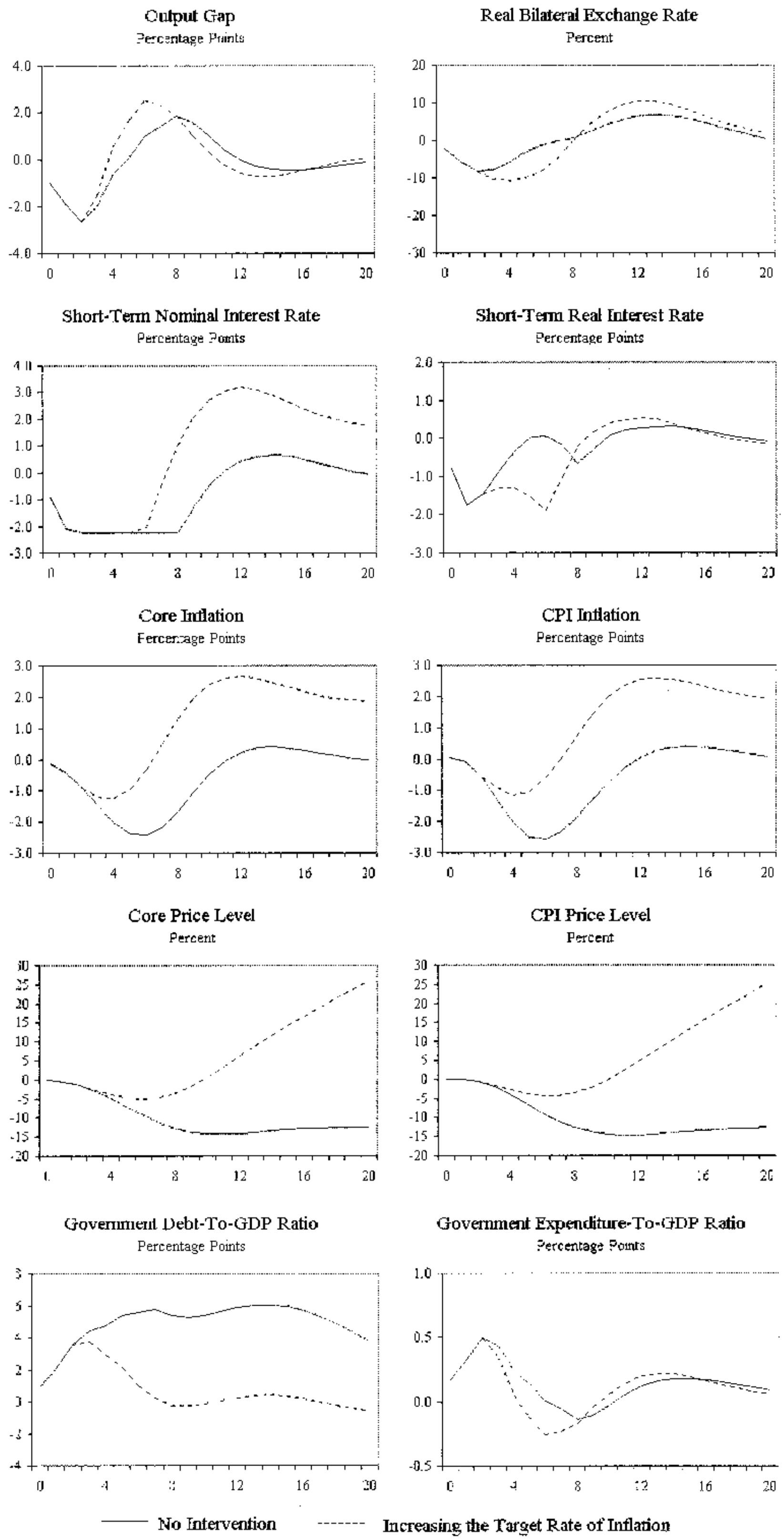

Figure 4. Increasing the Target Rate of Inflation
Deviations from Control

D. Stronger Policy Responses

This section presents the stylized shock under a modified monetary policy reaction function. The response coefficients on the policymaker's estimate of the output gap and forecast of current inflation are doubled (from 0.5 and 1.0 to 1.0 and 2.0 respectively). Increasing the strength of the policy response can potentially have two opposite effects on the frequency with which the ZIF becomes binding. In the first instance, simply responding more strongly to inflation and output gaps is going to increase the frequency with which the constraint becomes binding. For a given level of a negative output gap or inflation gap, the stronger is the policy response, the greater is the probability that the unconstrained policy rule will call for a negative nominal interest rate. However, responding more strongly in the first instance to negative output and inflation gaps will decrease the probability of the constraint becoming binding in the future if additional negative shocks arrive. An important point worth noting is that as the target rate of inflation declines, the scope for large rapid reductions in interest rates to offset negative shocks to aggregate demand is limited by the presence of the zero bound. Because of the way this simple shock unfolds, the simulation results will be biased towards allowing the first round effect to dominate.

To see these two opposite effects consider the simulation details provided in Table 5. In these simulations the policymaker correctly perceives the level of potential output. Results are provided for the base-case response coefficients and a policy rule that doubles the magnitudes of these coefficients. When the inflation target is 2.0, 1.0 or 0.5 percent, the first effect dominates. The nominal short-term interest rate is constrained at the ZIF in more years under the stronger response coefficients. The indications of the second round effect are apparent in the smaller negative output gaps and the smaller decline in inflation. They are not in this instance, however, sufficient to offset the initial impact effect of responding more strongly. A comparison of the results under the 0.0 percent inflation target is more suggestive of the second effect. Interest rates are constrained at the floor for the same number of years under the stronger-response case, inflation doesn't decline as much and the negative output gaps are smaller. The second round effect is more pronounced in Table 6, which presents similar statistics for the case where the policymaker misperceives the level of potential output. Under the 0.375 percent inflation target, interest rates are constrained at the lower bound for fewer periods when policy responds more strongly to inflation and output gaps.

Table 5: Simulation Statistics—No Potential Output Uncertainty

	Base-Case Response Coefficients			
	Π* = 2.0	Π* = 1.0	Π* = 0.5	Π* = 0.0
Number of years that the constraint binds	0	3	4	7
Trough in deviation of inflation from target	-1.4	-1.5	-1.7	-2.4
Trough in output gap	-2.4	-2.4	-2.5	-2.6
	Stronger Policy Response Coefficients			
	Π* = 2.0	Π* = 1.0	Π* = 0.5	Π* = 0.0
Number of years that the constraint binds	2	4	6	7
Trough in deviation of inflation from target	-1.1	-1.3	-1.4	-2.0
Trough in output gap	-1.9	-2.1	-2.2	-2.5

Table 6: Simulation Statistics—Potential Output Uncertainty

	Base-Case Policy Response Coefficients			
	Π* = 1.5	Π* = 1.0	Π* = 0.5	Π* = 0.375
Number of years that the constraint binds	2	5	6	9
Trough in deviation of inflation from target	-1.9	-2.1	-2.5	-3.4
Trough in output gap	-2.6	-2.6	-2.7	-2.7
	Stronger Policy Response Coefficients			
	Π* = 1.5	Π* = 1.0	Π* = 0.5	Π* = 0.375
Number of years that the constraint binds	4	5	7	8
Trough in deviation of inflation from target	-1.7	-1.0	-2.2	-2.4
Trough in output gap	-2.3	-2.3	-2.4	-2.5

IV. Stochastic Simulations

This section presents summary statistics calculated from artificial data that is generated by performing stochastic simulations on MULTIMOD. Under stochastic simulations, the model is perturbed each period by unexpected shocks that directly affect the key behavioral equations in the model. In each period, agents are aware of the disturbances that are currently hitting the economy, but they believe that the expected values of all disturbances in the future are equal to zero. Stochastic simulations are designed to capture an important dimension of the uncertainty under which policymakers must take decisions; uncertainty about how the future will unfold. A large number of artificial data sets are generated so that statistical inferences can be made about the probability of certain events occurring and how different policy frameworks can alter those probabilities. For the summary statistics presented here, we generate 100 data sets (draws) that each covers a 100-year period. This provides 10,000 annual observations to use to calculate summary statistics.

The standard deviations of the stochastic disturbances that are generally used for this exercise are based on the historical residuals from the associated estimated behavioral equations. However, for the results presented in the first part of this section, the stochastic disturbances are only 80 percent of the magnitude of our best measures of the actual stochastic shocks in our historical database. This reduction in the magnitudes of the shocks was necessary because there were too many solution failures under the 0.0 percent inflation target with the standard shocks.[27] Reducing the magnitudes of the shock terms means that the summary statistics will understate the absolute magnitude of the negative impact that the nominal interest rate constraint will have on economic performance.

A. The Base-Case Policy Rule

Table 7 presents some statistics summarizing the simulation results under the base-case policy reaction function. As the inflation target declines from 2.0 to 0.0 percent, the probability that the constraint will become binding increases nonlinearly. The impact of the increasing frequency with which the constraint binds shows up in an average deviation of inflation from target that is declining and an average level of the output gap that is also declining. In terms of

[27] Theoretical work examining the implications of the zero bound on nominal interest rates, like that present in Uhlig (2000) and Benhabib and others (2001), considers that multiple equilibria are a possibility under the nonlinearity caused by the zero-interest-rate floor. However, the numerical solution technique employed here is only capable of finding solution paths under which the economy converges to a steady state with the policymaker's specified target rate of inflation without violating the non-negativity constraint. When deflationary spirals become entrenched, the solution algorithm fails because it cannot find such a path given these constraints and those of the model's structure. As we shall show, an important component of the model's structure that has a significant impact on the ability to find solution paths satisfying all of the constraints is the monetary policy rule.

macroeconomic variability, the increasing frequency of the constraint becoming binding leads to greater variability in core inflation, but not output. Compared to the results in Reifschnieder and Williams (1999), the summary statistics presented in Table 7 suggest that the constraint is binding less often in Japan than in the United States and the resulting impact on macroeconomic performance is more benign. This is not the case. One factor generating this result is the reduction in the magnitude of the shocks that was required under the base-case policy rule.[28] Another important factor is that the summary statistics presented in the table are biased.

The statistics presented in Table 7 are underestimating the true impact of the zero constraint as target inflation declines because we are reporting the summary statistics for all the draws that did not fail under each target rate of inflation.[29] Even though the magnitudes of the stochastic disturbances are only 80 percent of their estimated historical magnitude, the algorithm was unable to find solutions in 24 of the 100 draws under the 0.0 percent inflation target. This compares to failures in only 6 of the 100 draws for the inflation target of 0.5 percent and 3 out of 100 draws for an inflation target of 1.0 percent. No draws failed under the inflation target of 2.0 percent. Splitting the data from the case where the inflation target is 0.5 percent into two sets can shed some light on how large this bias might be. First, consider the set of draws that did not fail under the 0.0 percent target (76 draws). For this set of draws under the 0.5 percent inflation target, the average deviation of inflation from target is 0.026 and the constraint binds 4 percent of the time. The second set of draws includes those that failed under the 0.0 percent target, but not under the 0.5 percent target (18 draws). In this set of draws under the 0.5 percent inflation target, the average deviation of inflation from target is -0.12 and the constraint binds 9 percent of the time. This illustrates that the 18 draws that failed under the 0.0 percent inflation target, but not under the 0.5 percent target are those in which the shocks are pushing the economy more towards deflationary spirals. Clearly, not being able to include these draws in the summary statistics under the 0.0 percent inflation target is biasing the results reported in the table towards underestimating the deleterious implications of the zero bound.

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[28] In Reifschnider and Williams (1999), deflationary spirals, and thus solutions failures, are more easily avoided under a very similar monetary policy rule for three reasons. First, the macroeconomic model that they use, FRB/US, has more inflation persistence than does the Japan block of MULTIMOD. Second, they incorporate a fiscal policy rule that automatically stimulates the economy if interest rates are constrained at the zero bound for long periods of time. Finally, the authors increase the actual target rates of inflation that appear in the policy rule to compensate for the decline in average inflation outcomes that will otherwise arise in the face of this nonlinearity. For example, to achieve an average outcome of 0.0 percent inflation, the actual target rate for inflation specified in the policy rule is 0.7 percent.

[29] Looking at only the set of draws that did not fail for all target rates of inflation would also bias the results towards underestimating the impact of the nonnegativity constraint. This occurs because all of the draws that embody the shocks that drive the economy into deflationary spirals under low target rates of inflation are then excluded.

Table 7: The Base-Case Policy Rule

	The Policymaker's Target Inflation Rate			
	$\Pi^* = 2.0$	$\Pi^* = 1.0$	$\Pi^* = 0.5$	$\Pi^* = 0.0$
Average deviation of core Inflation from target	0.028	0.024	-0.002	-0.049
Average output gap	-0.03	-0.03	-0.03	-0.04
Percent of time that the constraint binds	1	2	5	9
Variance of core inflation	0.62	0.62	0.66	0.72
Variance of the output gap	1.31	1.31	1.31	1.31
Percent of draws that failed	0	3	6	24

B. A More Aggressive Monetary Policy Response

Replicating the stochastic experiment presented above, but doubling the magnitude of the response coefficients that appear in the monetary policy rule, illustrates how a stronger policy response influences the impact of the non-negativity constraint. In the simulation results from this experiment, there is evidence of both of the first and second round impacts of a stronger policy response discussed in the previous section. If we consider only the 76 draws for which a solution was found under the 0.0 percent inflation target, the first round effect (under the 0.0 percent inflation target) is to increase the frequency with which the non-negativity constraint binds from 9 to 13 percent. However, under the stronger policy response there are only 7 rather than 24 draws out of the 100 for which a solution cannot be found. The stronger policy response does a better job of avoiding deflationary spirals.

The qualitative nature of the implications of the ZIF can be inferred from examining the results from the draws that did not fail under the more aggressive policy rule—see Table 8. As can be seen in Table 8, the average level of the output gap declines as the inflation target is reduced from 2.0 percent to 0.0 percent and when the target is 0.0 percent there is significant deviation of core inflation from the target (-0.07 percentage points). The nonlinear impact of the constraint is evident in the change in the frequency with which the constraint becomes binding. As was the case under the base-case rule, the deterioration in macro variability shows up in inflation variability, but not in output variability.

Table 8: A More Aggressive Policy Response

	The Policymaker's Target Inflation Rate			
	$\Pi^* = 2.0$	$\Pi^* = 1.0$	$\Pi^* = 0.5$	$\Pi^* = 0.0$
Average deviation of core inflation from target	0.016	-0.009	-0.03	-0.07
Average output gap	-0.02	-0.03	-0.03	-0.04
Percent of time that the constraint binds	2	5	8	14
Variance of core inflation	0.71	0.73	0.76	0.80
Variance of the output gap	1.15	1.15	1.15	1.15
Percent of draws that failed	0	0	2	7

C. Committing to Unwinding Declines in the Price Level

In a previous section we examined the implications of a one-off policy intervention in which the monetary authority committed to unwinding any declines in the price level that arose because of deflation. Here we consider the implications of incorporating such a commitment systematically into the monetary policy rule. Statistics summarizing the results under the base-case policy rule coefficients with the addition of this price-level commitment are presented in Table 9. The first point worth noting is that there is a dramatic reduction in the number of solution failures. Using this policy rule only a single draw fails under the 0.0 percent inflation target and there were no failures under any of the higher target inflation rates.

There are several interesting points to note about the results in Table 9. First, even though virtually all of the draws that previously pushed the economy into deflationary spirals under the 0.0 percent inflation target can now be solved, the proportion of the time that the constraint binds increases only marginally from 9 to 10 percent. It is lower than the 14 percent achieved under the more aggressive policy rule. Second, the average deviation of inflation from target rises now as the target inflation rate falls. This reflects the behavior of inflation that is required to unwind declines in the price level. Under a 0.0 percent inflation target all declines in inflation below target must be completely matched with periods of inflation above target. Third, even with this need to generate more inflation in response to deflationary impulses, the variability of inflation actually declines as the target inflation rate falls. Essentially the price-level commitment on the part of the monetary authority works to constrain the declines in inflation sufficiently to more than offset the additional variability that arises from the need to generate more periods of inflation above target. Fourth, both the average level of the output gap and its variability now rise as the inflation target falls.

Table 9: Systematically Committing to Unwinding Declines in the Price Level

	The Policymaker's Target Inflation Rate			
	$\Pi^* = 2.0$	$\Pi^* = 1.0$	$\Pi^* = 0.5$	$\Pi^* = 0.0$
Average deviation of core Inflation from target	0.028	0.041	0.117	0.322
Average output gap	-0.03	-0.03	-0.02	-0.01
Percent of time that the constraint binds	1	4	7	10
Variance of core inflation	0.62	0.62	0.58	0.50
Variance of the output gap	1.31	1.34	1.39	1.49
Percent of draws that failed	0	0	0	1

D. Price-Level Targeting

Rather than only committing to unwind declines in the price level, the policymaker could commit to a price-level target. Riefscnieder and Williams (1999), show that price-level targeting is an effective means of mitigating the implications of the zero bound on nominal interest rates. Under such a rule, the policymaker commits to achieving a specified target path for the price level. That target path could have a constant growth rate, reflecting a positive rate of underlying inflation, or the path could be a constant with an underlying inflation rate of zero. We replicate the stochastic experiment under a price-level monetary policy rule. The policymaker's target paths for the price level embody the four underlying target rates of inflation considered previously. Under such a rule, the policymaker is striving to set the integral of the deviations of inflation from target equal to zero. A search over horizons from contemporaneous to five years ahead for this price-level term indicated that that the optimal horizon was contemporaneous.

The statistics summarizing the results obtained under price-level targeting are presented in Table 10. The price-level rule does help mitigate the implications of the zero bound in the sense that there were fewer simulation failures than under inflation targeting. Under the constant-price-level target, 4 draws failed compared to 24 under an inflation target of 0.0 percent. Compared to inflation targeting, the price-level rule delivers lower inflation variability at the cost of greater output variability.

Table 10: Price-Level Targeting and Restoring Declines in the Price Level[1]

	Annual Rate of Change in Price-Level Target (Target Rate of Inflation)			
	Π* = 2.0	Π* = 1.0	Π* = 0.5	Π* = 0.0
Average deviation of core inflation from target	-0.012 (0.028)	-0.053 (0.041)	-0.069 (0.117)	-0.083 (0.322)
Average output gap	-0.06 (-0.03)	-0.06 -0.03	-0.07 (-0.02)	-0.08 (-0.01)
Percent of time that the constraint binds	1 (1)	5 (4)	8 (7)	14 (10)
Variance of core inflation	0.50 (0.62)	0.54 (0.62)	0.59 (0.58)	0.71 (0.50)
Variance of the output gap	2.22 (1.31)	2.25 (1.34)	2.30 (1.39)	2.40 (1.49)
Percent of draws that failed	0 (0)	0 (0)	1 (0)	4 (1)

[1] The statistics presented in parenthesis are the results when the policymaker commits to unwinding all the declines that occur in the price level from periods of deflation. These are the summary statistics from Table 9.

The summary statistics in parentheses in Table 10 are the results achieved under the policy rule that unwinds all the declines in the price level that occur from periods of deflation. Comparing the summary statistics in parentheses to those achieved under price-level targeting illustrates an interesting point. The asymmetric rule that responds only to restore price level declines, does a much better job of combating the negative implications of the zero floor on nominal interest rates. The case where the target rate of inflation is 0.0 percent and the policymaker unwinds all price level declines is perfectly asymmetric relative to the constant-price-level-target case. Under the 0.0 percent inflation target and a commitment to unwind price level declines, the price level is perfectly bounded from below. Under the constant-price-level target, the price level is perfectly bounded from above and below. The first point to note is that the constraint binds a lower portion of the time under the asymmetric rule. It is also worth recalling that because there are slightly more failed draws under the constant-price-level target, the percentage of time that the constraint binds reported in the table is biased slightly downwards for that rule. Under the 0.0 percent inflation target with the asymmetric price-level component, the average level of the output gap is higher and the variances of both the output gap and inflation are considerably lower. The number of failed draws is also slightly lower under the asymmetric price-level commitment, suggesting that it does a little better job of avoiding deflationary spirals.

Given the fact that the lower bound on nominal interest rates introduces a significant nonlinearity into the monetary control problem, it is not surprising that a nonlinear monetary policy rule is the preferred way to respond. The improvements in the macroeconomic outcomes that result under the asymmetric-price-level commitment arise for two reasons. First, because the policymaker is bounding the price level only from below, policy is not overly concerned with overshooting when generating the required inflation to achieve the price-level objective. Consequently, such a commitment works very effectively to generate expectations of future inflation when required. Second, when the policymaker is bounding the price level from above as well, periods of inflation must be followed by periods of deflation. However, during those periods of required deflation, unexpected negative shocks can more easily drive nominal interest rates down to their lower bound and possibly the economy into deflationary spirals.

In macroeconomic models like MULTIMOD, that have a nontrivial forward-looking component in inflation expectations, price-level-targeting rules work well because of the implicit credibility that monetary policy enjoys. Consequently, moving from an inflation-targeting rule to a rule with a price-level component may be an effective means of combating the implications of the ZIF. The commitment to generate future inflation is believed by private agents. This raises an important issue regarding how successful such a policy may be in practice. Some might argue that only by committing to a price-level target always and everywhere could a policymaker, through its performance, gain the credibility that it needs. Credibility comes from "putting runs on the board" so to speak. However, as these simulation results suggest, bounding the price level from below and above may entail both greater variability in output and a lower average level of output relative to the case of an asymmetric price-level target. Consequently, private agents may find the asymmetric price-level target more credible as it is more consistent with the policymaker's preferences for output and inflation stability.

In addition, both politically and institutionally, the will to generate inflation when required is probably much easier to find than the will to generate deflation.

E. Shocks Consistent with Japan's Historical Experience

For the simulations results summarized in Table 11, the magnitude of the stochastic disturbances that hit the economy are not reduced. Using the policy rule that embodies a commitment on the part of the monetary authority to unwind any declines that occur in the price level helps to dramatically reduce the number of solution failures under the 0.0 percent inflation target.[30] Compared to the results presented earlier, these results are less biased estimates of how the choice of the target rate of inflation influences the probability that the zero bound on

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[30] We examined a policy rule that contained stronger response coefficients and the asymmetric price-level component. The addition of the stronger response coefficients actually increased the number of solution failures and the proportion of time that the constraint was binding.

nominal interest rates will become binding provided that the policymaker is behaving according to a good policy rule. The results achieved under stochastic shocks consistent with historical experience and the symmetric price-level rule are presented in Appendix 1.

Even with this policy rule, 5 of the 100 draws could not be solved under the 0.0 percent inflation target. Consequently, these results are still slightly biased towards underestimating the macroeconomic impact of the zero bound on nominal interest rates. However, one can say that under an inflation target of 0.0 percent and a very good monetary policy rule, the probability that the zero bound on nominal interest rates will become binding is greater than 16 percent. Even under an inflation target of 1.0 percent, there is at least a 7 percent probability that the constraint will bind. Under a good monetary policy rule, choosing an inflation target of 0.0 rather 2.0 percent leads to a lower average level of output, higher output variability and slightly lower inflation variability.

Table 11: Stochastic Disturbances Consistent with Japan's Historical Experience—Asymmetric Policy Rule Unwinding Price Level Declines

	The Policymaker's Target Inflation Rate			
	$\Pi^* = 2.0$	$\Pi^* = 1.0$	$\Pi^* = 0.5$	$\Pi^* = 0.0$
Average deviation of core Inflation from target	0.035	0.071	0.178	0.397
Average output gap	-0.04	-0.04	-0.05	-0.05
Percent of time that the constraint binds	2	7	12	16
Variance of core inflation	0.98	0.97	0.92	0.90
Variance of the output gap	2.07	2.14	2.25	2.40
Percent of draws that failed	0	3	4	5

V. Conclusions

Given the experience in Japan in the late 1990s, Larry Summers' comments in 1991 have turned out to be prescient. Because nominal interest rates cannot be driven below zero, achieving very low target rates of inflation can impede a monetary authority's ability to lower real interest rates. The MULTIMOD analysis presented in this paper suggests that, for Japan, aiming at a target rate of inflation below 2.0 percent may often give rise to persistent periods where monetary policy finds itself unable to reduce real interest rates to the extent desired. In practice, the measurement bias in price indices and the difficulties associated with estimating the level of potential output would argue for a target rate of inflation above the 2.0 percent suggested by our stochastic simulation analysis. The analysis illustrates that although there are modifications to systematic monetary policy that can mitigate the impact of this constraint, choosing a sufficiently high target rate of inflation appears to be the most effective component for avoiding the problems associated with the lower bound on nominal interest rates.

Once nominal interest rates have become constrained by the ZIF, MULTIMOD simulations suggest that there are one-off policy actions that will stimulate aggregate demand and help avoid deflationary spirals. Although both monetary and fiscal policy actions can be effective, either monetary policy intervention or a combination of monetary and fiscal policy action will result in notably less deterioration in the government debt position.

The fundamental point emerging from this work is that there are cures available for the economic malaise that can arise because of the ZIF. However, prevention, in the form of a sufficiently high rate of target inflation, may be the optimal strategy. One might question this policy advice if the optimal rate of inflation being prescribed was 10 or 20 percent. However, most research examining the real output costs of inflation finds little or no evidence that an inflation rate as high as 2 or 3 percent entails any significant output sacrifice.[31] In fact, in the face of nominal rigidities, there may be benefits associated with low positive rates of inflation if they facilitate the relative price changes that are required for efficient resource allocation.

[31]Khan and Senhadji (2000) provide some empirical evidence that inflation only has negative effects on growth when it is higher than 1 to 3 percent in industrial countries and higher than 7 to 11 percent in developing countries.

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Stochastic Disturbances Consistent with Japan's Historical Experience
Price-Level Targeting and Restoring Declines in the Price Level[1]

	Annual Rate of Change in Price-Level Target (Target Rate of Inflation)			
	$\Pi^* = 2.0$	$\Pi^* = 1.0$	$\Pi^* = 0.5$	$\Pi^* = 0.0$
Average deviation of core Inflation from target	-0.012 (0.035)	-0.054 (0.071)	-0.070 (0.117)	-0.084 (0.397)
Average output gap	-0.09 (-0.04)	-0.10 (-0.04)	-0.10 (-0.05)	-0.10 (-0.05)
Percent of time that the constraint binds	4 (2)	9 (7)	14 (12)	20 (16)
Variance of core inflation	0.80 (0.98)	0.87 (0.97)	0.98 (0.92)	1.08 (0.90)
Variance of the output gap	3.46 (2.07)	3.51 (2.14)	3.57 (2.25)	3.53 (2.40)
Percent of draws that failed	0 (0)	2 (3)	6 (4)	30 (5)

[1] The statistics presented in parenthesis are the results when the policymaker commits to unwinding all the declines that occur in the price level from periods of deflation. These are the summary statistics from Table 10.