International Deflation Risks Under Alternative Macroeconomic Policies∗

Kevin Clinton, Marianne Johnson, Ondra Kamenik, and Douglas Laxton

Abstract

We use a G3 version of the Global Projection Model to assess options for dealing with the looming risk of international deflation. The zero floor to interest rates constrains monetary policy. Confidence intervals, derived from stochastic simulations, indicate ranges of uncertainty. The results suggest a high probability of a declining price level for a couple of quarters in 2009. Suitable policy adaptations reduce the risk that this might turn into a prolonged, global deflation. These include: a price level path target for monetary policy, which would respond to previous, as well as expected, shortfalls from the desired inflation rate; a more stimulative fiscal policy; and an increase in the long-run target for inflation.

JEL Classification Numbers: E3, E5, E6

Keywords: Monetary Policy; Price Level Path Targeting; Deflation; Fiscal Policy

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A. Introduction

Current economic turmoil is raising a growing risk that monetary policy may, for the first time since the Great Depression, have to deal with global deflation. By deflation we mean that current and expected rates of change in the price level, over a horizon of at least a year, are negative. A decline in the headline CPI for a few quarters, resulting for example from a slump in energy prices, under this definition is not deflation, and it does not pose a special problem for monetary policy. However, at the present time, given the overall weakness of the economy, there is some risk that the zero interest rate floor (ZIF) blocks the normal remedy of lower interest rates. If nominal interest rates on the safest, most liquid, assets are at zero, the cost of credit to firms and households would be positive, and the real cost of credit (adjusted for the expected deflation) could be high enough to impede economic recovery. This situation, in which conventional monetary policy might not have an effective instrument to stop a deepening spiral, poses a particularly difficult problem.¹

This paper describes results from a G3 (the United States, the euro area, and Japan) version of the GPM. We set up stochastic simulation experiments to assess the risk of a deflation problem, and see how different options for monetary policy might affect it. An international model is apt because the issues are global. At the ZIF, a monetary action in any one area could still have an expansionary effect through depreciation of the exchange rate—most obviously, an official, unsterilized, purchase of foreign exchange. But this remedy too might be ineffective when all regions face the deflation problem, since currencies cannot simultaneously depreciate against each other.

One strategic option, to reduce the risk of a deflation spiral, is to raise the long-run objective for the rate of inflation. Economists (e.g. Summers, 1991) have long recognized that a higher objective would reduce the risk of an encounter with the ZIF. The consensus view in the major industrialized countries has been that this risk would not, in itself, rule out an objective for inflation in the low single digits. But in the light of present difficulties, it is worth investigating how a long-run target of, e.g., 3 percent inflation might compare with 1 or 2 percent.

A second option for monetary policy relates to the path for the price level. Under pure inflation targeting (IT), bygones are bygones: the central bank pursues the same target going forward, regardless of any deviations from target that may have occurred in the past; the price level may therefore drift. The expected path of the price level would have a positive slope equal to the target rate of inflation but the confidence interval around the expected path would widen without bound into the future. The essence of price level path targeting (PLPT) is that the central bank would react to past, as well as current or expected, deviations from target, so as to stabilize the average rate of inflation over periods of years.² The confidence interval around the

¹Smith (2006) provides a survey of international historical evidence. Over the centuries there have been numerous episodes of deflation. Some of these episodes saw good growth and prosperity. Bad outcomes, however, have almost always been associated with the kinds of shocks that we see in 2008—e.g. imploding asset values and financial fragility.

²Svensson (2001) and Eggertsson and Woodford (2003) call this a “history dependent” inflation target.
(rising) price level path would then not widen without limit into the future. In a deflationary period, as long as the actual rate of inflation fell below the target rate, a credible PLPT program would create increasing expectations of inflation in the years just ahead. The real interest rate would then continue to fall, even at a zero nominal rate. This would potentially reduce the frequency and severity of deflation episodes.

For fiscal policy, we consider 2 levels of stimulus. The first corresponds to the programs already enacted in early 2009 (including the February 2009 package in the United States). The second is a coordinated, higher level of stimulus, equivalent to 1 percent of GDP, in each of the 3 economies, in 2010.

Model simulations indicate how the various policy options might affect the deflation risk over the next 3 years. Our work breaks new ground, in several ways:

- an empirically estimated nonlinear model, with an embodied zero interest floor constraint
- initial conditions corresponding to today’s global deflationary environment
- optimized coefficients for the PLPT rule

Previous research has tackled aspects of these issues, in isolation. The simulation experiments have usually involved random perturbations from a starting point of general equilibrium. To-day’s environment is not at all like this, and much less tractable for modeling as well as for policy making.

The paper is organized as follows. Section B discusses aspects of policy credibility in a deflationary environment. Section C gives a brief description of the model. Section D describes the simulation results. Section E presents some conclusions.

### B. Credibility and Policy Rules

In a widely cited statement Woodford (2005) observed: “… not only do expectations about monetary policy matter, but at least under current conditions, very little else matters.” This applies in 2009 with a force that Woodford could not have anticipated. To a significant extent, the crisis is a crisis of confidence. Deflation risk largely depends on the public’s expectations of future price level developments. Confidence that the central bank will, within the near future, restore the rate of inflation to the desired positive level would reduce the risk of a deflation problem.

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3Examples are Coenen (2003), Coenen and Wieland, 2003, Coenen and others (2004), and Svensson (2001).

4Carabenciov and others (2008a and b) provide more detail on the motivation, structure, and properties of the model.
We assume throughout that the policy rules that we test are credible. That is, at any given moment, the public’s expectations of inflation differ from the announced long-run target of the central bank only to the extent that people give some weight, over short horizons, to recently experienced rates of inflation. The assumption that long-run expectations align with long-run inflation targets provides the system with its nominal anchor.

Under a conventional IT rule, the central bank adjusts the policy interest rate to close any gap between the expected inflation rate in the quarters just ahead and the target rate. Many central banks over the past 2 decades, including those that have adopted explicit inflation targets, as well as the G3, have followed rules of this kind. To judge from evidence on inflation expectations, and from the time series properties of inflation itself, the public has come to trust such rules.

The counterfactual PLPT rule keeps the average inflation rate, over time, on target. Whereas the IT rule looks forward, ignoring any deviations from target that may have occurred in the past, PLPT implies a time-varying, history-dependent, short-run inflation target. To offset the cumulative effect of current deviations from target, the central bank would, for a while in the future, create deviations in the opposite direction. This affects the dynamics of inflation. While inflation would eventually return to the target rate, medium-term expectations would vary inversely with just-experienced inflation gaps. For the case in point, following a succession of undershoots, people would expect a relatively high rate of inflation in the quarters immediately ahead. In a model this countercyclical property adds a stabilizing factor to the actual inflation rate.

It is unlikely that time-varying short-run inflation targets would cause a special credibility problem for PLPT. Credibility is not a function of technicalities; and the credibility of monetary policy in particular is not about short-run price changes. Instead, credibility concerns the rule that the central bank follows over time in pursuit of its price stability objective. If the credibility that the central banks have achieved over the past 2 decades means anything, it should survive a technical change, the essence of which is to make the targets apply to the average rate of inflation over periods of years, rather than one year at a time. Going forward, people would find that on average the central bank was achieving the inflation target with a higher degree of accuracy than under a pure IT regime.

Any effective remedy for a deflation problem requires the central bank to boost confidence that prices will eventually rise. Since PLPT provides a conceptual framework in which this message is amplified, it would reinforce a confidence-building communications strategy. Svensson (2001) and Woodford (2003) make two supporting proposals. First, the central bank would operate with a high degree of transparency, so that the public has a large set of information with which to evaluate monetary policy. For example, it would publish the expected short-run

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5In other projects, GPM has been modified to include an endogenous credibility process, according to which credibility is gained only with the consistent pursuit of a given policy rule over time—see, e.g. Argov and others (2007) and Alichi and others (2008).

6See, e.g., Kamenik and others (2008). The argument is consistent with our own results, presented in section D.
rate of inflation, rather than leave it to the public to calculate the time-varying intermediate inflation target consistent with PLPT. Second, monetary policy would consistently pursue PLPT in response to all cumulative deviations from target, regardless of sign, at all times.

In the model, a credible PLPT component in the policy rule has 2 substantive effects when current or expected inflation is below target. First, relative to IT, a PLPT rule cuts the policy interest rate relatively quickly, and holds it below the equilibrium value for longer period, since it deliberately aims for a period of overshooting, to make up for the emerging negative deviation. Second, during a continuing deflation the expected rate of inflation keeps increasing. The larger is the observed cumulative negative deviation from the target path, the greater would be the expected future positive deviations from the long-run target rate of the central bank. At the zero nominal interest rate floor, this inflation-expectations effect could allow the real interest rate to decline progressively during a deflation, and thereby provide economic stimulus. Thus, expectations of inflation would tend to stabilize output. Through the augmented Phillips curve, this effect, and the direct impact of expectations, in principle, make the inflation rate less susceptible to deflationary impulses under PLPT than IT.

We simulate both IT and PLPT rules over an identical array of alternative inflation targets (1, 2, and 3 percent) and fiscal policies (lower and higher stimulus). It turns out that over the 3-year simulation horizon, relative to IT, PLPT leads to a greater frequency of ZIF, but more rapid elimination of the negative deviations from the inflation target. This represents a more aggressive response, as monetary policy seeks not just a return to the target inflation rate, but a temporary overshoot, to restore the price level to its desired path.

C. The Model

C.0.1 Overview

GPM is well suited to analysis of the problem at hand. Moreover, we employ a Bayesian system estimation technique that takes account of the data, and of theory, including restrictions implied by the model as whole. The structure therefore has an empirical basis that is lacking in purely calibrated numerical models. Expectations in GPM are formed from both backward- and forward-looking elements, with empirically determined weights. The model allows for important nonlinearities, including the zero bound on interest rates. It offers various options for the definition of monetary policy rules, which may be estimated from the data, or set to represent counterfactual options. In the simulations of the PLPT rule, we determine the coefficients by an optimization (loss-minimizing) process.

GPM builds from the standard modern monetary policy model, with equations determining:

- the output gap
- the inflation rate (an augmented Phillips curve)
• the exchange rate, and
• the interest rate (a monetary policy rule)

Output is represented by GDP; the output gap is the difference between actual and potential.\(^7\) The inflation rate is the annualized quarterly change in the CPI. The US exchange rate is euro or yen per dollar (an increase corresponding to US dollar appreciation); the real exchange rate adjusts for differential changes in CPIs (an increase implying an increase in the relative price of US goods). It is convenient to express all variables as deviations from long-run equilibrium, i.e. in gap format.

The United States sector includes endogenous credit conditions. We construct an index of bank lending tightening (BLT) in the United States from the Federal Reserve Board’s Senior Loan Officer Survey. The index subtracts the percentage of ”eased” responses against the percentage of ”tightened.” A BLT in excess of 50 percent means unusually tight credit conditions; in 2008Q4 the index reached an unprecedented 80 percent.

The policy rule for the short-term interest rate has a general form, which allows for IT, or for PLPT (the IT rule sets the coefficient of the price level gap to zero). We estimated empirically, the coefficients in the IT version, via a simultaneous, full model, procedure. Since the PLPT rule is counterfactual, we use a quadratic policy loss function, rather than direct estimation, to derive optimal coefficients.

Bayesian methodology provides an estimate of the posterior distribution of the system parameters, as well as of the variance-covariance matrix of disturbance terms. We work with the mode of the posterior distribution, and condition all the remaining experiments on this point estimate. Unobservable historical variables, such as potential output, are estimated simultaneously, using a linear Kalman filter, conditioned on the posterior mode.

Stochastic simulations establish the forecast distribution of the relevant variables, given a set of assumptions about policy. The mode provides a time line for the central tendency of each variable, while confidence intervals around the mode provide a measure of risk.\(^8\) We compare the distributions for given variables, deriving from alternative sets of assumptions, to assess the results from the differing policy options.

**Variable definitions for country \(j\)**

- \(y_{j,t}\): output gap, actual-minus-potential logarithm of GDP
- \(i_{j,t}\): nominal interest rate

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\(^7\) All lower case variables except interest rates are in natural logarithms. For all intents and purposes, this means that, e.g., the output gap is measured as a proportion of potential GDP.

\(^8\) The simulations assume that, in a given period, people expect all the future shocks to be zero–i.e., economic agents are repeatedly surprised by shocks as they occur. Thus, we neglect certain aspects of behavior related to uncertainty.
\( r_{j,t} \): real interest rate gap, actual-minus-equilibrium

\( \pi_{j,t} \): annualized quarterly inflation

\( \pi_{4j,t} \): year-on-year inflation

\( Z_{j,k,t} \): logarithm real exchange rate against currency \( k \)

\( z_{j,k,t} \): deviation from equilibrium logarithm real exchange rate

\( Z_{j,k,t}^e \): expected exchange rate of next period

\( BLT_{US,t} \): credit tightening

\( RPOIL_{US,t} \): log of the real price of oil

A bar above a variable, e.g. \( \tilde{r}_{j,t} \), indicates long-run equilibrium value.

### C.1 Behavioral Equations

#### C.1.1 Output gap of country \( j \)

\[
y_{j,t} = \beta_{j,1}y_{j,t-1} + \beta_{j,2}y_{j,t+1} - \beta_{j,3}r_{j,t-1} + \beta_{j,4} \sum_k \omega_{j,k,4}z_{j,k,t-1}
+ \beta_{j,5} \sum_k \omega_{j,k,5}y_{k,t-1} + \theta_j \eta_{j,t} + \epsilon_{y,j,t}
\]

Equation (1) determines the output gap as a function of

- lags and leads of its own values
- the real interest rate gap
- the weighted trading partner output gap
- the weighted real exchange rate gap
- bank lending tightening (BLT, US equation only), and
- a disturbance term
The lag from the output gap itself captures both intrinsic delays due to adjustment costs, and the adaptive component of expectations, or habit persistence. The lead corresponds to forward-looking investment and consumption behavior, in anticipation of expected future output and income.

Normal cyclical variations in the availability of credit are accounted for implicitly by the interest rate and other variables in the equation. However, shocks to lending practices will have an independent impact, which is not so captured. Their effect is represented by the term $\eta_{US,t}$ which is defined to be a distributed lag of the non-systematic component of the variable BLT. We measure these shocks as the residuals of a simple estimated equation.

**C.1.2 Inflation equation for country j**

$$\pi_{j,t} = \lambda_{j,1}\pi_{j,t+4} + (1 - \lambda_{j,1})\pi_{4,j,t-1} + \lambda_{j,2}\pi_{j,t-1} + \lambda_{j,3}\sum_k \omega_{j,k,3}\Delta Z_{j,k,t}$$

$$+ v_{j,1}\pi_{RP OIL, j,t} + v_{j,2}\pi_{RP OIL, j,t-1} - \varepsilon_{j,t}$$

The augmented Phillips curve, equation (2), has inflation as a function of

- inflation expectations—a weighted average of past and model-consistent future rates
- the lagged output gap
- the change in the real exchange rate
- the current and lagged increase in the real price of oil, and
- a disturbance term

The model-consistent aspect relates to price setting based on predictions of future inflation. When monetary policy adheres to a stable policy rule, expectations eventually converge on the inflation path targeted by the central bank.

The greater the weight on the forward-looking component ($\lambda_{j,1}$), the more rapid is the convergence to the policy target. The backward-looking component, in contrast, reflects adaptive behavior, which slows the adjustment.

The coefficient on the lagged output gap embodies the familiar short-run output-inflation trade-off. This is the crucial link between the real sector of the economy and the price level.

The coefficients on the changes in the real exchange rate and in the real price of oil reflect the pass-through to the CPI of changes to import and oil prices.

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C.1.3 Policy interest rate equation for country j

\[ i_{j,t} = \gamma_{j,1} i_{j,t-1} + (1 - \gamma_{j,1}) \left[ \hat{p}_{j,t} + \pi_{4,j,t+3} + \gamma_{j,2} (\pi_{4,j,t+3} - \pi^*_j) \right] \\
+ \gamma_{j,3} (p_{j,t+8} - p^*_j) + \gamma_{j,4} y_{j,t} \right] + \varepsilon_{i,j,t} \]  

(3)

This policy rule sets a key short-term interest rate (Federal Funds rate for the United States, 30-day interbank rates for the euro area and Japan). The own lag provides smoothed policy responses, in line with the incremental movements typical of central bank decisions.\(^9\)

In a steady state, with inflation on target, and the price level on track, the central bank sets the actual nominal interest rate, \(i_{j,t}\) at the long-run equilibrium level (equal to the equilibrium real rate plus the rate of inflation). Otherwise, it opens a corrective interest rate gap. There are both IT and PLPT components to the rule in equation (3):

- the coefficient \(\gamma_{j,2}\) on the expected year-over-year inflation rate 3 quarters ahead, which is positive, has the central bank cut the real interest rate when expected inflation is below the target rate
- the coefficient \(\gamma_{j,3}\) reflects the extent to which policy reacts to cumulative deviations from target—in the case of pure IT, \(\gamma_{j,3}\) is zero
- the coefficient \(\gamma_{j,4}\) captures the response to the output gap

A disturbance term allows for interest rate actions (possible policy errors) not indicated by the equation.

The equation is constrained to respect the zero lower bound to the interest rate. To investigate alternative options for monetary policy, we vary the policy rule across 2 dimensions. First, we set the target rate at three alternatives—2, or 2.5, or 3 percent—common to all regions. Second, we compare the estimated pure IT rule (with \(\gamma_{j,3}\) weight constrained to zero), against a PLPT rule, the coefficients of which are derived by minimizing a quadratic loss function.\(^10\) The latter assumes an aversion to output gaps, deviations of inflation from target, and variability of the interest rate.

**Estimated parameters for IT policy rule** The estimation technique for the coefficients of the IT rule involves the full model, taking full account of the simultaneity in the system. The

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\(^9\)Woodford (2003) provides a theoretical rationale for the smoothed reaction. In essence, smoothing increases the impact of changes in short-term rates on longer-term rates, because it gives the changes some persistence.

\(^10\)The optimization was done with a linear approximation to the nonlinear model.
estimated coefficients differ somewhat from country to country, and are based on an assumption about their preferred target. Although none of the 3 central banks in the model announces an official target, in each case their statements and behavior, as well as the interpretations of market participants, suggest a plausible implicit target.

For the United States, we assume an objective for the rate of increase of the CPI of 2.5 percent. This is derived from recent Federal Open Market Committee medium-term forecasts for the rate of increase of the deflator of consumer expenditure, which lie between 1.8 and 2 percent; this would yield a forecast for the CPI about half a percentage point higher.\textsuperscript{11} For the euro area, considering the official statement that “The ECB aims at inflation rates of below, but close to, 2\% over the medium term,” we assume a long-run objective of 1.9 percent.\textsuperscript{12} The Bank of Japan is guided by the Board Members’ “understanding of medium- to long-term price stability,” which is currently defined as CPI inflation ranging between 0 and 2 percent, with the median across members at about 1 percent.\textsuperscript{13}

Table 1 contains the estimated values for an IT rule. The smoothing coefficient for Japan is relatively high, indicating slow adjustment of the policy interest rate, while the coefficient on the output gap is low, suggesting more tolerance for output gap persistence. The reaction function for the euro area has a larger coefficient on expected inflation than in either the United States or Japan.

The coefficients for the forward-looking rule in GPM cannot be directly compared to simple Taylor rules.\textsuperscript{14} In particular, since the model-consistent forecast of inflation captures information from the current output gap, one can expect the coefficient on this variable to be quite low in QPM. Thus, while the values for $\gamma_{j,4}$ in Table 1 are considerably below the 0.5 in the Taylor rule, the output gap in GPM has an additional effect on the interest rate though its effect on expected inflation, via the Phillips curve.

\textsuperscript{11}See the Minutes of the Federal Open Market Committee, June 2008, Table 1, Economic Projections of Federal Reserve Governors and Reserve Bank Presidents. For the differences between the consumption deflator and the CPI see McCully and others (2007). Bernanke (2005), Yellen (2006), and Mishkin (2008) provide insider views on the Fed’s “comfort zone” for inflation.

\textsuperscript{12}The quotation is from the ECB website, http://www.ecb.int/mopo/html/index.en.html. In an ECB Working Paper, Christoffel and others (2008), citing the same statement, also adopt a 1.9 percent target.

\textsuperscript{13}Hara, Kimura and Okina (2008) refer to the need for the Bank of Japan to take “insurance against deflation.” See also a speech by Deputy Governor Muto entitled “The Battle Against Deflation,” New York, 2003.

\textsuperscript{14}The specification does though satisfy the Taylor principle that the nominal policy rate move by more than the expected rate of inflation, unless the ZIF is binding.
Table 1

<table>
<thead>
<tr>
<th>Estimated short-run coefficients</th>
<th>US</th>
<th>euro area</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate Smoothing ($\gamma_{j,1}$)</td>
<td>0.73</td>
<td>0.70</td>
<td>0.80</td>
</tr>
<tr>
<td>Expected Inflation ($1-\gamma_{j,1}(1+\gamma_{j,2})$)</td>
<td>0.52</td>
<td>0.68</td>
<td>0.43</td>
</tr>
<tr>
<td>Output gap ($1-\gamma_{j,1}\gamma_{j,4}$)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Optimized short-run coefficients</th>
<th>US</th>
<th>euro area</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate smoothing ($\gamma_{j,1}$)</td>
<td>0.67</td>
<td>0.49</td>
<td>0.88</td>
</tr>
<tr>
<td>Expected Inflation ($1-\gamma_{j,1}(1+\gamma_{j,2})$)</td>
<td>0.27</td>
<td>0.30</td>
<td>0.21</td>
</tr>
<tr>
<td>PLPT gap ($1-\gamma_{j,1}\gamma_{j,3}$)</td>
<td>0.63</td>
<td>0.41</td>
<td>0.12</td>
</tr>
<tr>
<td>Output gap ($1-\gamma_{j,1}\gamma_{j,4}$)</td>
<td>0.51</td>
<td>1.16</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**Optimized parameters for PLPT rule**  Because no central bank has adopted PLPT, we have no data from which to estimate the coefficients of a PLPT rule. Instead, we generate a set of hypothetical optimal parameters. These minimize the policy loss function, given the estimated variance-covariance matrix of disturbance terms, and given the estimated structural parameters. The coefficients are optimized by minimizing the loss function where the loss is a function of the traditional components of an Orphanides-type loss function, similar to the type of rule used in many central banks. This rule has been shown to fit the data of the Volker-Greenspan period quite well. Note that we do not explicitly include the benefits of a making the price level more predictable in the objective function is because we want this to be a very marginal change from existing policy rules. We optimize jointly, over the whole model, all 3 regions together. For each region, the loss function takes the form:

\[
L = w_{\Delta i} \text{Var}(\Delta i) + w_{\pi 4} \text{Var}(\pi 4 - \pi^*) + w_y \text{Var}(y) ,
\]

where \(\text{Var}(\Delta i)\), \(\text{Var}(\pi 4)\) and \(\text{Var}(y)\) are unconditional (long run) variances of the quarterly change in the policy interest rate, the year-over-year inflation deviation, and the output gap. We choose the weights in the loss function to be \(w_{\Delta i} = 0.5\), \(w_{\pi 4} = 1\) and \(w_y = 1\). We use the unconstrained OSR algorithm in Dynare (Sims’ CSIMNEW optimization algorithm). This repeatedly evaluates the loss function, in four steps. First, the derivatives of the equations are evaluated for the specific parameters of the optimized policy rule. Second, the Blanchard-Kahn algorithm is invoked to obtain a reduced form of the model. Third, the unconditional variance-covariance matrix of the endogenous variables is derived, using the reduced form, and the given variance-covariance matrix of the structural disturbance terms. And fourth, the loss function is evaluated from the disturbance term variance-covariance matrix. We apply the optimization procedure jointly to the 3 monetary areas.
Table 2 displays the optimized coefficients for the PLPT rules. Japan is again quite different from the United States or the euro area: the interest rate smoothing coefficient is much higher than for the United States and, especially, Europe; and the coefficients on the PLPT and output gaps are much smaller.

The estimates for the United States put a high weight on the PLPT gap, and for the euro area on the output gap. In the 3 regions, the greater weights on the output gap, in comparison to the pure IT rule, provide a mechanism that will help reduce output variability.

C.1.4 US dollar exchange rate equation for country $j$

$$4 \left( Z_{j,t+1}^e - Z_{j,t} \right) = \left( R_{j,t} - R_{us,t} \right) - \left( \bar{R}_{j,t} - \bar{R}_{us,t} \right) + \varepsilon Z_{j,t}^e - Z $$ \hspace{1cm} (5)

This embodies a modified uncovered interest parity condition. But whereas simple uncovered interest parity would imply equality of all exchange-rate adjusted short-term interest rates, equation (5) allows cross-country differences in equilibrium real interest rates ($\bar{R}_{j,t} - \bar{R}_{us,t}$), even in the long-run equilibrium. That is, each currency has a risk premium against the United States, which may be positive or negative, or zero. The model also has an expectations process for the real exchange rate that has lagged and model-consistent (forward-looking) components—see Carabenciov and others (2008).

C.1.5 Variance and covariance of disturbances

Shocks to the variables are not independent. The present version of GPM contains 3 cross-equation correlations, between:

- potential output and inflation disturbances—negative covariance representing supply shocks—e.g. a positive shock to potential output reduces the current inflation rate;

- potential output growth and output gap disturbances—positive covariance representing the expected income effect of a change in growth, which has an immediate effect on spending and output;

- potential output growth and BLT disturbances in the United States—a negative covariance representing asset market/output market interactions—e.g. a negative growth shock tightens bank credit (because lower growth implies reduced asset values and returns), and in the short run an anticipatory cut in spending produces a negative output gap.
C.2 Underlying Equilibrium Values and Stochastic Processes

Underlying real equilibrium values, which determine the long-run paths of real variables, are not directly observable, but within the context of the model, the Bayesian technique allows us to estimate these values, given the stochastic process for each variable.

C.2.1 Potential output

Potential output follows a stochastic trend with disturbances which may affect its level permanently, and its growth rate over a finite period. In addition, increases in the international price of oil have a negative effect on potential output. Disturbances may affect the level of potential output, but its growth rate over time will eventually return to its steady-state growth rate.

C.2.2 Real equilibrium interest rate and exchange rate

Shocks may cause both short- and long-run changes in the equilibrium values of the interest rate and the US dollar exchange rate. The equilibrium real exchange rate follows a random walk. Since the $n$-$l$ exchange rate equations are defined uniformly vis-à-vis the US dollar, shocks to individual currencies automatically apply to the all cross rates.

C.2.3 Oil price

The log of the real equilibrium price of oil (in inflation-adjusted US dollars), is modeled as a stochastic trend where the current price gradually adjusts to a long-term equilibrium that contains a unit root. In model simulations, the nominal price of oil in the United States rises with the US inflation rate, and in other countries by the rate of exchange against the US dollar. Changes in the price of oil will have various effects in the model. For example, a permanent decrease in the real price of oil will result in a permanent increase in potential output and a temporary decline in inflation. The policy rule will require a cut in real interest rates. Thus, an exogenous fall in the oil price in deflationary conditions would increase the risk that monetary policy would encounter the ZIF.
D. Model Results for Different Policy Options

D.1 Initial conditions

We derive projections, for the 3 economic regions, over 12 quarters starting 2008Q4. Initial conditions for some key variables are shown in Table 3.

<table>
<thead>
<tr>
<th>Interest rate</th>
<th>US</th>
<th>Euro area</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>nominal CPI</td>
<td>1.00</td>
<td>3.20</td>
<td>0.30</td>
</tr>
<tr>
<td>real* inflation</td>
<td>2.12</td>
<td>2.60</td>
<td>1.64</td>
</tr>
<tr>
<td>long-run equilibrium</td>
<td>1.74</td>
<td>1.95</td>
<td>0.67</td>
</tr>
<tr>
<td>Output gap BLT</td>
<td>1.50</td>
<td>2.27</td>
<td>1.00</td>
</tr>
<tr>
<td>-1.82</td>
<td>-3.12</td>
<td>-2.88</td>
<td></td>
</tr>
<tr>
<td>80.7</td>
<td>na</td>
<td>na</td>
<td></td>
</tr>
</tbody>
</table>

* Nominal rate minus model-derived expected inflation

The starting point matters. The United States (the only country for which we have included a BLT variable) has extremely tight credit conditions, without historical precedent. In effect, the Fed starts from a position in which it confronts extreme financial headwinds in its efforts to stabilize the US economy.

The initial output gaps, which are already putting considerable downward pressure on inflation, are even larger in Europe and Japan than in the United States.

Somewhat surprisingly, in view of the large cuts in interest rates in the second half of 2008, monetary policy in the fourth quarter was not providing much of a counter to the deflationary forces. Indeed, real interest rates, calculated with model-generated inflation expectations, were above the long-run equilibrium rate—suggesting an unusually tight stance, given the circumstances.

D.2 Simulated outcomes for different policy options

Confidence intervals, encapsulating the exogenous random variables of the model, are a key aspect of our risk analysis. We derive them from 1600 drawings, over the whole projection

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15 Both the Bank of Japan and ECB have surveys of Bank Lending Standards, but at this point explicit measures of BLT have not been factored into the analysis.

16 See Carabencio and others (2008a) for a discussion of the much less severe credit squeeze of the early 1990s.

17 The model attributes differences in real equilibrium interest rates to country risk premiums.
period, from the estimated probability distributions of the stochastic terms. Because of the numerous interacting variables, to obtain reliable representations of the distributions of stochastic shocks efficiently, we use Latin hypercube sampling. We use the results of the stochastic simulations to assess how well the variants on the baseline policy rule cope with the risks of deflation inherent in the outlook. For each economic area, we present figures for year-over year inflation, the policy interest rate, the output gap, GDP growth, and the price level. For Europe and Japan, these are followed by a figure for the exchange rate. Finally, for each region, a bar chart summarizes results from the whole set of simulations for the frequency of the ZIF (zifhits), the cumulative output gap, and the price level.

Subsections D.4.3-D.4.5 discuss the policy rule options, by economic region, respectively: the United States (Figures 1-6); the euro area (figures 7-13); and Japan (figures 14-20). The timeline figures show 5 confidence intervals, successively narrower as the probability level declines (the levels are 0.95, 0.70, 0.50, 0.30, and 0.10). At the centre of these intervals is the median of the distribution. The top pair of panels in these figures assume that the central banks each pursue a 2 percent inflation rate, which would not be much out of line with current practice (as described above in the preceding section). These panels also assume that each area implements current budgetary measures (denoted “lower fiscal stimulus,” although it does include recently enacted initiatives, such as the February 2009 Obama package). The column of panels on the left of each figure is for pure IT, while the column on the right is for PLPT aiming for the same annual percentage increase in the price level.

The second row shows the effect of a more expansionary monetary policy option—i.e. a 3 percent target rate of price increase. The third row shows the effect of a more expansionary fiscal policy (equivalent to an additional 1 percent of GDP in 2010).

Two cautionary notes are in order. First, attempts to simulate a common target rate of inflation of 1 percent broke down. The failure to converge on a solution path suggests that in the model a target rate this low, for all countries together, would result in dynamic instability, i.e. an intractable deflation problem. Second, under current circumstances, the shocks may be more persistent, and more highly correlated across countries, than in the data period. To this extent, our estimates of deflationary risks would have a downward bias.

**D.3 United States**

Figure 1, for the rate of inflation, suggests that a sharp drop, to negative numbers in 2009 and the first half of 2010, is unavoidable, regardless of the policies adopted. Because of the usual lags in the effects of policy, differences in outcomes only start to show in 2010.

The top left panel of suggests that the usual IT rule will lead to an undershoot of the 2 percent target, through 2011—indeed, the median forecast path sticks at below 1 percent. A PLPT rule gets the inflation rate on a more rapid path to target, but it still does not reach 2 percent by end-2011. A 3 percent target (second row) raises the 2010-11 inflation rate by about 1 percent, as compared to the 2 percent target, but the median forecast again falls short of the raised target.
The confidence bands for the inflation rate are narrower for PLPT than for pure IT. Indeed, whereas the bands for the 2 percent IT rule indicate a material risk of deflation through 2011, those for the 2 percent PLPT rule do not.

The higher fiscal stimulus (third row) eventually leads to a more rapid approach to the 2 percent inflation target—but not before 2011. For achieving the desired inflation rate, the best combination seems to be the higher fiscal stimulus, allied to a price level target path.

Figure 2, for the Federal Funds rate, shows marked differences across the IT and PLPT options. Whereas the IT approach implies a trough near zero, only in the first half of 2009, PLPT would hold the rate firmly at the zero floor until 2010. PLPT is more aggressive because it aims to make up for the emerging negative deviations from target, whereas IT does not. This is reflected also in the somewhat wider bands for the confidence interval.

The output gap shows a drop in 2009, to about -5 percent of potential GDP (Figure 3). With a 2 percent inflation target, and existing fiscal policies, the gap starts to close in 2010, but remains below -3 percent through 2011. As one would expect, more expansionary policies close the gap more quickly. However, a 1 percent increase in the inflation target has less effect than a move either to PLPT, or to a bigger fiscal stimulus. Indeed, the median forecast for the PLPT/higher fiscal stimulus combination shows a strong narrowing in 2010, with a positive output gap (excess demand) in 2011. This combination also narrows the confidence bands around the median forecast.

The same story can be told in terms of output growth (Figure 4). Recovery from the steep drop in 2009 gets underway in 2010, more strongly with the extra fiscal boost, and with PLPT.

Figure 6 shows some summary statistics for the United States. The light-shaded bars are for the pure IT policy rule, the solid-shaded for the PLPT rule with the same slope. The top pair of panels, “zifhits”, shows the number of periods in which the solution involved the zero interest floor, as a percentage of all simulation periods. Because of its more aggressive response to the recession, PLPT produces many more zifhits than the IT rule. The higher fiscal stimulus (top, right panel) moderately reduces the frequency of the zero interest floor for either monetary policy rule. The second row indicates that moving to PLPT, or to more fiscal stimulus, produces a sizable narrowing of the negative cumulative output gap. Raising the inflation target, however, has a minor effect.

For keeping the increase in the price level close to target, over the 3-year horizon, the bottom row of Figure 6 indicates that the most effective option is PLPT. If this monetary policy option is adopted, a more expansionary fiscal policy adds little to the price level. The conventional IT rule falls well short, but under this rule the higher fiscal stimulus does give a more visible boost to prices.

Finally, Figure 6 presents results for the inflation target (pietar) of 2.5 percent, which are not shown in the other figures. In line with intuition, the results for this intermediate policy option fall midway between those for the 1 and 3 percent targets. This finding also holds for the euro area and Japan.
D.4 Euro area

Figure 7 suggests that in the euro area the IT approach may falter over time (first column). Following a drop and a rebound in 2009, inflation declines again by mid-2010, and stays well below target through 2011. The PLPT approach, in contrast, works well, getting inflation to target by 2010 Q1, and holding it stable. The option for higher fiscal stimulus does not make much difference to this outcome.

One reason for the superiority of PLPT becomes clear in the results for the policy interest rate (Figure 8). PLPT involves a sharp cut in euro area interest rates in 2009, to zero in the median projection (second column). In contrast, the IT rule yields a more modest rate decline.

In line with the results for inflation control, Figure 9 indicates that PLPT also produces better results for the output gap. Whereas the median projection under pure IT shows a large cumulative loss of output through 2011 (first column), under a PLPT rule the gap almost vanishes, and its confidence band is much narrower (second column). Higher fiscal stimulus helps close the gap, especially under the PLPT rule.

Figure 10, showing growth rates of output, indicates that the IT rule may be unduly sluggish. The rate of growth of output is still increasing at the end of the 3-year simulation period. In contrast, under the PLPT rule, output growth accelerates more quickly in 2010, but has settled near its long-run rate by the end of 2011.

The median path of the euro/dollar exchange rate shows a modest upward movement for a few quarters under the IT rule (Figure 12). This would reflect the more rapid interest rate cut in the United States. With the passage of time, the central tendency of the exchange rate is flat, with a widening confidence band over the forecast horizon (the same applies to the yen/dollar rate, Figure 19).

The summary statistics (Figure 13) again show that PLPT results in greater frequency of zifhits than IT (first row, light shaded versus solid bars). This yields large benefits in terms of a reduced cumulative output gap (second row), and larger price increases (third row). The higher fiscal stimulus also brings gains, of considerable size under the IT monetary policy option.

D.5 Japan

Figure 14 suggests that an IT rule in Japan, as in the euro area, would be slow to achieve its objective. A PLPT rule performs better, if with less success than in Europe. The higher fiscal stimulus helps both approaches get closer to target.

Whereas the IT rule produces a fluctuating median interest rate, with a wide confidence band, PLPT calls for the rate to fall to zero, in 2009 and 2010, with a very narrow confidence band (Figure 15, second column). The more expansionary policies (monetary and fiscal alike) increase upside risk for the interest rate in the later years of the projection.
Figure 16 suggests that Japan requires the higher fiscal stimulus to eliminate the negative output gap by the end of 2011, and to reduce the range of uncertainty around the gap. The paths for output growth in Figure 17 tell a similar story, with a faster recovery from mid-2009 to mid-2010 for the higher fiscal stimulus. A PLPT approach to monetary policy would also speed the path back to potential output.

The summary statistics (Figure 20) for Japan repeat features seen for the United States and the euro area. Under PLPT, in comparison to IT, the more aggressive response to the drop in inflation produces a much higher frequency of zifhits, smaller cumulative losses of output, and a larger increase in the price level (which, under the circumstances, is desirable). In similar fashion, with the higher fiscal stimulus, the cumulative negative output gap is smaller, and the price level higher. However, as one would expect, a more expansionary budget results in a somewhat lower frequency of the zero interest floor, since monetary conditions do not need to be as easy.

E. Conclusions

The median forecast, regardless of the policy options, shows a sharp widening of the negative output gap, and price declines in 2009. Confidence bands indicate a high probability that policy interest rates will be at the zero floor through 2009 and much of 2010.

With current fiscal stimulus and 2 percent inflation targets, the median forecast has growth resuming in 2010. But this would be a weak cyclical recovery: a negative output gap lasts through 2011; and inflation falls short of the 2 percent target.

Several alternative options might improve this picture:

- adding a price level path to the inflation target
- increasing the target inflation rate
- a coordinated, higher fiscal stimulus

The experiments suggest that PLPT and the higher fiscal stimulus would help eliminate the negative output gap and keep inflation closer to target. These options also result in narrower confidence bands—reduced margins of uncertainty—around the key variables.

An increase in the inflation target, from 2 to 2.5 or 3 percent, would also have positive effects—but less striking than a switch from IT to PLPT. The importance of the level of the target becomes clearer in experiments with targets below 2 percent: the model often would not solve for targets of 1 percent. This suggests that pursuit of long-run inflation targets of less than 2 percent might create an intractable deflation problem if it confronts shocks of the kind that hit the international economy in 2008–09.
PLPT requires a more aggressive and prolonged monetary easing than IT, given the same long-run inflation target. PLPT, or a raised inflation target, would both mean higher frequency of ZIF in the forecast period. A move to PLPT, under deflationary conditions, captures the short-run benefits of a simple increase in a pure inflation target, while avoiding the long-run drawbacks—distortions and inequities, and awkward questions about the coherence of such an increase with the goal of price stability.
References


Figure 1
US Inflation
IT (left) and PLPT (right)
Figure 2
US Short-term Interest Rate
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 3
US Output Gap
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 4
US GDP Growth
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 5
US Price Level
IT (left) and PLPT (right)

Lower fiscal stimulus and inflation targets = 2%

98  100  102  104  106  108  110

Lower fiscal stimulus and inflation targets = 3%

98  100  102  104  106  108  110

Higher fiscal stimulus and targets = 2%

98  100  102  104  106  108  110
Figure 6
US Summary Statistics
Current fiscal stimulus (left) and higher fiscal stimulus (right)
Figure 7
Euro Area Inflation
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 8
Euro Area Short-term Interest Rate
IT (left) and PLPT (right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 9
Euro Area Output Gap
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 10
Euro Area GDP Growth
IT (left) and PLPT (right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 11
Euro Area Price Level
IT (left) and PLPT(right)
Figure 12
Euro/USD Exchange Rate
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

0.6 0.7 0.8 0.9 1 1.1

Lower fiscal stimulus and inflation targets = 3%

0.6 0.7 0.8 0.9 1 1.1

Higher fiscal stimulus and targets = 2%

0.6 0.7 0.8 0.9 1 1.1
Figure 13
Euro Area Summary Statistics
Current fiscal stimulus (left) and higher fiscal stimulus (right)
Figure 14
Japan Inflation
IT (left) and PLPT (right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 15
Japan Short-term Interest Rate
IT (left) and PLPT (right)

- Lower fiscal stimulus and inflation targets = 2%
- Lower fiscal stimulus and inflation targets = 3%
- Higher fiscal stimulus and targets = 2%
Figure 16
Japan Output Gap
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 17
Japan GDP Growth
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 18
Japan Price Level
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 19
Yen/USD Exchange Rate
IT (left) and PLPT(right)

Lower fiscal stimulus and inflation targets = 2%

Lower fiscal stimulus and inflation targets = 3%

Higher fiscal stimulus and targets = 2%
Figure 20
Japan Summary Statistics
Current fiscal stimulus (left) and higher fiscal stimulus (right)