The Zero-Interest-Rate Bound and the Role of the Exchange Rate for Monetary Policy in Japan [*],[†]

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Abstract

In this paper we study the role of the exchange rate in conducting monetary policy in an economy with near-zero nominal interest rates as experienced in Japan since the mid-1990s. Our analysis is based on an estimated model of Japan, the United States and the euro area with rational expectations and nominal rigidities. First, we provide a quantitative analysis of the impact of the zero bound on the effectiveness of interest rate policy in Japan in terms of stabilizing output and inflation. Then we evaluate three concrete proposals that focus on depreciation of the currency as a way to ameliorate the effect of the zero bound and evade a potential liquidity trap. Finally, we investigate the international consequences of these proposals.

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1 Introduction

Having achieved consistently low inflation rates monetary policymakers in industrialized countries are now confronted with a new challenge—namely how to prevent or escape deflation. Deflationary episodes present a particular problem for monetary policy because the usefulness of its principal instrument, that is the short-term nominal interest rate, may be limited by the zero lower bound. Nominal interest rates on deposits cannot fall substantially below zero, as long as interest-free currency constitutes an alternative store of value.[1] Thus, with interest rates near zero policymakers will not be able to stave off recessionary shocks by lowering nominal and thereby real interest rates. Even worse, with nominal interest rates constrained at zero deflationary shocks may raise real interest rates and induce or deepen a recession. This challenge for monetary policy has become most apparent in Japan with the advent of recession, zero interest rates and deflation in the second half of the 1990s.[2] In response to this challenge, researchers, practitioners and policymakers alike have presented alternative proposals for avoiding or if necessary escaping deflation.[3]

In this paper, we provide a quantitative evaluation of the importance of the zero-interest-rate bound and the likelihood of a liquidity trap in Japan. Then, we proceed to investigate three recent proposals on how to stimulate and re-inflate the Japanese economy by exploiting the exchange rate channel of monetary policy. These three proposals, which are based on studies by McCallum (2000, 2001), Orphanides and Wieland (2000) and Svensson (2001), all present concrete strategies for evading the liquidity trap via depreciation of the Japanese Yen.

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[1] For a theoretical analysis of this claim the reader is referred to McCallum (2000). Goodfriend (2000), Buiter and Panigirtzoglou (1999) and Buiter (2001) discuss how the zero bound may be circumvented by imposing a tax on currency and reserve holdings.

[2] Ahearne et al. (2002) provide a detailed analysis of the period leading up to deflation in Japan.

[3] For example, Krugman (1998) proposed to commit to a higher inflation target to generate inflationary expectations, while Meltzer (1998, 1999) proposed to expand the money supply and exploit the imperfect substitutability of financial assets to stimulate demand. See also Kimura et al. (2002) in this regard. Posen (1998) suggested a variable inflation target. Clouse et al. (2000) and Johnson et al. (1999) have studied the role of policy options other than traditional open market operations that might help ameliorate the effect of the zero bound. Bernanke (2002) reviews available policy instruments for avoiding and evading deflation including potential depreciation of the currency.

Our quantitative analysis is based on an estimated macroeconomic model with rational expectations and nominal rigidities that covers the three largest economies, the United States, the euro area and Japan. We recognize the zero-interest-rate bound explicitly in the analysis and use numerical methods for solving nonlinear rational expectations models.[4] First, we consider a benchmark scenario of a severe recession and deflation. Then, we assess the importance of the zero bound by computing the stationary distributions of key macroeconomic variables under alternative policy regimes.[5] Finally, we proceed to investigate the role of the exchange rate for monetary policy as proposed by Orphanides and Wieland (2000), McCallum (2000, 2001) and Svensson (2001).

Orphanides and Wieland (2000) (OW) emphasize that base money may have some direct effect on aggregate demand and inflation even when the nominal interest rate is constrained at zero. In particular they focus on the portfolio-balance effect, which implies that the exchange rate will respond to changes in the relative domestic and foreign money supplies even when interest rates remain constant at zero. As a result, persistent deviations from uncovered interest parity are possible. Of course, this effect is likely small enough to be irrelevant under normal circumstances, i.e. when nominal interest rates are greater than zero, and estimated rather imprecisely when data from such circumstances is used. OW discuss the policy stance in terms of base money and derive the optimal policy in the presence of a small and highly uncertain portfolio-balance effect. They show that the optimal policy under uncertainty implies a drastic expansion of base money with a resulting depreciation of the currency whenever the zero bound is effective.

McCallum (2000, 2001) (MC) also advocates a depreciation of the currency to evade the liquidity trap. In fact, he recommends switching to a policy rule that responds to output

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[4] The solution algorithm is discussed further in the appendix to this paper.

[5] Our approach builds on several earlier quantitative studies. Fuhrer and Madigan (1997) first explored the response of the U.S. economy to a negative demand shock in the presence of the zero bound by deterministic simulations. Similarly, Laxton and Prasad (1997) studied the effect of an appreciation. Orphanides and Wieland (1998) provided a first study of the effect of the zero bound on the distributions of output and inflation in the U.S. economy. Building on this analysis Reifschneider and Williams (2000) explored the consequences of the zero bound in the Federal Reserve Board's FRB/U.S. model and Hunt and Laxton (2001) in the Japan block of the International Monetary Fund's MULTIMOD model.

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and inflation deviations similar to a Taylor-style interest rate rule, but instead considers the change in the nominal exchange rate as the relevant policy instrument.

Svensson (2001) (SV) recommends a devaluation and temporary exchange-rate peg in combination with a price-level target path that implies a positive rate of inflation. Its goal would be to raise inflationary expectations and jump-start the economy. SV emphasizes that the existence of a portfolio-balance effect is not a necessary ingredient for such a strategy. By standing ready to sell Yen and buy foreign exchange at the pegged exchange rate, the central bank will be able to enforce the devaluation. Once the peg is credible, exchange rate expectations will adjust accordingly and the nominal interest rate will rise to the level required by uncovered interest parity.

These authors presented their proposals in stylized, small open economy models. In this paper, we evaluate these proposals in an estimated macroeconomic model, which also takes into account the international repercussions that result when a large open economy such as Japan adopts a strategy based on drastic depreciation of its currency. In addition, we improve upon the following shortcomings. While OW used a reduced-form relationship between real exchange rate, interest rates and base money, we treat uncovered interest parity and potential deviations from it explicitly in the model. While MC compares interest rate and exchange rate rules within linear models we account for the nonlinearity due to the zero bound when switching from one to the other and retain uncovered interest parity in both cases. Finally, we investigate the consequences of all three proposed strategies for the United States and the euro area.

Our findings indicate that the zero bound induces noticeable losses in terms of output and inflation stabilization in Japan, if the equilibrium nominal interest rate, that is the sum of the policymaker's inflation target and the equilibrium real interest rate, is 2% or lower. We show that aggressive liquidity expansions when interest rates are constrained at zero, may largely offset the effect of the zero bound. Furthermore, we illustrate the potential of the three proposed strategies to evade a liquity trap during a severe recession and deflation. Finally, we show that the proposed strategies have non-negligible beggar-

thy-neighbor effects and may require the tacit approval of the main trading partners for their success.

The paper proceeds as follows. Section 2 reviews the estimated three-country macro model. In section 3 we discuss the consequences of the zero-interest-rate bound, first in case of a severe recession and deflation scenario, and then on average given the distribution of historical shocks as identified by the estimation of our model. In section 4 we explore the performance of the three different proposals for avoiding or escaping the liquidity trap by means of exchange rate depreciation. Section 5 concludes.

2   The Model

The macroeconomic model used in this study is taken from Coenen and Wieland (2002). Monetary policy is neutral in the long-run, because expectations in financial markets, goods markets and labor markets are formed in a rational, model-consistent manner. However, short-run real effects arise due to the presence of nominal rigidities in the form of staggered contracts.[6] The model comprises the three largest world economies, the United States, the euro area and Japan. Model parameters are estimated using quarterly data from 1974 to 1999 and the model fits empirical inflation and output dynamics in these three economies surprisingly well. In Coenen and Wieland (2002) we have investigated the three staggered contracts specifications that have been most popular in the recent literature, the nominal wage contracting models proposed by Calvo (1983) and Taylor (1980, 1993a) with random-duration and fixed-duration contracts respectively, as well as the relative real-wage contracting model proposed by Buiter and Jewitt (1981) and estimated by Fuhrer and Moore (1995a). The Taylor specification obtained the best empirical fit for the euro area and Japan, while the Fuhrer-Moore specification performed better for the United States.[7]

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[6]With this approach we follow Taylor (1993a) and Fuhrer and Moore (1995a, 1995b). Also, our model exhibits many similarities to the calibrated model considered by Svensson (2001).

[7]Coenen and Wieland (2002) also show that Calvo-style contracts do not fit observed inflation dynamics under the assumption of rational expectations.

Table 1 provides an overview of the model. Due to the existence of staggered contracts, the aggregate price level p_t corresponds to the weighted average of wages on overlapping contracts x_t (equation (M-1) in **Table 1**). The weights f_i ($i = 1, \ldots, \eta(x)$) on contract wages from different periods are assumed to be non-negative, non-increasing and time-invariant and need to sum to one. $\eta(x)$ corresponds to the maximum contract length. Workers negotiate long-term contracts and compare the contract wage to past contracts that are still in effect and future contracts that will be negotiated over the life of this contract. As indicated by equation (M-2a) Taylor's nominal wage contracting specification implies that the contract wage x_t is negotiated with reference to the price level that is expected to prevail over the life of the contract as well as the expected deviations of output from potential, q_t. The sensitivity of contract wages to excess demand is measured by γ. The contract wage shock $\epsilon_{x,t}$, which is assumed to be serially uncorrelated with zero mean and unit variance, is scaled by the parameter σ_{ϵ_x}.

The distinction between Taylor-style contracts and Fuhrer-Moore's relative real wage contracts concerns the definition of the wage indices that form the basis of the intertemporal comparison underlying the determination of the current nominal contract wage. The Fuhrer-Moore specification assumes that workers negotiating their nominal wage compare the implied real wage with the real wages on overlapping contracts in the recent past and near future. As shown in equation (M-2b) in **Table 1** the expected real wage under contracts signed in the current period is set with reference to the average real contract wage index expected to prevail over the current and the next following quarters, where $v_t = \sum_{i=0}^{\eta(x)} f_i \left(x_{t-i} - p_{t-i} \right)$ refers to the average of real contract wages that are effective at time t.

Output dynamics are described by the open-economy aggregate demand equation (M-3), which relates the output gap to several lags of itself, to the lagged ex-ante long-term real interest rate r_{t-1} and to the trade-weighted real exchange rate $e_t{}^w$. The demand shock $\epsilon_{d,t}$ in equation (M-3) is assumed to be serially uncorrelated with mean zero and unit variance

Table 1: Model Equations

Price Level	$p_t = \sum_{i=0}^{\eta(x)} f_i\, x_{t-i},$	(M-1)
	where $f_i > 0, \quad f_i \geq f_{i+1}$ and $\sum_{i=0}^{\eta(x)} f_i = 1$	
Contract Wage: Taylor	$x_t = E_t \left[\sum_{i=0}^{\eta(x)} f_i\, p_{t+i} + \gamma \sum_{i=0}^{\eta(x)} f_i\, q_{t+i} \right] + \sigma_{\epsilon_x}\, \epsilon_{x,t},$	(M-2a)
	where $q_t = y_t - y_t^*$	
Contract Wage: Fuhrer-Moore	$x_t - p_t = E_t \left[\sum_{i=0}^{\eta(x)} f_i\, v_{t+i} + \gamma \sum_{i=0}^{\eta(x)} f_i\, q_{t+i} \right] + \sigma_{\epsilon_x}\, \epsilon_{x,t},$	(M-2b)
	where $v_t = \sum_{i=0}^{\eta(x)} f_i\, (x_{t-i} - p_{t-i})$	
Aggregate Demand	$q_t = \delta(L)\, q_{t-1} + \phi\, (r_{t-1} - r^*) + \psi\, e_t^w + \sigma_{\epsilon_d}\, \epsilon_{d,t},$	(M-3)
	where $\delta(L) = \sum_{j=1}^{\eta(q)} \delta_j\, L^{j-1}$	
Real Interest Rate	$r_t = l_t - 4\, E_t \left[\frac{1}{\eta(l)}\, (p_{t+\eta(l)} - p_t) \right]$	(M-4)
Term Structure	$l_t = E_t \left[\frac{1}{\eta(l)} \sum_{j=1}^{\eta(l)} i_{t+j-1} \right]$	(M-5)
Monetary Policy Rule	$i_t = r^* + \pi_t^{(4)} + 0.5\, (\pi_t^{(4)} - \pi^*) + 0.5\, q_t,$	(M-6)
	where $\pi_t^{(4)} = p_t - p_{t-4}$	
Trade-Weighted Real Exchange Rate	$e_t^{w,(i)} = w_{(i,j)}\, e_t^{(i,j)} + w_{(i,k)}\, e_t^{(i,k)}$	(M-7)
Uncovered Interest Parity	$e_t^{(i,j)} = E_t \left[e_{t+1}^{(i,j)} \right] + 0.25 \left(i_t^{(j)} - 4\, E_t \left[p_{t+1}^{(j)} - p_t^{(j)} \right] \right)$	
	$\qquad\qquad - 0.25 \left(i_t^{(i)} - 4\, E_t \left[p_{t+1}^{(i)} - p_t^{(i)} \right] \right)$	(M-8)

Notes: p: aggregate price level; x: nominal contract wage; q: output gap; y: actual output; y^*: potential output ϵ_x: contract wage shock; v: real contract wage index; r: ex-ante long-term real interest rate; r^*: equilibrium real interest rate; e^w: trade-weighted real exchange rate; ϵ_d: aggregate demand shock; l: long-term nominal interest rate; i: short-term nominal interest rate; $\pi^{(4)}$: annual inflation; π^*: inflation target; e: bilateral real exchange rate.

and is scaled with the parameter σ_{ϵ_d}.[8]

The long-term real interest rate is related to the long-term nominal rate and inflation

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[8]A possible rationale for including lags of output is to account for habit persistence in consumption as well as adjustment costs and accelerator effects in investment. We use the lagged instead of the contemporaneous value of the real interest rate to allow for a transmission lag of monetary policy. The trade-weighted real exchange rate enters the aggregate demand equation because it influences net exports.

expectations by the Fisher equation (M-4). As to the term structure that is defined in (M-5), we rely on the accumulated forecasts of the short rate over $\eta(l)$ quarters which, under the expectations hypothesis, will coincide with the long rate forecast for this horizon. The term premium is assumed to be constant and equal to zero.

The short-term nominal interest rate is usually considered the primary policy instrument of the central bank. As a benchmark for analysis we assume that nominal interest rates in Japan, the United States and the euro area are set according to Taylor's (1993b) rule, (equation (M-6)), which implies a policy response to deviations of inflation from the policymaker's inflation target π^* and to deviations of output from potential. While such a rule is effective in stabilizing output and inflation in a variety of economic models (cf. Taylor (1999)) under normal circumstances, it needs to be augmented with a prescription for monetary policy in the presence of the zero bound. In the following, we will show that such a prescription may focus on the role of base money and of the nominal exchange rate as instruments of monetary policy. An alternative benchmark that could be used instead of Taylor's original rule are the estimated variants for Japan, the United States and the euro area that were reported in Coenen and Wieland (2002). In fact, the historical covariance matrix of demand and contract wage shocks that we will use for stochastic simulations is based on the estimated rules. Thus, in the final section of the paper we report a sensitivity study that makes use of the estimated Taylor-style interest rate rules.

The trade-weighted real exchange rate is defined by equation (M-7). The superscripts (i, j, k) are intended to refer to the economies within the model without being explicit about the respective economy concerned. Thus, $e^{(i,j)}$ represents the bilateral real exchange rate between countries i and j, $e^{(i,k)}$ the bilateral real exchange rate between countries i and k, and consequently equation (M-7) defines the trade-weighted real exchange rate for country i. The bilateral trade-weights are denoted by $(w_{(i,j)}, w_{(i,k)}, \ldots)$. Finally, equation (M-8) constitutes the uncovered interest parity condition with respect to the bilateral exchange rate between countries i and j in real terms. It implies that the difference between today's real exchange rate and the expectation of next quarter's real exchange rate is set equal to

the expected real interest rate differential between countries j and i.

Table 2: Parameter Estimates: Staggered Contracts and Aggregate Demand

Taylor Contracts	f_0	f_1	f_2	f_3	γ	σ_{ϵ_x}
Japan [a,b]	0.3301 (0.0303)	0.2393 (0.0062)	0.2393	0.1912	0.0185 (0.0057)	0.0068 (0.0006)
Euro Area [a,c]	0.2846 (0.0129)	0.2828 (0.0111)	0.2443 (0.0131)	0.1883	0.0158 (0.0059)	0.0042 (0.0003)
Fuhrer-Moore Contracts	f_0	f_1	f_2	f_3	γ	σ_{ϵ_x}
United States [a,b]	0.6788 (0.0458)	0.2103 (0.0220)	0.0676 (0.0207)	0.0432	0.0014 (0.0008)	0.0004 (0.0001)
Aggregate Demand	δ_1	δ_2	δ_3	ϕ	ψ	σ_{ϵ_d}
Japan [d,b]	0.9071 (0.0124)			-0.0781 (0.0272)	0.0122 (0.0053)	0.0068
Euro Area [d,c,e]	1.0521 (0.0381)	0.0779 (0.0417)	-0.1558 (0.0342)	-0.0787 (0.0335)	0.0188 (0.0047)	0.0054
United States [d,b]	1.2184 (0.0320)	-0.1381 (0.0672)	-0.2116 (0.0532)	-0.0867 (0.0193)	0.0188 (0.0061)	0.0071

Notes: [a] Simulation-based indirect estimates using a VAR(3) model of quarterly inflation and the output gap as auxiliary model. Standard errors in parentheses. [b] Output gap measure constructed using OECD data. [c] Inflation in deviation from linear trend and and output in deviation from log-linear trend. [d] GMM estimates using a constant, lagged values (up to order three) of the output gap, the quarterly inflation rate, the short-term nominal interest rate and the real effective exchange rate as instruments. In addition, current and lagged values (up to order two) of the foreign inflation and short-term nominal interest rates have been included in the instrument set. Robust standard errors in parentheses. [e] For the euro area, the German long-term real interest rate has been used in the estimation. Similarly, German inflation and short-term nominal interest rates have been used as instruments.

Thus, the model takes into account two important international linkages, namely, the uncovered interest parity condition and the effect of the real exchange rate on aggregate demand. However, it does not include a direct effect of foreign demand for exports in the output gap equation, nor does it allow for a direct effect of the exchange rate on consumer price inflation via import prices. We shortly discuss the sensitivity of our findings in the

final section of the paper but have to leave an extension of the empirical model for future research.

In the deterministic steady state of this model the output gap is zero and the long-term real interest rate equals its equilibrium value r^*. The equilibrium value of the real exchange rate is normalized to zero. Since the overlapping contracts specifications of the wage-price block do not impose any restriction on the steady-state inflation rate, it is determined by monetary policy alone and equals the target rate π^* in the policy rule.

Parameter estimates for the preferred staggered contracts specifications and the aggregate demand equations are presented in **Table 2**. For a more detailed discussion of these results we refer the reader to Coenen and Wieland (2002). The model fits historical output and inflation dynamics in the United States, the euro area and Japan quite well as indicated by the absence of significant serial correlation in the historical shocks (see Figure 1 in Coenen and Wieland (2002)) and the finding that the autocorrelation functions of output and inflation implied by the three-country model are not significantly different from those implied by bivariate unconstrained VAR models (see Figure 2 in Coenen and Wieland (2002)).

3 Recession, Deflation and the Zero-Interest-Rate Bound

3.1 The Zero-Interest-Rate Bound

Under normal circumstances, when the short-term nominal interest rate is well above zero, the central bank can ease monetary policy by expanding the supply of the monetary base and bringing down the short-term rate of interest. Since prices of goods and services adjust more slowly than those on financial instruments, such a money injection reduces real interest rates and provides a stimulus to the economy. Whenever monetary policy is expressed in form of a Taylor-style interest rate rule such as equation (M-6), it is implicitly assumed that the central bank injects liquidity so as to achieve the rate that is prescribed by the interest rate rule. Thus, the appropriate quantity of base money can be determined recursively from the relevant base money demand equation. Of course, at the zero bound further injections

of liquidity have no additional effect on the nominal interest rate, and a negative interest rate prescribed by the interest rate rule cannot be implemented.

Orphanides and Wieland (2000) illustrate this point using recent data for Japan. They use the concept of the "Marshallian K", which corresponds to the ratio of the monetary base, that is the sum of domestic credit and foreign exchange reserves, $M_t = DC_t + FXR_t$, and nominal GDP, P_tY_t. Thus, $K_t = M_t/P_tY_t$, or in logs, $k_t = m_t - p_t - y_t$. The relationship between the short-term nominal interest rate and the Marshallian k can then be described by an inverted base money demand equation:[9]

$$ i_t \;\; = \;\; [\, i^* - \theta(k_t - k^*) + \epsilon_{k,t}\,]_+, \tag{1} $$

where i^* and k^* denote the corresponding equilibrium levels that would obtain if the economy were to settle down to the policymaker's inflation target π^*. $\epsilon_{k,t}$, which summarizes other influences to the demand for money, in addition to changes in interest rates or income, is set to zero in the remainder of the analysis.[10]

The function $[\cdot]_+$ truncates the quantity inside the brackets at zero and implements the zero bound.[11] As shown by OW, Japanese data from 1970 to 1995 suggests that increasing the Marshallian K by one percentage point would be associated with a decline in the short-term nominal rate of interest of about four percentage points. However, increases in the Marshallian K in the second half of the 1990s, when the nominal interest rate was close to zero, had no further effect on the rate of interest just as indicated by equation (1). We do not estimate θ but rather follow OW in setting $\theta = 1$, implicitly normalizing the definition of k. This choice allows a simple translation of policies when stated in terms of interest rates and in terms of the Marshallian k. With this normalization, raising the nominal interest rate by one percentage point is equivalent to lowering k by one percentage point under

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[9]An implicit restriction of such a specification is that of a unit income elasticity on money demand.

[10]This term includes short-run shocks to money demand but also reflects changes in the transactions or payments technology or in preferences that may have long-lasting and even permanent effects on the level of the Marshallian k consistent with the steady state inflation rate π^*. Regardless of its determinants, since the central bank controls k_t and can easily observe the nominal interest rate i_t, $\epsilon_{k,t}$ is essentially observable to the central bank. That is, fixing k_t, even a slight movement in the nominal interest rate can be immediately recognized as a change in $\epsilon_{k,t}$ and, if desired, immediately counteracted.

[11]McCallum (2000) analyses how this bound is related to preferences and transactions technology.

normal circumstances. Alternatively—and this is the convention used by OW—whenever we refer to changing k by one percentage point, we imply a change in k as much as would be necessary to effect a change in the nominal interest rate by one percentage point under normal circumstances.

As discussed above, one implication of the zero bound will be a reduction in the effectiveness of monetary policy. A further important implication is that the model with the zero bound, as written so far in **Table 1**, will be globally unstable. Once shocks to aggregate demand and/or supply push the economy into a sufficiently deep deflation, a zero interest rate policy may not be able to return the economy to the original equilibrium. With a shock large enough to sustain deflationary expecations and to keep the real interest rate above its equilibrium level, aggregate demand is suppressed further sending the economy into a deflationary spiral. Orphanides and Wieland (1998) resolved this global instability problem by assuming that at some point, in a depression-like situation, fiscal policy would turn sufficiently expansionary to rescue the economy from a deflationary spiral. Orphanides and Wieland (2000) instead concentrated on the role of other channels of the monetary transmission mechanism that may continue to operate even when the interest rate channel is ineffective. An example of such a channel that we will include in this paper, is the portfolio-balance effect.

3.2 A Severe Recession and Deflation Scenario

To illustrate the potentially dramatic consequences of the zero-interest-rate bound and deflation we simulate an extended period of recessionary and deflationary shocks in the Japan block of our three-country model. Initial conditions are set to steady state with an inflation target of 1%, a real equilibrium rate of 1%, and thus an equilibrium nominal interest rate of 2%. Then the Japanese economy is hit by a sequence of negative demand and contract price shocks for a total period of 5 years. The magnitude of the demand and contract price shocks is set equal to 1.5 and -1 percentage points respectively.

Figure 1: The Effect of the Zero Bound in a Severe Recession and Deflation
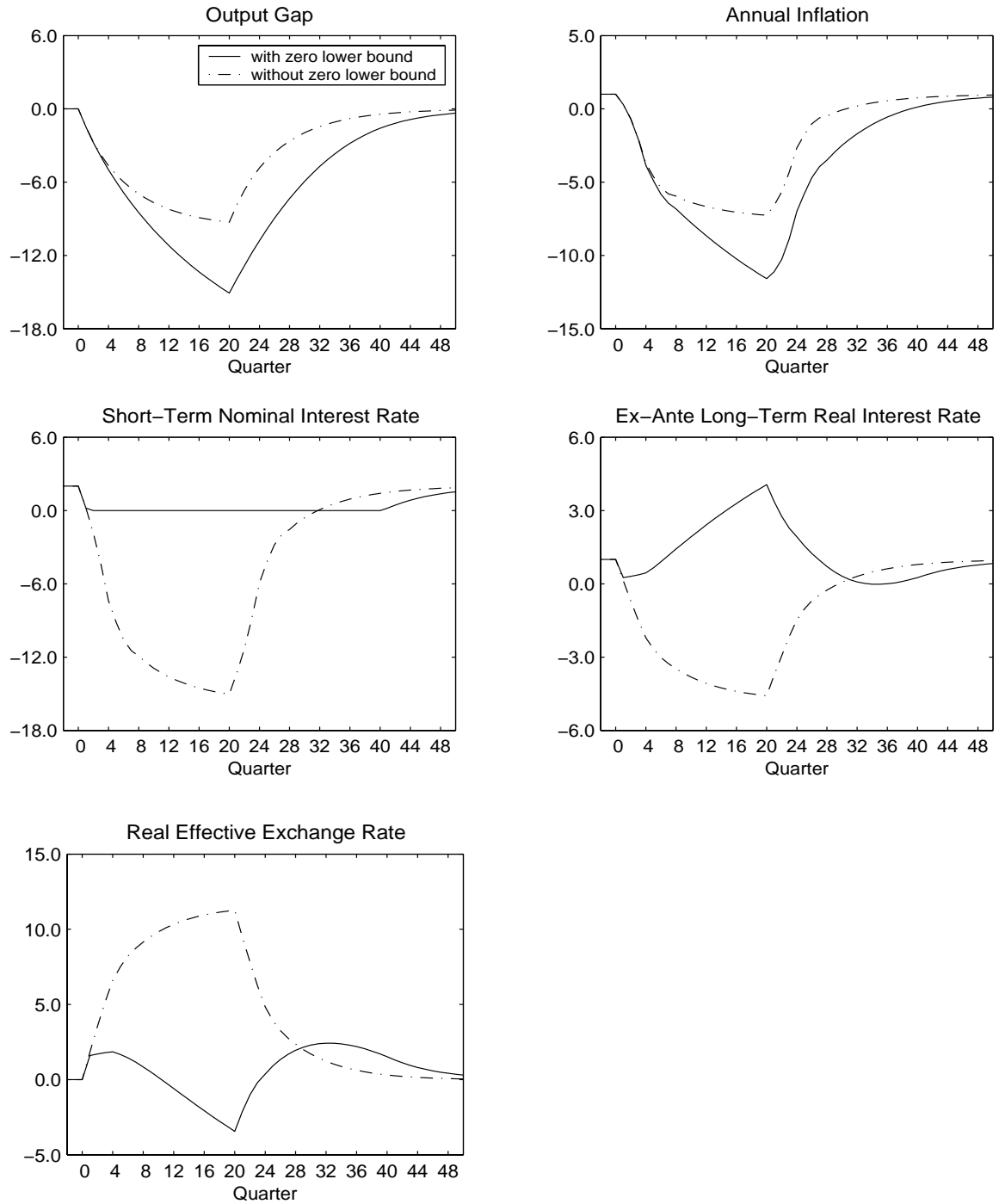
Figure 1 compares the outcome of this sequence of contractionary and deflationary shocks when the zero bound is imposed explicitly (solid line) to the case when the zero bound is disregarded and the nominal interest rate is allowed to go negative (dashed-dotted line). As indicated by the dashed-dotted line, the central bank would like to respond to the onset of recession and disinflation by drastically lowering nominal interest rates. If this were possible, that is, if interest rates were not constrained at zero, the long-term real interest rate would decline by about 6% and the central bank would be able to contain the output gap and deflation both around -8%. The reduction in nominal interest rates would be accompanied by a 12% real depreciation of the currency.

However, once the zero lower bound is enforced, the recessionary and deflationary shocks are shown to throw the Japanese economy into a liquidity trap. Nominal interest rates are constrained at zero for almost a decade. Deflation leads to increases in the long-term real interest rate up to 4%. As a result, Japan experiences a double-digit recession that lasts substantially longer than in the absence of the zero bound. Rather than depreciating, the currency temporarily appreciates in real terms. The economy only returns slowly to steady state once the shocks subside.

Of course, the likelihood of such a sequence of severe shocks is extremely small. We have chosen this scenario only to illustrate the potential impact of the zero bound as a constraint on Japanese monetary policy. It is not meant to match the length and extent of deflation and recession observed in Japan. While Japan has now experienced near-zero short-term nominal interest rates and deflation for almost eight years, the inflation rate measured in terms of the CPI or the GDP Deflator has not fallen below -2 percent. To assess the likelihood of a severe recession and deflation scenario such as the one discussed above, we now compute the distributions of output and inflation in the presence of the zero bound by means of stochastic simulations.

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Figure 2: Frequency of Bind of the Zero Lower Bound on Nominal Interest Rates
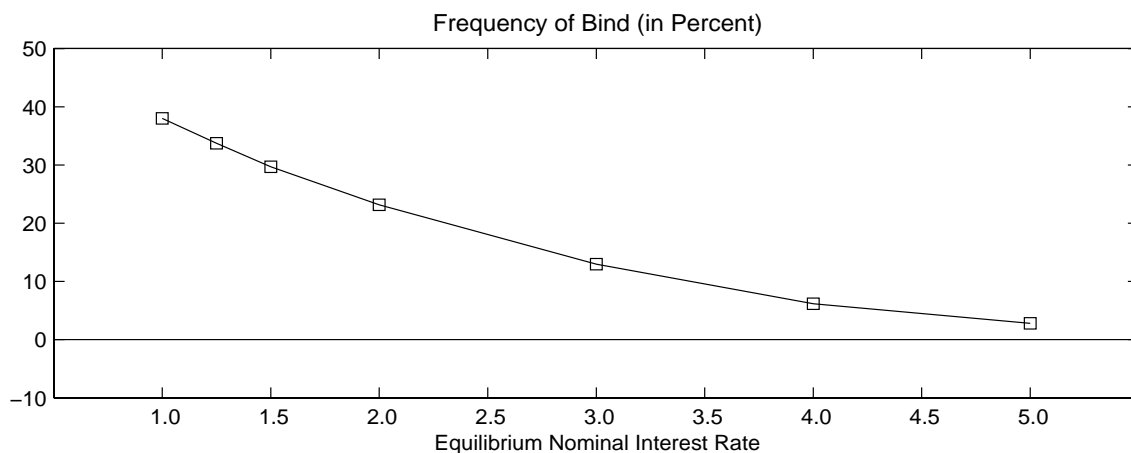
3.3 The Importance of the Zero Bound in Japan

The likelihood that nominal interest rates are constrained at zero depends on a number of key factors, in particular the size of the shocks to the economy, the propagation of those shocks throughout the economy (i.e. the degree of persistence exhibited by important endogenous variables), the level of the equilibrium nominal interest rate (i.e. the sum of the policymaker's inflation target and the equilibrium real interest rate) and the choice of the policy rule. In the following we present results from stochastic simulations of our model with the shocks drawn from the covariance matrix of historical shocks.[12] In these simulations we consider alternative values of the equilibrium nominal interest rate, $i^* = r^* + \pi^*$, varying between 1% and 5%. Taylor's rule is maintained throughout these simulations except if the nominal interest rate is constrained at zero.

**Figure 2** shows the frequency of zero nominal interest rates as a function of the level of the equilibrium rate i^*. With an equilibrium nominal rate of 3%, the zero bound represents a constraint for monetary policy for about 10% of the time. It becomes substantially more

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[12]The derivation of this covariance matrix and the nature of the stochastic simulations are discussed in more detail in the appendix.

important for lower equilibrium nominal rates and occurs almost 40% of the time with a rate of 1%, which corresponds, for example, to an inflation target of 0% and an equilibrium real rate of 1%.

Figure 3: Distortion of Stationary Distributions of Output and Annual Inflation
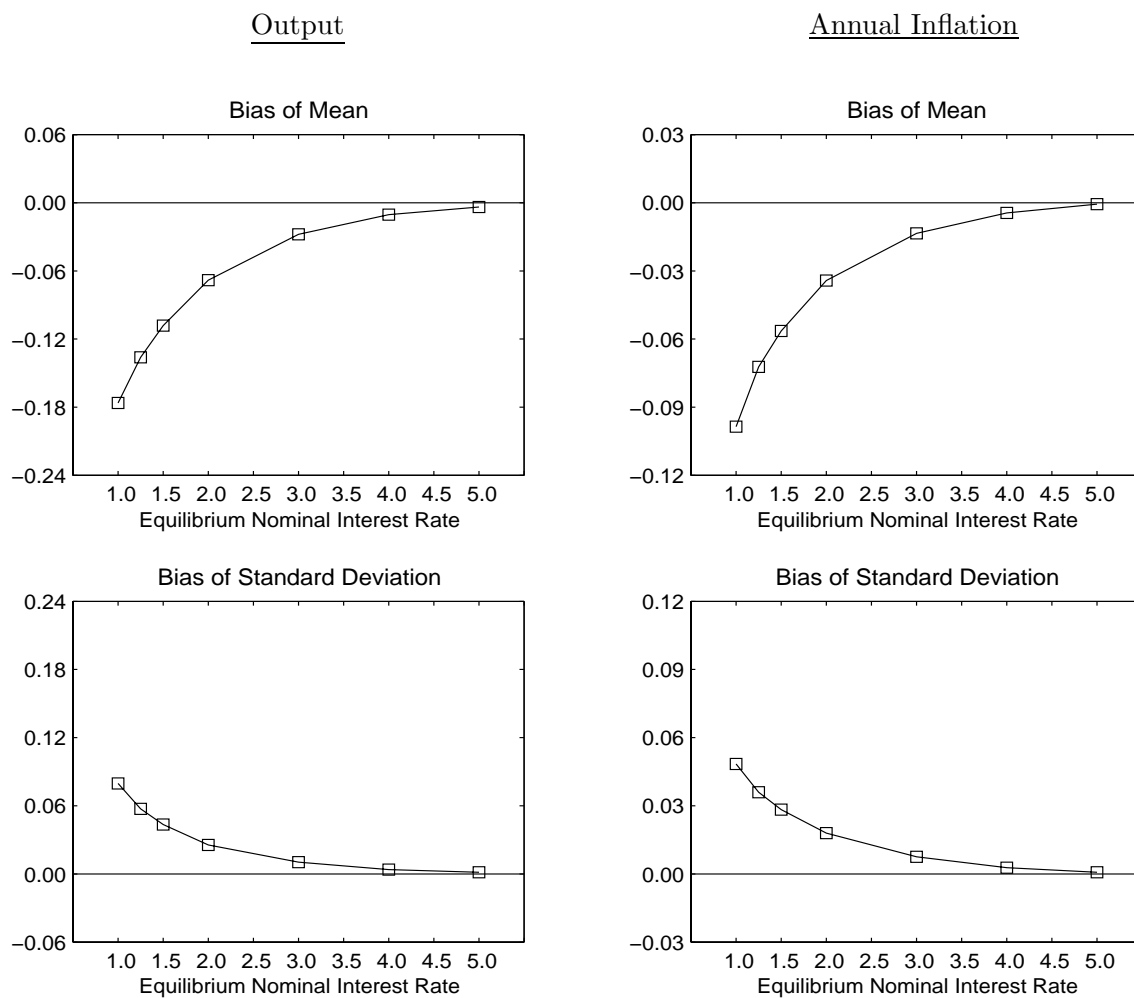

Whenever the zero bound is binding, nominal interest rates will be higher than prescribed by Taylor's rule. Similarly, the real interest rate will be higher and stabilization of output and inflation will be less effective. Since there exists no similar constraint on the upside an asymmetry will arise. The consequences of this asymmetry are apparent from

Figure 3. As shown in the top left and top right panels, on average output will be somewhat below potential and inflation will be somewhat below target. Both panels display this bias in the mean output gap and mean inflation rate as a function of the equilibrium nominal interest rate. With an equilibrium nominal rate of 1% the downward bias in the means is about 0.2% and 0.1% respectively. The lower-left and lower-right panels in **Figure 3** indicate the upward bias in the standard deviation of output and inflation as a function of the equilibrium nominal interest rate. For example, for an i^* of 1% the standard deviation of the output gap increases from 1.51 to 1.59 percent, while the standard deviation of inflation increases from 1.65 to 1.70 percent.

Figure 4: Stationary Distributions of the Output Gap and the Inflation Gap
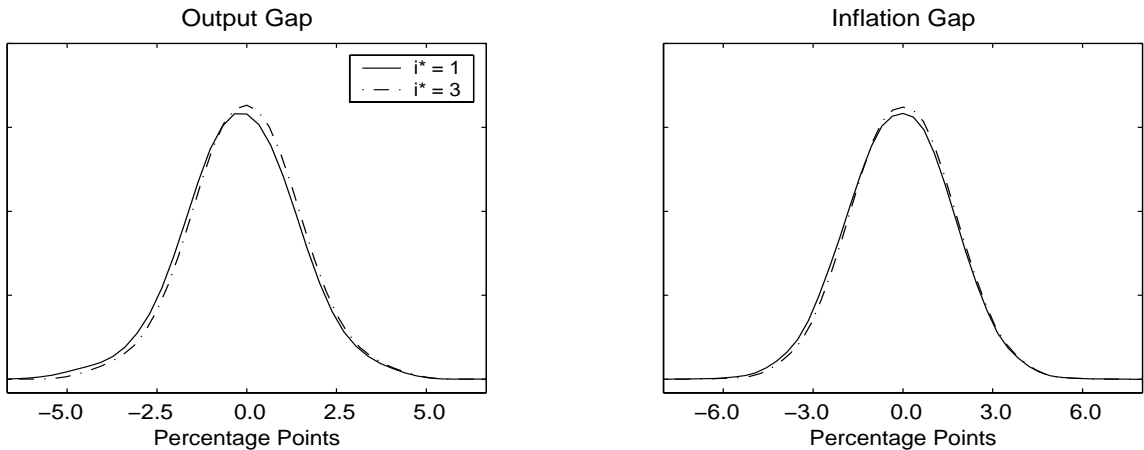
Figure 4 illustrates how the stationary distributions of the output and inflation gaps change with increased frequency of zero interest rates. Each of the two panels shows two distributions, generated with an equilibrium nominal interest rate of 3% and 1% respectively. In the latter case, the distribution becomes substantially more asymmetric. The pronounced left tails of the distributions indicate an increased incidence of deep recessions and deflationary periods. For example, for an i^* of 1% the probability of a recession of -1.5 times the standard deviation of the output gap which would prevail if the zero bound were

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absent is 8.8 percent compared to 6.7 percent if the interest rate were unconstrained.

As we discussed in the preceding subsection these deep recessions carry with them the potential of a deflationary spiral, where the zero bound keeps the real interest rate sufficiently high so that output stays below potential and re-enforces further deflation. This points to a limitation inherent in linear models which rely on the real interest rate as the sole channel for monetary policy. But it also brings into focus the extreme limiting argument regarding the ineffectiveness of monetary policy in a liquidity trap. Orphanides and Wieland (1998), which conducted such a stochastic simulation analysis for a model of the U.S. economy, ensured global stability of the model by specifying a nonlinear fiscal expansion rule that would boost aggregate demand in a severe deflation until deflation returns to near zero levels. In this paper, we will instead follow Orphanides and Wieland (2000) and introduce a direct effect of base money, the portfolio-balance effect, that will remain active even when nominal interest rates are constrained at zero. This effect will ensure global stability under all circumstances. With regard to the preceding simulation results, we note that deflationary spirals did not yet arise for the variability of shocks and the level of the nominal equilibrium rate considered so far.

As discussed above, the distortion of output and inflation distributions is driven by a distortion of the real interest rate. The left-hand panels of **Figure 5** report the upward bias in the mean real rate and the downward bias in the variability of the real rate depending on the level of the nominal equilibrium rate of interest. The downward bias in the variability of the real rate accounts for the reduced effectiveness of stabilization policy. What is perhaps more surprising, is the appreciation bias in the mean of the real exchange rate and the downward bias in its variability as shown in the right-hand panels of **Figure 5**. This reduction in the stabilizing function of the real exchange rate is consistent with what we observed in the recession and deflation scenario discussed in the preceding subsection.

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Figure 5: Distortion of Stationary Distributions of the Determinants of Output

Ex-Ante Long-Term Real Interest Rate　　　　Real Effective Exchange Rate
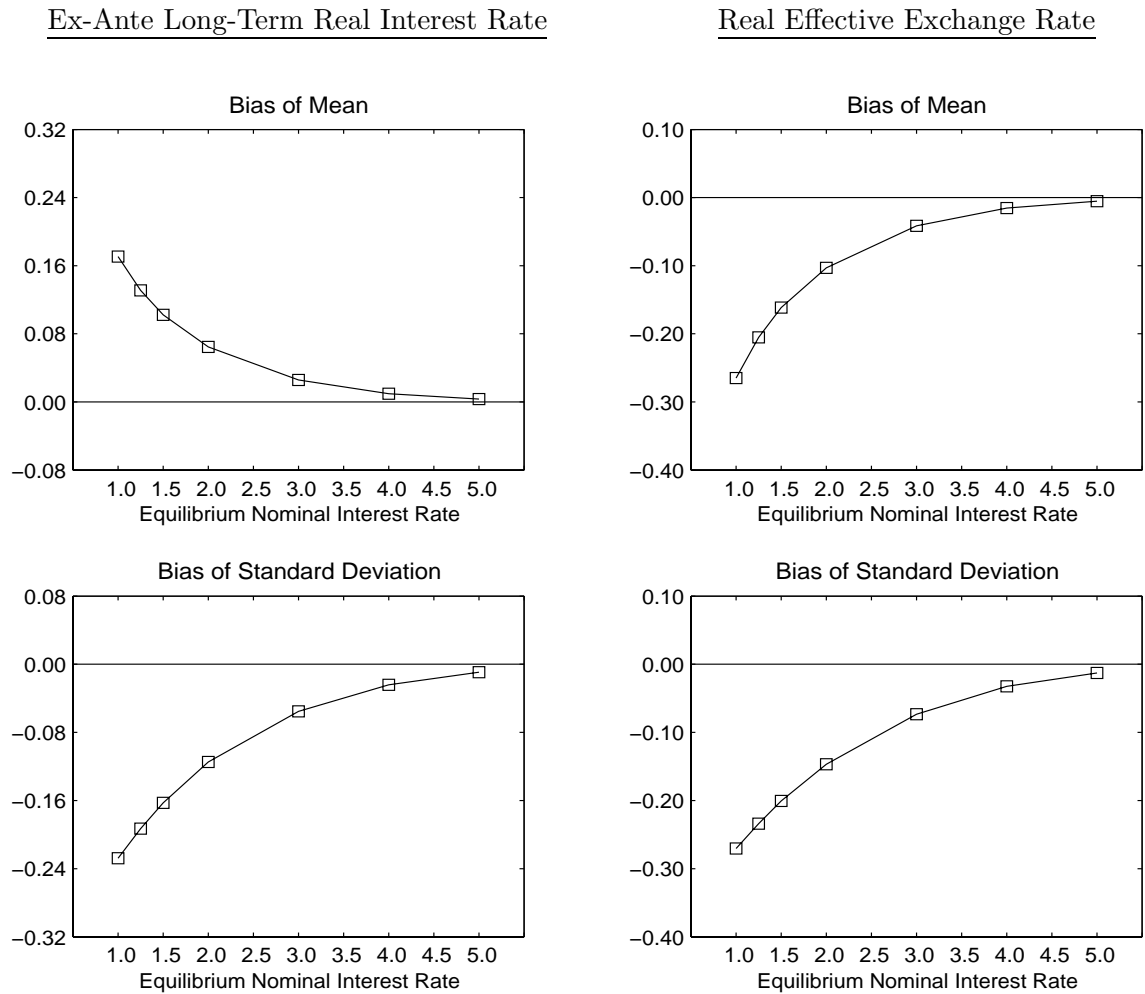
4　Exploiting the Exchange Rate Channel of Monetary Policy to Evade the Liquidity Trap

4.1　A Proposal by Orphanides and Wieland (2000)

Orphanides and Wieland (2000) (OW) recommend expanding the monetary base aggressively during episodes of zero interest rates to exploit direct quantity effects such as a portfolio-balance effect. The objective of this proposal is to stimulate aggregate demand and fuel inflation by a depreciation of the currency that can be achieved by simply buying

a large enough quantity of foreign exchange reserves with domestic currency. OW indicate a concrete strategy for implementing this proposal within a small calibrated and largely backward-looking model.[13] Following OW we use equation (1) to express the policy setting implied by Taylor's interest rate rule (equation (M-6)) in terms of the monetary base:

$$k_t - k^* = -\left[\kappa_\pi \left(\pi_t^{(4)} - \pi^* \right) + \kappa_q \, q_t \right], \tag{2}$$

where the response coefficients (κ_π, κ_q) correspond to Taylor's coefficients of 1.5 and 0.5 given the normalization of $\theta = 1$ used by OW and discussed in section 3.1.

Next, we allow the relative quantities of base money at home and abroad to have a direct effect on the exchange rate in addition to the effect of interest rate differentials. Due to this so-called portfolio-balance effect, the nominal exchange rate s_t need not satisfy uncovered interest parity (UIP) exactly:[14]

$$s_t^{(i,j)} = \mathrm{E}_t \left[s_{t+1}^{(i,j)} \right] + 0.25 \left(i_t^{(j)} - i_t^{(i)} \right) + \lambda_b \left(b_t^{(i)} - b_t^{(j)} - s_t^{(i,j)} \right), \tag{3}$$

Here the superscripts (i, j) refer to the two respective countries. b_t represents the log of government debt including base money in the two countries. Rewriting UIP in real terms and substituting in the monetary base as the relevant component of b_t for our purposes, we obtain an extended version of the expected real exchange rate differential originally defined by equation (M-8) in **Table 1**:

$$
\begin{aligned}
e_t^{(i,j)} = \; & \mathrm{E}_t \left[e_{t+1}^{(i,j)} \right] + 0.25 \left(i_t^{(j)} - 4 \, \mathrm{E}_t \left[p_{t+1}^{(j)} - p_t^{(j)} \right] \right) \\
& - 0.25 \left(i_t^{(i)} - 4 \, \mathrm{E}_t \left[p_{t+1}^{(i)} - p_t^{(i)} \right] \right) \\
& + \lambda_k \left(k_t^{(i)} - k_t^{(j)} - e_t^{(i,j)} \right).
\end{aligned}
\tag{4}
$$

Given $\lambda_k > 0$, the monetary base still has an effect on aggregate demand via the real exchange rate even when the interest rate channel is turned off because of the zero bound.

---

[13]As a short-cut they specify a reduced-form relationship between the real exchange rate, real interest rate differentials and the differential Marshallian k instead of the uncovered interest parity condition.

[14]This specification from Dornbusch (1980, 1987) is also considered by McCallum (2000) and Svensson (2001).

Figure 6: Liquidity Expansion and Depreciation in a Severe Recession and Deflation
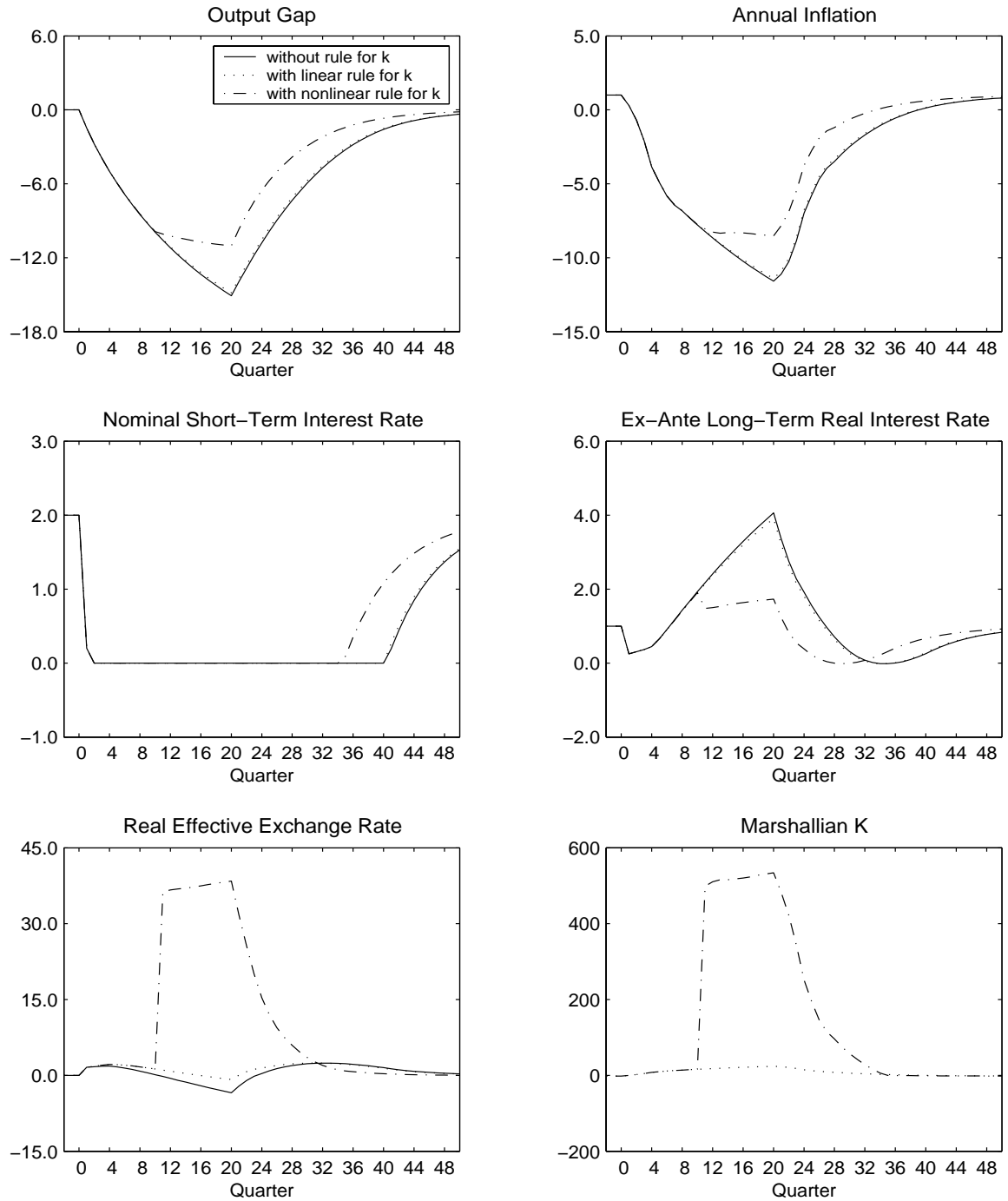
Thus, a policy rule defined in terms of the monetary base, such as (2), may also be carried out when nominal interest rates are constrained at zero. Increased liquidity injection due to the recessionary and deflationary impact of the zero bound will tend to depreciate the currency and help stabilize the economy.

However, the portfolio-balance effect is at best very small. Empirical studies by Frankel (1984), Dooley and Isard (1983) and others failed to find empirical support. Of course, the data used stemmed from normal episodes when nominal interest rates were positive and interest differentials would dominate the effect of relative base money supplies. More recently, empirical studies such as Evans and Lyons (2001) and research using data on Japanese foreign exchange interventions such as Ito (2002) and Fatum and Hutchison (2002) are more supportive of a portfolio-balance effect. Ito (2002) finds that Japanese interventions in the second half of the 1990s have been effective in changing the exchange rate. Fatum and Hutchinson (2002) conclude that intervention might be a useful policy instrument during the zero-interest-rate policy period, effectively depreciating the value of the yen exchange rate, but that the effects are likely to be short-term in nature. We follow Orphanides and Wieland (2000) and calibrate λ_k so that it is small enough not to be noticeable in times of non-zero interest rates and choose a value of 0.025.

Given such a small portfolio-balance effect, the liquidity expansion that follows from a linear base money rule such as (2) is likely to be of little consequence. This is confirmed by the simulation results reported in **Figure 6**. The solid line in each panel repeats the recession-cum-deflation scenario from the preceding section where no portfolio-balance effect is present. The dotted line, which differs only very little from the solid line, indicates the outcome with a small portfolio-balance effect under the linear base money rule (2). In this case, the Marshallian k continues to expand a bit while the interest rate is constrained at zero, and the exchange rate depreciates slightly.

As an alternative, OW proposed a *nonlinear* policy rule, which results in a drastic liquidity expansion (i.e. increase in the Marshallian k) whenever the nominal interest is constrained at zero. The optimal nonlinear base money rules under uncertainty computed by

Figure 7: Distortion of Stationary Distributions of Output and Annual Inflation

Output

Annual Inflation
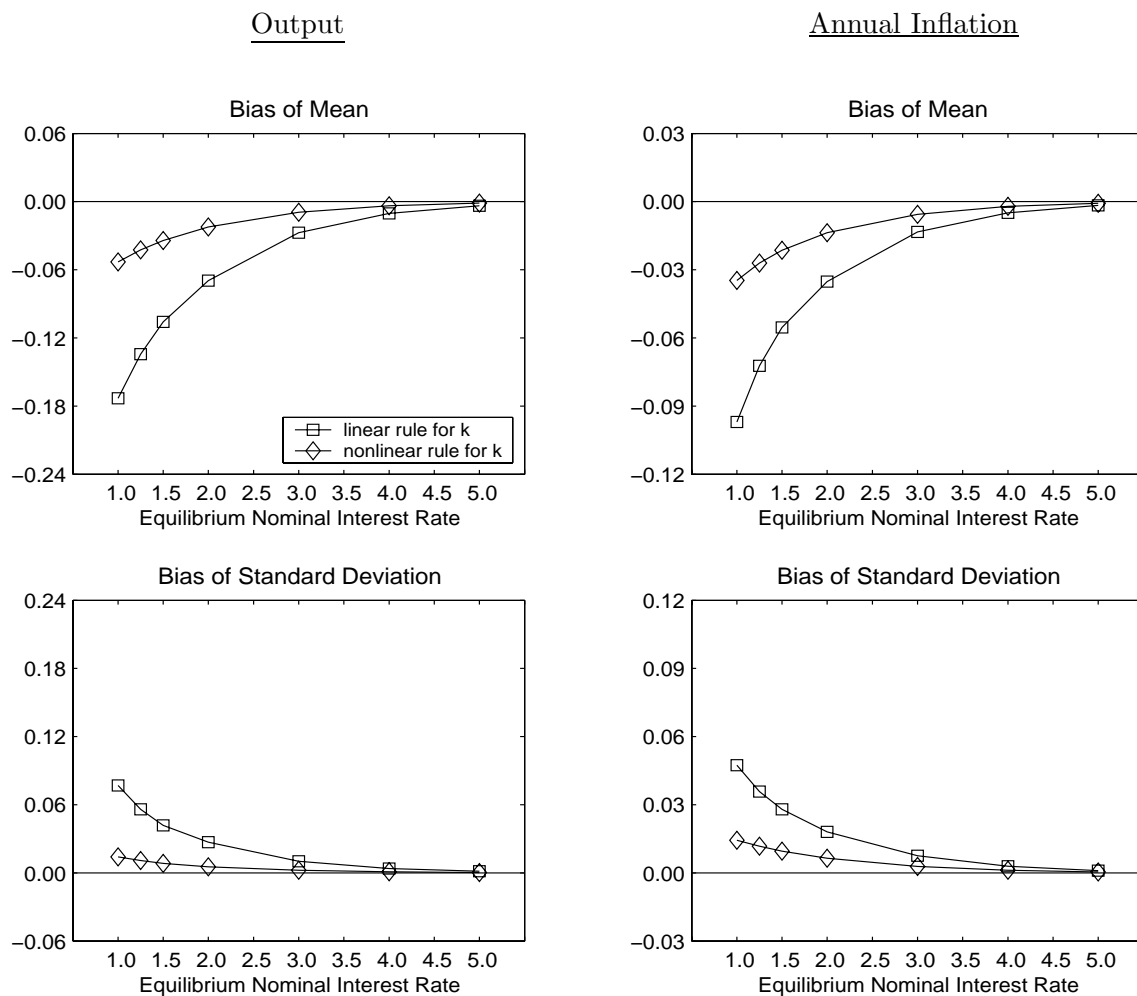
OW using a small calibrated model raise the aggressiveness of the policy response to output and inflation deviations by factors of 20 to 50, whenever the interest rate is constrained at zero. We choose an intermediate case by scaling up the policy response by a factor of 30 whenever the nominal interest rate is zero, and switching back to Taylor's rule when interest rates turn positive:

$$
k_t - k^* = \begin{cases} - \left[\kappa_\pi \left(\pi_t^{(4)} - \pi^* \right) + \kappa_q \, q_t \right], & \text{if } i_t > 0 \\ -30 \left[\kappa_\pi \left(\pi_t^{(4)} - \pi^* \right) + \kappa_q \, q_t \right], & \text{if } i_t = 0. \end{cases}
\tag{5}
$$

Figure 8: Distortion of Stationary Distribution of the Real Effective Exchange Rate
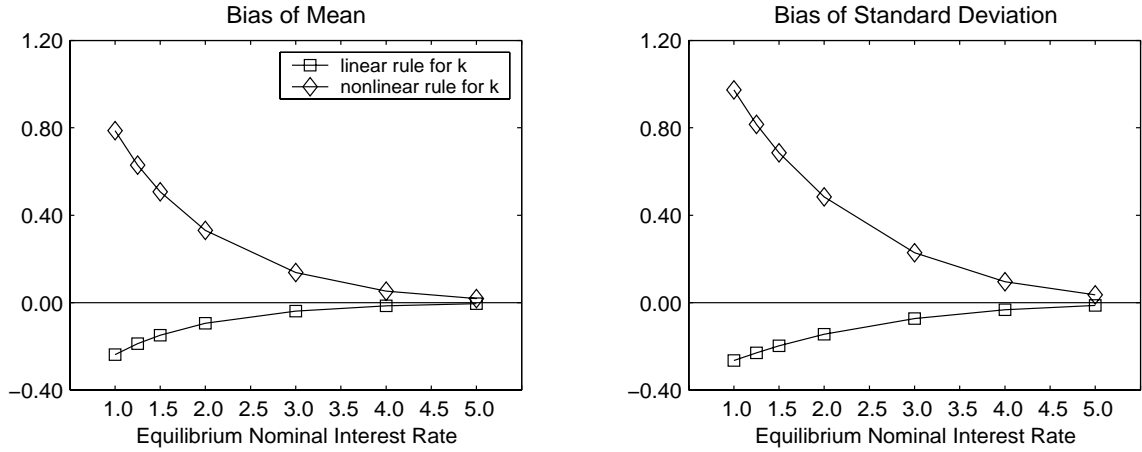
First, we illustrate an initial transition to the OW proposal after the central bank has observed 10 quarters of near zero interest rates in the recession and deflation scenario of subsection 3.2. This scenario corresponds to the dashed-dotted line in each panel of **Figure 6**. The huge expansion of liquidity results in a dramatic real depreciation of up to 40%. As a result of this depreciation the recessionary and deflationary impact of the shocks to the economy is dampened substantially. The depth of the recession and deflation is similar to the first simulation shown in **Figure 1**, where interest rates were allowed to go negative. Thus, in principle the proposal of OW is effective in ameliorating the impact of the zero bound in a deflationary period.

Next, we proceed to evaluate the effectiveness of the nonlinear base money rule (5) in terms of its ability to reduce the biases and asymmetries in output and inflation distributions resulting from the zero bound that we discussed in the preceding section. To do so we conduct further stochastic simulations based on the covariance matrix of historical shocks. The central bank is now assumed to scale up its policy response *immediately* every time that the nominal interest rate is constrained. The results are summarized in **Figure 7**, which compares the biases in the means and standard deviations of output and inflation

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gaps under the linear and nonlinar rules for the Marshallian k, denoted by squares and diamonds respectively. Clearly, the biases are substantially reduced even for very low levels of the equilibrium nominal interest rate.

However, the improvement in output and inflation distributions comes at the expense of substantially higher variability of the real exchange rate as well as a depreciation bias in its mean as depicted in **Figure 8**. The variability of the real exchange rate is substantially higher than in the case of the linear rule. Of course, aggressive depreciation of the currency of a large open economy will have beggar-thy-neighbor-type spillover effects on its trading partner. **Figure 9** provides a quantitative assessment of these spillover effects in the United States and the euro area when monetary policy in Japan follows the nonlinear rule defined in (5). We observe a small downward bias in the means of output and inflation and small upward biases in their variability. Of course, the central banks in those countries have the ability to respond to this development by easing policy more aggressively themselves.

The approach suggested by OW and others, namely to express policy in terms of a base money rule and substantially expand liquidity when nominal interest rates are constrained at zero has been criticized for relying too heavily on the existence of direct quantity effects. The portfolio-balance effect, for example, is at best small and rather imprecisely estimated, which may make it difficult to determine the appropriate policy stance in terms of base money. OW show that this is a problem of multiplicative parameter uncertainty as in Brainard (1967), which can be addressed appropriately by reducing the responsiveness of the base money rule compared to the degree that would be optimal when the portfolio-balance effect is known with certainty.

A related criticism concerns the other effects on the demand for base money summarized by the shock term $\epsilon_{k,t}$ in equation (1) that needs to be accounted for in determining the appropriate policy stance. Under normal circumstances, that is, when the nominal interest rate is positive, these factors can be dealt with by active money supply management because the interest rate is observed continuously. By fixing k_t, even a slight movement in the nominal interest rate can be immediately recognized as a change in $\epsilon_{k,t}$ and counteracted.

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Figure 9: Distortion of Output and Inflation Distributions in the Euro Area and the U.S.

Output

Annual Inflation
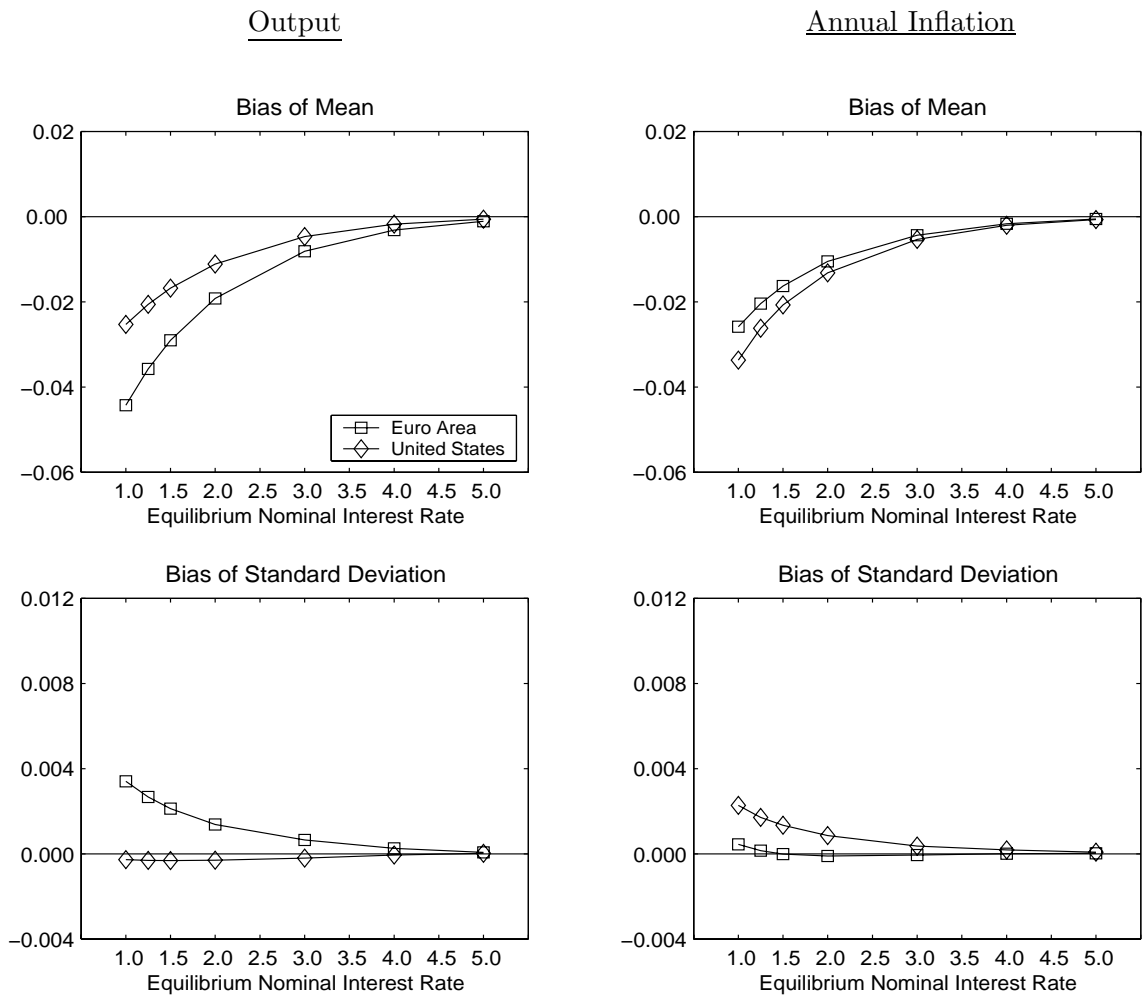
It is exactly these additional influences that encourage the treatment of the nominal interest rate as the central bank's operating instrument rather than a quantity of base money.

Unfortunately, when the nominal interest rate is constrained at zero, it provides no useful information for money supply management anymore. However, there exists an alternative choice for the central bank's operating instrument, namely the nominal exchange rate, which can be observed continously even when the interest rate is constrained at zero. Thus, one could instead specify a policy rule for the nominal exchange rate and then conduct

interventions in the foreign exchange market as required to achieve the desired exchange rate. A further advantage is that one need not know the size of a possible portfolio-balance effect, nor is it a required element for the formulation of the strategy.

4.2 A Proposal by McCallum (2000, 2001)

McCallum (2000, 2001) (MC) recommends a switch to the nominal exchange rate as the policy instrument whenever the economy is stuck at the zero bound. He suggests to set the rate of change of the nominal exchange rate just like a Taylor-style interest rate rule in response to deviations of inflation from target and output from potential. Thus, in case of a deflation and recession the policy rule will respond by depreciating the currency. If credible this will imply that expectations of future exchange rates will reflect the policy rule and help in stabilizing the economy. The necessary level of the exchange rate may be achieved by standing ready to buy foreign currency at the rate prescribed by the rule.
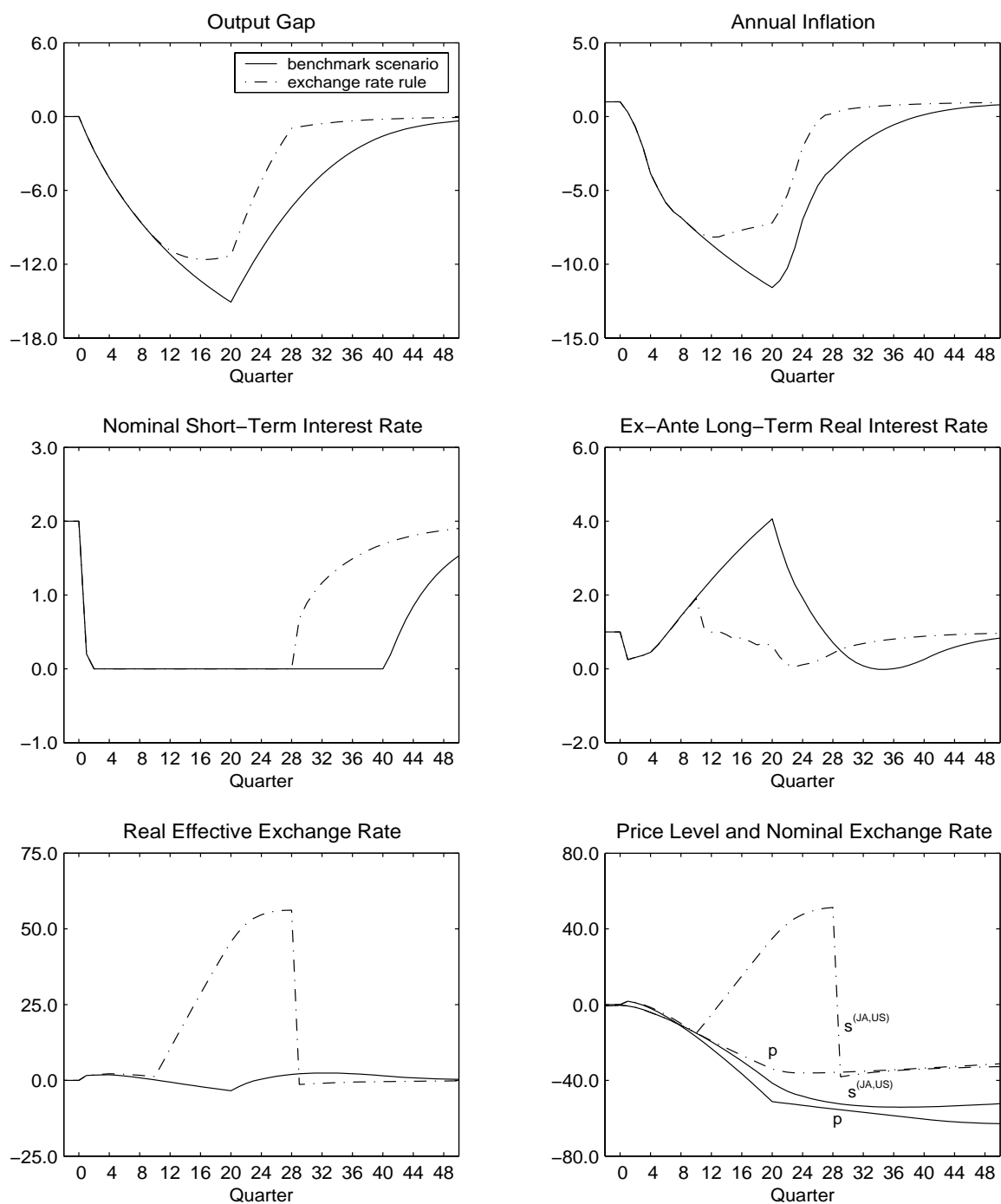
We implement McCallum's proposal as follows:

- if $i_t > 0$, then i_t is set according to Taylor's rule (equation (M-6) in **Table 1**), k_t is determined recursively from the money demand equation (1), and s_t is determined by the extended uncovered interest parity condition as defined in equation (4);

- if $i_t = 0$, then s_t is set according to

$$s_t - s_{t-1} \;\; = \;\; - \chi_\pi \left(\pi_t^{(4)} - \pi^* \right) - \chi_q \, q_t \tag{6}$$

and k_t is determined recursively so that the portfolio-balance term adjusts to satisfy the extended uncovered interest parity condition (4).

MC compares two types of scenarios. In one scenario nominal interest rates are set endogenously according to an interest rate rule but the zero bound is never enforced and the exchange rate results from uncovered interest parity. In the second scenario, the nominal interest rate is always held at zero, the uncovered interest parity equation is dropped from the model, and the nominal exchange rate is set according to the rule defined by equation

Figure 10: Directly Setting the Rate of Depreciation According to a State-Dependent Rule

Output Gap

Annual Inflation

Nominal Short–Term Interest Rate

Ex–Ante Long–Term Real Interest Rate

Real Effective Exchange Rate

Price Level and Nominal Exchange Rate

benchmark scenario
exchange rate rule

$s^{(JA,US)}$

p

$s^{(JA,US)}$

p

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(6). Thus, he can analyze both scenarios in a linear model. Instead, we consider the nonlinearity that results from a temporary period of zero nominal interest rates explicitly in our analysis.

In what follows we implement the exchange rate rule with respect to the bilateral nominal exchange rate of the Japanese Yen vis-à-vis the U.S. Dollar. **Figure 10** provides a comparison between the benchmark simulation of a severe recession and deflation (solid line in each panel) and a simulation, in which the Japanese central bank switches to the exchange rate rule defined by equation (6) after observing an interest rate near or equal to zero for 10 quarters (dashed-dotted line in each panel). We have set the response coefficients in the exchange rate rule χ_π, χ_q equal to 0.25, which we found to be sufficient to largely offset the impact of the zero bound on Japanese output and inflation just like the OW proposal with a scale factor of 30 in section 4.1.

The exchange rate rule generates a substantial nominal and real depreciation. As a result, inflationary expectations increase and the ex-ante long-term real interest rate falls slightly rather than increases as in the benchmark scenario and the recession and deflation are signficantly dampened. The exchange rate rule is abandoned in favor of the original interest rate rule when the interest rate implied by the interest rate rule returns above zero. At that point the Marshallian k is again determined by the base-money demand equation, (1), and the nominal exchange rate adjusts to satisfy uncovered interest parity, (4). This adjustment implies a sharp nominal and real appreciation, which could be smoothed by a more gradual transition from the exchange rate to the interest rate rule.

4.3 A Proposal by Svensson (2001)

Svensson (2001) (SV) offers what he calls a foolproof way of escaping from a liquidity trap. With interest rates constrained at zero and ongoing deflation he recommends that the central bank stimulates the economy and raises inflationary expectations by switching to an exchange rate peg at a substantially devalued exchange rate and announcing a price-level target path. The exchange rate peg is intended to be temporary and should be abandoned

in favor of price-level or inflation targeting when the price-level target is reached.

SV delineates the concrete proposal as follows:

- announce an upward-sloping price-level target path for the domestic price level,

$$p_t^* = p_{t_0}^* + \pi^* (t - t_0), \quad t \geq t_0 \tag{7}$$

with $p_{t_0}^* > p_{t_0}$ and $\pi^* > 0$;

- announce that the domestic currency will be devalued and that the nominal exchange rate will be pegged to a fixed or possibly crawling exchange rate target,

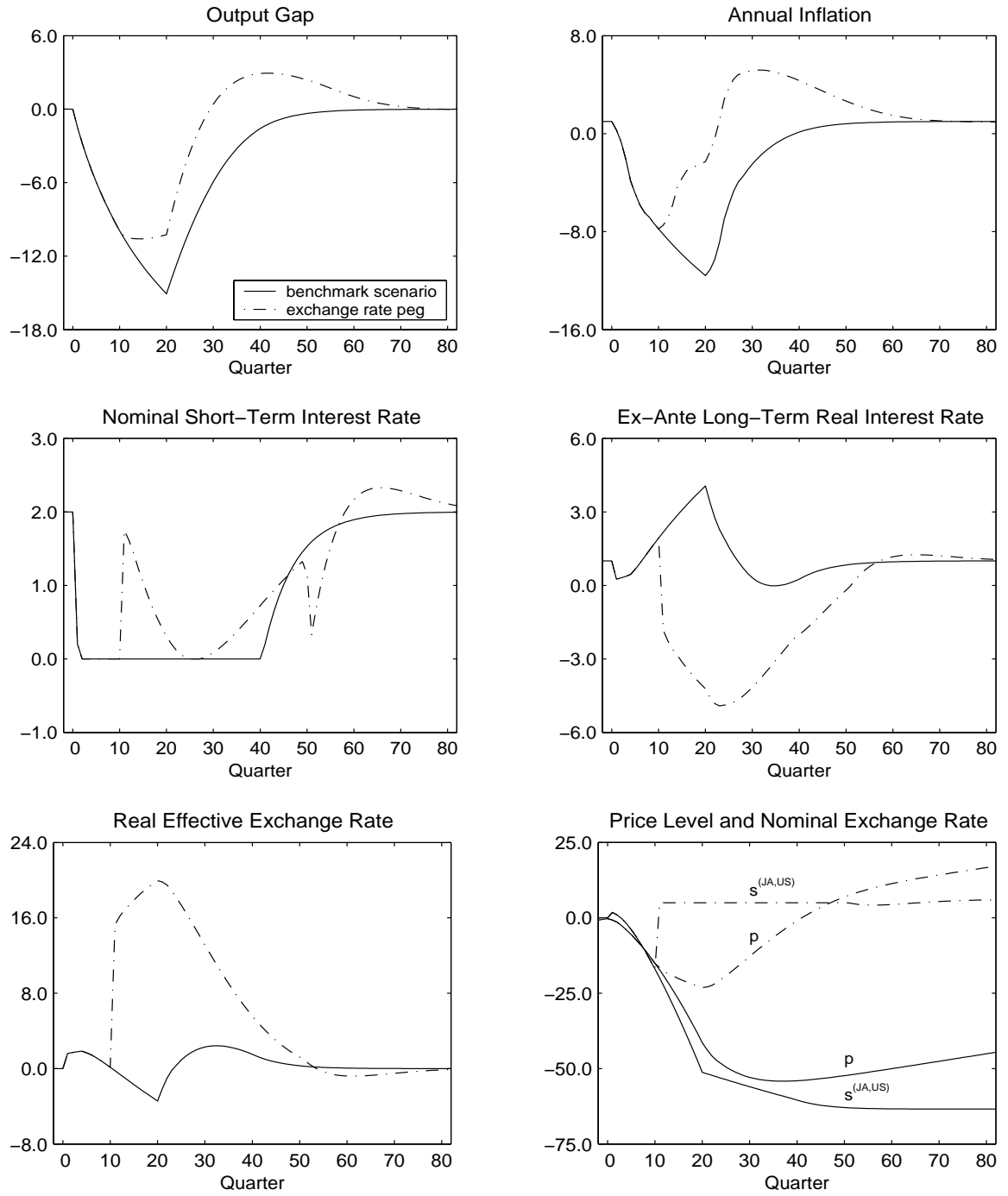$$s_t^{(i,j)} = \bar{s}_t^{(i,j)}, \quad t \geq t_0 \tag{8}$$

where $\bar{s}_t^{(i,j)} = \bar{s}_{t_0}^{(i,j)} + (\pi^{*,(i)} - \pi^{*,(j)})(t - t_0)$;

- announce that when the price-level target path has been reached, the peg will be abandoned, either in favor of price-level targeting or inflation targeting with the same inflation target.

This will result in a temporary crawling or fixed peg depending on the difference between domestic and foreign target inflation rates. SV combines the exchange rate peg with a switch to price-level targeting because he expects the latter to stimulate inflationary expectations more strongly than an inflation target. Of course, this choice will become less important the longer the exchange rate peg lasts.

SV emphasizes that the existence of a portfolio-balance effect is not necessary to be able to implement this proposal. The central bank should be able to enforce the peg at a devalued rate by standing ready to buy up foreign currency at this rate to an unlimited extent if necessary. This will be possible because the central bank can supply whatever amount of domestic currency is needed to buy foreign currency at the pegged exchange rate. This situation differs from the defense of an overvalued exchange rate, which requires selling foreign currency and poses the risk of running out of foreign exchange reserves.

Figure 11: Switching to an Exchange Rate Peg

Output Gap

Annual Inflation

Nominal Short–Term Interest Rate

Ex–Ante Long–Term Real Interest Rate

Real Effective Exchange Rate

Price Level and Nominal Exchange Rate

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Thus, SV considers the outcome of an exchange rate peg when uncovered interest parity holds exactly, that is, without a portfolio-balance effect:

$$s_t^{(i,j)} \quad = \quad \mathrm{E}_t \left[s_{t+1}^{(i,j)} \right] + 0.25 \left(i_t^{(j)} - i_t^{(i)} \right).$$ (9)

The UIP condition and exchange rate expectations play a key role. Suppose, for example, the central bank announces a fixed peg at the rate $\bar{s}$ and this peg is credible, then the expected exchange rate change ought to be zero and the nominal interest rate needs to rise to the level of the foreign nominal interest rate absent any foreign exchange risk premium. Thus, as soon as the exchange rate peg has become credible the nominal interest rate will jump to the level of the foreign rate and the period of zero interest rates will end.

Here we allow for an important difference to our analysis of the proposals by OW and MC. In those cases we specified the policy rule such that the depreciation-oriented policy stance (by aggressively expanding liquidity or by setting the change of the exchange rate directly) was implemented only when the nominal interest rate was equal zero. The resulting deviation from exact UIP was made up by the portfolio-balance effect and an appropriate adjustment of base money. Here, however, the peg continues for a specified period even though the nominal interest rate will rise immediately to satisfy UIP.

We investigate the consequences of Svensson's proposal if it is adopted during the severe recession and deflation scenario discussed in the preceding sections. The outcome is shown in **Figure 11**. The solid line in each panel repeats the benchmark scenario from the earlier sections. The dashed-dotted line indicates the outcome following Svensson's proposal. Again we assume that the central bank adopts the proposal in the 11th period of the simulation. Important choice variables are the initial price level of the implied target path, the extent of the devaluation and the length of the peg. Credibility of the peg turns out to be essential.

The peg is implemented with respect to the bilateral nominal exchange rate of the Japanese Yen vis-à-vis the U.S. Dollar. The implied devaluation and the associated price-level target path are shown in the lower-right panel of **Figure 11**. The middle-left panel

Figure 12: A Fixed versus a Crawling Peg
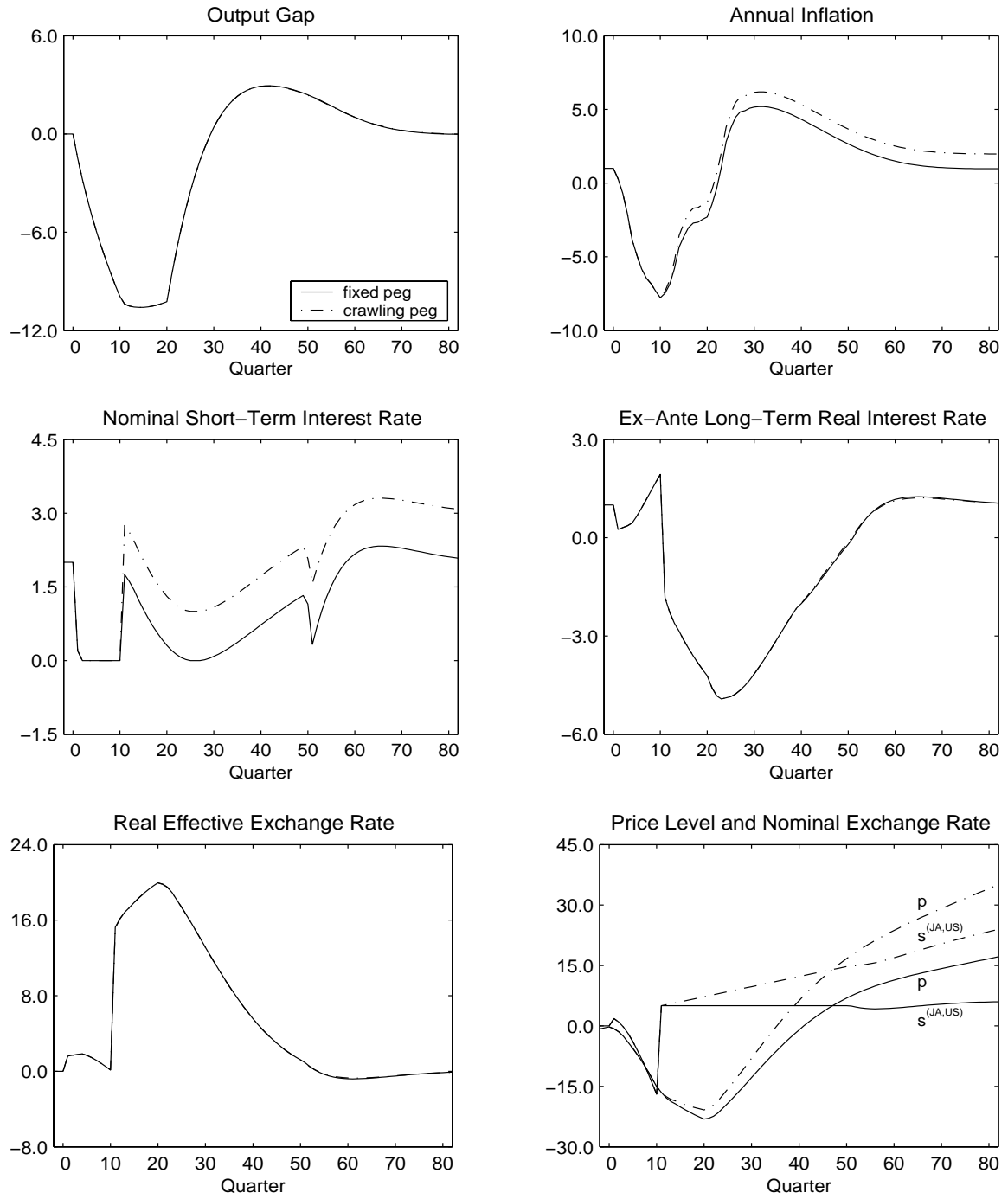
shows that the nominal interest rate jumps to a positive level immediately upon the start of the peg, as required by the UIP condition. The nominal devaluation results in a 16% real depreciation in the trade-weighted exchange rate. The peg delivers the intended results. Inflationary expectations are jump-started and rise very quickly. As a result the real interest rate declines very rapidly, and the economy recovers from recession. This decline in the real interest rate is substantially stronger than in the case of the other two proposals. A key factor driving this increase in inflationary expectations is the central banks explicit and credible commitment to a future exchange rate path.

However, the simulation in **Figure 11** also indicates that the exchange rate peg may not be as easy to implement as it seems at first glance. In particular, if the devaluation is larger or the peg period shorter than shown, the short-term nominal interest rate will fall back to zero either during the peg or at the end of the peg period. Such a recurrence of zero interest rates may render the communication of the policy to the public more difficult. Furthermore, absent any risk premium (or portfolio balance effect) a Japanese nominal interest rate of zero during the peg would imply that the foreign nominal interest rate also reaches zero.

We avoided a return to zero interest rates by fine-tuning the length of the peg, the initial target price level and the size of the devaluation. In the end this required a very long peg period of over 10 years.[15] In practice such a long peg would be considered a seemingly permanent rather than a temporary policy change. The risk of returning to zero interest rates is reduced with a crawling peg instead of a fixed peg as shown in **Figure 12**, where the dashed-dotted line indicates the path under the crawling peg. As can be seen from the middle-left panel, the nominal interest rate remains positive throughout the peg period.

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[15]The nominal Yen / U.S. Dollar exchange rate was pegged at a level which lies 5 percent above the initial exchange rate level, while the initial target price level was set at -3 percent below the initial price level. At the period when the peg is implemented the bilateral exchange rate depreciates by 22 percent where as the announced price-level target path is 16 percent higher than the actual price level.

Figure 13: The Consequences of Anti-Deflation Policies in Japan for the United States
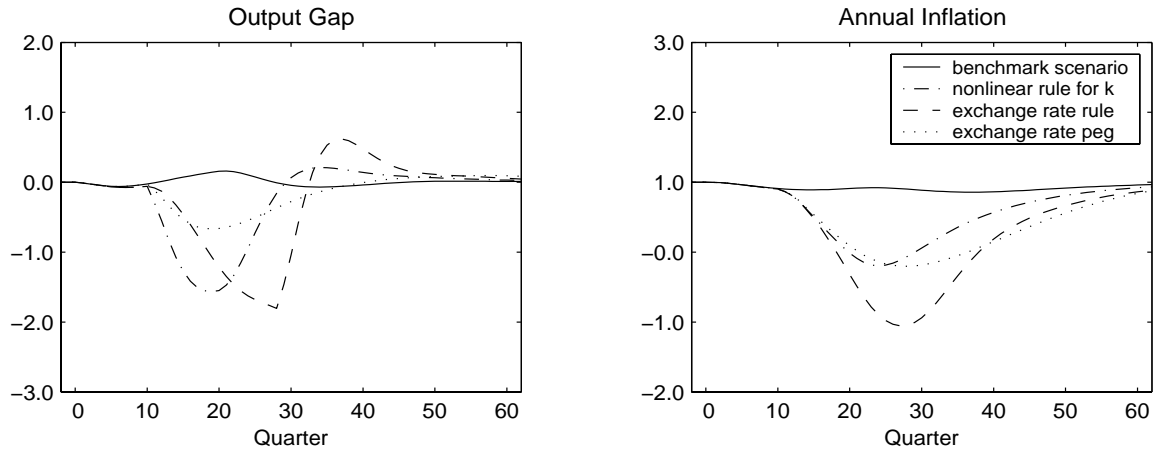
4.4 Beggar-Thy-Neighbor Effects and International Cooperation

All three proposals for avoiding or evading the liquidity trap that we have analyzed have
one important drawback, namely, that they require at least the tacit cooperation of Japan's
main trading partners. Their central banks need to allow Japan to depreciate or devalue
its currency substantially more than would be necessary if nominal interest rates were not
constrained at zero. We have already indicated the potential implications for the euro area
and the United States based on the stochastic simulations of the nonlinear Marshallian k
rule proposed by OW in subsection 4.1. Essentially the trading partners need to expect a
beggar-thy-neighbor-type effect from this depreciation.

To further assess these spillover effects, **Figure 13** reports the consequences of the
three alternative deprecation-based strategies for evading the liquidity trap for output and
inflation in the United States. As discussed in section 3.2., in the benchmark scenario
the zero bound induces a slight appreciation of the Yen with a very small positive effect
on output and inflation in the United States. For the three deprecation-based strategies,
however, we observe a noticeable recession and disinflation as a result of the drastic U.S.
Dollar appreciation. Output declines between 0.6 and 1.8 percent, while the inflation rate

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falls between 1.2 and 2.1 percent. The biggest declines occur under the state-dependent exchange-rate rule, which induces a real appreciation of the trade-weighted US$ exchange rate of about 20% for about two years, and an output gap of 1.8 %. The exchange rate peg appears to perform most favorably with the smallest decline in output and a similar inflation deviation as in the case of the nonlinear base money rule.

Table 3: Sensitivity Analysis: Cumulated Output Losses in the U.S.

	Nonlinear Rule for k	Exchange Rate Rule	Exchange Rate Peg
A. Policy Rules in the Euro Area and the U.S.			
Taylor Rule	-15.31	-15.15	-8.70
Estimated Rule	-13.51	-11.88	-6.31
B. Exchange Rate Responses in the Euro Area and the U.S.			
0.00	-15.31	-15.15	-8.70
0.05	-13.42	-11.83	-6.95
0.10	-11.56	-8.50	-5.20
C. Scale of the Trade Weights			
1.00	-15.31	-15.15	-8.70
0.75	-12.71	-12.10	-6.90
0.50	-9.60	-8.70	-4.92

These spillover effects suggest that implementing exchange-rate-based strategies for evading the liquidity trap may require some cooperation of Japan's major trading partners. Of course, the extent of the spillover effects depends on the particular interest rate policy of Japan's trading partners. As an alternative to Taylor's rule we have also considered the estimated rules for the United States and the euro area from Coenen and Wieland (2002) and a version of Taylor's rule augmented by a policy response to the trade-weighted real exchange rate for those countries. In **Table 2** we report the results of this sensitivity

study with regard to the cumulative sum of quarterly output gaps in the United States. As can be seen from the first two rows, the estimated policy rule is more effective in stabilizing U.S. output. Similarly, including exchange rate responses in Taylor's rule with response coefficients of 0.05 and 0.1 improves output performance in the United States under all scenarios for Japanese policy, while the implied Yen depreciation remains effective in stimulating Japanese output and inflation.

In assessing the above spillover effects it is important to recognize the limitations of our model, in which export and import demand are not modelled separately, foreign income terms are omitted from the aggregate demand specification and from which a direct effect of the exchange rate on aggregate prices via import prices is absent. A comparison with the Federal Reserve's global model (FRB/GLOBAL), a large-scale multi-country model, suggests that the effect of a real appreciation of the trade-weighted US-Dollar exchange rate on U.S. output is significantly larger in our model, which may be largely accounted for by the fact that the trade weights we computed based on trade volume data supplied by the Bank for International Settlements are more than twice as large as the export weights used in FRB/GLOBAL.[16] A further sensitivity study reported in the last three rows of **Table 2** indicates that reducing the trade weights by 50% also cuts the spillover effect in terms of cumulative output loss almost in half. Furthermore, a foreign income effect in the output gap equation would imply that the Japanese recession spills over to the United States even in the benchmark scenario where the exchange rate does not depreciate. As a result, any improvement in the Japanese output gap would also have a positive impact on U.S. output. However, assessing this effect properly would require re-estimating the aggregate demand specifications of our model with a trade-weighted foreign income term. Finally, if we were to recognize a direct effect of the exchange rate on Japanese prices, the depreciation required to evade deflation would be smaller and the implied spillover effects to Japan's trading partners should be further reduced. We leave a more detailed investigation of these issues

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[16]We thank Chris Gust from the Federal Reserve Board for supplying information on the export weights and benchmark simulations in FRB/Global.

for future research.

5   Conclusion

Based on an estimated macroeconomic model of Japan, the United States and the euro area, we have been able to quantify the effect of the zero bound on stabilization performance in Japan. Furthermore, we have evaluated three concrete proposals for avoiding or evading the impact of the zero-interest-rate bound by depreciating the Yen with regard to the euro and the U.S. Dollar. Finally, we have quantified the resulting spillover effects to the United States and the euro area.

We have focused our analysis on the case where all three central banks follow Taylor's (1993b) nominal interest rate rule. Our findings indicate that the zero bound should be expected to induce noticeable losses in terms of output and inflation stabilization in Japan once the nominal equilibrium interest rate, that is the sum of the policymaker's inflation target and the real equilibrium interest rate, is set at 2% or lower. On average, these losses are not very large but they may turn out to be quite substantial in the event of repeated adverse demand and price shocks. However, we note that our analysis abstracts from some important factors that have played a role in the 1990s in Japan. In particular, our model cannot capture the miserable state of Japan's banking sector, which is often cited as a major factor concerning the disappointing growth performance of the Japanese economy in the latter half of the 1990s.

Rather, we evaluate the potential of monetary policy to improve Japan's economic performance under zero interest rates. We have included a small direct effect of base money on the exchange rate in our model. Due to this portfolio-balance effect monetary policy remains effective even when nominal interest rates are constrained at zero, however this effect is so small that it is usually not noticeable. As proposed by Orphanides and Wieland (2000), we have shown that aggressive liquidity expansions when interest rates are constrained at zero may largely offset the effect of the zero bound. Furthermore, we have illustrated the potential of the proposals by McCallum (2000, 2001) and Svensson (2001)

to evade a liquity trap during a severe recession and deflation by setting a state-dependent or exogenous path for the nominal exchange rate.

Our findings indicate that the proposed strategies have non-negligible beggar-thy-neighbor effects and may require the tacit approval of the main trading partners for their success. The implied decline in output in the United States appears smallest when we implement Svensson's proposal for a devaluation of the Yen. Sensitivity studies indicate that the negative spillover effects are smaller when nominal interest rates in the U.S. and in the euro area are set according to estimated policy rules or when the Taylor rule is augmented by a policy response to the exchange rate. Our analysis of spillover effects of a Yen devaluation is limited by the fact that Japan's major Asian trading partners are not included in our model. Thus, an interesting project for future research would be to assess the performance of the alternative depreciation-based proposals in a multi-country model that also accounts for the large share of Japan's trade with Asian countries.

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Appendix: Simulation Techniques

We conduct stochastic simulations of the model to obtain the stationary distributions of the endogenous variables under alternative monetary policy strategies. In preparation for these simulations, we first computed the structural residuals of the model based on Japanese, euro area and U.S. data from 1980:Q1 to 1998:Q4. The process of calculating the structural residuals would be straightforward if the model in question were a purely backward-looking model. For a rational expectations model, however, structural residuals can be computed only by simulating the full model and computing the time series of model-consistent expectations with respect to historical data. The structural shocks differ from the estimated residuals to the extent of agents' forecast errors. We obtained the structural shocks by solving the model algebraically for the reduced form using the AIM implementation (Anderson and Moore, 1985, and Anderson, 1987) of the Blanchard and Kahn (1980) method for solving linear rational expectations models. We calculated the covariance matrix of those structural shocks and using this covariance matrix, we generated 100 sets of artificial normally-distributed shocks with 100 quarters of shocks in each set from which the first 20 twenty quarters of shocks were discarded in order to guarantee that the effect of the initial values die out. We then used the sets of retained shocks to conduct stochastic simulations under alternative values of the equilibrium nominal interest rate, while imposing the non-negativity constraint on nominal interest rates. If it were not for this nonlinearity, we could use the reduced form of the model to compute unconditional moments of the endogenous variables without having to resort to stochastic simulations. We simulated the model using an efficient algorithm that was recently implemented in TROLL based on work by Boucekkine (1995), Juillard (1994) and Laffargue (1990) and is related to the Fair-Taylor (1983) extended path algorithm. A limitation of the algorithm is that the model-consistent expectations of market participants are computed under the counterfactual assumption that "certainty equivalence" holds in the nonlinear model.[17] There are other solution algorithms for that do not impose certainty equivalence. But these alternative algorithms would be prohibitively costly to use with our model, which has more than twenty state variables.

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[17]When solving for the dynamic path of the endogenous variables from a given period onwards, the algorithm sets future shocks equal to their expected value of zero.