Exchange-rate policy and the zero bound on nominal interest rates

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Exchange-Rate Policy and the Zero Bound on Nominal Interest Rates*,†

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Abstract

In this paper, we study the effectiveness of monetary policy in a severe recession and deflation when nominal interest rates are bounded at zero. We compare two alternative proposals for ameliorating the effect of the zero bound: an exchange-rate peg and price-level targeting. We conduct this quantitative comparison in an empirical macroeconometric model of Japan, the United States and the euro area. Furthermore, we use a stylized micro-founded two-country model to check our qualitative findings. We find that both proposals succeed in generating inflationary expectations and work almost equally well under full credibility of monetary policy. However, price-level targeting may be less effective under imperfect credibility, because the announced price-level target path is not directly observable.

JEL Classification System: E31, E52, E58, E61

Keywords: monetary policy rules, zero-interest-rate bound, liquidity trap, rational expectations, nominal rigidities, exchange rates, monetary transmission.

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1 Introduction

Due to the recent experience in Japan the threat of deflation and a liquidity trap has taken center stage in the debate on the proper formulation of monetary policy. Deflationary episodes present a particular problem for monetary policy because the effectiveness of its main instrument, the short-term nominal interest rate, may be limited by the zero lower bound.[1] With interest rates near zero, the central bank will not be able to offset recessionary shocks by lowering nominal and thereby real interest rates. Furthermore, deflationary shocks may raise real interest rates and worsen such a recession.

Researchers, practitioners and policymakers alike have made proposals for avoiding and if necessary escaping deflation.[2] In this paper, we focus on two proposals that have dominated the debate most recently: an exchange-rate peg and price-level targeting. Svensson (2001, 2002, 2003), in particular, has emphasized that the central bank may create expectations of inflation by devaluing and pegging the exchange rate for some time.[3] Alternatively, the central bank can try to manage expectations regarding future interest-rate policy by announcing a target path for the price level and thus induce inflationary expectations. The latter proposal goes back to Wolman (1998) but has been pushed most recently by Eggertsson and Woodford (2003).

Our objective is to compare the effectiveness of an exchange-rate peg and price-level targeting in stimulating the Japanese economy in a severe recession and deflation scenario when nominal interest rates are bounded at zero. We conduct a quantitative evaluation in the estimated macroeconomic model with rational expectations and nominal rigidities of Coenen and Wieland (2002) that covers the three largest economies, the United States, the

[1]Nominal interest rates on deposits cannot fall substantially below zero, as long as interest-free currency constitutes an alternative store of value (McCallum (2000)).

[2]See for example, Krugman (1998), Wolman (1998, 2003), Meltzer (1998, 1999), Posen (1998), Orphanides and Wieland (1998, 2000), Buiter and Panigirtzoglou (1999), Buiter (2001), Goodfriend (2000), Clouse et al. (2000), Johnson et al. (1999), Benhabib, Schmitt-Grohé and Uribe (2002), Svensson (2001, 2002, 2003), Bernanke (2002), Eggertsson (2003), Eggertsson and Woodford (2003), McCallum (2002), Coenen and Wieland (2003) and Adam and Billi (2003).

[3]Related proposals for depreciating the exchange rate have been made by Orphanides and Wieland (2000) and McCallum (2002) and have been compared with Svensson's proposal by Coenen and Wieland (2003).

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] Since this model is not fully developed from microeconomic foundations we also cross-check our findings using a stylized two-country model with imperfect competition that is derived from optimizing behavior of households and firms given Calvo-type price contracts. This model is taken from Benigno and Benigno (2001). The qualitative findings regarding the impact of the zero bound and the two alternative proposals are quite similar in the two models. Not surprisingly, the dynamics observed in the optimizing model are highly stylized and lack the persistence observed in the data, but they provide some additional support for our conclusions from a theoretical perspective.

Our quantitative findings in the estimated three-country model indicate an economically significant impact of the zero bound. Furthermore, we show that exchange-rate-based and price-level-target-based proposals are equally effective in inducing inflationary expectations and stimulating the economy. This result depends on the assumptions of rational expectations and full credibility of monetary policy. Price-level targeting may be less effective under imperfect credibility, because the announced price-level target path is not directly observable. In particular, we show that if a significant percentage of market participants doubts that the central bank has truly adopted a price-level target, the central bank's announcement is not anymore as effective in mitigating the impact of the zero bound. The exchange-rate peg at least offers the advantage that the public can observe every period whether the central bank maintains the exchange-rate peg.

The paper proceeds as follows. In Section 2 we discuss the impact of the zero bound in the estimated macroeconomic model. Section 3 compares the two proposals. In Section 4 we review the implications of the micro-founded model and in Section 5 we present the

[4]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. Our approach builds on several earlier quantitative studies (c.f. Fuhrer and Madigan (1997), Laxton and Prasad (1997), Orphanides and Wieland (1998), Reifschneider and Williams (2000), Hunt and Laxton (2001) and Coenen and Wieland (2003)).

implications of imperfect credibility for price-level targeting. Section 6 concludes. Both models are presented in detail in the appendix of the paper, which also contains some additional simulation results for the micro-founded model.

2 Recession, deflation and the zero-interest-rate bound

In the estimated model 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. The model comprises the three largest 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.[5]

As a benchmark for our analysis we assume that monetary policy follows Taylor's (1993b) rule. Thus, the nominal short-term interest rate, i_t, responds to deviations of inflation, π_t, from the central banks' inflation target, π^*, and deviations of actual output from potential, q_t, as follows:

$$i_t = r^* + \pi_t + 0.5\,(\pi_t - \pi^*) + 0.5\,q_t, \tag{1}$$

where r^* refers to the real equilibrium interest rate. 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 an interest-rate rule,

[5] This modeling approach follows Taylor (1993a) and Fuhrer and Moore (1995a, 1995b). 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. The Calvo specification did not fit the data under the assumption of rational expectations.

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.[6]

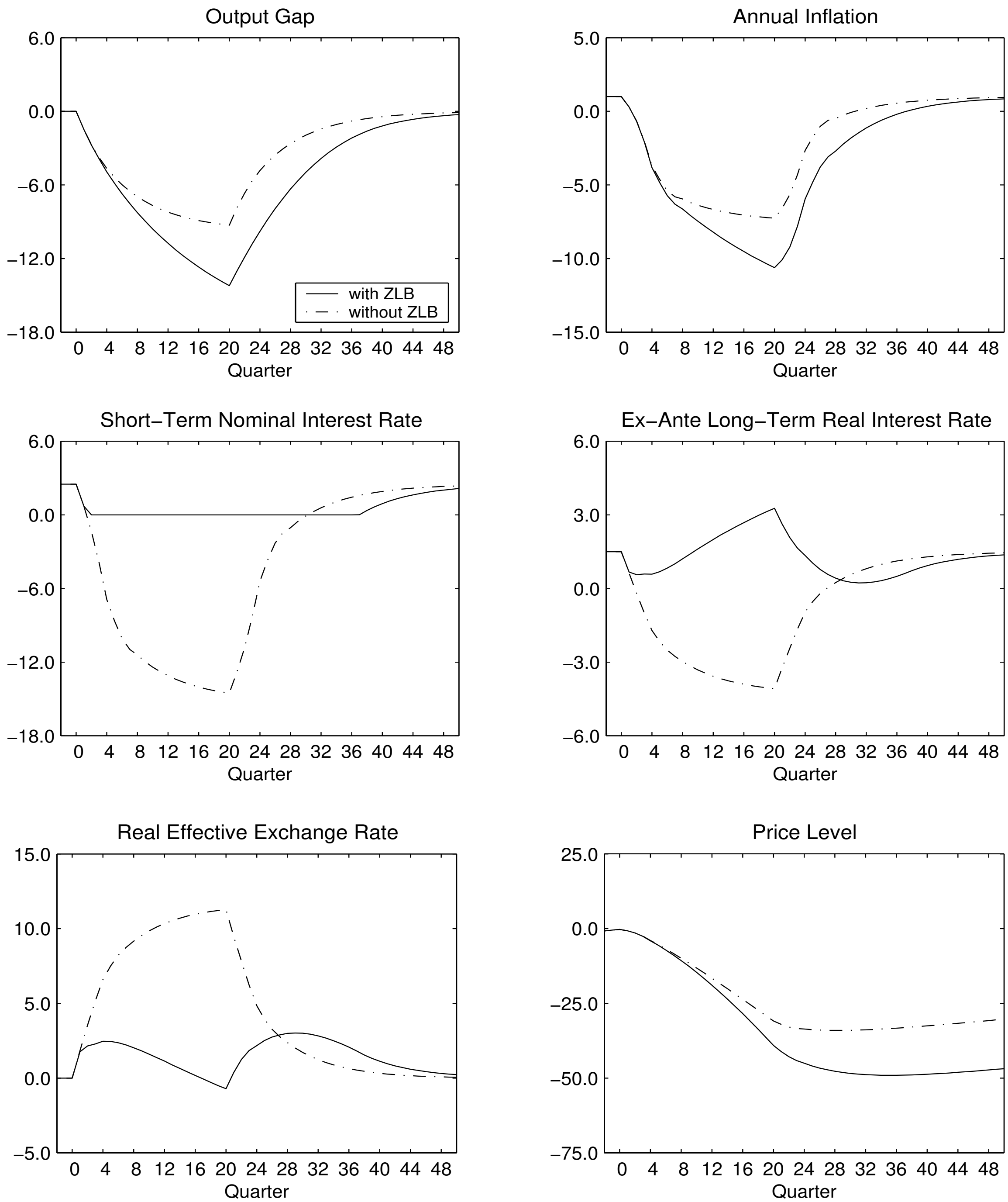
To illustrate the potentially dramatic consequences of the zero-interest-rate bound and deflation we simulate an extended period of recessionary and deflationary shocks in the Japan block of our three-country model. This is essentially the same scenario as considered in Coenen and Wieland (2003). Initial conditions are set to steady state with an inflation target of 1%, a real equilibrium rate of 1.5%, and thus an equilibrium nominal interest rate of 2.5%. 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.[7]

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 4% and the central bank would be able to contain the output gap and deflation around -9% and -8%, respectively. The reduction in nominal interest rates would be accompanied by a 11% real depreciation of the currency in trade-weighted

[6]Orphanides and Wieland (2000) illustrate this point using recent data for Japan. For a further discussion of the relationship of money and interest rates near zero we refer the reader to that paper.

[7]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%.

Figure 1: A Severe Recession and Deflation in Japan: Estimated Model



terms.

However, once the zero lower bound is enforced, the recessionary and deflationary shocks 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.

It is important to emphasize that in this scenario expectations of future inflation are sufficient to return the economy ultimately to steady state. In this sense, the long period of zero interest rates shown above does not represent a trap from which no escape is possible but rather a long period of reduced policy effectiveness. Of course, it is well-known that the model with the zero bound, as presented so far in **Table A** in the appendix would 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 and a deflationary spiral would result. However, the sequence of extreme shocks simulated above was still not sufficient to reach this point of no return in our model of the Japanese economy.[8]

3 Exchange-rate peg versus price-level targeting

Svensson (2001) 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.

[8]There would be a number of ways to resolve this global instability. For example Orphanides and Wieland (1998) assume 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 concentrate on the role of other channels of the monetary transmission mechanism that may continue to operate even when the interest-rate channel is ineffective such as a portfolio-balance effect.

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. Svensson delineates the concrete proposal as follows:

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

$$p_t^* \quad = \quad p_{t_0}^* + 0.25\,\pi^*\,(t - t_0), \qquad t \geq t_0 \tag{2}$$

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

- announce that the domestic currency will be devalued and that the nominal exchange rate, $s_t^{(i,j)}$, will be pegged to a fixed or possibly crawling exchange-rate target,

$$s_t^{(i,j)} \quad = \quad \bar{s}_t^{(i,j)}, \qquad t \geq t_0 \tag{3}$$

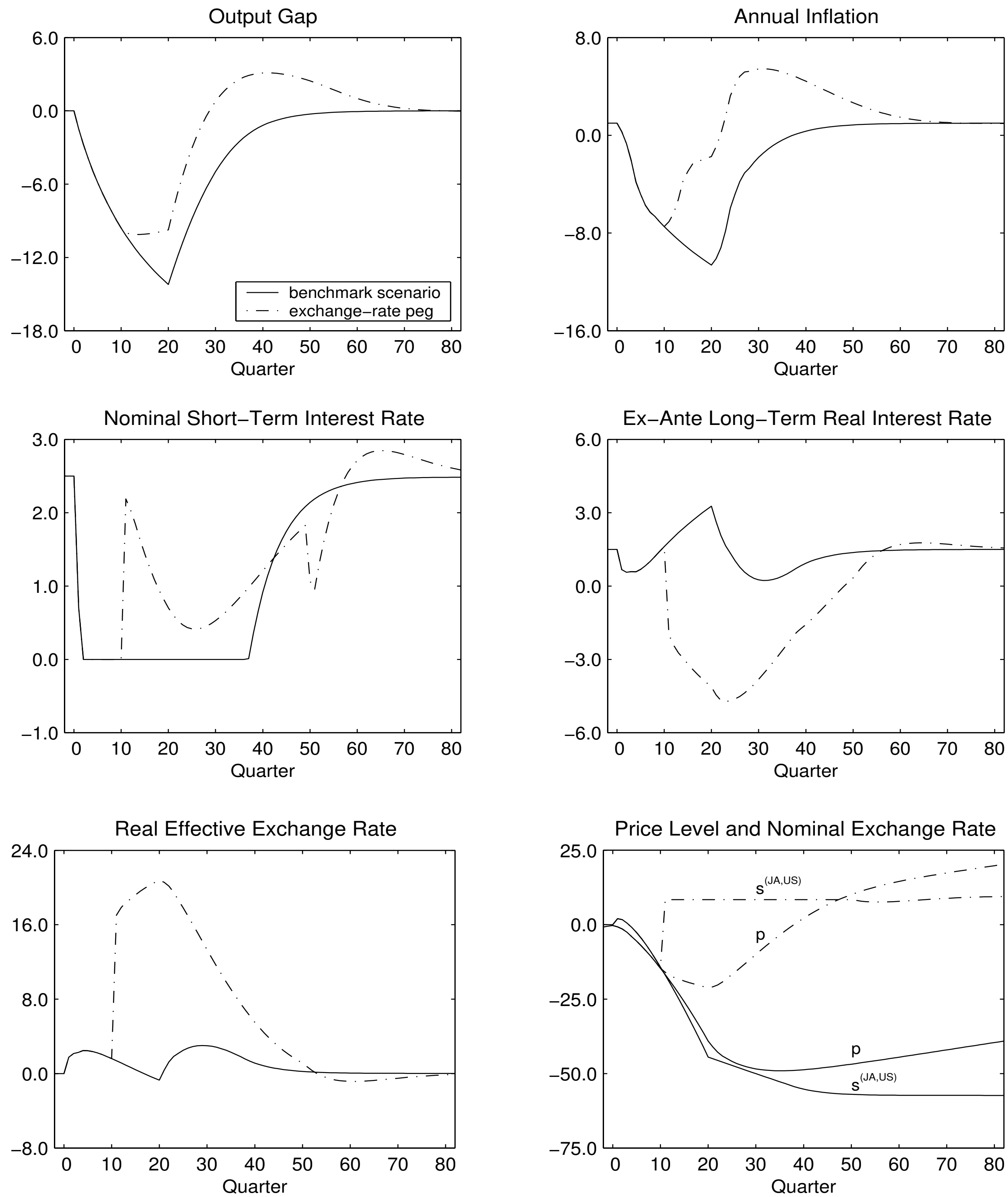
  where $\bar{s}_t^{(i,j)} = \bar{s}_{t_0}^{(i,j)} + 0.25\,(\,\pi^{*,(i)} - \pi^{*,(j)}\,)\,(t - t_0)$ and the superscripts (i, j) are intended to refer to the economies concerned;

- 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. Svensson 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. Further below we will investigate the effectiveness of price-level targeting alone without the exchange-rate peg.

Svensson emphasizes that 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 2: Switch from Taylor Rule to Exchange-Rate Peg



We investigate the consequences of Svensson's proposal if it is adopted during the severe recession and deflation scenario after the central bank has observed 9 quarters of zero nominal interest rates. The outcome is shown in **Figure 2**. The solid line in each panel repeats the benchmark scenario from **Figure 1** where the central bank sticks with Taylor's rule. The dashed-dotted line indicates the outcome under Svensson's proposal. 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.

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 2**. The nominal devaluation results in a 15% real depreciation in the trade-weighted exchange rate. The peg delivers the intended results. Inflationary expectations are jump-started and rise very quickly. The real interest rate declines very rapidly, and the economy recovers from recession.

The uncovered-interest-parity condition and exchange-rate expectations play a key role. Once the central bank announces the fixed peg the expected exchange-rate change is zero and the nominal interest rate rises to the level of the foreign nominal interest rate absent any foreign-exchange risk premium. The middle-left panel shows that the nominal interest rate jumps to a positive level immediately upon the start of the peg as required by uncovered interest parity.[9]

The preceding analysis of Svensson's proposed exchange-rate peg emphasizes that escaping from the liquidity trap requires generating expectations of inflation. However, the exchange-rate peg is not a necessary ingredient. Already Krugman (1998) pointed out that inflationary expectations can be achieved by inducing expectations of future policy easing. Using a model with staggered price contracts of fixed duration, Wolman (1998) showed that

[9] We avoided a return to zero interest rates by fine-tuning the length of the peg, the size of the devaluation and the initial target price level. In the end this required a very long peg period of over 10 years. At the period when the peg is implemented the nominal Yen/U.S. Dollar exchange rate depreciates by 22.5 percent, whereas the announced price-level target path is 18.5 percent higher than the actual price level.

such expectations can be induced by implementing a policy rule that keeps the price level trend-stationary. More recently, Eggertsson and Woodford (2003) analyze the possibility of managing expectations regarding future policy easing in a model with imperfect competition and random-duration Calvo-style price contracts. Eggertsson and Woodford (2003) show that it is optimal for the central bank to commit to keeping nominal interest rates lower in the future in order to affect expectations of inflation while the zero bound is still binding. Eggertsson and Woodford also show that the optimal policy can be implemented through commitment to a history-dependent rule using a price-level target that evolves over time. Furthermore, they find that a simpler rule with a fixed price-level target achieves most of the benefits of the optimal policy.

The four-quarter Taylor-style contracts in the Japan block of our macroeconometric model imply a still greater degree of inflation persistence than the Calvo-style contracts considered by Eggertsson and Woodford (2003). Inspired by their findings we investigate whether switching to a price-level target alone would be sufficient to stimulate inflationary expectations in our estimated model. More precisely, we consider the performance of the following policy proposal:

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

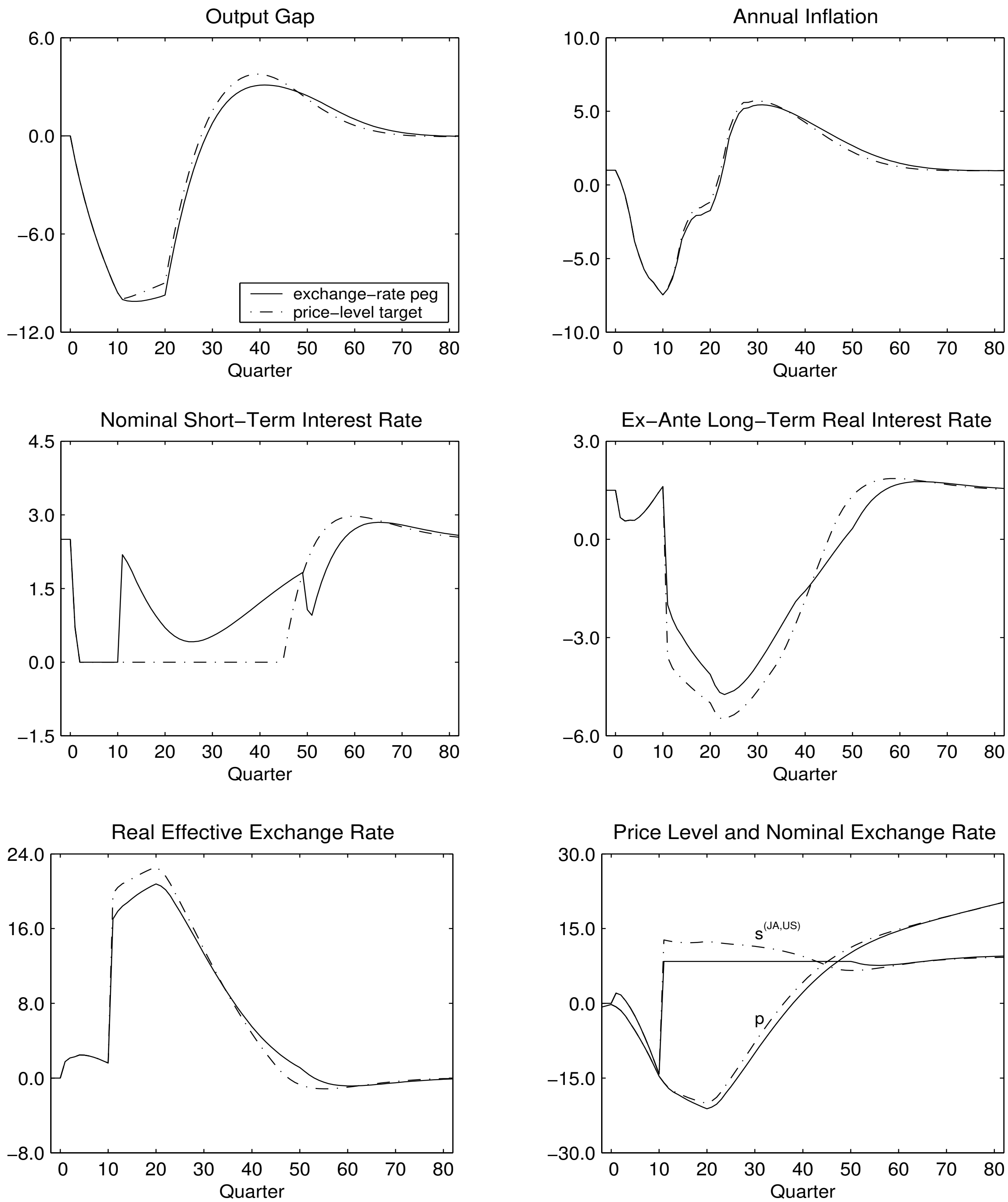
  $$p_t^* \quad = \quad p_{t_0}^* + 0.25\,\pi^*\,(t - t_0), \quad t \geq t_0$$

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

- replace the inflation target in the Taylor rule (equation (1)) with the above price-level target and, thus, commit to lower interest rates in the future until the price gap is completely closed.

Figure 3 compares the performance of the Japanese economy in our model when the central bank switches to the price-level target (dash-dotted line) after 9 quarters of zero interest rates with the switch to the exchange-rate peg (solid line). Surprisingly, switching to the price-level target is just as effective in generating inflationary expectations as the

Figure 3: Switch from Taylor Rule with Inflation Target to Price-Level Target



exchange-rate peg. As shown in the two top panels output and inflation return to steady state even a little bit faster than under the exchange-rate peg, the reason being that the nominal interest rate remains at zero much longer and consequently the long-term real rate falls lower and the real depreciation is a bit larger than under the exchange-rate peg.

4 Microeconomic foundations

The strength of the estimated three-country model of Coenen and Wieland (2002) lies in its ability to match the observed degree of persistence of output and inflation in Japan, the U.S. and the euro area. However, the model differs from a standard New-Keynesian micro-founded model in several ways, most importantly because lags of the output gap are included in the behavioral demand equations. To further gauge the validity of our results from a theoretical perspective we simulate a recession and deflation scenario in the micro-founded two-country model of Benigno and Benigno (2001).[10]

We start from the log-linear approximation derived by Benigno and Benigno and implement the zero bound in the same manner as in the estimated three-country model. Then, we proceed to simulate a combination of government spending (-3 percentage points) and productivity shocks (2 percentage points) that induce a negative output gap and deflation. The outcome of this simulation is shown in **Figure 4**. We obtain results that are qualitatively similar to those for our estimated three-country model as far as the effect of the zero bound on output, inflation and interest rates is concerned. However, the effect of the zero bound is rather small and the dynamics of the micro-founded model are highly stylized due to the lack of intrinsic persistence.[11]

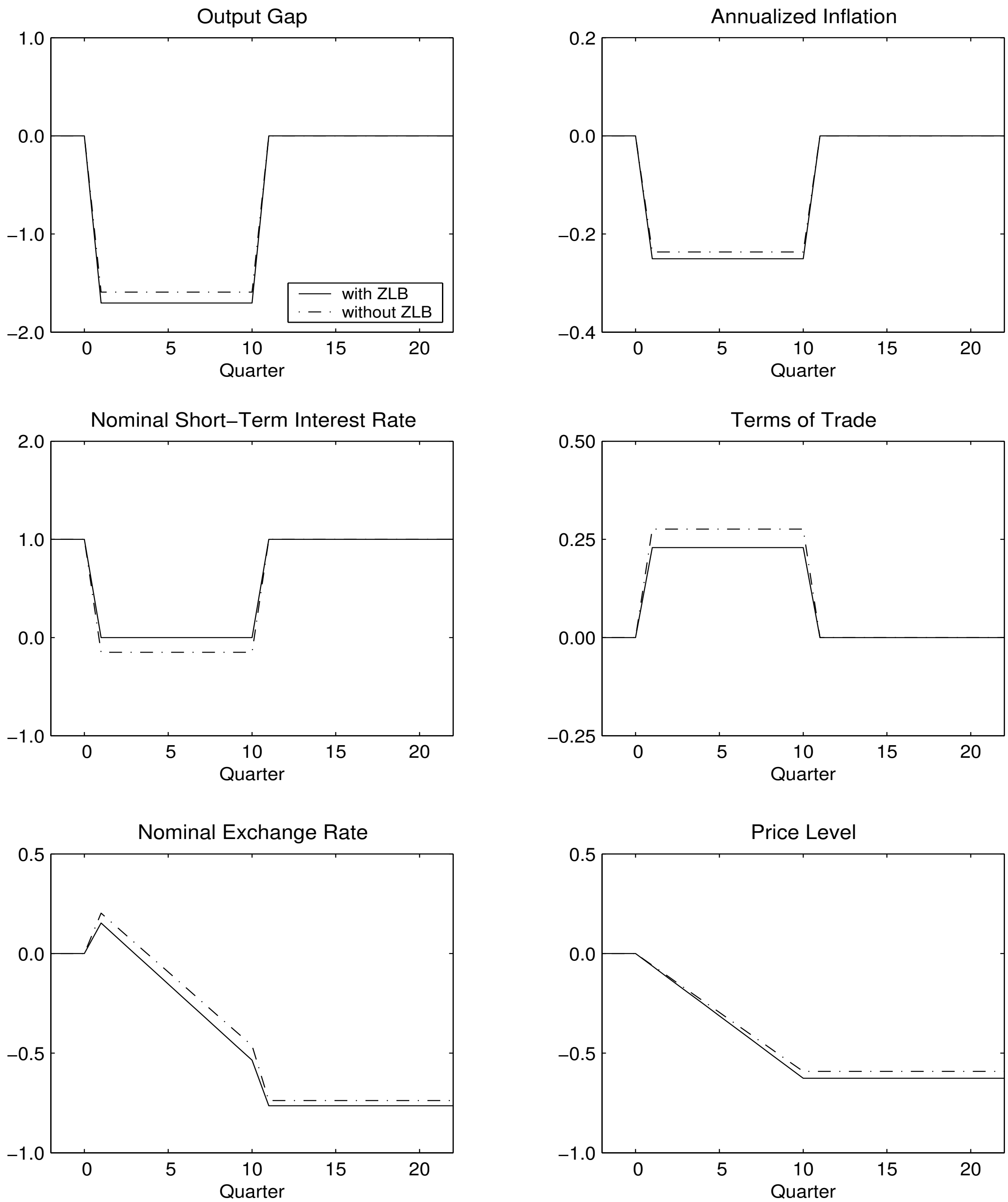
We take this finding as a further corroboration of the results obtained in the estimated model from a theoretical perspective.[12] We do not follow the practice of adding ad-hoc serial correlation to the shocks in this type of model so as to obtain empirically more plausible

[10]The model is described in more detail in Appendix A.2.

[11]We have simulated white-noise shocks without any ad-hoc serial correlation.

[12]Note that we intend to explore alternative shock combinations that may result in a more dramatic effect of the zero bound in the micro-founded model

Figure 4: The Effect of the Zero Bound in the Micro-Founded Model



impulse responses.[13] In the appendix, we provide additional figures of simulations, which show that the hoped-for benefits of a switch to an exchange-rate peg or to a price-level target also obtain in the micro-founded model (cf. **Figures A** and **B** in Appendix A.3).

5 Implications of imperfect credibility

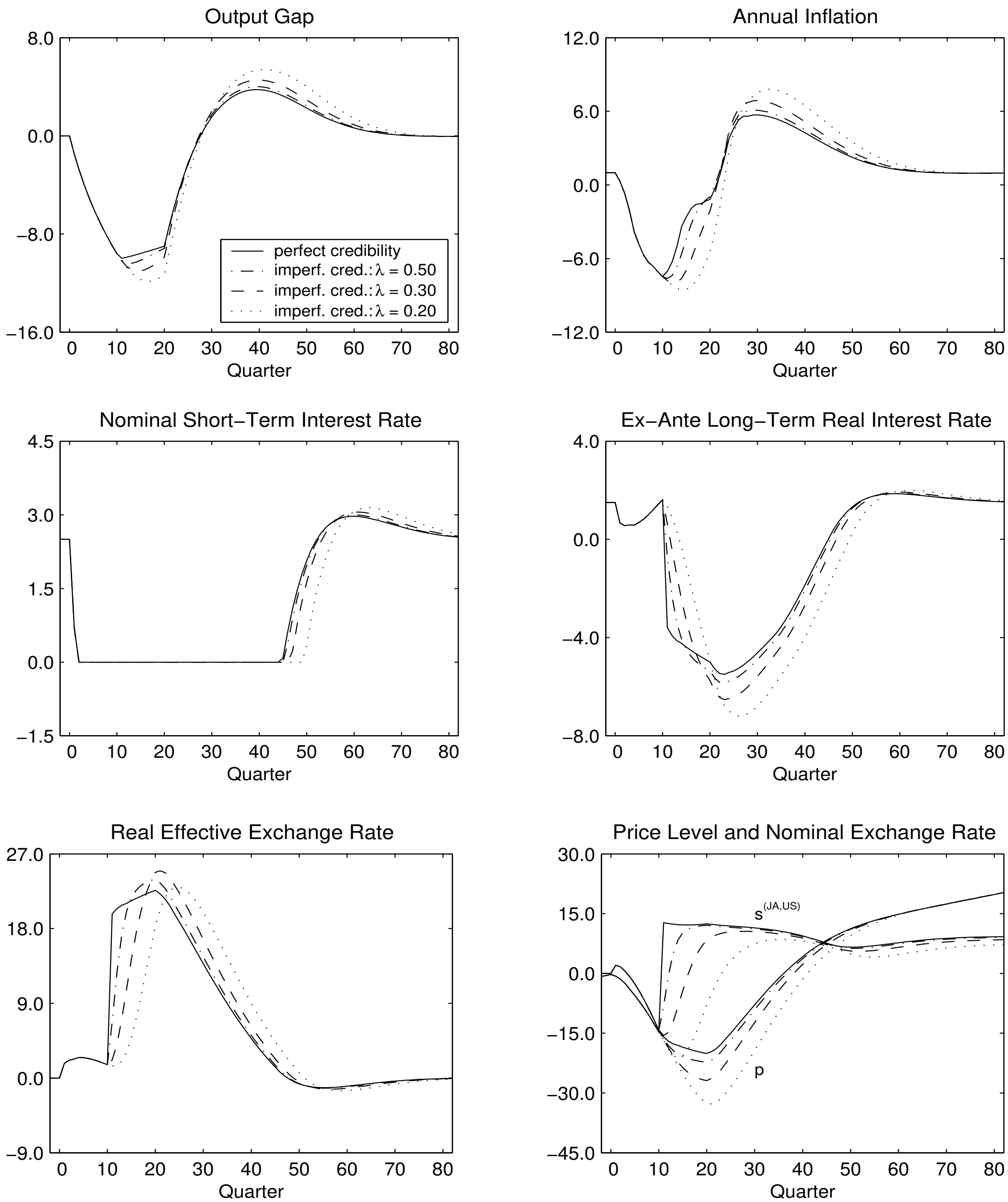
So far, exchange-rate-based and price-level-target-based approaches appear equally effective in inducing inflationary expectations in a liquidity trap. From a practical perspective, however, there is an important difference. While the exchange-rate peg can be verified every day that the central bank maintains it, the price-level target path announced by the central bank and the resulting price gap are not directly observable by the public. Thus, the success of price-level targeting may depend particularly on the credibility of the announced target path.

To gauge the validity of our findings from a practical perspective, we consider an alternative scenario, in which a share λ of market participants trust the central bank's commitment to a price-level target ($0 \leq \lambda \leq 1$) while the others remain skeptical regarding the policy switch ($1-\lambda$). Skeptical market participants still believe that the central bank will pursue an inflation target rather than a price-level target. In other words, they do not believe that the central bank intends to induce sufficient inflation in the future to fully make up the price-level gap. We assume that the share λ of market participants that trust the central bank converges to 1 at an exponential rate.

We report the outcomes for alternative values of λ in **Figure 5**. The solid line repeats the scenario from **Figure 3** with a perfectly credible switch to a price-level target ($\lambda = 1$). Alternatively, we consider values of 0.5 (dashed-dotted line), 0.3 (dashed line) and 0.2 (dotted line). The results we obtain indicate that the benefits of a switch to price-level targeting are reduced substantially if more than half of the market participants do not immediately believe the central bank's announcement.

[13] The ongoing research program that involves adding further frictions to the model to improve the empirical performance of these models however seems very promising.

Figure 5: Imperfect Credibility of the Price-Level Target: Estimated Model



6 Conclusions

Using an estimated three-country model we have found that the zero bound on nominal interest rates significantly worsens the macroeconomic performance of the Japanese economy in a recession and deflation scenario. Even though nominal interest rates are constrained at zero, the central bank may improve performance substantially by devaluing the exchange rate and switching to an exchange-rate peg or by committing to a price-level target path and an interest-rate rule that will close the price gap in the future. A similar analysis in a more stylized micro-founded model reinforces the plausibility of these findings from a theoretical perspective. From a practical perspective, however, lack of credibility may render a price-level-target-based proposal for escaping from a liquidity trap less effective.

References

Adam, K. and R. M. Billi, 2003, Optimal monetary policy under commitment with a zero bound on nominal interest rates, unpublished manuscript, University of Frankfurt, December.

Benhabib, J., S. Schmitt-Grohé and M. Uribe, 2002, Avoiding liquidity traps, Journal of Political Economy, 110, 535-563.

Benigno, G. and P. Benigno, 2001, Monetary policy rules and the exchange rate, CEPR Dicsussion Paper No. 2807, May.

Bernanke, B., 2002, Deflation: Making sure "It" doesn't happen here, Speech before the National Economists Club, Washington D.C., November 21, 2002.

Buiter, W. H., 2001, The liquidity trap in an open economy, CEPR Discussion Paper, DP 2923.

Buiter, W. H. and I. Jewitt, 1981, Staggered wage setting with real wage relativities: Variations on a theme of Taylor, The Manchester School, 49, 211-228, reprinted in W. H. Buiter (ed.), 1989, Macroeconomic theory and stabilization policy, Manchester: Manchester University Press.

Buiter, W. H. and N. Panigirtzoglou, 1999, Liquidity traps: How to avoid them and how to escape them, unpublished manuscript, March.

Boucekkine, R., 1995, An alternative methodology for solving nonlinear forward-looking models, Journal of Economic Dynamics and Control, 19, 771-734.

Calvo, G. A., 1983, Staggered prices in a utility-maximizing framework, Journal of Monetary Economics, 12, 383-398.

Clouse, J., D. Henderson, A. Orphanides, D. Small, and P. Tinsley, 2000, Monetary policy when the nominal short-term interest rate is zero, Finance and Economics Discussion Series, 2000-51, Board of Governors of the Federal Reserve System, November.

Coenen, G. and V. Wieland, 2002, Inflation dynamics and international linkages: A model of the United States, the euro area and Japan, ECB Working Paper No. 181, September.

Coenen, G. and V. Wieland, 2003, The zero-interest-rate bound and the role of the exchange rate for monetary policy in Japan, Journal of Monetary Economics, 50(5), 1071-1101.

Dornbusch, R., 1980, Exchange-rate economics: Where do we stand?, Brookings Papers on Economic Activity, 3, 537-584.

Dornbusch, R., 1987, Exchange-rate economics: 1986, Econonomic Journal, 97, 1-18.

Eggertsson, G. B., 2003, How to fight deflation in a liquidity trap: Comitting to being irresponsible, IMF Working Paper No. 03/64, March.

Eggertsson, G. B. and M. Woodford, 2003, The zero bound on interest rates and optimal monetary policy, Brookings Papers on Economic Activity, 1, 139-233.

Fair, R. and J. B. Taylor, 1983, Solution and maximum likelihood estimation of dynamic nonlinear rational expectations models, Econometrica, 51, 1169-1185.

Fuhrer, J. C. and B. F. Madigan, 1997, Monetary policy when interest rates are bounded at zero, Review of Economics and Statistics, 79, 573-585.

Fuhrer, J. C. and G. R. Moore, 1995a, Inflation persistence, Quarterly Journal of Economics, 110, 127-159.

Fuhrer, J. C. and G. R. Moore, 1995b, Monetary policy trade-offs and the correlation between nominal interest rates and real output, American Economic Review, 85, 219-239.

Goodfriend, M., 2000, Overcoming the zero bound on interest rate policy, Journal of Money, Credit and Banking, 32, 1007-1035.

Hunt, B. and D. Laxton, 2001, The zero interest rate floor and its implications for monetary policy in Japan, IMF Working Paper, WP/01/186, International Monetary Fund.

Johnson, K., D. Small and R. Tryon, 1999, Monetary policy and price stability, Federal Reserve Board, International Finance Discussion Paper 1999-641, July.

Juillard, M., 1994, DYNARE - A program for the resolution of non-linear models with forward-looking variables, Release 1.1, mimeo, CEPREMAP.

Krugman, P., 1998, It's baaack: Japan's slump and the return of the liquidity trap, Brookings Papers on Economic Activity, 2, 137-187.

Laffargue, J., 1990, Résolution d'un modèle macroéconomique avec anticipations rationnelles, Annales d'Economie et de Statistique, 17, 97-119.

Laxton, D. and E. Prasad, 1997, Possible effects of European Monetary Union on Switzerland: A case study of policy dilemmas caused by low inflation and the nominal interest rate floor, IMF Working paper, WP/97/23, International Monetary Fund.

McCallum, B. T., 2000, Theoretical analysis regarding a zero lower bound on nominal interest rates, Journal of Money, Credit and Banking, 32, 870-904.

McCallum, B. T., 2002, Inflation targeting and the liquidity trap, in N. Loayza and R. Soto (eds.), Inflation targeting: design, performance, challenges, Santiago: Central Bank of Chile.

Meltzer, A., 1998, Time to print money, Financial Times, July 17.

Meltzer, A., 1999, Monetary policy at zero inflation, August.

Orphanides, A. and V. Wieland, 1998, Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero, Finance and Economics Discussion Series, 98-35, Board of Governors of the Federal Reserve System, June.

Orphanides, A. and V. Wieland, 2000, Efficient monetary policy design near price stability, Journal of the Japanese and International Economies, 14, 327-365.

Posen, A., 1998, Restoring Japan's economic growth, Institute for International Economics, Washington D.C..

Reifschneider, D. and J. C. Williams, 2000, Three lessons for monetary policy in a low inflation era, Journal of Money, Credit and Banking, 32, 936-966.

Svensson, L. E. O., 2001, The zero bound in an open-economy: A foolproof way of escaping from a liquidity trap, Monetary and Economic Studies, 19, 277-312.

Svensson, L. E. O., 2002, Escaping from a liquidity trap and deflation: The foolproof way and others, Journal of Economic Perspectives, forthcoming.

Svensson, L. E. O., 2003, The magic of the exchange rate: Optimal escape from a liquidity trap in small and large open economies, unpublished manuscript, Princeton University, December.

Taylor, J. B., 1980, Aggregate dynamics and staggered contracts, Journal of Political Economy, 88, 1-24.

Taylor, J. B., 1993a, Macroeconomic policy in the world economy: From econometric design to practical operation, New York: W.W. Norton.

Taylor, J. B., 1993b, Discretion versus policy rules in practice, Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

Wolman, A. L., 1998, Staggered price setting and the zero bound on nominal interest rates, Federal Reserve Bank of Richmond Quarterly, 84, 1-22.

Wolman, A. L., 2003, Real implications of the zero bound on nominal interest rates, Journal of Money, Credit and Banking, forthcoming.

Appendix

A.1 The model of Coenen and Wieland (2002)

Table A 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 A**). 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 actual 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 A** 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 $v_t = \sum_{i=0}^{\eta(x)} f_i \, (x_{t-i} - p_{t-i})$ 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 and is scaled with the parameter σ_{ϵ_d}.[14]

[14] 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.

Table A: 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	$x_t = \mathrm{E}_t \left[\sum_{i=0}^{\eta(x)} f_i\, p_{t+i} + \gamma \sum_{i=0}^{\eta(x)} f_i\, q_{t+i} \right] + \sigma_{\epsilon_x}\, \epsilon_{x,t},$	(M-2a)
	where $q_t = y_t - y_t^*$	
Contract Wage: Fuhrer-Moore	$x_t - p_t = \mathrm{E}_t \left[\sum_{i=0}^{\eta(x)} f_i\, v_{t+i} + \gamma \sum_{i=0}^{\eta(x)} f_i\, q_{t+i} \right] + \sigma_{\epsilon_x}\, \epsilon_{x,t},$	(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	$r_t = l_t - 4\, \mathrm{E}_t \left[\frac{1}{\eta(l)}\, (p_{t+\eta(l)} - p_t) \right]$	(M-4)
Term Structure	$l_t = \mathrm{E}_t \left[\frac{1}{\eta(l)} \sum_{j=1}^{\eta(l)} i_{t+j-1} \right]$	(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	$e_t^{(i,j)} = \mathrm{E}_t \left[e_{t+1}^{(i,j)} \right] + 0.25 \left(i_t^{(j)} - 4\, \mathrm{E}_t \left[p_{t+1}^{(j)} - p_t^{(j)} \right] \right)$	
	$- 0.25 \left(i_t^{(i)} - 4\, \mathrm{E}_t \left[p_{t+1}^{(i)} - p_t^{(i)} \right] \right)$	(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.

The long-term real interest rate is related to the long-term nominal rate and inflation 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 our 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 central banks's inflation target π^* and to deviations of actual output from potential.

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. Alternatively, we can 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 bilateral exchange rate need not satisfy uncovered interest parity exactly.[15]

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 B**. 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)).

[15] Such specification (cf. Dornbusch (1980, 1987)) is also considered by McCallum (2000) and Svensson (2001).

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

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 quartely 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.

A.2 The model of Benigno and Benigno (2001)

Key features of the model

- The model assumes imperfect competition and nominal rigidities due to Calvo-style contracts.
- There are many differentiated goods falling in two classes, home goods (H) and foreign goods (F).
- Markets are complete and the law of one price holds. There is perfect risk sharing in consumption.
- There are two types of shocks, government spending shocks (g) and productivity shocks (a).
- Country-specific demand shocks and the terms of trade can create dispersion of output across countries.
- We use symmetric parameter values taken from Benigno and Benigno (2001).
- Notation: Y (output), C (world consumption), S (nominal exchange rate), P (producer price level), i (nominal interest rate), $T = SP^F/P^H$ (terms of trade), π (inflation), R (flex-price world real interest rate).
- Gaps concern the difference between actual values and flex-price equilibrium values.

Key equations

Home and foreign output:

$$\begin{aligned} Y_t^H &= (1-n)T_t + C_t + g_t^H \\ Y_t^F &= -nT_t + C_t + g_t^F \end{aligned}$$

World output gap:

$$\begin{aligned} \mathrm{E}_t[y_{t+1}^W] &= y_t^W + d_1(i_t^H - \mathrm{E}_t[\pi_{t+1}^H] - R_t) \\ &\quad + d_2(i_t^F - \mathrm{E}_t[\pi_{t+1}^F] - R_t) \end{aligned}$$

Terms of trade:

$$T_t = T_{t-1} + \Delta S_t + \pi_t^F - \pi_t^H$$

Uncovered interest parity:

$$\mathrm{E}_t[\Delta S_{t+1}] = i_t^H - i_t^F$$

Home and foreign inflation:

$$\begin{aligned} \pi_t^H &= k_1^H tt_t + k_2^H y_t^W + k_3^H \,\mathrm{E}_t[\pi_{t+1}^H] \\ \pi_t^F &= k_1^F tt_t + k_2^F y_t^W + k_3^F \,\mathrm{E}_t[\pi_{t+1}^F], \end{aligned}$$

where tt stands for terms-of-trade gap.

A.3 Additional simulation results for the micro-founded model

Figure A: Devaluation and Exchange-Rate Peg

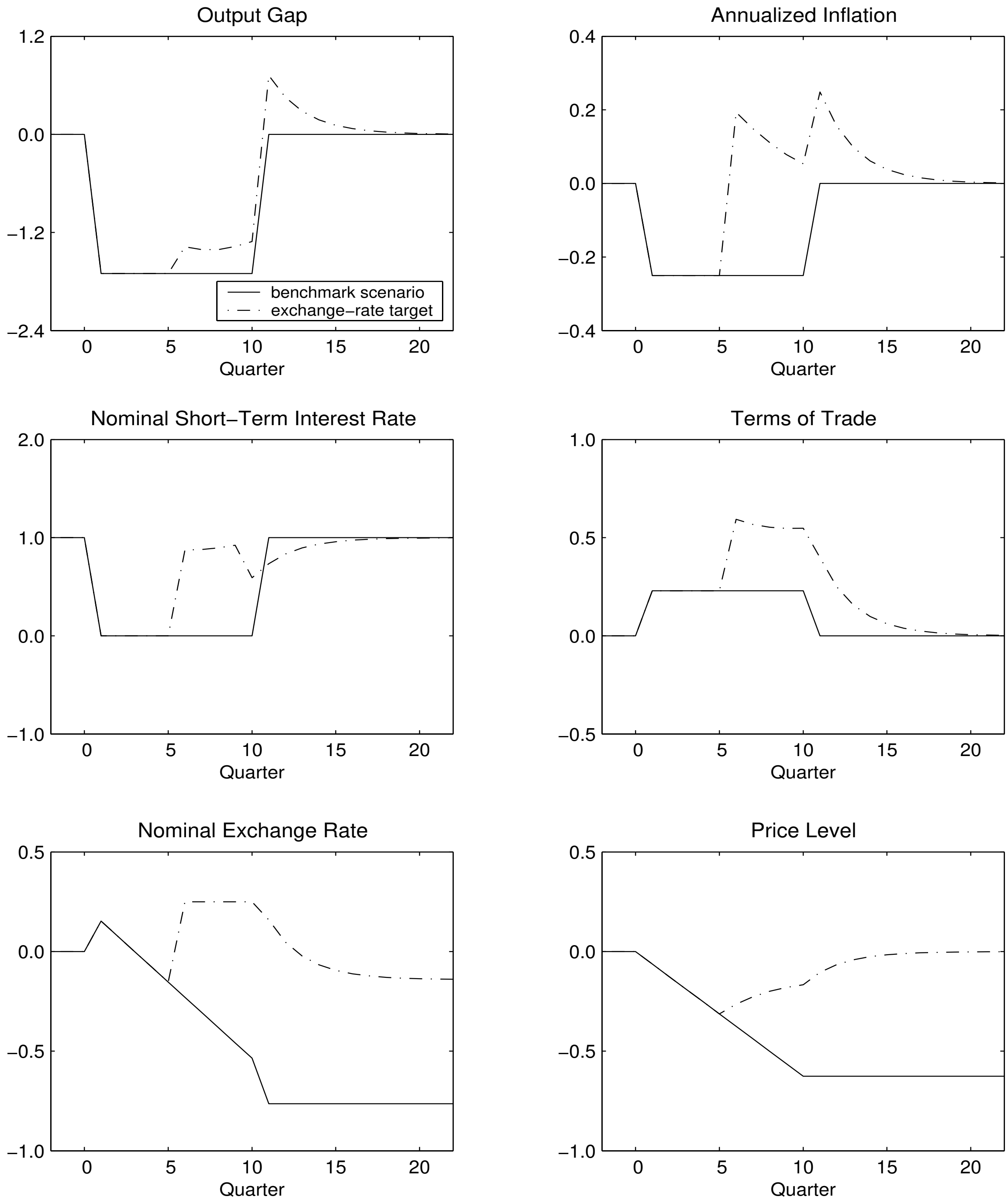


Figure B: Price-Level Targeting versus Exchange-Rate Peg