WP/08/25

IMF Working Paper

Why is Canada's Price Level So Predictable?

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INTERNATIONAL MONETARY FUND

 WP/08/25

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Western Hemisphere Department

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Authorized for distribution by Tamim Bayoumi

January 2008

Abstract

One of the pioneers of inflation targeting (IT), the Bank of Canada is now considering a possibility of switching to price-level-path targeting (PLPT), where past deviations of inflation from the target would have to be offset in the future, bringing the price level back to a predetermined path. This paper draws attention to the fact that the price level in Canada has strayed little from the path implied by the two percent inflation target since its introduction in December 1994, and has tended to revert to that path after temporary deviations. Econometric analysis using Bayesian estimation suggests that a low probability can be assigned to explaining this behavior by sheer luck manifesting itself in mutually offsetting shocks. Much more plausible is the assumption that inflation expectations and interest rates are determined in a way that is consistent with an element of PLPT. This suggests that the difference between IT as it is actually practiced (or perceived) and PLPT may be less stark than what pure theoretical constructs posit, and that the transition to a full-fledged PLPT regime will likely be considerably easier than what was previously thought. The paper also shows that inflation expectations are a major driver of actual inflation in Canada, which makes it easier to keep inflation close to the target without large output costs.

JEL Classification Numbers: E31, E52, E58

Keywords: Inflation targeting, Price level targeting, Bayesian estimation.

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[1] The authors gratefully acknowledge comments and contributions by Tamim Bayoumi, Michel Juillard, and seminar participants at the IMF and the Department of Finance, Canada, as well as excellent research assistance provided by Volodymyr Tulin.

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I. INTRODUCTION

Canada was the second country in the world to introduce inflation targeting (IT). After more than fifteen years in operation, the regime is largely judged as highly successful (Bayoumi and Klyuev, 2007), and the inflation-control agreement between the Bank of Canada and the Government of Canada has recently been renewed until the end of 2011. IT regimes have now been successfully adopted in about two dozen advanced and emerging-market countries across the globe.[2]

While recognizing the success of IT, several academics (Svensson, 1999; Cecchetti and Kim, 2005) and central bankers (King, 1999; Dodge, 2005) have wondered whether price-level-path targeting (PLPT) might be more consistent with the mandate for price stability that most central banks have and whether it might also have better stabilization properties, especially in the vicinity of the zero lower bound on interest rates.[3] At the latest renewal of the inflation-targeting agreement in November 2006, the Bank of Canada formally announced its interest in studying the benefits and costs of price-level targeting, particularly in conjunction with a lower inflation target, and launched a research program to inform its decision on whether to change its regime in 2011.

This interest has stimulated substantial amount of research dedicated to studying the relative merits of IT and PLPT.[4] With PLPT never actually implemented, the comparisons are often based on the performance of these regimes in model economies, typically of the DSGE type. These models assume pure, “textbook” versions of the two regimes.[5] Specifically, under pure IT, bygones are bygones, and the central bank always tries to bring *the inflation rate* smoothly to the target, regardless of whether the target was overshot or undershot in the past. In contrast, a PLPT central bank would aim to bring *the price level* to the path implied by the targeted rate of inflation and the initial level of the price index at the time the regime is established. This is equivalent to targeting *average inflation* over time and requires compensating past deviations from the targeted inflation rate by future deviations in the opposite direction.

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[2] See Batini and Laxton (2007).

[3] See Laxton, N’Diaye and Pesenti, (LNP: 2006). LNP prefer the term Price-Level-Path Targeting to Price-Level Targeting as the former explicitly recognizes that there must be a positive slope to the target path to avoid costly deflationary spirals caused by hitting the zero interest rate floor.

[4] A representative sample of this work can be found in the proceedings of the Bank of Canada’s conference on the *New Developments in Monetary Policy Design*.

[5] Hybrid regimes are also occasionally considered.

While the difference between PLPT and IT is clear cut theoretically, it may be much less clear to market participants. According to Mervyn King (2000), "in the public eye there is a much less clear distinction between price level and inflation targeting than in the academic literature." In the Canadian framework, the inflation target is described as "the 2 per cent mid-point of the 1 to 3 per cent inflation-control range." While the Bank of Canada's Monetary Policy Reports (MPR) and interest rates announcements provide broad indications about how monetary policy will guide the inflation rate to the two percent target in the future, the Bank does not publish an explicit path for the policy rate.[6] At the same time, assessments of past performance invariably emphasize that average inflation has been close to that target since it was introduced. And indeed, the behavior of Canada's consumer price index (CPI) since December 1994, when the 2 percent target became effective, resembles much closer a stationary process around a constant trend than a random walk with drift, which is the process it would follow under pure IT.[7]

While such behavior may be due to luck, with positive shocks to inflation exactly offsetting negative ones, this paper suggests that such happenstance is very unlikely. A much more plausible explanation involves a term on the deviation of the expected price level from a targeted path in the monetary policy reaction function. This could be because the Bank of Canada is genuinely concerned about these deviations and tries to correct them or because market participants believe that it behaves in this way and factor these beliefs into their forecasts of interest rates and their effects on future inflation.

To distinguish between these alternative explanations, the paper applies Bayesian estimation techniques to a simple model of the Canadian economy. The model is built around Woodford-style three-equation systems for Canada and the United States, connected through an interest-rate parity condition and augmented with stochastic processes for equilibrium variables (such as potential output, natural rate of unemployment, neutral interest rate, equilibrium exchange rate, and the inflation target). This is a familiar, widely-used model, with a relatively small number of parameters, which facilitates system estimation on a fairly

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[6] Publishing a path for the policy rate as well as all the assumptions that are used to construct the baseline forecast and confidence bands would make it considerably easier to evaluate performance from an ex ante perspective and allow researchers to more easily distinguish between competing interpretations of outcomes. For example, outcomes will depend critically on expectations by participants in the bond market about the expected systematic component of monetary policy, as this will influence the market-based interest rates and asset prices that are relevant for spending decisions. Following New Zealand, the Norges Bank and Riksbank have recently started to publish the endogenous interest rate forecast paths that are used to anchor inflation in their macro projections. In addition, the Czech National Bank has also announced plans to start releasing this information to improve operational transparency.

[7] Average inflation has also been close to the target in a number of other industrial countries with IT regimes, such as the United Kingdom.

short sample. This model represents a quasi reduced form of several different structural models, so we do not have to take a position on what the "true" structure of the economy is. Bayesian estimation has several advantages over classical estimation for the purposes of this project. It allows flexible stochastic processes and deals easily with unit roots. Bayesian estimation works better in small samples, as it facilitates bringing relevant information into the process and restricts the parameter space to plausible values. It also allows model validation and comparisons between models in terms of their plausibility, and yields useful estimates of uncertainty.

In the next section, we remind the reader of the basic differences between IT and PLPT. We then state several reasons why an IT central bank might be, or appear to be, mindful of where the price level is relative to an implied target. Section III introduces the model. Section IV presents estimation results. The last section concludes.

II. Differences Between IT and PLPT in Theory and in Practice

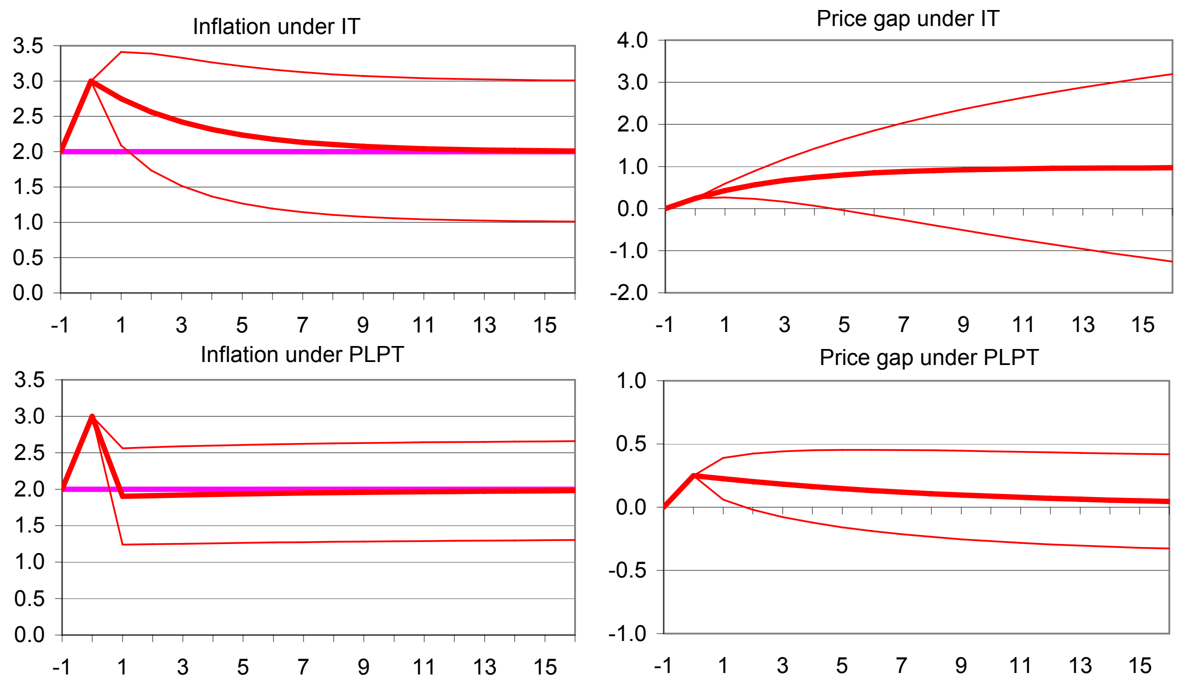
Under pure IT, the central bank may attempt to bring the rate of inflation smoothly back to the target without regard to historical deviations of past inflation from the target. As a result, the path that the bank envisages for inflation might never cross the target rate, but rather may converge to it gradually from above or below the target.[8] The top left panel of Figure 1 provides an example of a forecast for inflation where the initial value for inflation is 1 percentage point above the target. While the inflation rate will be stationary under IT, the price level will follow a random walk with drift, and the conditional forecast variance of the deviation of the price level from a path implied by a constant inflation rate will grow without bound (Figure 1, top right).

In contrast, the targeted path of inflation under PLPT depends not only on where the inflation rate currently is relative to the target, but also on where the price level is, i.e. what inflation has been in the past. If both the inflation rate and the price level are initially at their respective targets, and then a shock pushes the inflation rate up, monetary policy will have to bring the inflation rate below its long-term target for some period (Figure 1, bottom left), so that the price level converges back to the target (Figure 1, bottom right). Under that regime, the deviations of the price level from the target will be mean-reverting, and their forecast variances will be bounded at long horizons. Moreover, in models with significant forward-looking behavior, the unconditional variance of inflation will also be lower when the

[8] Strictly speaking, this is true of "core" inflation, since headline inflation may be affected by base effects and by changes in indirect taxes.

monetary authority targets a price-level path than when it targets inflation, for the same distribution of shocks and the same variability in the policy rates.[9]

Figure 1. Inflation rate and the deviation of the price level from constant growth path after one-period shock under inflation targeting and price level path targeting.



Note: Thin lines show illustrative bands based on 1 standard deviation.

Source: Authors' simulations.

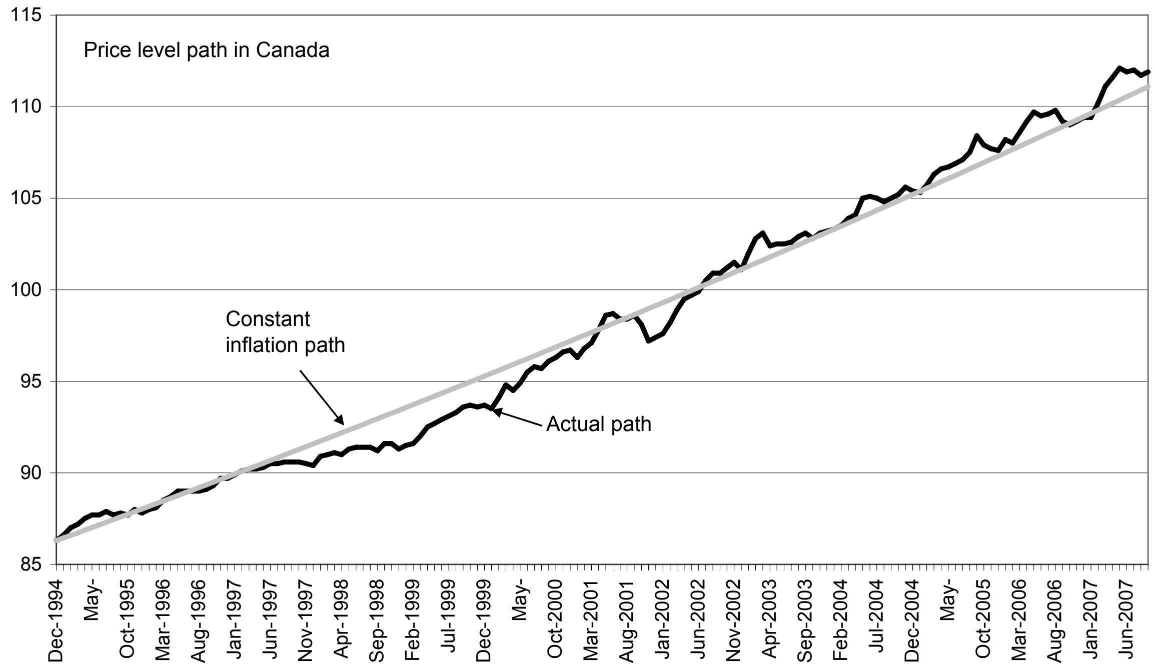
If one looks at the actual behavior of the CPI level in Canada (Figure 2), it is striking how little that path has strayed from the constant inflation path and how it tends to revert to that path after temporary deviations. The gap between the price level and its implicit target hardly resembles a random walk (Figure 3).

This fact, of course, has not escaped notice. Governor Dodge (2005), when he discussed the possibility of introducing PLPT in Canada in the future, noted that the actual price level at the time was very close to what it would have been had inflation stayed exactly on target since December 1994. He also added that under the current regime the price level might well deviate in the future from that path if a series of shocks moved inflation predominantly in one direction, implicitly ascribing the apparent mean reversion to happenstance.

[9] Fillion and Tetlow (1994) find that a price-level target improves inflation control, but at the cost of increased output variability. Black, Macklem, and Rose (1997) show that this depends importantly on how expectations are formed and that when expectations are forward looking, price level targeting can reduce the variance of both inflation and output.

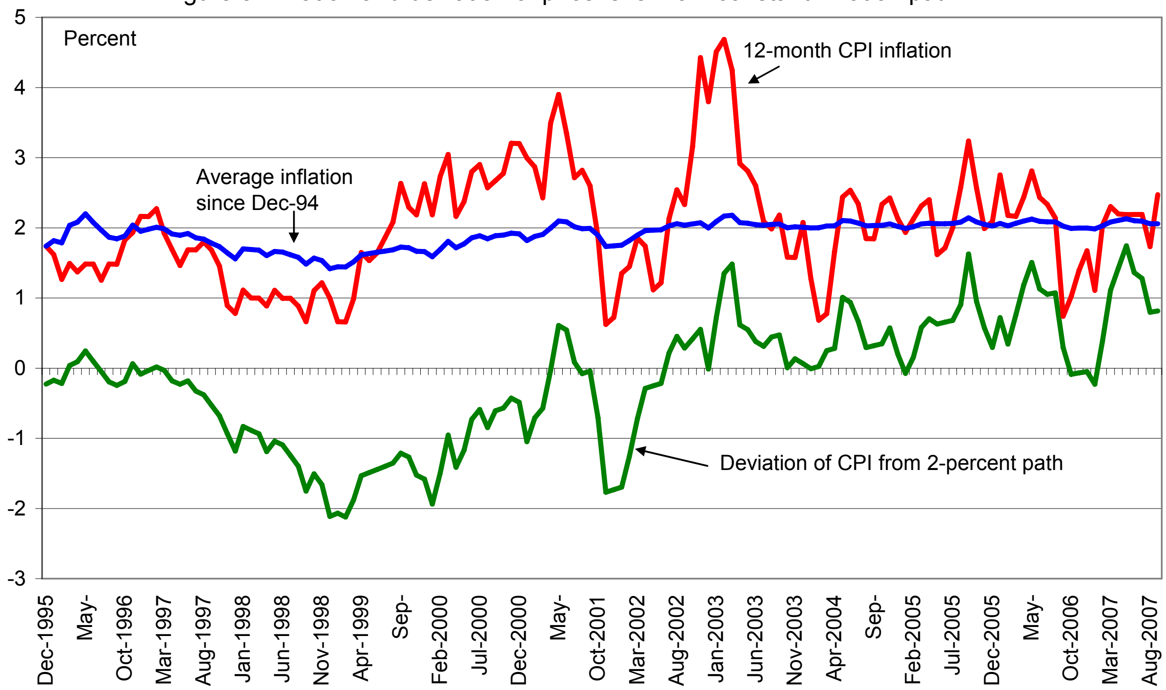
While being struck with exactly offsetting shocks over the period that is longer than a decade is not impossible, one would want to consider alternative explanations. For given shocks and the structure of the economy, inflation outcomes are determined by monetary policy and by market expectations of future interest rates and inflation. So it is natural to entertain a

Figure 2. Evolution of CPI in Canada since introduction of the 2 percent target.



Note: The straight line shows a path implied by constant 2 percent inflation.
Sources: Statistics Canada; and authors' calculations.

Figure 3. Inflation and deviation of price level from constant inflation path.



Sources: Statistics Canada; and authors' calculations.

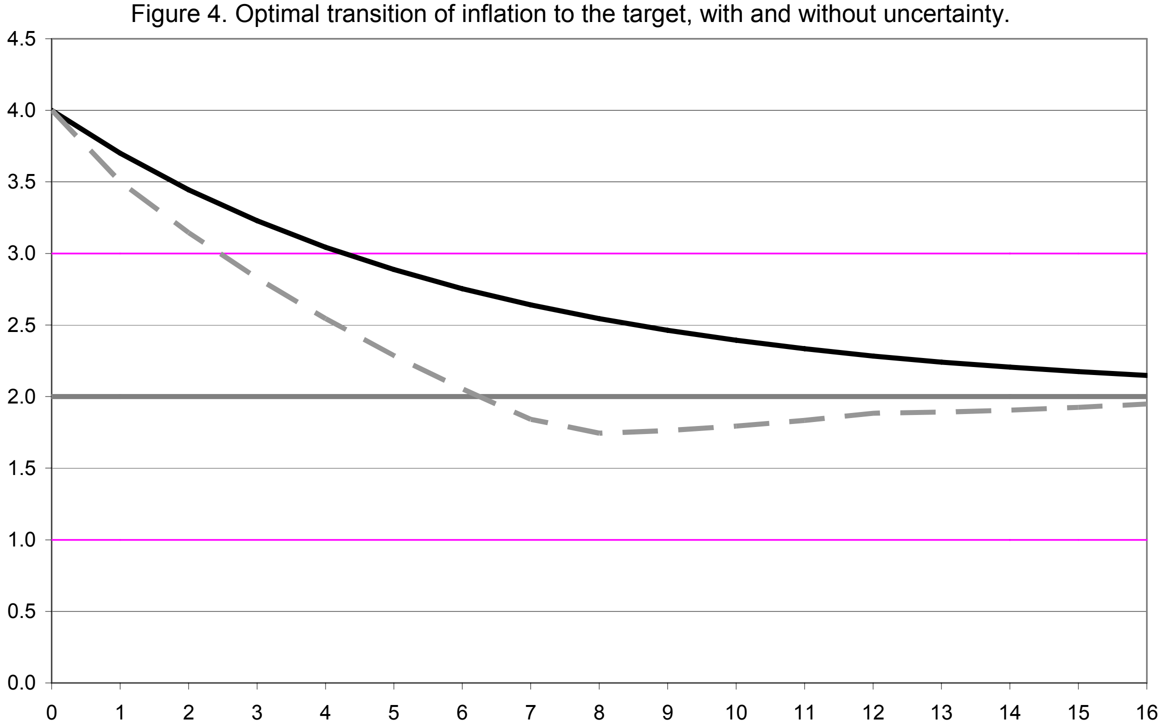
hypothesis that interest setting and expectation formation are consistent with an element of PLPT.

Why would a central bank that professes IT in fact guide the price level, perhaps over a long period, toward a certain path, or why could it be perceived as doing so by the markets? We suggest two reasons. One has to do with accountability, communication, and credibility, and the other with optimization under uncertainty.

Mervyn King (1999) finds the contrast between IT and PLPT "somewhat artificial." He points out that the central bank is accountable to the public and to the parliament. The central bank will be perceived as doing a good job as an inflation targeter if the average inflation over the IT period has been close to the target. This backward-looking criterion is much easier to understand and verify than whether the bank is successful in targeting future inflation or the inflation forecast—a notion that is elusive and not readily verifiable. Indeed, the Bank of Canada has offered the fact that average inflation has been close to the 2 percent target as evidence of the success of its monetary policy (Longworth, 2002). This accomplishment is also featured prominently in the recent *Joint Statement of the Government of Canada and the Bank of Canada on the Renewal of the Inflation-Control Target*—the highest-level document defining Canada's monetary policy regime. However, one can easily see that keeping average inflation close to the target is equivalent to PLPT. Moreover, if the public expects the central bank to keep inflation rather close to the target on average, the central bank cannot ignore these expectations, as frustrating them might undermine the bank's credibility and complicate its control of the economy.

There is an important second reason for adjusting interest rates more aggressively than pure IT would suggest and pushing inflation temporarily to the other side of the inflation target after a shock. It has to do with optimization under uncertainty with an objective function where the cost of deviating from the inflation target grows more than proportionately with the deviation. Suppose that the optimal trajectory for bringing the inflation rate to the target after a temporary deviation in the absence of further shocks were the path shown by the solid line in Figure 4. If the central bank sets its interest rate to target that path, future shocks will push inflation off that trajectory, and actual inflation may overshoot or undershoot the solid line. If the bank has a quadratic loss function, or is very averse to inflation staying outside its target band, the bank will not be indifferent between overshooting and undershooting. Hence, in the presence of uncertainty (about future shocks as well as about the effects of monetary policy) it is likely to target a lower path, like the one shown by dashes, which may take inflation below the target for some time. While the projections in the *Monetary Policy Report* always show a smooth convergence of (core) inflation to the target from above or from below, depending on the initial position (like the solid line), most optimizing stochastic models will select a transition path with overshooting to the other side of the inflation target (like the dashed line). Hence, optimal monetary policy under uncertainty involves some correction in the price level, even if that level is not in the objective function.

Figure 4. Optimal transition of inflation to the target, with and without uncertainty.



Sources: Authors' simulations.

A variation of this argument stresses the fact that the Bank of Canada puts an emphasis in its communications on keeping inflation within the 1–3 percent target band. This may lead market participants to believe that the Bank aims to keep inflation within the band a very large proportion of the time. Given that PLPT shrinks the distribution of inflation outcomes, the markets may form their expectations in a way consistent with a positive term on the price gap in the monetary policy reaction function.

III. Model

To test the relative likelihood of the explanations of the apparent trend-stationarity, we estimate a small model of the Canadian economy. The model is built around a popular three-equation system: the IS curve, the Phillips curve, and a forward-looking Taylor rule.

The IS equation (1) relates Canada's output gap (y_t) to past and expected future output gap, the deviations of the real interest rate (r_t) and the real exchange rate (z_t) from their equilibrium values, and the U.S. output gap. The real interest rate is defined as the nominal interest rate minus expected inflation, and the real exchange rate is defined in such a way that an increase means depreciation.

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t+1} + \beta_3 \left(r_{t-1} - \overline{r}_{t-1} \right) + \beta_4 \left(z_{t-1} - \overline{z}_{t-1} \right) + \beta_5 y_t^{US} + \varepsilon_t^y \qquad (1)$$

In the Phillips curve (2), the inflation rate (π_t) depends on the expected future and past 4-quarter inflation ($\pi 4_{t+4}$ and $\pi 4_{t-1}$, with coefficients adding up to one), the lagged value of the output gap, and the rate of real depreciation.

$$\pi_t = \lambda_1 \pi 4_{t+4} + \left(1 - \lambda_1\right) \pi 4_{t-1} + \lambda_2 y_{t-1} + \lambda_3 \Delta z_t + \varepsilon_t^{\pi} \qquad (2)$$

The interest rate equation (3) takes the form of a forward-looking Taylor rule. The nominal interest rate (i_t) is a function of the past rate, the neutral real rate, expected future inflation, the output gap, and the deviations of expected inflation and the price level from their respective targets. If the coefficient γ_3 on the price level gap equals zero, we have the standard Taylor rule. If the coefficient is positive, we have a hybrid Taylor rule, which will guarantee the stationarity of deviations of the price level from the targeted path over the long run. Since bringing the price level back to the target would require more aggressive interest rate action and hence a larger swing in the output gap than bringing inflation back to the target over the same time horizon, the monetary authority is assumed to target the price level 8 quarters into the future, while the horizon for the inflation target is taken to be 4 quarters.

$$i_t = \gamma_1 i_{t-1} + \left(1 - \gamma_1\right) \left[\overline{r}_t + \pi 4_{t+4} + \gamma_2 \left(\pi 4_{t+4} - \overline{\pi} \right) + \gamma_3 \left(p_{t+8} - \overline{p}_{t+8} \right) + \gamma_4 y_t \right] + \varepsilon_t^i \qquad (3)$$

To match the model to the data, we need to specify a process for potential output, so that we can add potential output to the output gap and obtain real GDP. We posit a very flexible process for potential output (equation 4), allowing shocks to its level and persistent deviations from trend growth (equation 5).

$$\overline{y}_t = \overline{y}_{t-1} + \frac{g_t}{4} + \varepsilon_t^{\overline{y}} \tag{4}$$

$$g_t = \tau_1 g^{ss} + \left(1 - \tau_1\right) g_{t-1} + \varepsilon_t^g \tag{5}$$

To help identify the output gap, we posit that it is linked to the deviations of the unemployment rate and the industrial capacity utilization rate from their equilibrium values (equations 6 and 7), with equilibrium values following random walk processes (equations 8 and 9).

$$u_t - \overline{u}_t = \omega_1 \left(u_{t-1} - \overline{u}_{t-1}\right) + \omega_2 y_t + \varepsilon_t^{\left(u_t - \overline{u}_t\right)} \tag{6}$$

$$capu_t - \overline{capu}_t = y_t + \varepsilon_t^{\left(capu_t - \overline{capu}_t\right)} \tag{7}$$

$$\overline{u}_t = \overline{u}_{t-1} + \varepsilon_t^{\overline{u}} \tag{8}$$

$$\overline{capu}_t = \overline{capu}_{t-1} + \varepsilon_t^{\overline{capu}} \tag{9}$$

The equilibrium real exchange rate is also assumed to be a random walk (10), while the equilibrium real interest rate follows an AR(1) process (11).

$$\overline{z}_t = \overline{z}_{t-1} + \varepsilon_t^{\overline{z}} \tag{10}$$

$$\overline{r}_t = \rho \overline{r}^{ss} + \left(1 - \rho\right) \overline{r}_{t-1} + \varepsilon_t^{\overline{r}} \tag{11}$$

The U.S. economy is characterized by a similar set of equations, with a few exceptions. Specifically, there are no terms on foreign output or the exchange rate in the IS curve; the unemployment rate and the capacity utilization rate are not brought into the picture; and there is no price level target in the Taylor rule. Since the United States does not have a formal inflation target, the inflation target in the U.S. Taylor rule is assumed to follow a random walk process.[10]

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[10] This does not mean that we believe that the Fed randomly picks an inflation target every quarter. Specifying processes as random walks allows us to accommodate slow changes in equilibrium variables without taking a position on what drives these changes.

Finally, the interest parity condition (12) links the U.S. and Canadian economies.

$$r_t - r_t^{US} = 4\left[\left(\phi z_{t+1} - (1-\phi) z_{t-1}\right) - z_t\right] + \left(\bar{r}_t - \bar{r}_t^{US}\right) + \varepsilon_t^z \qquad (12)$$

The condition is fairly standard, except it allows the "expected" exchange rate to be a linear combination of the model-consistent and backward-looking expectations and incorporates an equilibrium risk premium. The factor 4 before the square brackets annualizes the expected quarterly depreciation rate, to make it consistent with the interest rate quoted on the annual basis.

IV. ESTIMATION

We estimate the parameters of the system described in the previous section using Bayesian techniques on quarterly data from 1994Q4 to 2006Q4. Inflation is measured as a change in the log of the consumer price index, and the interest rate is the policy rate (the overnight interbank rate for Canada and the federal funds rate for the United States). We impose the following priors, based on previous work with similar models (Table 1).

Table 1. Priors of model parameters.

Param.	Mean	Distr.	St. dev.	Param.	Mean	Distr.	St. dev.
λ_2	0.25	gamma	0.05	$\overline{r}^{ss}$	2	normal	0.5
λ_3	0.1	gamma	0.05	ω_1	0.8	beta	0.1
β_1	0.75	gamma	0.1	ω_2	0.3	gamma	0.2
β_2	0.15	beta	0.05	g_f^{ss}	3	normal	0.5
β_3	0.2	gamma	0.05	$\overline{r}_f^{ss}$	2	normal	0.2
β_4	0.05	gamma	0.003	β_f^1	0.75	beta	0.1
β_5	0.3	gamma	0.1	β_f^2	0.15	beta	0.05
γ_1	0.75	beta	0.05	β_f^3	0.2	gamma	0.05
γ_2	1.5	gamma	0.2	λ_f^1	0.4	beta	0.1
λ_2	0.25	gamma	0.05	λ_f^2	0.25	gamma	0.05
γ_4	0.5	gamma	0.05	γ_f^1	0.75	beta	0.1
τ	0.1	beta	0.05	γ_f^2	1.5	gamma	0.3
g^{ss}	3	normal	0.5	γ_f^4	0.5	gamma	0.2
ϕ	0.6	beta	0.2	γ_f^4	0.5	gamma	0.2
ρ	0.2	beta	0.07				

The main parameters we experiment with are λ_1 (the coefficient on inflation expectations in the Phillips curve) and γ_3—the coefficient on the gap between the expected price level and its implicit target in the Taylor rule. The metric used to evaluate how well the model (including the prior restrictions on the parameters) fits the data is the marginal data density. The ratios of the exponentials of these numbers may be interpreted as odds ratios—the relative probabilities of the models being consistent with the historical data.

Table 2 contains the results of our four main experiments.[11] We consider two different assumptions about how "agile" the economy is, with a high (0.75) and a low (0.25) prior on the forward-looking coefficient λ_1 in the inflation equation. In both cases the priors are quite tight, with the standard deviations of 0.05. Secondly, we either allow an element of price level targeting or set the coefficient γ_3 on the price level gap to zero.

[11] More detailed estimation results and impulse response functions are provided in the Appendix.

Table 2. Estimation results.

	prior						posterior					
	λ_1			γ_3			λ_1		γ_3		LDD	Odds
	mean	st.dev	distr.	mean	st.dev	distr.	mode	st. dev	mode	st.dev		
1	0.75	0.05	beta	0.3	0.1	normal	0.742	0.054	0.368	0.092	-424.84	100
2	0.75	0.05	beta	0	0		0.783	0.056			-434.31	0.007713141
3	0.25	0.05	beta	0.3	0.1	normal	0.336	0.092	0.234	0.120	-450.29	8.85534E-10
4	0.25	0.05	beta	0	0		0.292	0.060			-444.63	2.5428E-07

Note: LDD is log data density. Odds are relative to case number 1

Of the four cases considered, the first one fits the data by far the best. This case assumes a high weight on inflation expectations in the Phillips curve, which makes it easier for the central bank to stabilize inflation around the target without having to move the output gap too much, and an element of PLPT, with the estimated coefficient of 0.37 on the price level gap.

The model where the inflation process is as forward-looking, but price level plays no role in the interest rate setting fits the data substantially worse, with the odds of 1 to 10000 that the data-generating process looks like that model rather than the previous one. This tells us that chances are rather slim that a particular configuration of shocks was responsible for pulling repeatedly the price level to the path implied by a constant 2 percent inflation rate, without interest rates reacting to the price level gap.

Imposing a lower weight on expected inflation, thus making the Phillips curve more backward-looking, results in a dramatically lower marginal data density. Comparing the posterior with the prior, one can see that the data pushes the estimate of λ_1 up. The data does not appear to be consistent with the notion that the Canadian economy is highly inertial. This is in line with the results of Bayoumi and Klyuev (2007), who find that the Phillips curve has become substantially more forward-looking in Canada since the introduction of inflation targeting and estimate the coefficient on expected inflation at 0.71.

The case with a backward-looking Phillips curve and a term on the price level gap in the Taylor rule fits the data particularly poorly. The reason for that is that in a highly inertial economy, interest rates would have to stay rather high (and output gap depressed) for a fairly long period of time to bring the price level back to the target after an inflationary shock. Such persistence, however, is not present in the data.

We conclude that the data are explained the best by a model that features a low degree of inflation persistence and a hybrid Taylor rule, with the interest rate raised by 37 basis points for one percent deviation of the price level expected 8 quarters into the future from the target path. Hence, an element of PLPT in interest rate setting is a considerably more plausible explanation of the behavior of Canada's CPI since the end of 1994 than pure happenstance.

It is important to emphasize that while these empirical results strongly reject a pure IT regime in favor of a PLPT regime, it may be more difficult to distinguish between alternative models that could be observationally equivalent over a small sample. Some of these competing explanations have predictions that are actually pretty close to PLPT. These include the following:

- The Bank based its interest rate setting on a view of the monetary transmission mechanism that had longer lags than what turned out to be the case ex post. This would not necessarily be exactly equivalent to PLPT, but might be observationally equivalent in a small sample.

- Market participants believed that the Bank was trying to keep inflation inside the 1-3 percent bands a very high proportion of the time. As illustrated in Figure 1, PLPT not only produces average inflation outcomes that are close to the target, but it also shrinks the unconditional distribution of inflation relative to a pure IT regime, where bygones are bygones.

- The price level gap may be simply a proxy for a nonlinear reaction function. On the upside the Bank may be concerned that persistent deviations above the 3 percent upper band may damage credibility and as a consequence they might respond more aggressively in such circumstances. On the downside the Bank may be concerned that persistent deviations below the 1 percent lower band risk flirting with deflation, which may also justify a more aggressive policy response. Both of these types of policy responses might be associated with some moderate overshooting to guard against the potential costs of not responding more aggressively.

We performed a large number of robustness checks. They included changing the lag structure in equations (1)–(3), changing the horizons for the inflation target and the price level target in the Taylor rule, replacing four-quarter inflation with one-quarter inflation in the Phillips curve and in the Taylor rule, using alternative measures of short-term interest rates, restricting the sample to shorter periods, and assigning different priors (including means, standard errors, and distribution shapes) to a number of estimated parameters. In particular, both the normal and the gamma distributions were used as priors for γ_3, and the no-PLPT case was also run with a normal prior distribution around zero on γ_3 rather than simply setting it to zero as was done in our baseline. All these experiments, whose results are available upon request, confirm our basic findings.

V. CONCLUSIONS

Our results suggest that interest rate setting in Canada since the mid-1990s has been consistent with a hybrid monetary policy rule, putting some weight on the deviations of inflation from the target and some on the deviations of the price level from the path implied by that target. This rule implies that bygones are not completely bygones, and the price level is (trend-) stationary in the long run. The alternative explanation, whereby the shocks that buffeted the Canadian economy over that period just happened to offset one another, so the price level only appears to be stationary, has fairly little likelihood.[12]

One reason why the Bank of Canada may be pursuing price stability (with a constant drift), or may be believed to be doing so by the markets is the perception that the average inflation should be close to the target if the Bank is doing a good job—a criterion in fact close to price level targeting. Another explanation could be that market participants believe that the Bank aims to keep inflation within the target band a large portion of the time—a goal whose achievement would be facilitated by targeting a price-level path. Our analysis is not designed to uncover the reason, or differentiate between the central bank's behavior and market beliefs.

This paper does not take a stand on whether PLPT is preferable to IT. Our results suggest, however, that should the Bank of Canada make a formal switch to PLPT, this step will likely be perceived by the markets as being a incremental innovation given that past outcomes have not been inconsistent with it. Consequently, it is likely that the credibility of the existing regime will carry over to the new regime, and the transition should involve little disruption.

Another way to interpret our results is that to the extent that there are benefits to PLPT relative to IT, the Bank of Canada may be reaping some of them already. At the same time, a formal announcement may still be very beneficial. In particular, the potential benefits of PLPT may be particularly hefty in case of a large deflationary shock, when a commitment to higher inflation in the short run raises inflationary expectations and lowers the ex-ante real interest rate substantially without the central bank having to move the nominal rate too close to the zero bound. Since the Bank of Canada has largely been untested in a deflationary environment, a formal commitment to PLPT would likely guide market expectations better than their inferences from past experience.

[12] It would be interesting to conduct a similar analysis for other industrial countries where average inflation has stayed close to the target.

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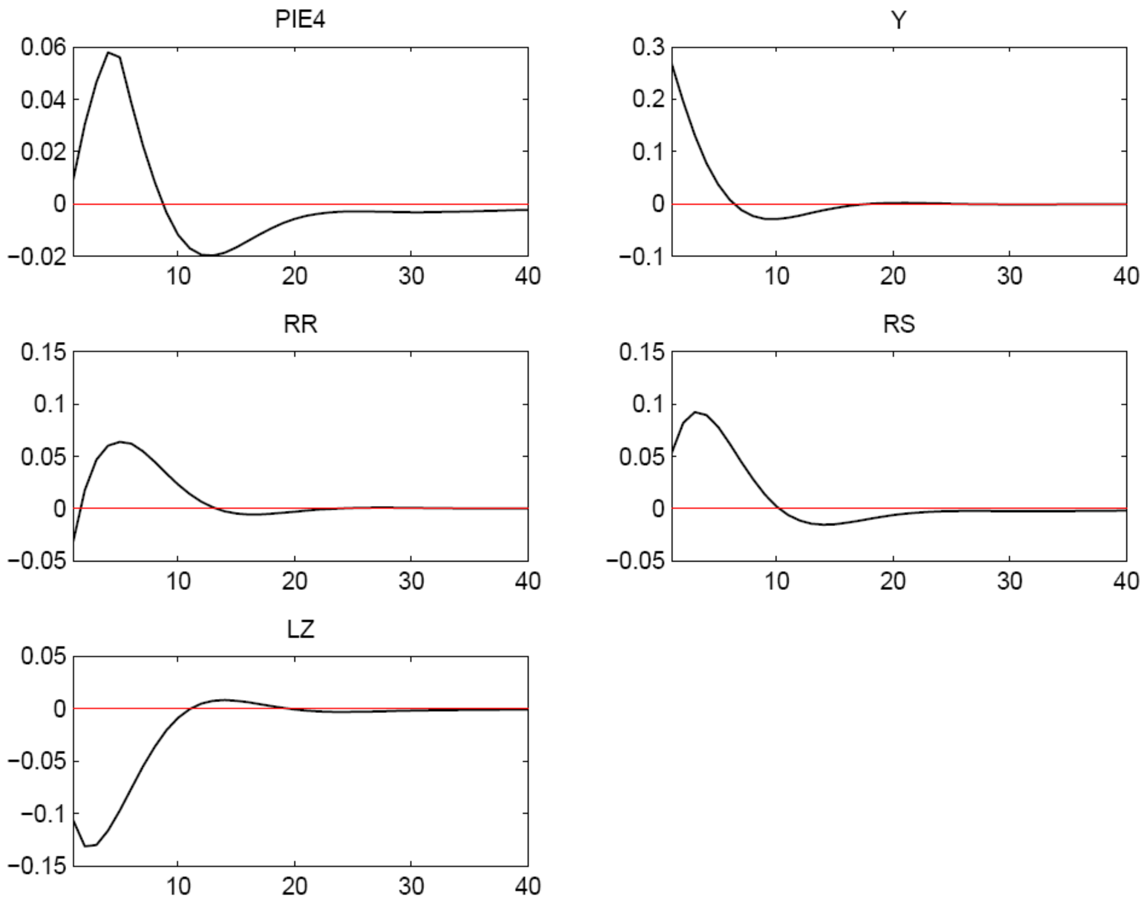
Appendix--Estimated Parameters and Impulse-Response Functions

Case 1. High λ_1, positive γ_3

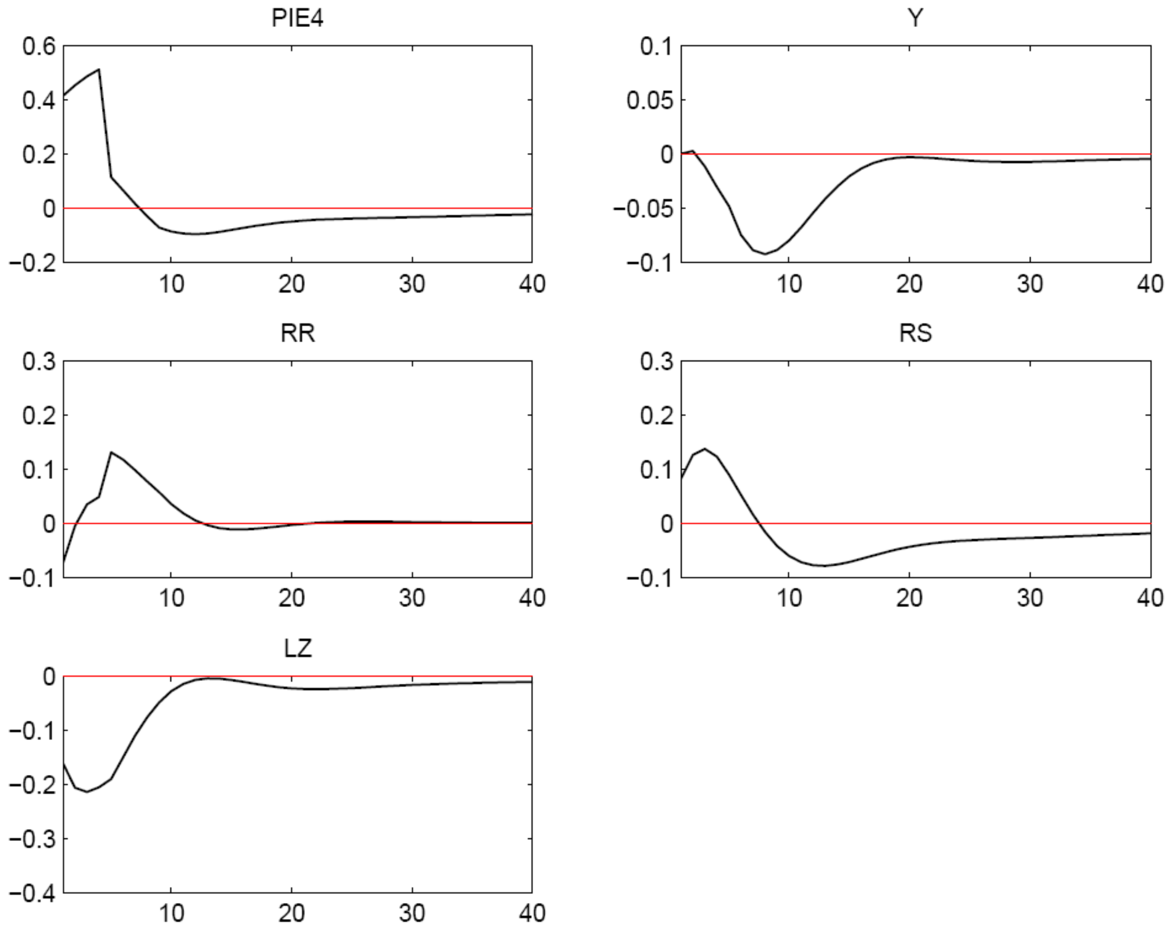
Table A1. Results from Posterior Maximization. Case 1						
parameters	**prior mean**	**mode**	**s.d.**	**t-stat**	**prior**	**pstdev**
λ_1	0.75	0.7419	0.0536	13.847	beta	0.05
λ_2	0.25	0.2047	0.0385	5.3138	gamma	0.05
λ_3	0.1	0.0435	0.0244	1.7873	gamma	0.05
β_1	0.75	0.6677	0.0709	9.4165	gamma	0.1
β_2	0.15	0.1259	0.0433	2.9048	beta	0.05
β_3	0.2	0.1673	0.0332	5.0376	gamma	0.05
β_4	0.05	0.0496	0.003	16.6668	gamma	0.003
β_5	0.3	0.1296	0.0412	3.1471	gamma	0.1
γ_1	0.75	0.8196	0.0316	25.9154	beta	0.05
γ_2	1.5	1.4636	0.1971	7.4258	gamma	0.2
γ_3	0.3	0.3684	0.0916	4.0223	normal	0.1
γ_4	0.5	0.4982	0.0499	9.9744	gamma	0.05
τ	0.1	0.0833	0.0392	2.1215	beta	0.05
g^{ss}	3	2.9849	0.3645	8.1888	normal	0.5
ϕ	0.6	0.8705	0.0632	13.7667	beta	0.2
ρ	0.2	0.1486	0.0854	1.7392	beta	0.07
$\overline{r}^{ss}$	2	2.7543	0.6217	4.4303	normal	0.5
ω_1	0.8	0.7676	0.0877	8.7491	beta	0.1
ω_2	0.3	0.1197	0.0407	2.9425	gamma	0.2
g_f^{ss}	3	3.0641	0.1482	20.6779	normal	0.5
$\overline{r}_f^{ss}$	2	1.7916	0.2273	7.8809	normal	0.2
β_f^1	0.75	0.853	0.382	2.2331	beta	0.1
β_f^2	0.15	0.1176	0.3431	0.3428	beta	0.05
β_f^3	0.2	0.0709	0.0659	1.0771	gamma	0.05
λ_f^1	0.4	0.4909	0.0715	6.8684	beta	0.1
λ_f^2	0.25	0.1612	0.1197	1.3472	gamma	0.05
γ_f^1	0.75	0.8501	0.0898	9.4701	beta	0.1
γ_f^2	1.5	1.1508	0.22	5.2316	gamma	0.3
γ_f^4	0.5	0.7885	0.6063	1.3006	gamma	0.2

Figure A1. The impulse responses to a one standard deviation shock to ε^y. Case 1



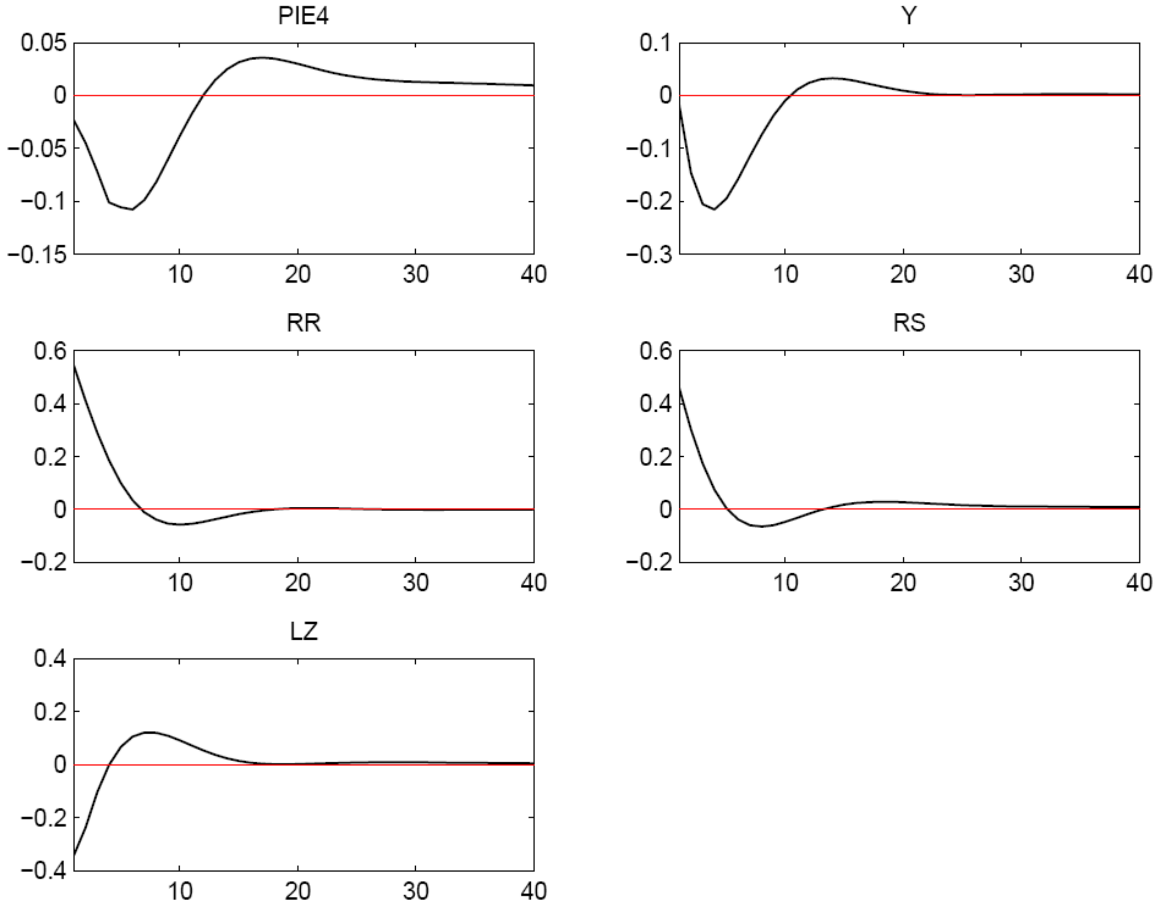
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A2. The impulse responses to a one standard deviation shock to ε^{π}. Case 1



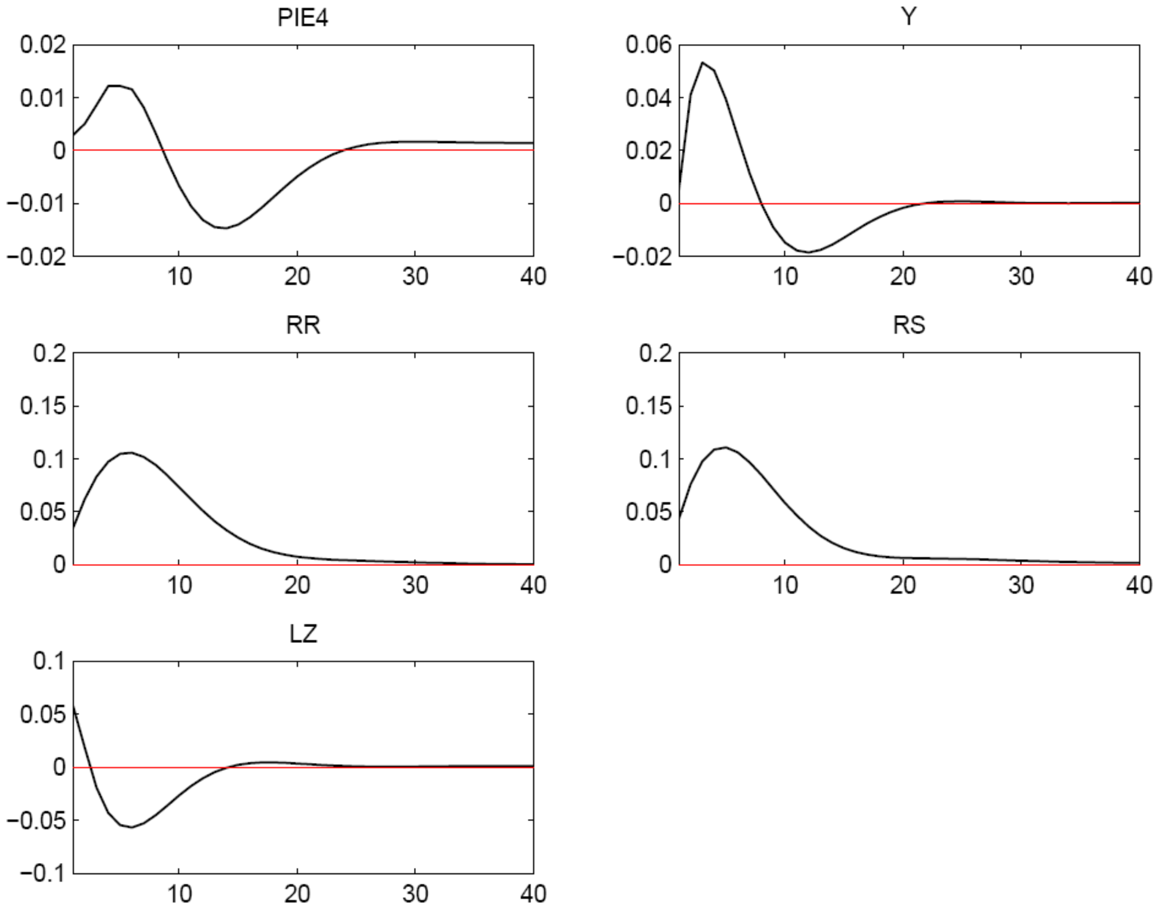
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A3. The impulse responses to a one standard deviation shock to ε^i . Case 1



Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A4. The impulse responses to a one standard deviation shock to $\varepsilon^{\bar{r}}$. Case 1

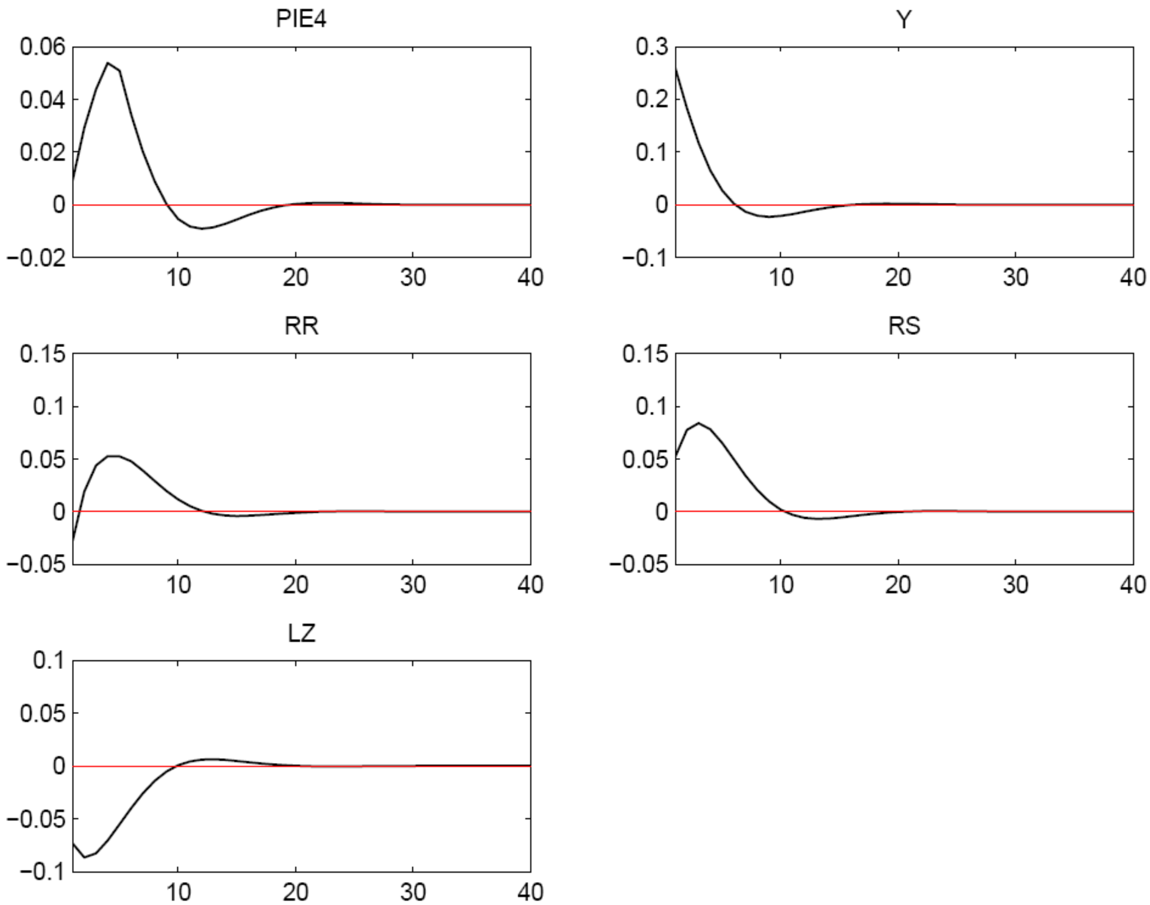


Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Case 2. High λ_1, zero γ_3

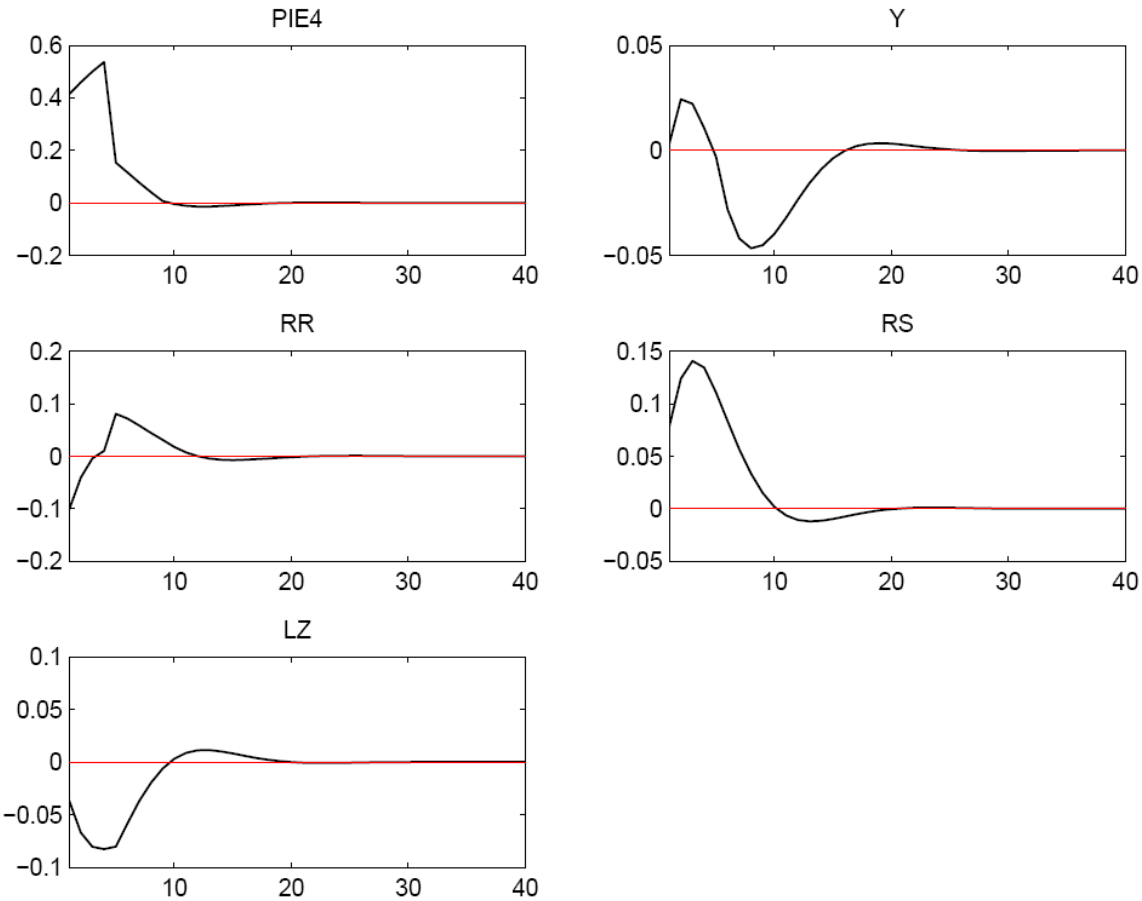
Table A2. Results From Posterior Maximization. Case 2						
parameters	**prior mean**	**mode**	**s.d.**	**t-stat**	**prior**	**pstdev**
λ_1	0.75	0.783	0.0558	14.0345	beta	0.05
λ_2	0.25	0.1983	0.0395	5.0173	gamma	0.05
λ_3	0.1	0.0395	0.0216	1.8264	gamma	0.05
β_1	0.75	0.6384	0.076	8.3977	gamma	0.1
β_2	0.15	0.1295	0.0475	2.7273	beta	0.05
β_3	0.2	0.2089	0.0529	3.9526	gamma	0.05
β_4	0.05	0.0493	0.003	16.644	gamma	0.003
β_5	0.3	0.1227	0.0441	2.7828	gamma	0.1
γ_1	0.75	0.7988	0.0389	20.5423	beta	0.05
γ_2	1.5	1.5243	0.2023	7.5335	gamma	0.2
γ_4	0.5	0.5037	0.0505	9.9829	gamma	0.05
τ	0.1	0.0814	0.0387	2.1023	beta	0.05
g^{ss}	3	2.9842	0.3657	8.1607	normal	0.5
ϕ	0.6	0.9251	0.0614	15.0668	beta	0.2
ρ	0.2	0.0776	0.0343	2.2612	beta	0.07
$\overline{r}^{ss}$	2	2.3366	0.3767	6.2027	normal	0.5
ω_1	0.8	0.7657	0.0845	9.0572	beta	0.1
ω_2	0.3	0.1237	0.0426	2.9045	gamma	0.2
g_f^{ss}	3	2.9767	0.1337	22.2704	normal	0.5
$\overline{r}_f^{ss}$	2	1.7592	0.1999	8.8002	normal	0.2
β_f^1	0.75	0.813	0.0356	22.8436	beta	0.1
β_f^2	0.15	0.1025	0.0351	2.924	beta	0.05
β_f^3	0.2	0.0556	0.0102	5.4643	gammaa	0.05
λ_f^1	0.4	0.562	0.0318	17.6611	beta	0.1
λ_f^2	0.25	0.1887	0.0341	5.5313	gammaa	0.05
γ_f^1	0.75	0.92	0.0226	40.6563	beta	0.1
γ_f^2	1.5	1.3251	0.2881	4.5992	gamma	0.3
γ_f^4	0.5	0.5459	0.2572	2.1223	gamma	0.2

Figure A5. The impulse responses to a one standard deviation shock to ε^{y}. Case 2



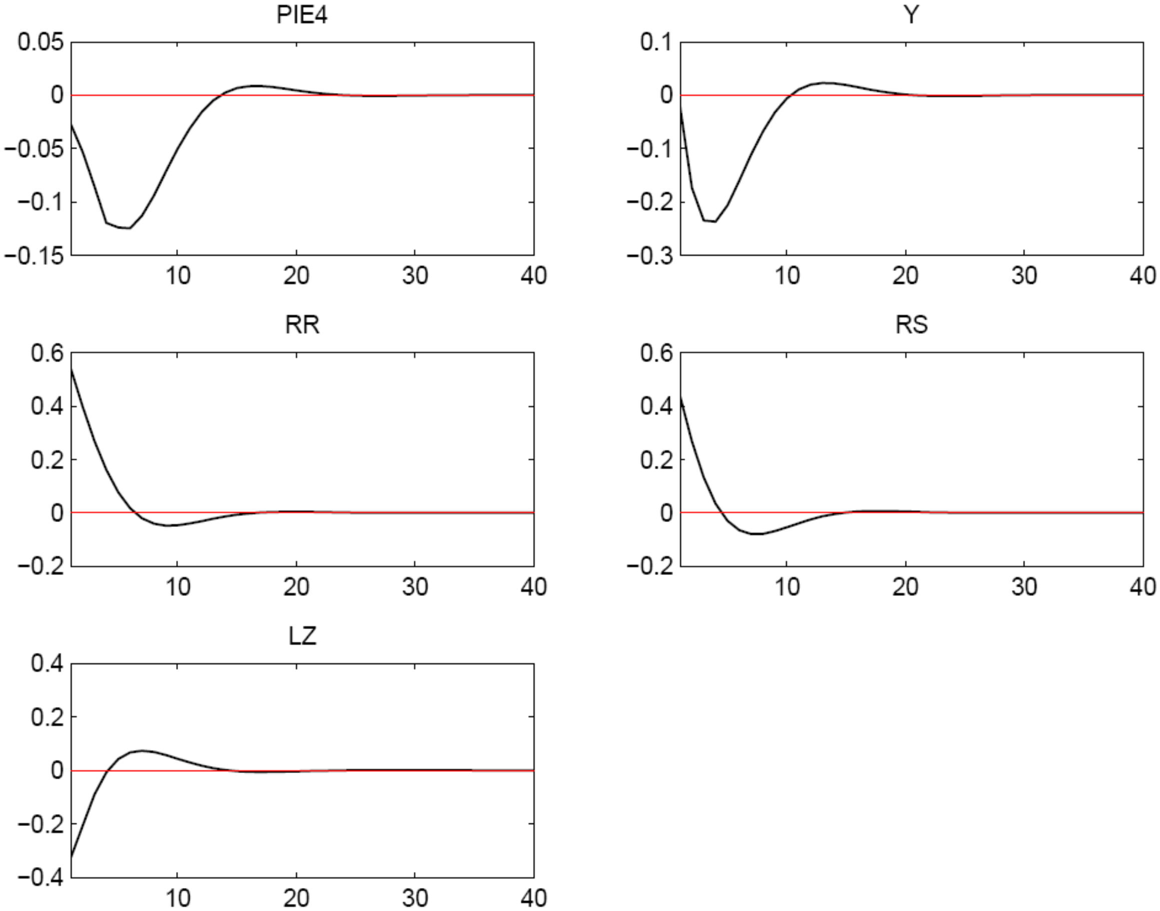
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A6. The impulse responses to a one standard deviation shock to ε^{π}. Case 2



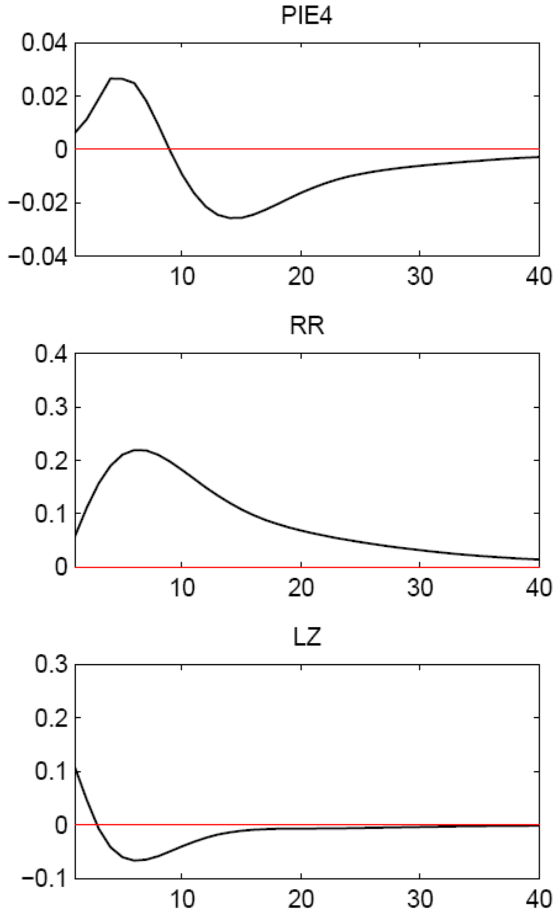
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A7. The impulse responses to a one standard deviation shock to ε^i . Case 2



Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A8. The impulse responses to a one standard deviation shock to $\varepsilon^{\bar{r}}$. Case 2



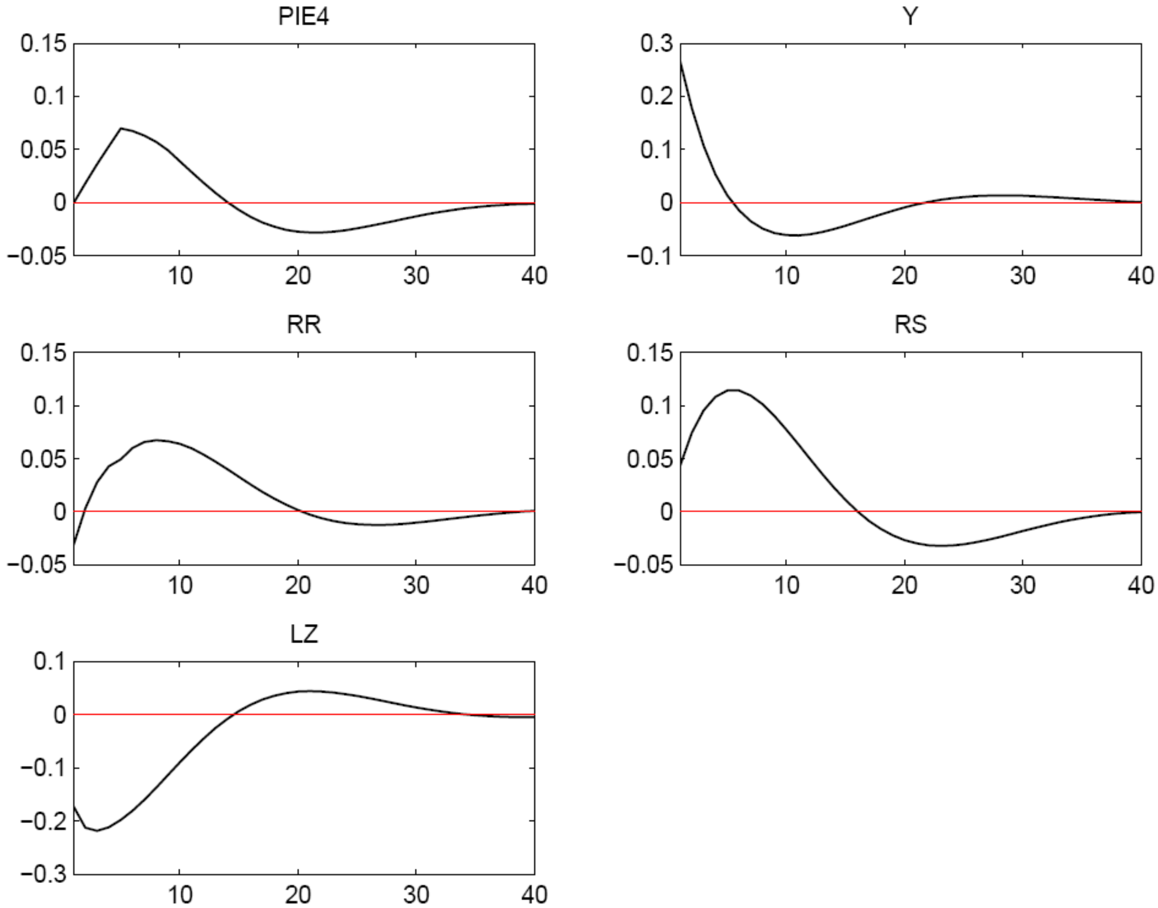
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Case 3. Low λ_1, positive γ_3

Table A3. Results From Posterior Maximization. Case 3

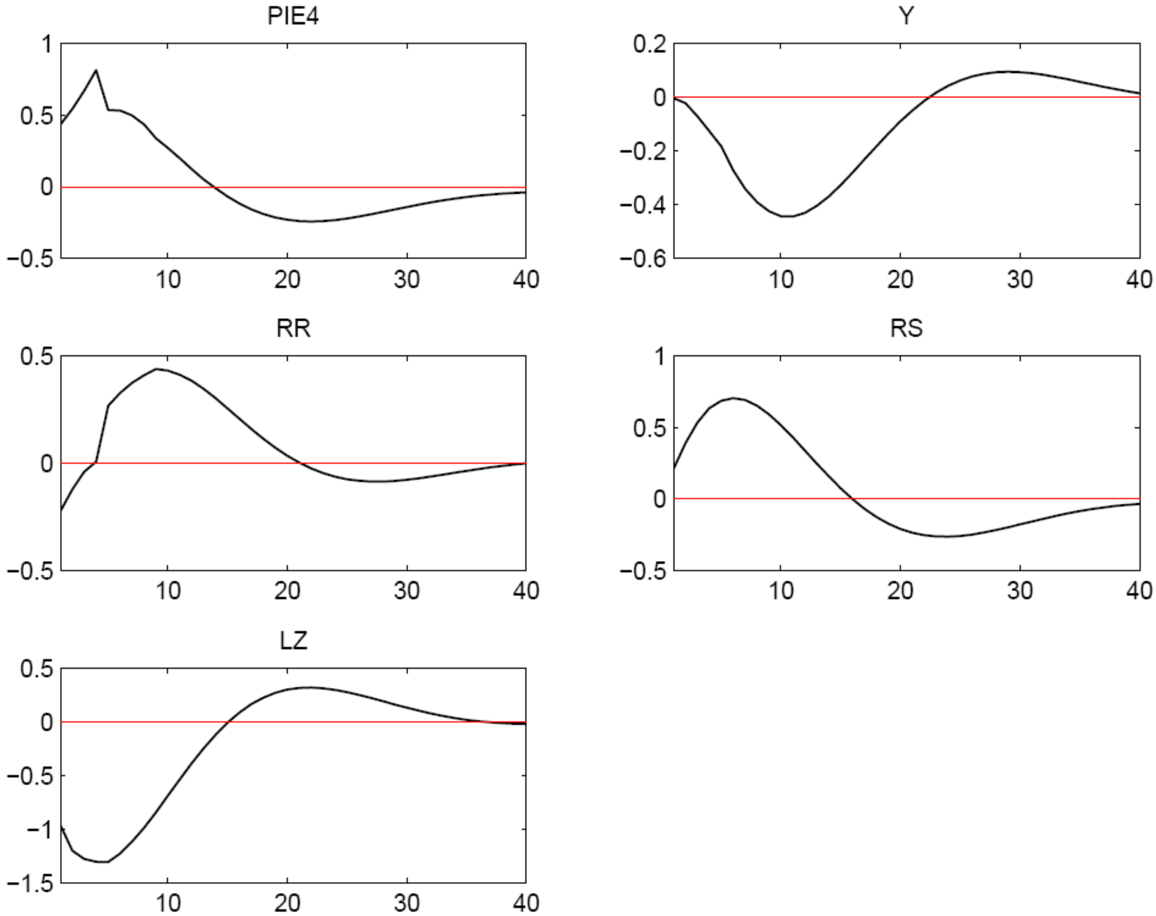
parameters	prior mean	mode	s.d.	t-stat	prior	pstdev
λ_1	0.25	0.3356	0.0924	3.6312	beta	0.05
λ_2	0.25	0.2203	0.042	5.2426	gamma	0.05
λ_3	0.1	0.1488	0.0656	2.2675	gamma	0.05
β_1	0.75	0.6249	0.0836	7.4754	gamma	0.1
β_2	0.15	0.1378	0.0471	2.9261	beta	0.05
β_3	0.2	0.1703	0.0294	5.7951	gamma	0.05
β_4	0.05	0.0498	0.003	16.8121	gamma	0.003
β_5	0.3	0.1848	0.0495	3.7328	gamma	0.1
γ_1	0.75	0.8666	0.0231	37.4487	beta	0.05
γ_2	1.5	1.3636	0.1861	7.3258	gamma	0.2
γ_3	0.3	0.2339	0.1197	1.9536	normal	0.1
γ_4	0.5	0.4958	0.0498	9.9554	gamma	0.05
τ	0.1	0.0866	0.0404	2.1442	beta	0.05
g^{ss}	3	2.9409	0.4024	7.3075	normal	0.5
ϕ	0.6	0.8492	0.0748	11.3476	beta	0.2
ρ	0.2	0.1744	0.0689	2.5311	beta	0.07
$\overline{r}^{ss}$	2	2.9415	0.6373	4.6154	normal	0.5
ω_1	0.8	0.7902	0.0863	9.1531	beta	0.1
ω_2	0.3	0.1227	0.0427	2.8711	gamma	0.2
g_f^{ss}	3	3.0492	0.1411	21.608	normal	0.5
$\overline{r}_f^{ss}$	2	1.7198	0.2011	8.5539	normal	0.2
β_f^1	0.75	0.8563	0.0379	22.5723	beta	0.1
β_f^2	0.15	0.116	0.0058	19.8427	beta	0.05
β_f^3	0.2	0.062	0.0202	3.065	gamma	0.05
λ_f^1	0.4	0.5191	0.0893	5.8115	beta	0.1
λ_f^2	0.25	0.1744	0.0068	25.5816	gamma	0.05
γ_f^1	0.75	0.8589	0.0031	276.0684	beta	0.1
γ_f^2	1.5	1.3057	0.0154	84.9646	gamma	0.3
γ_f^4	0.5	0.6786	0.0102	66.2189	gamma	0.2

Figure A9. The impulse responses to a one standard deviation shock to ε^y. Case 3



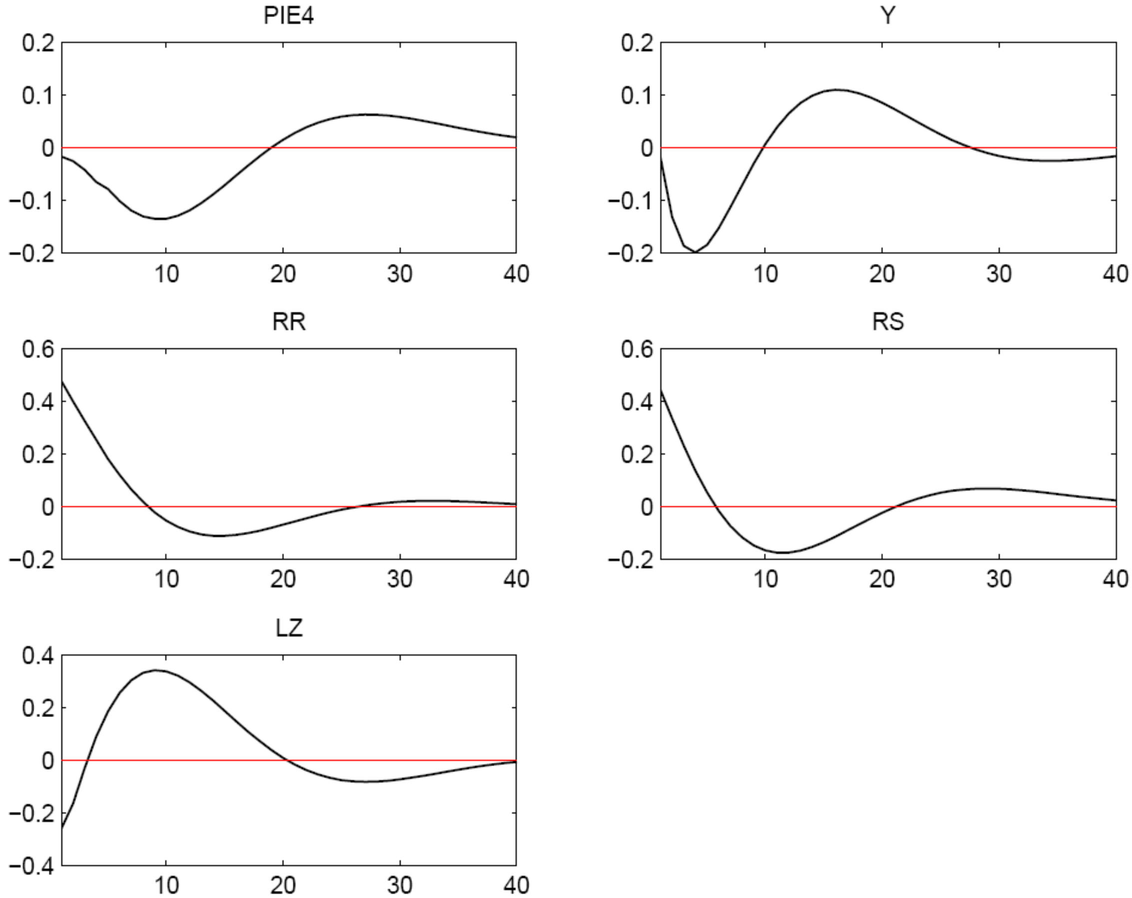
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A10. The impulse responses to a one standard deviation shock to ε^{π}. Case 3



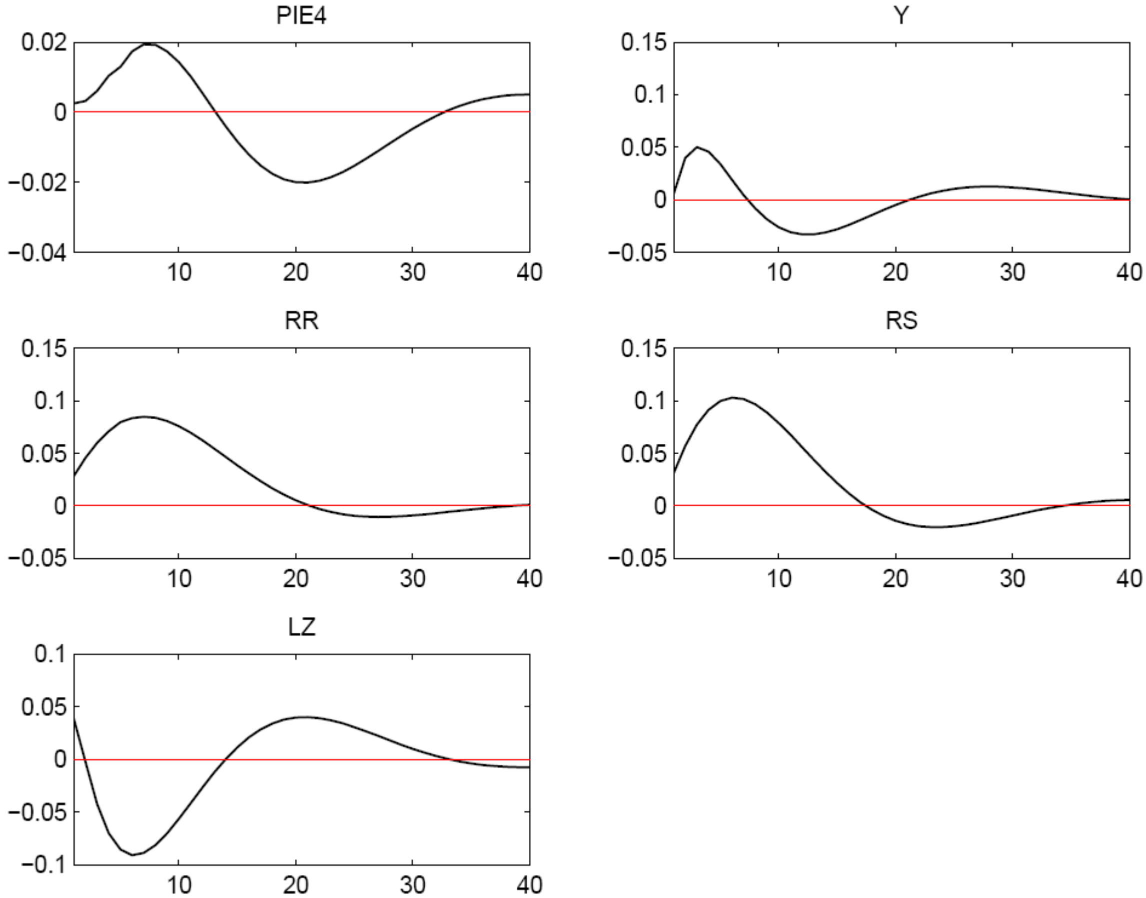
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A11. The impulse responses to a one standard deviation shock to ε^i . Case 3



Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A12. The impulse responses to a one standard deviation shock to $\varepsilon^{\bar{r}}$. Case 3

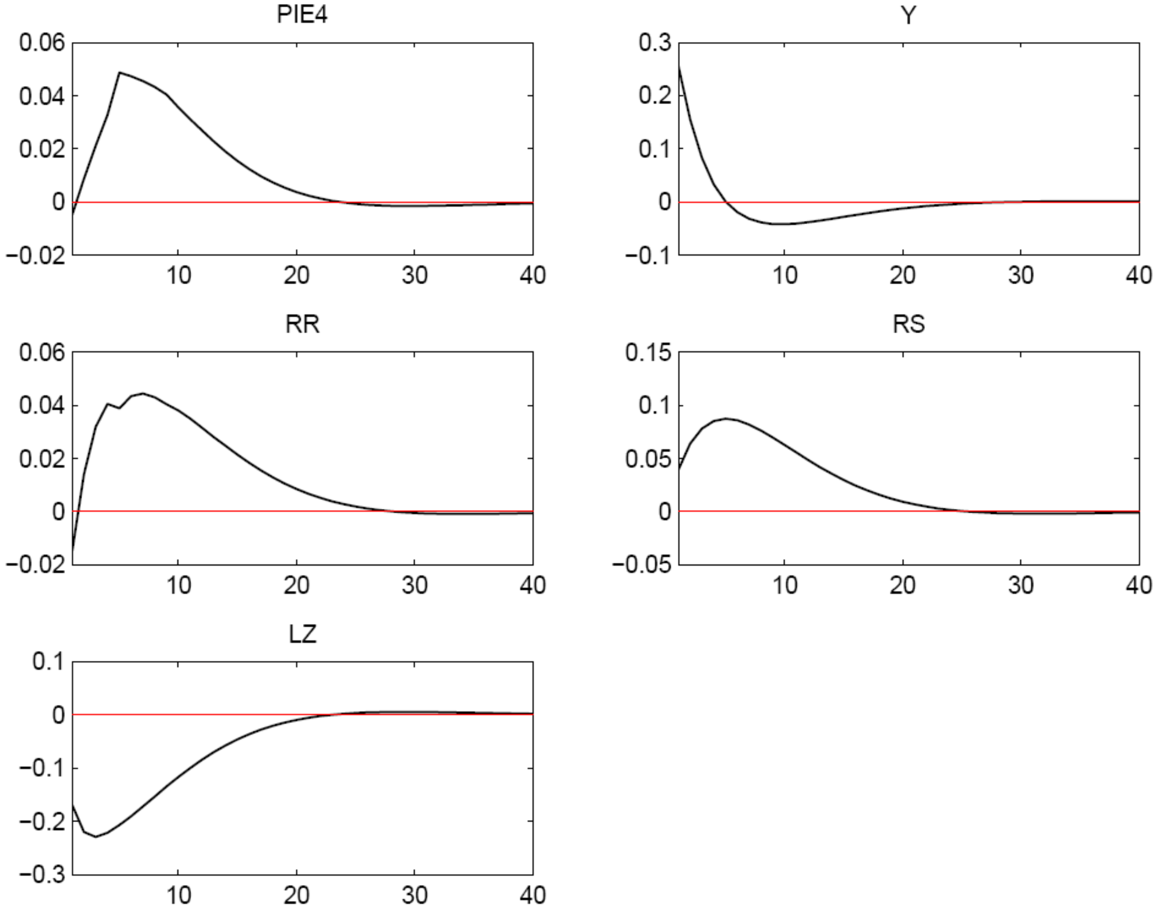


Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Case 4. Low λ_1, zero γ_3

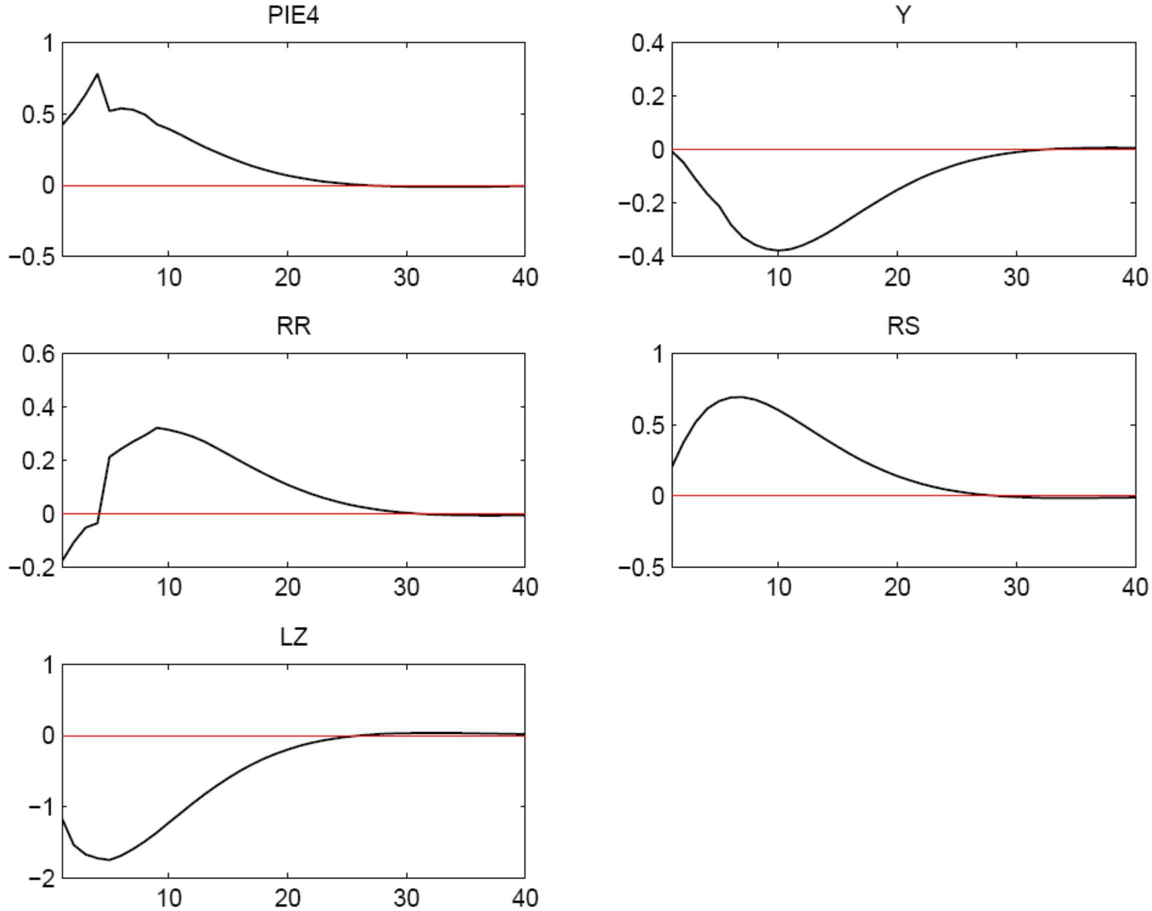
Table A4. Results From Posterior Maximization. Case 4						
parameters	**prior mean**	**mode**	**s.d.**	**t-stat**	**prior**	**pstdev**
λ_1	0.25	0.2922	0.0602	4.8556	beta	0.05
λ_2	0.25	0.2196	0.0392	5.6008	gamma	0.05
λ_3	0.1	0.1454	0.0485	3.0007	gamma	0.05
β_1	0.75	0.6296	0.0825	7.6331	gamma	0.1
β_2	0.15	0.1297	0.0443	2.9271	beta	0.05
β_3	0.2	0.1618	0.0293	5.5277	gamma	0.05
β_4	0.05	0.0496	0.003	16.7498	gamma	0.003
β_5	0.3	0.1982	0.055	3.6018	gamma	0.1
γ_1	0.75	0.8538	0.0234	36.5065	beta	0.05
γ_2	1.5	1.3801	0.1884	7.327	gamma	0.2
γ_4	0.5	0.4982	0.0499	9.9769	gamma	0.05
τ	0.1	0.0863	0.0402	2.1491	beta	0.05
g^{ss}	3	2.9584	0.3922	7.5423	normal	0.5
ϕ	0.6	0.868	0.0718	12.0809	beta	0.2
ρ	0.2	0.1742	0.0686	2.541	beta	0.07
$\bar{r}^{ss}$	2	2.717	0.299	9.0878	normal	0.5
ω_1	0.8	0.7736	0.0806	9.6022	beta	0.1
ω_2	0.3	0.1141	0.0408	2.7959	gamma	0.2
g_f^{ss}	3	3.0405	0.1278	23.7886	normal	0.5
$\bar{r}_f^{ss}$	2	1.7088	0.3181	5.372	normal	0.2
β_f^1	0.75	0.8549	0.0432	19.7911	beta	0.1
β_f^2	0.15	0.1149	0.0135	8.5306	beta	0.05
β_f^3	0.2	0.0623	0.0557	1.1185	gamma	0.05
λ_f^1	0.4	0.5277	0.0661	7.9827	beta	0.1
λ_f^2	0.25	0.1754	0.0229	7.656	gamma	0.05
γ_f^1	0.75	0.8644	0.0037	235.6206	beta	0.1
γ_f^2	1.5	1.3012	0.0462	28.1559	gamma	0.3
γ_f^4	0.5	0.6724	0.0321	20.9151	gamma	0.2

Figure A13. The impulse responses to a one standard deviation shock to ε^{y}. Case 4



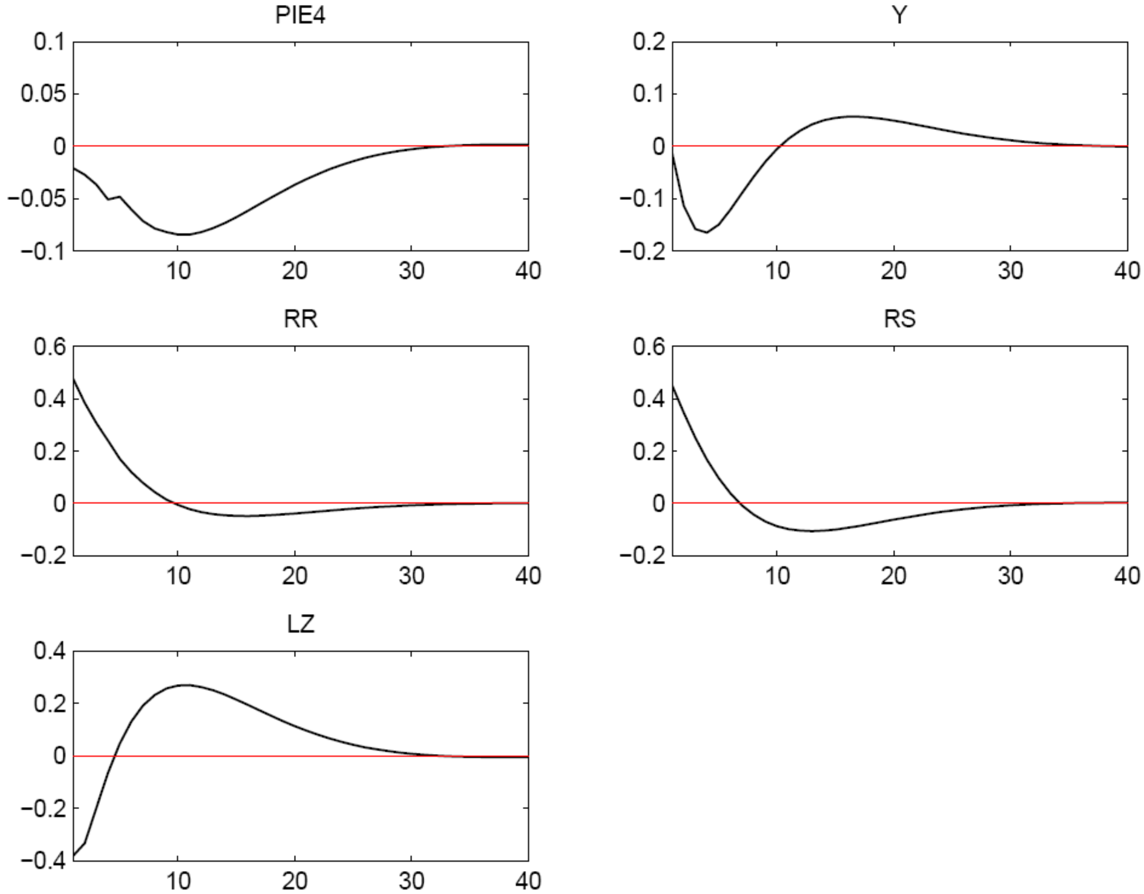
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A14. The impulse responses to a one standard deviation shock to ε^{π} . Case 4



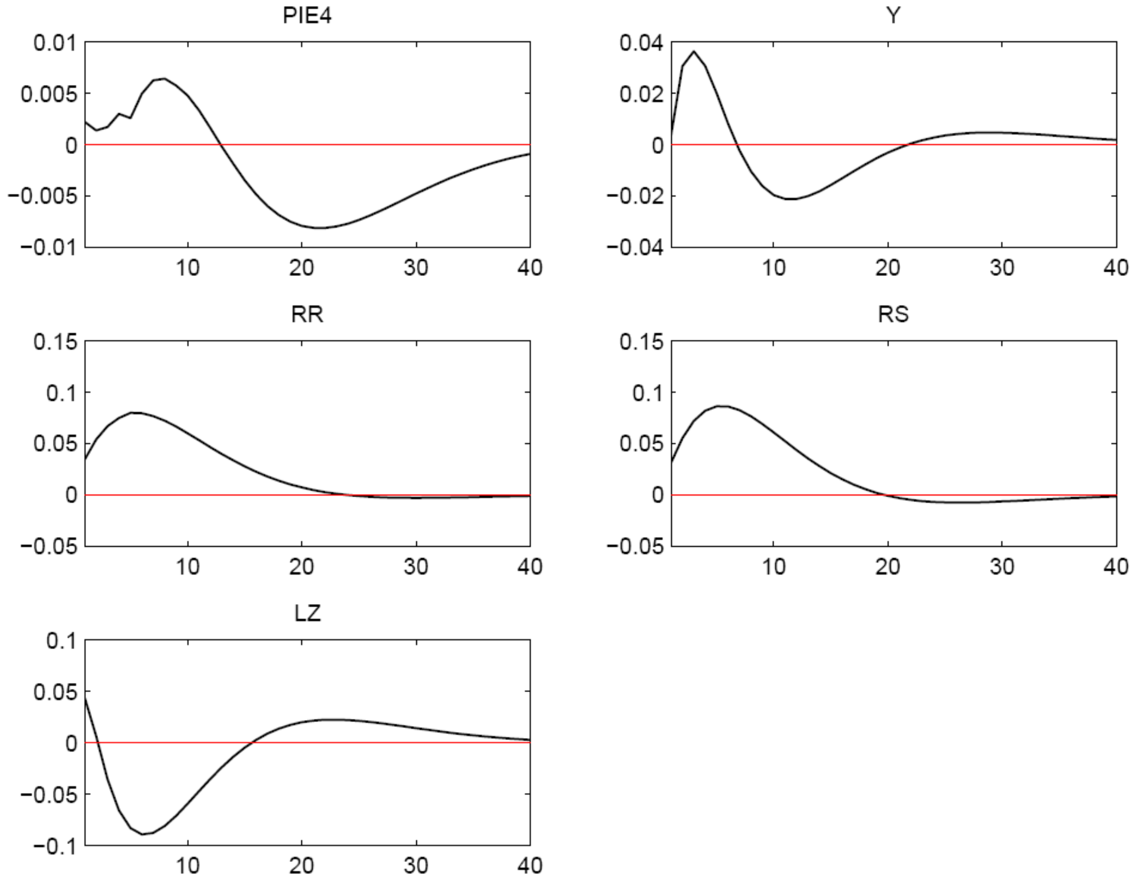
Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A15. The impulse responses to a one standard deviation shock to ε^{i} . Case 4



Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate

Figure A16. The impulse responses to a one standard deviation shock to $\varepsilon^{\bar{r}}$. Case 4



Note: PIE4 is 4-quarter inflation, Y is output gap, RR is real interest rate, RS is nominal interest rate