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The Macroeconomic Effects of Higher Oil Prices

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Abstract

The paper uses MULTIMOD to analyze the macroeconomic effects of oil price shocks, distinguishing between temporary, more persistent, and permanent shocks. It provides perspectives on several findings in the literature and the key role of monetary policy in influencing macroeconomic outcomes. Specific attention is paid to the channels through which oil price increases can pass through into core inflation, a possible explanation of the asymmetric relationship between oil prices and economic activity, the role of monetary policy credibility, the implications of delayed policy responses, and the relative merits of leaning in different directions when the correct policy response is uncertain.

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I. INTRODUCTION

Oil prices have risen very sharply over the past two years after declining to a 25-year low in February 1999. The change between early 1999 and the peak in September 2000 was the fourth major increase during the past three decades.[2] Given the macroeconomic developments that followed the oil shocks of the 1970s, the recent behavior of oil prices, which remain well above the average for the past two decades, has generated concerns about the prospects for world growth and inflation and integrally-related questions about the appropriate way for monetary policy to respond.

This paper uses the IMF's multicountry model, MULTIMOD, to analyze the macroeconomic effects of oil price shocks, with particular focus on the implications for economic activity and inflation in the industrial countries. The analysis provides perspectives on several findings in the literature, and on the role of monetary policy in influencing outcomes.

The macroeconomic turbulence that followed the two major oil shocks of the 1970s stimulated a large body of research examining the impact of oil price movements on economic activity and inflation.[3] This research has found clear negative correlations between oil prices and aggregate measures of economic activity, as well as significant correlations between oil prices and microeconomic data on output, employment, and real wages. In addition, there is strong evidence of asymmetry in the relationship between oil price changes and subsequent changes in economic activity.

Empirical research has generated evolving impressions about the magnitude of oil-price effects on aggregate economic activity and about the extent to which activity responds symmetrically to oil-price increases and oil-price declines. The empirical evidence presented in Hamilton (1983), based on linear VAR models, suggested that exogenous shocks to oil prices had significant effects on real economic activity in the United States. Subsequently, the fact that the large decline in oil prices in the mid-1980s did not result in an output boom seemed to suggest that the relationship had changed. Mork (1989) extended the work of Hamilton, allowing oil price shocks to have asymmetric effects and inferring that oil price increases reduced real output while oil price declines had no effect. Several years later, using data up to 1994, Hooker (1996) concluded that the relationship uncovered by Hamilton had broken down and that allowing for asymmetric output responses to price increases and price decreases did not alter that result. More recently, Hamilton (2000) has provided clear

[2] As shown in Figure 1 below, the real price of oil quadrupled during the first oil price shock of the 1970s, tripled during the shock at the end of the 1970s, doubled during the second half of 1990, and tripled during 1999-2000.

[3] See Hooker (1999) and Hamilton (2000) for references.

evidence of nonlinearity—"oil price increases are much more important than oil price decreases, and increases have significantly less predictive content if they simply correct earlier decreases."[4]

Most economists believe that monetary policy has played a role in generating the observed negative correlation between oil prices and economic activity, and perhaps in contributing to the apparent instability of the correlation over time. Bernanke and others (1997) provided analysis suggesting that monetary policy has been the primary reason that oil price increases have had negative output effects in the United States.[5] Needless to say, the rationale for monetary policy responses to exogenous increases in oil prices is to contain the effects on inflation. In that connection, however, recent work by Hooker (1999) suggests that in the United States since 1981, oil price shocks have only affected headline inflation, with no impact on core inflation. Should this be taken to imply that monetary policy no longer needs to respond to oil price innovations? According to the nonlinear relationship between oil-price movements and output as outlined in Hamilton (2000), the sharp rise in oil prices over the last few years could lead to a decline in real output growth. However, if Bernanke and others (1997) and Hooker (1999) are correct, an output decline might appear to be avoidable. In particular, if core inflation does not respond to oil price increases, then there might be no need for monetary policy to tighten, in which case the effects on real economic activity could be minimal.

MULTIMOD simulations can help shed light on these issues and provide more general perspectives on both the key channels through which exogenous oil price innovations affect the macroeconomy and the associated implications for monetary policy. The main points that our simulations are designed to illustrate are the following.

The first point is that even if the underlying structure of the economy allows for oil price shocks to potentially pass through into core inflation, the response to a *temporary* oil price increase can look very similar to the response that would be observed in an economy

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[4] Hamilton's (2000) approach to characterizing the relationship between oil price changes and GDP growth is flexible enough to test a broad class of nonlinear specifications but does not have the power to distinguish between the different forms of the nonlinearity proposed in Mork (1989), Lee and others (1995) and Hamilton (1996). Hamilton (2000) also demonstrates that the data support the hypothesis that oil prices have a linear (symmetric) effect on economic activity when the analysis is conducted with an instrumental variables regression in which identifiable exogenous disruptions in world petroleum supplies are used as instruments; this alternative interpretation appeals to the argument that the distribution of historically-observed exogenous shocks is asymmetric.

[5] The methodology of their paper elicited some questions from participants on the Brookings Panel to which it was presented, but participants generally accepted the conclusion that the output declines following oil price shocks had come mainly from monetary policy responses.

with no pass-through of oil price shocks into core inflation. This result suggests that the empirical evidence from the 1980s and 1990s, as analyzed by Hooker (1999), needs to be interpreted with caution. One possible reason why the data seem to suggest that oil price shocks no longer have an impact on core inflation may be the fact that the positive innovations to oil prices during the 1980s and most of the 1990s were very short lived. A second possibility is that monetary policy may have reacted differently to oil shocks during the 1980s and 1990s than it did during the 1970s. In that connection, Bernanke and others (1997) concluded that the declines in U.S. output following the 1979 and 1990 oil-price shocks were largely a result of monetary policy, whereas the recession in 1974-75 was primarily due to factors other than monetary policy. To the extent that this was the case, however, it would not be valid to interpret Hooker's (1999) findings as providing a rationale for monetary policy behavior to change again by no longer responding to oil price increases. As Lucas (1976) has emphasized, there are dangers in assuming that estimated reduced-form relationships are invariant to changes in the behavior of policy.

A second point that we address is the extent to which the observed nonlinearity in the relationship between oil prices and macroeconomic activity might be attributable to asymmetries at the microeconomic level. In particular, we illustrate that if most of the output effects arising from oil price shocks are associated with the monetary policy response, then asymmetric pressures on core inflation, arising perhaps from asymmetric responses of microeconomic agents to the impact effects of oil price changes on their real incomes, could help explain the asymmetric response of economic activity to oil price changes.

We also use MULTIMOD to illustrate that even when an oil price shock turns out to be persistent and core inflation responds, a slow reaction by policymakers will not necessarily magnify the macroeconomic implications. This raises the possibility that policymakers may have the luxury of waiting to respond until they see clear evidence that core inflation is increasing. We emphasize, however, that the scope for delay depends critically on whether the slow policy response leads private agents to doubt the inflation-fighting resolve of central banks. This is illustrated with a simulation showing that the economic dislocation arising from the shock can be considerably magnified if the slow response and the resulting deterioration in inflation performance lead to (temporary) erosion of policymakers' credibility.

Finally, to provide some perspective on how policymakers should respond in the face of uncertainty about wage/price behavior, MULTIMOD simulations are used to compare the costs of two possible types of policy errors in responding to a persistent increase in oil prices. The first error results from policymakers initially assuming that the oil price increase will have no core inflation effect when core inflation in fact responds positively and asymmetrically to changes in oil prices, and when monetary policy credibility can be eroded. The second error is the result of policymakers initially believing that agents will respond in the most inflationary manner when in fact they respond in the most benign manner. Comparing the estimated costs of these two errors suggests that, other things equal, policymakers might want to lean in the direction of high-side assumptions about the extent to which persistent oil price increases lead to core inflation pressures.

The remainder of the paper is structured as follows. Section II presents some stylized facts about the behavior of oil prices. Section III provides a brief outline of the structure of MULTIMOD and the channels through which oil price movements can influence the macroeconomy. Simulations of the impacts of oil prices under different behavioral assumptions are presented in Section IV, along with comparisons of the costs of making the two alternative monetary policy errors described above. Some conclusions are presented in Section V.

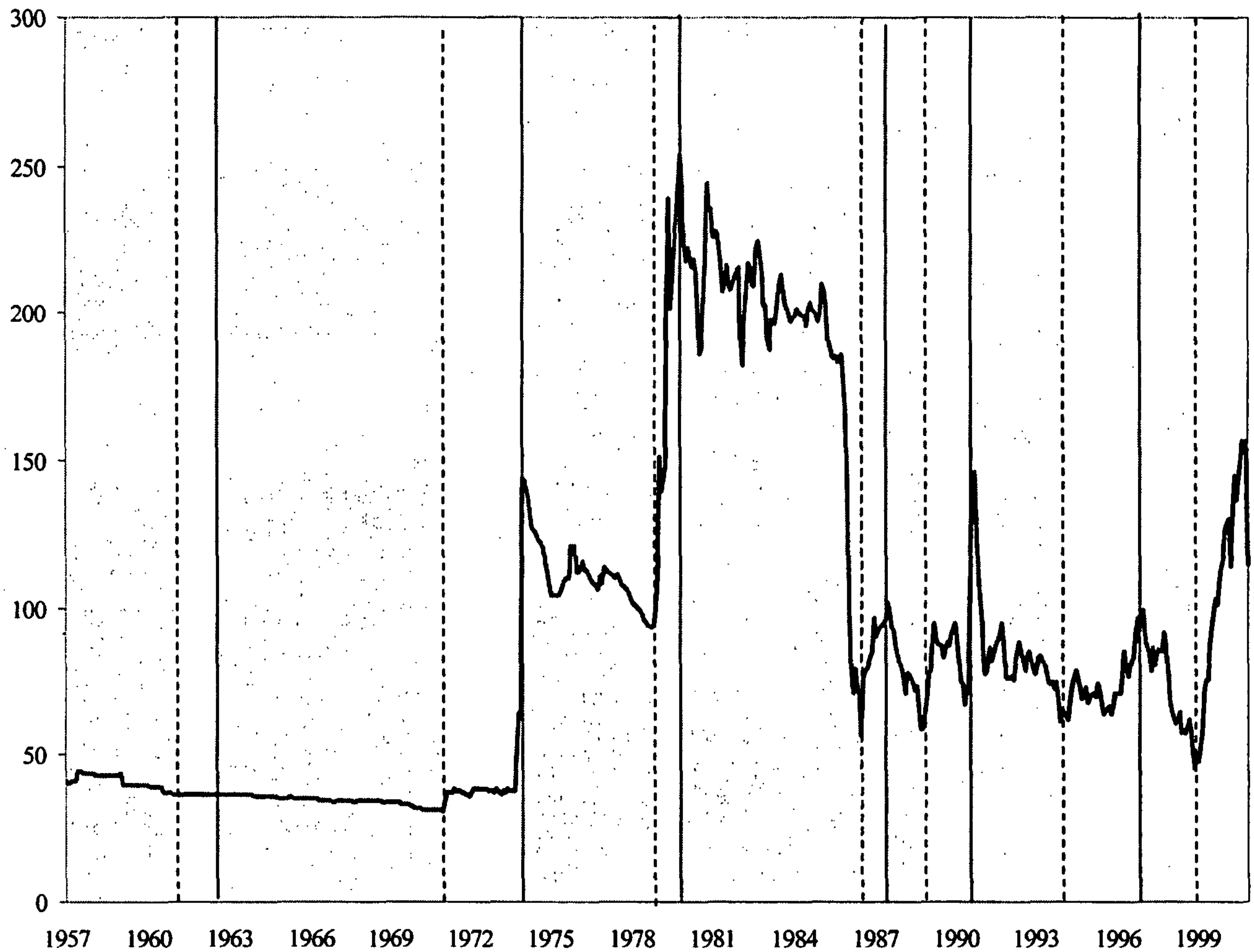
II. Oil Prices

The behavior of real oil prices since the late 1950s is graphed in Figure 1. The figure denotes periods of price booms and price slumps, the determination of which is based on a cycle-dating algorithm outlined in Cashin and others (1999). A number of points are worth noting. First, since their sharp decline in the mid-1980s, real oil prices have fluctuated around a fairly stable mean with most deviations from the average price being very short lived. This contrasts notably from the behavior of oil prices in the 1970s. Second, the run up in oil prices during 1999-2000 was comparable (measured trough to peak in percentage terms) to the oil price rise in the late 1970s, though significantly smaller than the first major increase in oil prices that occurred in the 1970s. Finally, the analysis in Cashin and others (1999) indicates that the historical behavior of oil prices does not allow one to predict how future oil price cycles will evolve. The severity of price movements provides no information about their likely duration, and the time spent in a current boom or slump provides no information about the likely future duration of that boom or slump.

Figure 2 shows the quarterly percent change in the US dollar price of oil and a net oil price increase series proposed in Hamilton (1996 and 2000). The latter series measures the amount by which oil prices in a given quarter exceed their peak value over the previous 12 months; if they do not exceed the previous peak, the measure is set to zero. The first series indicates that oil prices have been quite variable since the mid-1980s, while the second series shows less variability from 1982 through 1998. Hamilton (2000) presents evidence suggesting that his proposed measure performs significantly better in predicting the impact of oil price changes on real economic activity. From that perspective, Hamilton's transformed data series suggests that the episode of oil price increases that began in early 1999 has the potential to have significant macroeconomic effects.

Taken together these characteristics of oil prices suggest that, even though it is difficult to predict how long high oil prices might persist, their behavior during the past two years could have a significant impact on future economic performance. In the simulation analysis that follows, MULTIMOD is used to illustrate the potential macroeconomic implications of oil price shocks similar in magnitude to the recent experience. These simulations consider oil price shocks of various durations as well as alternative assumptions about the degree of pass-through into core inflation, the policy response, and the possible effects on private agents' perceptions about monetary policy objectives.

Figure 1. Cycles in Real Petroleum Prices, 1957:1–2000:12
(1990=100)

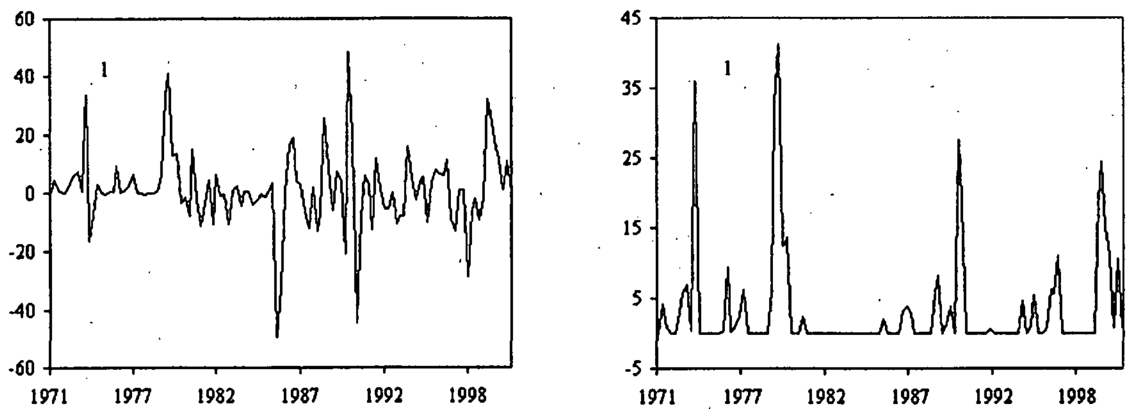


Source: Cashin, McDermott and Scott (1999). The deflator used to construct the series is a unit value index (in U.S. dollars) of the manufacturing exports of 20 developed countries.

Notes: Cycles are demarcated by peaks (solid line) and troughs (dashed line), with periods from peaks to troughs being slumps (dark shading), and periods from troughs to peaks being booms (light shading).

Figure 2. Measures of Oil Price Changes

a) Quarterly Percent Change in the U.S. Dollar Price b) Hamilton's Net Oil Price Increase Series*



*This series measures the perentage amount by which US dollar oil prices in a given quarter exceed their peak value over the previous 12 months; if they do not exceed the previous peak, the measure is equal to zero.

[1] Note: The observations in 1974Q1 for both measures have been reduced by 100 percentage points to avoid the scaling problem they create in the charts.

III. The Transmission of Oil Price Shocks in MULTIMOD

An oil price increase can influence macroeconomic behavior through several channels. Five of these seem particularly relevant in the first few years following the shock. First, the transfer of income from oil-importing countries to oil-exporting countries is expected to reduce global demand as demand in the oil-importing countries is likely to decline more than it will rise in the oil-exporting countries. This reflects an assumption that the propensity to spend in the oil-exporting countries is likely to be significantly smaller in the short run than in the oil-consuming countries. Second, the increase in the cost of inputs to production can reduce the amount of non-oil (potential) output that can be profitably supplied in the short run, given the existing capital stock and assuming that wages are relatively inflexible in the short run. Third, workers and producers may resist declines in their real wages and profit margins, putting upward pressure on unit labor costs and the prices of finished goods and services. Fourth, the impact of higher energy prices on headline price indexes (e.g., consumer price levels) and the potential for pass-through into core inflation may induce central banks to tighten monetary policy. And fifth, to the extent that policy reactions seem inconsistent with announced policy objectives, the credibility of the monetary authorities may be eroded, with consequences for inflation expectations and the inflation process.[6]

MULTIMOD is a multi-regional macroeconometric model developed by the IMF staff for the primary purpose of analyzing alternative scenarios for the World Economic Outlook (WEO). As such, it is based on annual data and takes the WEO forecast as an "exogenous" baseline. Its construction has gone though several stages. The simulations presented in this paper are based on the current Mark IV version[7] and focus primarily on the industrial countries.[8] Modern structural models like MULTIMOD have been designed to

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[6] This list abstracts from induced effects on asset values and their implications for aggregate demand and supply, and also from the effects of any induced changes in fiscal positions or fiscal policies.

[7] Laxton and others (1998) describe the Mark III version; see also Isard (2000). The Mark IV version will be described in Hunt and others (2001). Major changes from the Mark III version include: the incorporation of a Euro Area block; new base-case specifications of the behavior of monetary and fiscal policy; and a re-coding of the model that more easily permits solutions to the model in which countries choose different steady-state rates of inflation.

[8] The developing country sector of MULTIMOD contain highly oversimplified descriptions of macroeconomic behavior that serve to ensure the global consistency of MULTIMOD simulations but provide only a minimal characterization of the channels through which changes in oil prices affect the developing economies.

avoid first-order Lucas-critique problems and to provide insights on the key role of the monetary policy response in influencing the macroeconomic effects of various exogenous shocks.[9]

MULTIMOD's analysis of oil-price shocks hinges critically on the nature of wage/price behavior and the monetary policy reaction function. The former is described in detail at the end of this section. The latter reflects the Mark IV characterization of "normal" monetary policy behavior, which amounts to an inflation-forecast-based (IFB) rule.[10] As elaborated below, the monetary authorities are assumed to set the short-term interest rate at a level that depends both on the deviation of their *forecast* of inflation from some "target" inflation rate and on the magnitude of the output gap.

In characterizing the supply side of the economy, MULTIMOD assumes that production technology uses capital and labor inputs with no explicit role for inputs of primary or intermediate products.[11] Firms choose the profit maximizing level for the capital stock based on production technology, input costs, and output prices. In MULTIMOD input costs are approximated by the aggregate absorption price deflator and the GDP deflator represents the aggregate output price. Consequently, permanent oil price shocks drive a wedge between input and output prices that reflects the country's dependence on net imports of oil; and firms then adjust their desired capital stock accordingly. The new capital stock is achieved through adjustment in investment flows. In the long run, the level of potential output will reflect the new level of the capital stock. In reality, however, capital stock adjustment may occur much more rapidly than MULTIMOD suggests as firms have the ability to quickly retire capital that becomes relatively inefficient to operate following a permanent increase in oil prices. Costly reallocation of labor and capital across sectors and the discouraging effect of increased uncertainty on irreversible investment (behavioral features that MULTIMOD may not adequately capture) have also been cited in the literature as potentially important supply-side effects of oil price increases. These considerations suggest that MULTIMOD may underestimate the short-run effects of positive oil price

[9] MULTIMOD is by no means immune from Lucas Critique problems. The Phillips curve, for example, is a reduced-form equation, and there is potentially always the possibility that a major change in the pattern of monetary policy behavior could lead to significant changes in the nature of wage and price contracts and the dynamics of inflation expectations.

[10] For a discussion of the potential benefits of IFB rules see Isard, Laxton, and Eliasson (1999), Drew and Hunt (2000), and Clark, Laxton, and Rose (2001).

[11] Helliwell (1986, 1987) and McKibbin (1991) consider a more general production function that allows for a more explicit role for inputs of primary and intermediate products.

shocks on output. Elsewhere we have judgmentally adjusted potential output to allow for such effects,[12] but for present purposes this is not a matter of concern.[13]

A. The Effects of Oil Price Shocks on CPI and Core Inflation in MULTIMOD

This section describes the main channels through which oil price shocks can have direct inflationary effects in the Mark IV version of MULTIMOD. The discussion focuses on those equations of the model that play a key role in transmitting the effects of oil-price increases into the inflation process in the major industrial countries/blocks. A more detailed presentation of the Mark IV version and its estimation can be found in Hunt and others (2001).

MULTIMOD, like most macroeconomic policy models, relies on a reduced-form Phillips curve to characterize the behavior of inflation in the industrial countries.[14] The modeling of inflation and inflation expectations distinguishes between CPI inflation and core inflation, where core inflation is defined as the rate of change in the GDP deflator excluding oil and is taken to be the measure on which monetary policy decisions are based. Although MULTIMOD does not include explicit wage rates, the dynamics of inflation and inflation expectations are characterized in a manner that implicitly recognize important features of wage-setting behavior (in particular, contracting lags and wage-push elements), and these equations are sometimes referred to as the wage/price nexus.

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

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

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

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

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[12] IMF Research Department, "The Impact of Higher Oil Prices on the Global Economy," December, 2000.

[13] We would note that the degree of uncertainty about the level of potential output that could arise from even quite large oil price shocks seems very small relative to the magnitude of other uncertainties about potential output.

[14] Unlike many macroeconometric models, however, MULTIMOD's reduced-form Phillips curves are nonlinear with respect to labor market disequilibria. This feature allows for the possibility that large policy errors can have first-order welfare implications.

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

Table 1 reports the values of the parameters in the model that are critical for understanding the more direct channels of pass-through of oil prices into both CPI inflation and core inflation.[15] In particular, it reports estimates of the parameter values $10\delta_3$, δ_2, δ_1, ψ, α, and λ for each country/block, as well as average values for these parameters across all of the industrial country blocks.

Table 1. MULTIMOD Base-Case Parameters

	$10\,\delta_3$	δ_2	δ_1	ψ	α	Ω	λ
Average	0.22	0.58	0.08	0.54	0.26	0.57	0.48
United States	0.31	0.58	0.08	0.51	0.35	0.53	0.48
Euro Area	0.33	0.44	0.12	0.51	0.12	0.58	0.60
Japan	0.14	0.73	0.06	0.59	0.09	0.60	0.31
United Kingdom	0.15	0.69	0.11	0.58	0.42	0.60	0.34
Canada	0.20	0.61	0.06	0.51	0.16	0.50	0.41
Other Industrial Countries	0.18	0.41	0.08	0.55	0.42	0.60	0.74

[15] Equations 2 and 3 have been estimated for each of MULTIMOD's major industrial countries/blocks as part of an unobserved components model that also includes equations for the deterministic-NAIRU, the NAIRU, and an Okun's Law relationship between output and the unemployment rate. The estimation is done using the Kalman filter and constrained-maximum-likelihood procedure. Equation (1) was estimated with OLS. More details regarding the model and its estimation can be found in Hunt and others (2001).

B. Direct Contemporaneous Effects of Oil Price Shocks on the CPI

The direct contemporaneous effect of a change in oil prices on CPI inflation is measured by the parameter δ_3 in equation (1). For presentational purposes, the values of this parameter in Table 1 have been multiplied by a factor of 10 so that they can be reported with the same number of digits as the other parameter values. As can been seen in the table, the direct contemporaneous effects of an increase in π^{POIL} on π^{CPI} are significantly higher than the average value in the United States and the Euro Area; and the effects are significantly smaller than the average parameter estimate in Japan and the United Kingdom.

The estimates of δ_3 in Table 1 can be used to estimate the direct contemporaneous effects of an increase in π^{POIL} on π^{CPI}. Table 2 reports the contemporaneous direct effects on annual CPI inflation that would result from a 50 percent increase in the price of oil. Based on these estimates, a 50 per cent increase in the price of oil would have a direct positive effect on annual CPI inflation of 1.3 percentage points in both the United States and the Euro Area, 0.6 percentage points in both Japan and the United Kingdom; 0.8 percentage points in Canada and 0.7 percentage points in the block of other industrial countries.[16] Do these estimates seem plausible?

One common approach used to assess the plausibility of econometric estimates of the direct effect of oil price shocks on the CPI is to compare them with estimates derived from a more mechanical direct-accounting approach. This direct-accounting approach is usually based simply on estimates of the importance of gasoline and other petroleum products in the CPI baskets of these countries. For most countries, the MULTIMOD estimates are slightly larger than these estimates, reflecting the fact that in some of these countries, increases in the price of oil may result in increases in prices of other energy sources such as electricity and natural gas.

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[16] A 50 percent increase in the price of oil is equivalent to an increase in π^{POIL} of 40.55 because π^{POIL} is defined to be 100 times the first-difference of the log of the oil price. For changes as large as 50% there can be substantial differences between changes in logs and percent changes—see the notes in Table 2 for a discussion of when differences in logs will be poor approximations to percent changes.

Table 2. Contemporaneous Direct Effects on Annual CPI Inflation of a 50 Percent Increase in the Price of Oil
(Approximate deviations from control in percentage points)

Average	0.9
United States	1.3
Euro Area	1.3
Japan	0.6
United Kingdom	0.6
Canada	0.8
Other Industrial Countries	0.7

Table Notes:

The measures of inflation in the model in the main text [π^{CPI}, π^{M}, π^{POIL}, π^{C}] are defined to be 100 times the first-difference of the log of each variable. This measure of inflation will only be approximately equal to the percent change in the series when the change is fairly small. For example, suppose there is in an increase in the price of oil from $1.00 to $1.50. This represents an increase of 50 percent, but in this case the value of π^{POIL}, which is defined to be 100*[log(1.50)-log(1.00)], will only be 40.55.

Note, that if the change in any variable is 3 percent or less, then the difference in the log will represent a fairly accurate approximation because 100*[log(1.03)-log(1.00)] will be 2.96. When we report the full-model results later for 50 percent oil price shocks all deviations of inflation from control will be reported in percentage points, while in this section we report differences in logs so that the results can be compared directly with the key equations in the model. However, because the size of the shock has been chosen to be equivalent to an increase in the oil price of 50 percent, the numbers in this section are comparable to the full-model simulation results reported later.

Obviously, the differences between percent changes and log differences can be enormous for even larger changes in the price of oil. For example, in the 1973-74 period some measures of the price of crude oil quadrupled (increased by 300 percent), which would be equivalent to an increase in the price of oil from $1.00 to $4.00. In terms of log differences, a quadrupling in the price of oil would represent an increase of 100*[log(4.00)-log(1.00)], or 138.63.

C. Direct Dynamic Effects of Oil Price Shocks on the CPI and Core Inflation

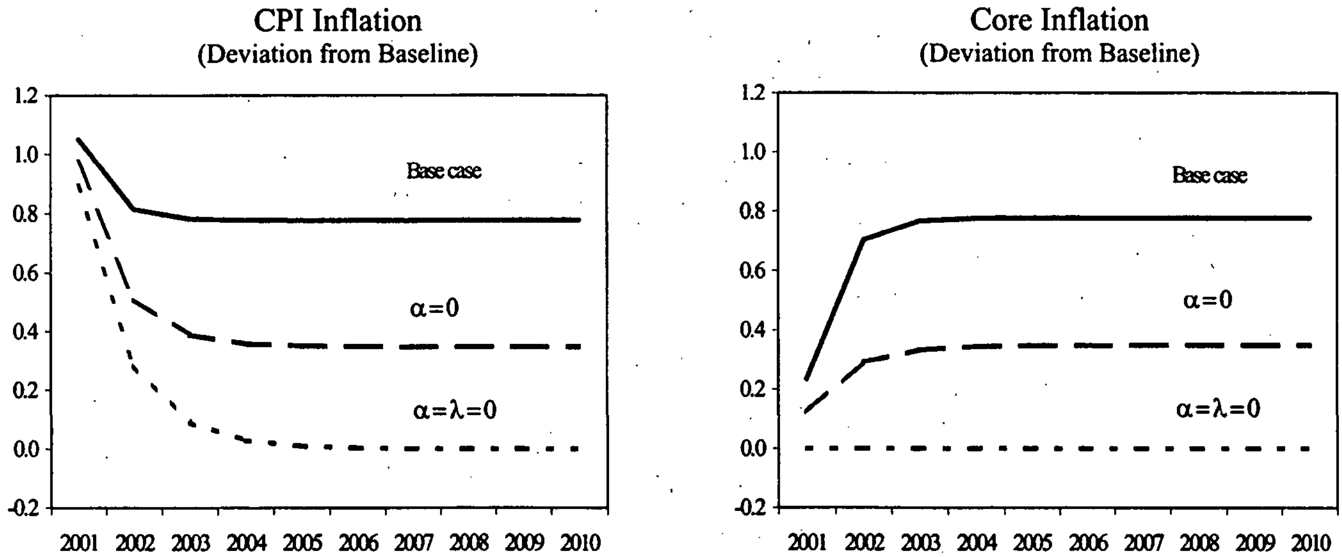
The equations described above can be used to study the direct dynamic effects of oil prices on both CPI and core inflation. The structure of MULTIMOD's inflation block allows for oil price movements to flow into core inflation [π^C] through two possible channels.

The first channel is an expectations channel with the potential impact given by the parameter λ. Indeed, as can be seen in equation 3, if λ was equal to zero the inflation expectations variable [π^e] that enters the core inflation equation would depend entirely on expected changes in the non-oil GDP price deflator and there would be no role for the CPI to influence core inflation through expectations. This extreme case might seem completely unrealistic given that many contracts are negotiated in terms of the CPI. The estimates in Table 1 suggests that the average value of λ is around 0.5, with the individual estimates ranging from a high of 0.74 in the block of other industrial countries to a low 0.27 for the United Kingdom.

The second channel is measured by the parameter α and represents the degree of real-wage catch-up in the bargaining process. For example, a value of α equal to zero would imply that workers do not attempt to resist reductions in their real consumption wage. The average value for α is 0.27 in MULTIMOD and ranges from a low of 0.09 in Japan to a high of 0.50 for the United Kingdom.

To illustrate the nature of pass-through to core inflation in MULTIMOD, Figure 3 reports some dynamic impulse response functions for π^{CPI} and π^C for the same oil price shock discussed earlier (a permanent 50 percent increase) under different assumptions about α and λ. These estimates of impulse response functions are based on three additional assumptions. First, it is assumed that the oil price shock is an innovation to the world price of oil and that changes in the domestic price of crude oil, measured by π^{POIL}, also reflect any induced changes in the exchange rate that might result from the oil price shock. Second, for the purpose of this experiment, it is assumed that both the unemployment gap [u*-u] and the real exchange rate are fixed. The latter assumption is implemented by adjusting import prices and the domestic price of oil one-for-one with any change in the non-oil price deflator. These assumptions are obviously unrealistic, but they are useful for illustrating some of the key linkages in the model.

Figure 3. Direct Effects on Inflation of a Permanent 50 Percent Increase in Oil Prices: Selected Estimates



No pass-through into core inflation

The short-dashed lines in Figure 3 report the impulse response functions for π^{CPI} and π^{C} when α and λ are set equal to zero and the other parameters are set at their average values for the industrial countries. In this case, because there are no catch-up effects [$\alpha = 0$] or any effects of changes in CPI inflation on the expected inflation term [$\lambda = 0$] there are no effects on core inflation. Consequently, CPI inflation rises by 0.9 percentage points in the first year and then reverts back to control very quickly. Under this choice of parameter values, market participants implicitly believe that the change in the oil price will require changes in relative prices in the economy without any significant change in core inflation, and that workers will not resist the relative price changes. Obviously, under these optimistic assumptions, it would not be necessary for monetary policymakers to tighten real monetary conditions (and create an excess-supply gap in the labor market) to contain pressures on core inflation.

Base-case pass-through into core inflation in MULTIMOD

The solid lines in Figure 3 report the impulse response functions for π^{CPI} and π^{C} when α and λ are equal to 0.26 and 0.48 respectively—the average values in MULTIMOD. Under these parameter values, there would be significant long-term effects on both CPI inflation and core inflation if policies were successful in holding both the real exchange rate and the unemployment gap fixed. Indeed, in this case even the direct impact effect on the CPI is 0.1 percentage point greater than the case where α and λ are equal to zero. This reflects the fact that inflation expectations are determined partly by a model-consistent component that increases in response to the increase in oil prices. As can be seen in the second panel of Figure 3, these assumptions result in a gradual increase in core inflation by 0.8 percentage points within 3 years, and both CPI and core inflation stabilize at rates that are permanently higher by 0.8 percentage points. Under these assumptions about pass-through, an attempt by the monetary authorities to offset the deleterious effects on real activity by holding the unemployment gap fixed would result in an ongoing wage-price spiral and a permanently higher rate of inflation. A clear implication is that when there is any significant pass-through into core inflation, monetary policy must at some point tighten real monetary conditions if it wants to avoid a permanent increase in inflation, other things equal.

Figure 3 also includes an intermediate case where inflation expectations are assumed to be determined partly by CPI inflation [λ is still 0.48], but the real-wage catch-up term has been turned off [α is imposed to be zero]. As can be seen in the figure, the long-run effects on inflation are about 0.4 percentage points, or about one half of the magnitude of the base-case results in which the two channels are functioning.

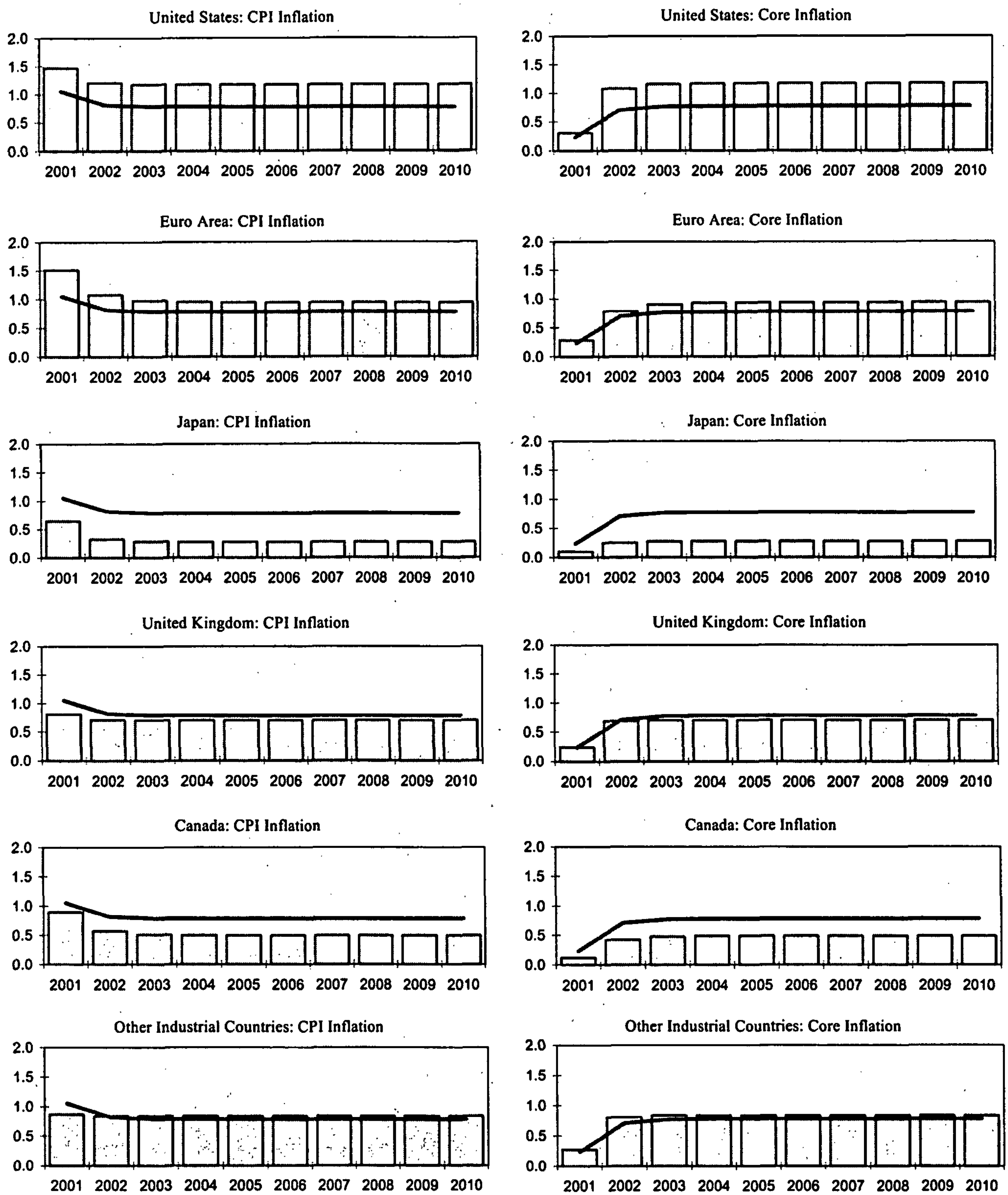
How does pass-through differ across countries in MULTIMOD?

Figure 4 reports coutry-specific results for the same simulation experiment based on the parameters in Table 1 that have been estimated for each country or block of countries. For comparison purposes the bar charts represent the results based on the individual country estimates while the solid line represents the average estimates that were previously reported in Figure 3. The MULTIMOD estimates indicate that oil price movements may have important effects on core inflation in all of the countries; but the effects are particularly strong in the United States and in the Euro Area, average in the United Kingdom and the block of other industrial countries, and significantly smaller in Canada and Japan.

IV. MULTIMOD SIMULATIONS

This section presents several sets of MULTIMOD simulations. The first describes the responses of real GDP and inflation to oil-price shocks of different duration, based on the estimated parameters of the model. The second compares the model's responses to transitory and more persistent oil-price shocks under two alternative structures of the wage/price nexus. The third set of simulations illustrates how asymmetric responses by microeconomic agents to changes in their real wages might help explain the observed nonlinear relationship between oil prices and macroeconomic activity. The fourth explores the implications of delaying the monetary policy response to a persistent increase in oil prices under both exogenous private-sector perceptions about the objectives of monetary policy and an alternative formulation that endogenizes those perceptions. And the last set of simulations explores the policy implications of uncertainty about the nature of estimated behavioral relationships.

Figure 4. Direct Effects on Inflation of a Permanent 50 Percent Increase in Oil Prices: Country-Specific Estimates



A. Responses to Shocks of Different Duration

We first consider how real GDP and inflation would be likely to respond to oil-price shocks of three different durations. Under the first oil-price innovation, here referred to as a *temporary* shock, the price of oil increases by 50 per cent in the first year and returns to baseline in the second year. The second innovation is a more *persistent* shock, with oil prices increasing to 50 per cent above baseline for the first two years and then declining at a steady rate that brings them back to the baseline level in the sixth year. The third shock involves a *permanent* 50 percent increase in oil prices. The analysis implicitly assumes that the behavior of futures prices allows market participants and policy authorities to correctly identify the types of oil price shocks to which they are responding.

As noted above, the modeling of inflation and inflation expectations in MULTIMOD distinguishes between CPI inflation and core inflation (i.e., the rate of change in the GDP deflator excluding oil) and includes two separate channels through which the impact effects of oil price shocks on CPI inflation can pass into core inflation. These two channels, and the monetary policy reaction functions, have an important influence on the simulation results reported below.

MULTIMOD's base-case monetary policy reaction function is a forward-looking inflation-forecast-based (IFB) rule. Specifically, the nominal short-term interest rate is adjusted—relative to the level associated with an equilibrium real interest rate—in proportion to the deviation of observed output from potential output and the deviation of *forecast* core inflation from an inflation target.[17] The choice of IFB rules rather than conventional Taylor rules—which look similar to IFB rules in most respects but focus on the deviation from target of current inflation rather than forecast inflation—reflects a view that central banks are indeed forward looking in their policy deliberations. It also reflects formal analysis indicating that conventional Taylor rules are not effective in maintaining macroeconomic stability in a world in which behavior is moderately nonlinear and private agents form their expectations in a (partially) forward-looking manner.[18]

Figure 5 presents the simulated outcomes for real GDP, CPI inflation, and core inflation for the three different shocks.[19] We restrict attention to results for the United States,

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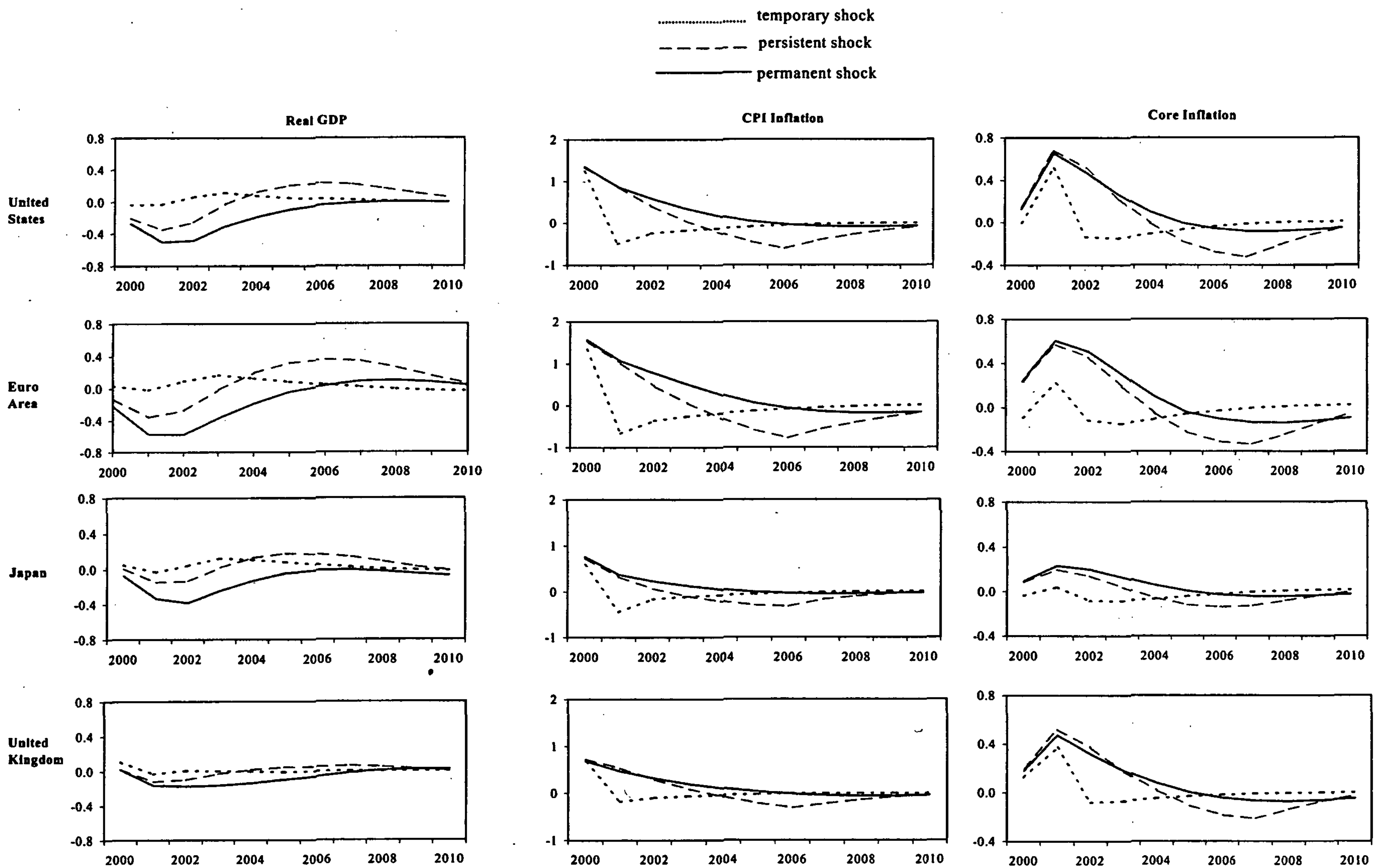
[17] The reaction function sets the short-term nominal interest rate equal to an "equilibrium" nominal interest rate plus 0.5 times the output gap plus 1.0 times the deviation from target of the one-year ahead forecast for core inflation. The equilibrium nominal interest rate is defined as an equilibrium real interest rate plus the expected rate of inflation (as given by equation 3 above).

[18] See, for example, Isard, Laxton, and Eliasson (1999).

[19] The simulated responses to the temporary and persistent shocks are also described in Table 3 below, while responses to the permanent shock are described in Table 4.

Figure 5. Responses of GDP and Inflation to a 50 Percent Increase in Oil Prices: Sensitivity to Duration of the Shock
(Shock minus control in percent of GDP and percentage points of inflation)



the Euro Area, Japan, and the United Kingdom, which are suggestive of the range of responses for the industrial countries in MULTIMOD.[20] It may be noted, for each country individually, that the three shocks have similar first-year effects on CPI inflation, which closely reflect the weights of oil in the CPIs of the different countries. Inflation subsides more gradually under the permanent shock than under the persistent shock, while the temporary shock leads to below-baseline inflation when oil prices decline in year two and for a period thereafter.

The simulations suggest that oil-price shocks have significantly different effects in different countries. The contrasts primarily reflect differences in the estimated parameters of the wage/price nexus and not the parameters of the monetary policy reaction functions, which are set at the same values for all countries. The relatively small effects on real GDP and inflation in Japan reflect both the relatively low degree of resistance to real-income declines and the relatively weak responsiveness of expected inflation to oil-price changes. The fact that the simulated effects are larger in the United States than in the United Kingdom reflects the greater responsiveness of expected inflation to oil-price increases in the United States. And the similarity of the responses in the United States and the Euro Area reflects the combination of a significantly higher degree of resistance to real-income declines in the United States with a significantly greater responsiveness of expectations to oil-price changes in the Euro Area.

The magnitudes of the simulated effects on GDP and inflation should be regarded as illustrative. The impact effects on CPI inflation are realistic, but the other estimates—while reasonably plausible—are obviously sensitive to MULTIMOD's descriptions of the wage/price nexus and the behavior of monetary authorities. It may be noted here again, as discussed in Section III, that several considerations suggest that MULTIMOD may somewhat underestimate the short-run supply-side effects of oil-price shocks on output. In other simulations, potential output has been judgmentally adjusted to allow for these effects;[21] but that is not done in this paper, since the main interest here is in relative magnitudes and qualitative results.

[20]The United States and the Euro Area exhibit the largest overall passthroughs of oil-price shocks into core inflation, with the Euro Area experiencing relatively strong transmission through the expectations channel and relatively weak real-income catch-up effects (recall Table 1). Japan exhibits relatively small real-income catch-up effects and the lowest overall pass-through into core inflation. The United Kingdom is in the middle of the overall pass-through range for MULTIMOD industrial countries/blocks and is also a net oil exporter.

[21] IMF Research Department, "The Impact of Higher Oil Prices on the Global Economy," December, 2000.

B. The Strength of the Pass-Through into Core Inflation

The simulations presented in this section are intended to provide perspectives on one of the puzzles that has emerged in empirical investigations of the effects of oil-price shocks—in particular, the finding that oil price shocks during the 1980s and 1990s had little apparent influence on core inflation in the United States.[22] For this purpose we present simulations that combine two sets of assumptions about the wage/price nexus with two sets of assumptions about the time profile (duration) of the oil-price shock. Version one of the wage/price nexus (V1) "turns off" the channels that allow oil price shocks to pass through into core inflation, version two (V2) allows these channels to operate under the estimated parameters of the model, and the two shocks correspond to the temporary shock (ts) and the more persistent shock (ps) defined earlier.

Figure 6 and Table 3 report the simulation results. The main point that we draw from these simulations is that when the shock is temporary, the responses of output and inflation under the two different wage/price structures are similar; the most significant differences are in the core inflation outcomes for countries that have relatively large estimated real-wage catch-up effects (i.e., the United States and the United Kingdom). This point deserves emphasis when interpreting empirical evidence on the effects of oil-price shocks during the 1980s and 1990s. Many of the shocks to oil prices that occurred during those decades lasted only one or two quarters—less than the one-year duration built into the MULTIMOD simulations. While it seems reasonable to assume that downward pressures on real incomes that last for a year or longer would start to have observable effects on the outcomes of the wage-bargaining process, the real-wage catch-up effects of oil-price shocks may not have been important in the late 1980s and 1990s, when oil-price shocks were very short lived.[23] In a world with many other shocks occurring as well, it easy to understand how attempts to estimate reduced-form Phillips curves might have trouble distinguishing between alternative structures of the wage/price nexus.[24]

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[22] Hooker (1999). Recall the discussion in Section I above.

[23] Accordingly, the simulation results presented in Figure 6 and Table 3 may overstate the differences that would have arisen under the two alternative wage/price structures in response to the very temporary innovations to oil prices that occurred during the late 1980s and 1990s.

[24] A Monte Carlo experiment could be set up to test this hypothesis more formally. Artificial data could be generated under the two alternative model structures allowing the oil price shocks in the experiment to differ in their persistence. Reduced-form Philips curves could then be estimated on the artificial data, testing whether the persistence of the oil shocks mattered for the identification of the true model.

Table 3. Temporary Versus Persistent Increases in Oil Prices
(shock minus control)

Country	Variable	Model & Shock	YEAR 1	2	3	4	5	6
United States	GDP	V1ts	0.0	0.0	0.0	0.0	0.0	0.0
		V2ts	0.0	0.0	0.0	0.0	0.0	0.0
		V1ps	0.0	0.0	0.0	0.0	0.0	0.0
		V2ps	-0.2	-0.4	-0.3	0.0	0.1	0.2
	Inflation	V1ts	1.3	-0.9	-0.3	-0.1	0.0	0.0
		V2ts	1.3	-0.5	-0.3	-0.2	-0.1	-0.1
		V1ps	1.3	0.4	-0.1	-0.3	-0.4	-0.4
		V2ps	1.4	0.9	0.4	0.1	-0.2	-0.5
	Core Inflation	V1ts	0.0	0.0	0.0	0.0	0.0	0.0
		V2ts	0.0	0.5	-0.1	-0.2	-0.1	0.1
		V1ps	0.0	0.0	0.0	0.0	0.0	0.0
		V2ps	0.2	0.7	0.5	0.2	0.0	-0.2
Euro Area	GDP	V1ts	0.0	-0.1	0.0	0.1	0.0	0.0
		V2ts	0.0	0.0	0.1	0.2	0.1	0.1
		V1ps	0.0	-0.1	-0.1	0.0	0.0	0.0
		V2ps	-0.1	-0.4	-0.3	0.0	0.2	0.3
	CPI Inflation	V1ts	1.4	-0.8	-0.4	-0.2	-0.1	-0.1
		V2ts	1.4	-0.7	-0.4	-0.3	-0.2	-0.1
		V1ps	1.5	0.6	0.0	-0.3	-0.5	-0.6
		V2ps	1.6	1.1	0.5	0.1	-0.3	-0.6
	Core Inflation	V1ts	0.0	0.0	0.0	0.0	0.0	0.0
		V2ts	-0.1	0.2	-0.1	-0.2	-0.1	-0.1
		V1ps	0.0	0.0	0.0	0.0	0.0	0.0
		V2ps	0.2	0.6	0.5	0.2	0.0	-0.2

Table Notes: V1 Denotes model with no core inflation effects from oil price shocks
V2 Denotes model with core inflation effects from oil price shocks
ts Denotes temporary shock
ps Denotes persistent shock

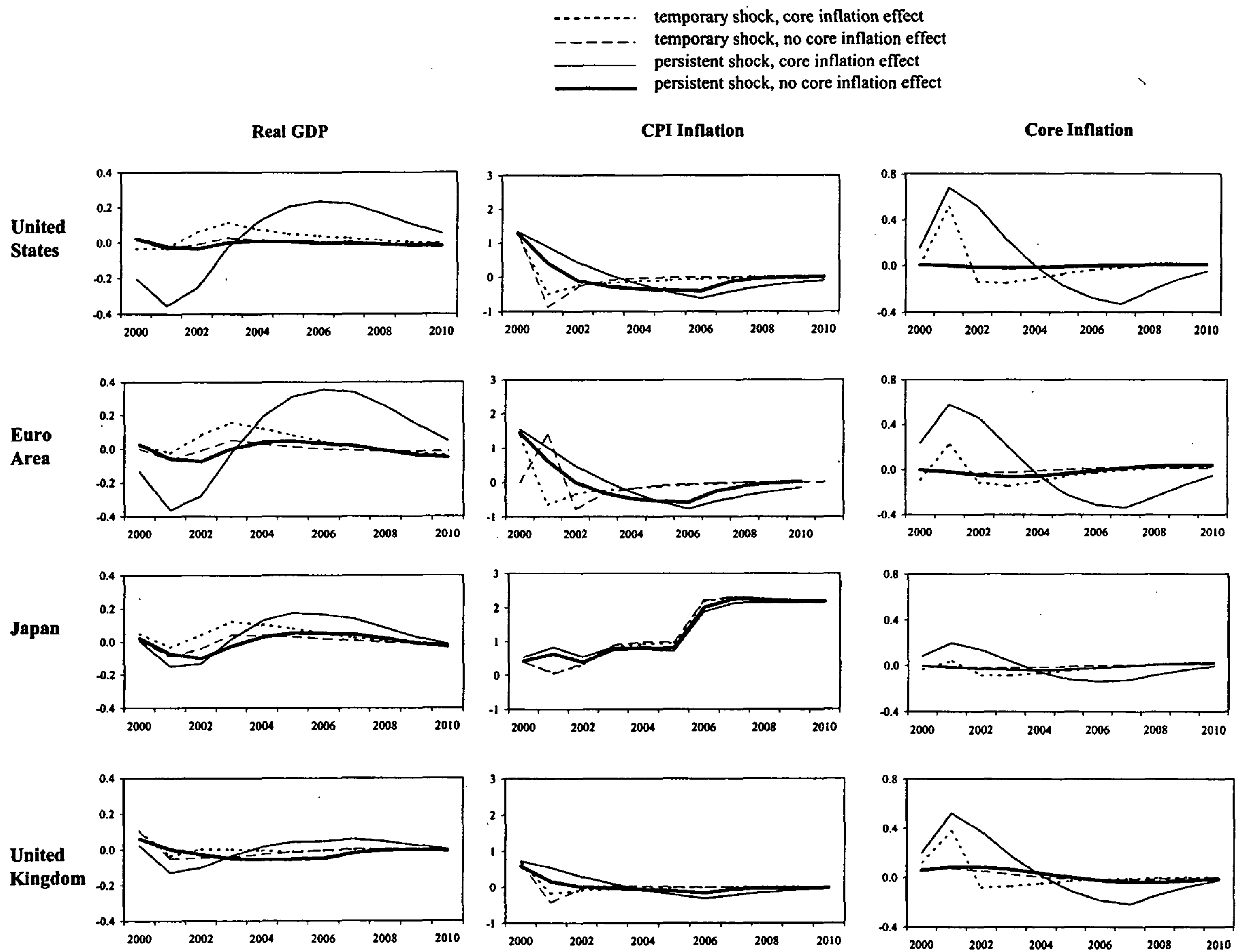
Table 3 Continued. Temporary Versus Persistent Increases in Oil Prices
(shock minus control)

Country	Variable	Model & Shock	YEAR 1	2	3	4	5	6
Japan	GDP	V1ts	0.0	-0.1	0.0	0.0	0.0	0.0
		V2ts	0.1	0.0	0.0	0.1	0.1	0.1
		V1ps	0.0	-0.1	-0.1	0.0	0.0	0.1
		V2ps	0.0	-0.1	-0.1	0.0	0.1	0.2
	CPI Inflation	V1ts	0.6	-0.5	-0.1	0.0	0.0	0.0
		V2ts	0.6	-0.4	-0.2	-0.1	-0.1	-0.1
		V1ps	0.6	0.1	-0.1	-0.2	-0.2	-0.2
		V2ps	0.8	0.3	0.1	-0.1	-0.2	-0.3
	Core Inflation	V1ts	0.0	0.0	0.0	0.0	0.0	0.0
		V2ts	0.0	0.0	-0.1	-0.1	-0.1	0.0
		V1ps	0.0	0.0	0.0	0.0	0.0	0.0
		V2ps	0.1	0.2	0.1	0.0	-0.1	-0.1
United Kingdom	GDP	V1ts	0.1	-0.1	-0.1	0.0	0.0	0.0
		V2ts	0.1	0.0	0.0	0.0	0.0	0.0
		V1ps	0.1	0.0	0.0	-0.1	-0.1	-0.1
		V2ps	0.0	-0.1	-0.1	0.0	0.1	0.2
	CPI Inflation	V1ts	0.6	-0.4	0.0	0.0	0.0	0.0
		V2ts	0.7	-0.2	-0.1	-0.1	0.0	0.0
		V1ps	0.6	0.2	0.0	0.0	-0.1	-0.1
		V2ps	0.7	0.6	0.3	0.1	-0.1	-0.2
	Core Inflation	V1ts	0.1	0.1	0.1	0.0	0.0	0.0
		V2ts	0.1	0.4	-0.1	-0.1	-0.1	0.0
		V1ps	0.1	0.1	0.1	0.1	0.0	0.0
		V2ps	0.2	0.5	0.4	0.2	0.0	-0.1

Table Notes:
- V1 Denotes model with no core inflation effects from oil price shocks
- V2 Denotes model with core inflation effects from oil price shocks
- ts Denotes temporary shock
- ps Denotes persistent shock

Figure 6. Responses of GDP and Inflation to a 50 Percent Increase in Oil Prices: Sensitivity to Pass-Through Effects

(Shock minus control in percent of GDP and percentage points of inflation)



C. Asymmetry in Real-Income Catch-Up Effects

There is clear empirical evidence of a nonlinear relationship between oil prices and aggregate measures of economic activity: oil prices and economic activity are negatively correlated, but oil price increases tend to be followed by larger changes in activity than oil price declines. It is also widely believed, with some support from empirical evidence, that monetary policy has played an important role in generating the observed relationship.

One hypothesis that could provide a consistent explanation would be that workers respond asymmetrically to oil-price increases and oil-price declines, pushing for higher wages to resist the declines in their real consumption power that result from positive oil price shocks, but not resisting the increases in real consumption power that result from oil price declines. This hypothesis, which is analogous to the popular notion that nominal wages are flexible upward but sticky downward, would also provide a rationale for policy reacting asymmetrically to oil price shocks, and for consequent asymmetry in the behavior of macroeconomic activity.

To examine how well the observed relationship between oil prices and macroeconomic activity can be explained by asymmetry in the real-wage catch-up effect, we present the model's simulated responses to both positive and negative oil price shocks under an asymmetric response to changes in households' real consumption wage. In this specification of the wage/price nexus, workers resist only declines in their real consumption wage.[25] To illustrate the effects of this asymmetry in real-income catch-up effects, we focus on *permanent* 50 percent changes (increases and decreases) in the price of oil.[26]

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[25] The empirical work undertaken in estimating MULTIMOD's wage/price nexus was unable to identify an asymmetric relationship, and the base-case version of MULTIMOD Mark IV contains a symmetric specification. The failure to identify an asymmetry is not surprising, given that an identical parsimonious specification was estimated for each country/block on annual data with few observations of persistent declines in oil prices.

[26] Simulations of *persistent* shocks analogous to that considered in the previous section (i.e., oil price changes that dissipate over a 5-year period) generate anomalous results under our simple characterization of the asymmetry in wage/price behavior. In particular, simulations of persistent increases and declines in oil prices suggest an even greater asymmetry in the first few years of the shock than simulations of permanent shocks, with persistent negative shocks to oil prices leading to *declines* in output after several years. The latter anomaly arises because the asymmetry in real-income catch-up effects has workers trying to lock in the real wage gains that occur when oil prices initially decline. As oil prices recover, workers resist the decline in real incomes from their recently improved levels and monetary policy then needs to tighten to combat the inflationary effect.

Table 4 presents the simulation results. It is readily apparent that the asymmetry in the real-wage catch-up effect generates asymmetry in the responses of output and inflation to the positive and negative oil price shocks. It is also evident that the degree to which output and inflation respond asymmetrically to oil price increases and decreases—as indicated by the ratio of the effects of the positive shock to the effects of the negative shock—varies among the different countries. Since the transmission of oil-price effects through the expectations channel is modeled symmetrically, the different degrees of asymmetry among the different countries can be largely attributed to differences in the strength of the real-wage catch-up effect. This is apparent in the fact that the asymmetries are most pronounced for the United States and the United Kingdom and smallest for Japan. It may be noted that asymmetry in the estimated real-wage catch-up effect does not, by itself, support the extreme view that positive oil-price shocks have contractionary effects while negative oil-price shocks have *no* effect on economic activity. In particular, the simulations suggest that negative oil-price shocks create downward pressure on core inflation (through the expectations channel) that allows monetary policy to ease, thereby stimulating the economy. However, asymmetry in the real-wage catch-up term does appear to be a potentially significant and plausible explanation of less extreme characterizations of the observed nonlinear relationship between oil prices and macroeconomic activity.[27]

D. The Implications of a Delayed Monetary Policy Response

Policymakers may have several reasons for delaying or moderating their responses to the recent run-up in oil prices. First, between mid-1999 and summer 2000, monetary policy in many industrial countries tightened following the easing that occurred in the aftermath of the financial turbulence in 1997. Policymakers have not yet seen the full impact of that change in policy stance and, consequently, they may be reluctant to tighten further. Uncertainty about the extent to which oil prices may come down in the period ahead, as well as uncertainty about the effects of the higher oil prices on core inflation, may also argue for not responding to the higher oil prices until their macroeconomic effects are more apparent.

The simulations presented in this section are designed to illustrate what the possible benefits and potential dangers of delaying the policy response might be. We use the version of the model that allows oil price innovations to pass through into core inflation, and consider the implications of both symmetric and asymmetric real-wage catch up effects. For certain other cases—in particular, for shocks that are very short lived or for economies in which there is no risk of pass-through into core inflation—delaying the policy response is the right thing to do.

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[27] As noted above, another plausible explanation of the observed nonlinearity is Hamilton's (2000) suggestion that the distribution of the exogenous component of historically-observed oil-price changes has been asymmetric, with most exogenous changes in oil prices consisting of price increases associated with war-induced petroleum supply disruptions.

Table 4. The Effects of Permanent Oil Price Shocks with Asymmetry in the Real-Wage Catch-Up Effect
(shock minus control)

Country	Variable	Shock	YEAR 1	2	3	4	5	6
United States	GDP	Positive	-0.3	-0.5	-0.5	-0.3	-0.2	-0.1
		Negative	0.1	0.2	0.2	0.1	0.0	0.0
	CPI Inflation	Positive	1.4	0.9	0.6	0.4	0.2	0.0
		Negative	-1.4	-0.6	-0.3	-0.1	0.0	0.0
	Core Inflation	Positive	0.1	0.7	0.5	0.3	0.1	0.0
		Negative	-0.1	-0.2	-0.2	-0.1	0.0	0.0
	Short-Term Interest Rate	Positive	1.1	1.0	0.7	0.4	0.2	0.1
		Negative	-0.4	-0.5	-0.2	-0.1	0.0	0.1
Euro Area	GDP	Positive	-0.2	-0.6	-0.6	-0.4	-0.2	-0.0
		Negative	0.1	0.3	0.3	0.2	0.1	0.0
	CPI Inflation	Positive	1.6	1.1	0.8	0.5	0.3	0.1
		Negative	-1.5	-0.9	-0.6	-0.3	-0.2	0.0
	Core Inflation	Positive	0.2	0.6	0.5	0.3	0.1	0.0
		Negative	-0.2	-0.4	-0.3	-0.2	0.0	0.1
	Short-Term Interest Rate	Positive	1.2	1.2	0.8	0.5	0.2	0.0
		Negative	-0.8	-0.9	-0.5	-0.2	0.0	0.1
Japan	GDP	Positive	-0.1	-0.3	-0.4	-0.2	-0.1	-0.0
		Negative	0.0	0.2	0.2	0.1	0.1	0.0
	CPI Inflation	Positive	0.8	0.4	0.2	0.1	0.1	0.0
		Negative	-0.7	-0.3	-0.1	-0.1	0.0	0.0
	Core Inflation	Positive	0.1	0.2	0.2	0.1	0.1	0.0
		Negative	-0.1	-0.1	-0.1	0.0	0.0	0.0
	Short-Term Interest Rate	Positive	0.4	0.3	0.2	0.1	0.0	0.0
		Negative	-0.2	-0.1	0.0	0.0	0.0	0.1

Table 4 Continued. The Effects of Permanent Oil Price Shocks with Asymmetry in the Real-Wage Catch-Up Effect
(shock minus control)

Country	Variable	Shock	YEAR 1	2	3	4	5	6
United Kingdom	GDP	Positive	0.0	-0.2	-0.2	-0.2	-0.1	-0.1
		Negative	-0.1	0.0	0.1	0.1	0.1	0.0
	CPI Inflation	Positive	0.7	0.5	0.3	0.2	0.1	0.0
		Negative	-0.7	-0.2	-0.1	-0.1	-0.1	0.0
	Core Inflation	Positive	0.2	0.5	0.3	0.2	0.1	0.0
		Negative	-0.1	-0.2	-0.1	-0.1	0.0	0.0
	Short-Term Interest Rate	Positive	1.0	0.7	0.6	0.3	0.2	0.1
		Negative	-0.4	-0.4	-0.3	-0.2	-0.1	0.0

It is widely recognized that the manner in which monetary policy responds to various shocks to the economy can have an important influence on inflation expectations. The main potential danger of delaying the response to an oil price increase stems from the possibility that delay may weaken the credibility of announced or perceived policy objectives and have an adverse effect on inflation expectations. Although modeling the evolution of policy credibility is a difficult task, analysis that abstracts from credibility issues can be very misleading.

For purposes of taking credibility issues into account, we compare simulations based on two alternative formulations of how delayed monetary policy reactions might affect the inflation expectations process. Recall that MULTIMOD's base-case monetary policy reaction function is a forward-looking inflation-forecast-based rule under which the nominal short-term interest rate is adjusted (relative to an equilibrium level) in proportion to changes in the deviation of observed output from potential output and the deviation of forecast core inflation from an inflation target. Under this reaction function, adjustments to changes in the output gap and the inflation forecast occur *with no delay.* Moreover, expected inflation is modeled as partly backward looking and partly forward looking, where the forward-looking component is model consistent in that it depends on the structure of the model, including the monetary policy reaction function. In the first formulation of what delayed monetary policy reactions might imply, we adopt the extreme assumption that delay has no effect on the inflation expectations process. In the second formulation, which is intended to illustrate the possible effects of an erosion of monetary policy credibility, we add an endogenous element to private agents' point estimate (perception) of the inflation target that enters the monetary policy reaction function. The inflation target perceived by private agents influences their expectations about future inflation, which in turn influences actual inflation outcomes.

We endogenize the perceived inflation target in a simple and admittedly ad hoc manner. Policymakers lose credibility if they do not respond to the shock and the outcome for core inflation exceeds the inflation target by more than one-half percentage point. When this occurs private agents, beginning in the next year, revise their perception of the policymaker's target to be equal to the previous year's core inflation outcome. Private agents continue to base their perception of the policymaker's target on inflation outcomes until core inflation is returned to within one-half percentage point of the "true" target. Once this occurs, private agents' perception of the target reverts to the true target. Because this model of endogenous policy credibility is ad hoc, it is important not to take the specific magnitudes of its effects too seriously; but the results provide a useful qualitative picture.

Figure 7 and Table 5 show the dynamic adjustment paths for output, core inflation, and the policy interest rate under the assumption of symmetric real-income catch-up effects, while Figure 8 and Table 6 describe the analogous adjustment paths under asymmetric real-income catch-up effects. Simulation results are provided for the cases of an immediate policy response (V2), a delayed response with exogenous policy credibility (V2dr), and a delayed response with endogenous policy credibility (V2drec); in each case the shock is the *persistent* 50 percent increase in oil-prices (i.e., an increase that persists for two years and then erodes over the next three years, as described earlier). For the cases in which the policy response is

Figure 7. GDP, Core Inflation, and the Policy Interest Rate when the Policy Reaction is Delayed: Responses to a Persistent 50 Percent Increase in Oil Prices when the Real-Income Catch-Up Effect is Symmetric
(Shock minus control in percent of GDP and percentage points of inflation)

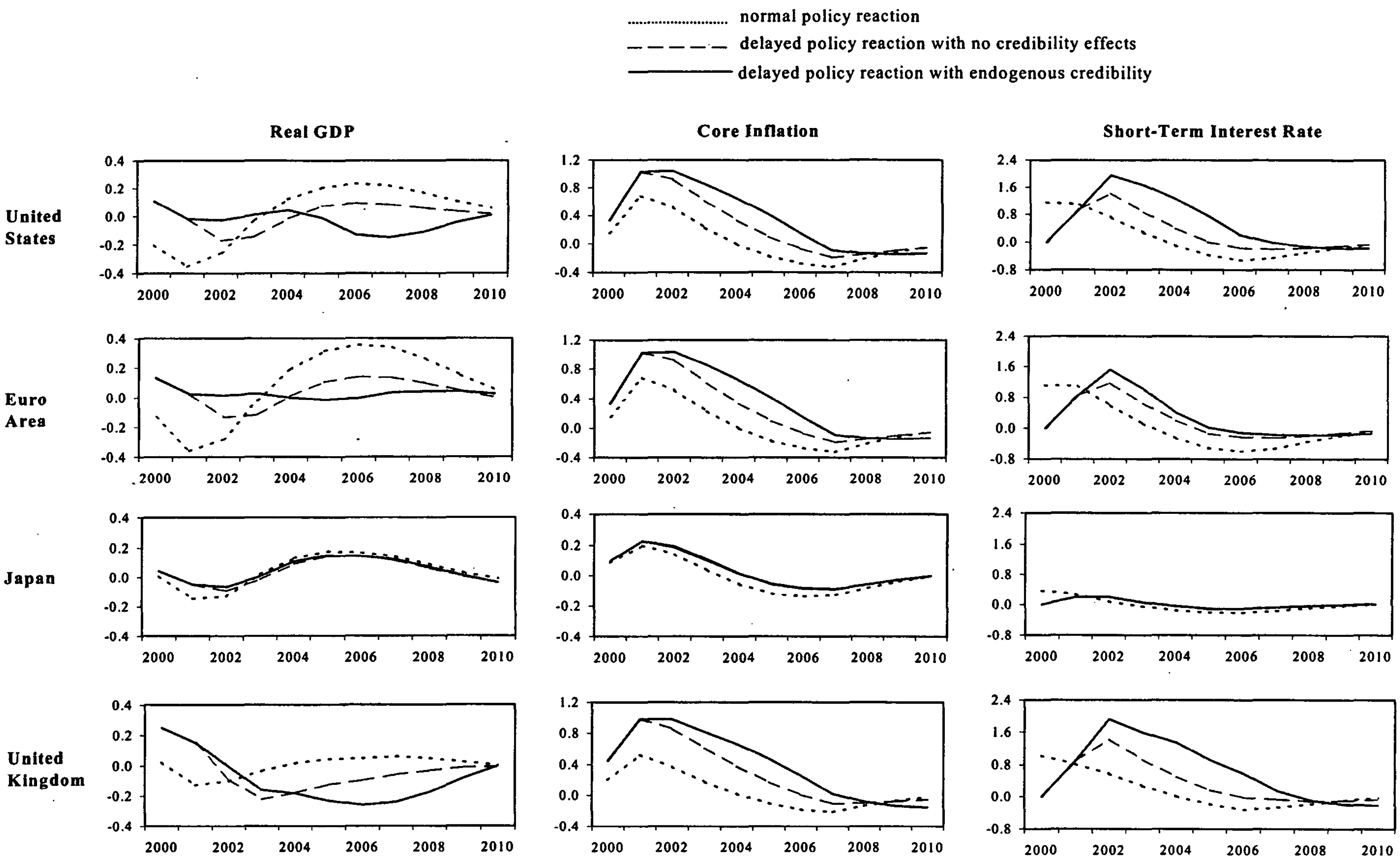

Table 5. The Effects of Persistent Oil Price Shocks
with a Delayed Policy Response – Symmetric Real-Wage Catch-Up
(shock minus control)

			YEAR								
Country	Variable	Model	1	2	3	4	5	6	7	8	9
United States	GDP	V2	-0.2	-0.4	-0.3	0.0	0.1	0.2	0.2	0.2	0.2
		V2dr	0.1	-0.0	-0.2	-0.1	0.0	0.1	0.1	0.1	0.1
		V2drec	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
	Core Inflation	V2	0.2	0.7	0.5	0.2	0.0	-0.2	-0.3	-0.3	-0.2
		V2dr	0.3	1.1	0.9	0.6	0.3	0.1	-0.1	-0.2	-0.2
		V2drec	0.3	1.1	1.1	0.9	0.7	0.4	0.1	-0.1	-0.1
	Short-Term Interest Rate	V2	1.2	1.1	0.7	0.3	-0.1	-0.4	-0.5	-0.5	-0.3
		V2dr	0.0	0.9	1.4	0.9	0.4	0.0	-0.2	-0.2	-0.2
		V2drec	0.0	0.9	2.0	1.7	1.3	0.8	0.2	0.0	-0.1
Euro Area	GDP	V2	-0.1	-0.4	-0.3	0.0	0.2	0.3	0.4	0.3	0.3
		V2dr	0.1	0.0	-0.1	-0.1	0.0	0.1	0.1	0.1	0.1
		V2drec	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Core Inflation	V2	0.2	0.6	0.5	0.2	0.0	-0.2	-0.3	-0.3	-0.3
		V2dr	0.3	0.8	0.8	0.6	0.3	0.1	-0.1	-0.2	-0.2
		V2drec	0.3	0.8	0.8	0.7	0.4	0.2	0.0	-0.1	-0.1
	Short-Term Interest Rate	V2	1.1	1.1	0.6	0.1	-0.3	-0.5	-0.6	-0.6	-0.4
		V2dr	0.0	0.9	1.2	0.7	0.2	-0.1	-0.2	-0.3	-0.2
		V2drec	0.0	0.9	1.5	1.1	0.4	0.0	-0.1	-0.2	-0.2

Table Notes:

V2	Denotes model with core inflation effects from oil price shocks
dr	Denotes delayed policy response
drec	Denotes delayed policy response and endogenous credibility

Table 5 Continued. The Effects of Persistent Oil Price Shocks with a Delayed Policy Response – Symmetric Real-Wage Catch-Up
(shock minus control)

			YEAR								
Country	Variable	Model	1	2	3	4	5	6	7	8	9
Japan	GDP	V2	0.0	-0.1	-0.1	0.0	0.1	0.2	0.2	0.1	0.1
		V2dr	0.0	0.0	-0.1	0.0	0.1	0.1	0.1	0.1	0.1
		V2drec	0.0	0.0	-0.1	0.0	0.1	0.1	0.2	0.1	0.1
	Core Inflation	V2	0.1	0.2	0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
		V2dr	0.1	0.2	0.2	0.1	0.0	-0.1	-0.1	-0.1	-0.1
		V2drec	0.1	0.2	0.2	0.1	0.0	-0.1	-0.1	-0.1	-0.1
	Short-Term Interest Rate	V2	0.4	0.3	0.1	0.0	-0.1	-0.2	-0.2	-0.2	-0.1
		V2dr	0.0	0.2	0.2	0.1	0.0	-0.1	-0.1	0.0	0.0
		V2drec	0.0	0.2	0.2	0.1	0.0	-0.1	-0.1	-0.1	0.0
United Kingdom	GDP	V2	0.0	-0.1	-0.1	0.0	0.0	0.0	0.1	0.1	0.1
		V2dr	0.3	0.2	-0.1	-0.2	-0.2	-0.1	-0.1	-0.1	0.0
		V2drec	0.3	0.2	0.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	Core Inflation	V2	0.2	0.5	0.4	0.2	0.0	-0.1	-0.2	-0.2	-0.1
		V2dr	0.5	1.0	0.9	0.6	0.4	0.2	0.0	-0.1	-0.1
		V2drec	0.5	1.0	1.0	0.8	0.7	0.5	0.3	0.0	-0.1
	Short-Term Interest Rate	V2	1.0	0.8	0.6	0.3	0.0	-0.2	-0.3	-0.3	-0.2
		V2dr	0.0	0.9	1.4	0.9	0.5	0.2	0.0	-0.1	-0.1
		V2drec	0.0	0.9	1.9	1.6	1.4	0.9	0.6	0.1	-0.1

Table Notes:
- V2 Denotes model with core inflation effects from oil price shocks
- dr Denotes delayed policy response
- drec Denotes delayed policy response and endogenous credibility

Figure 8. GDP, Core Inflation, and the Policy Interest Rate when the Policy Reaction is Delayed: Responses to a Persistent 50 Percent Increase in Oil Prices when the Real-Income Catch-Up Effect is Asymmetric

(Shock minus control in percent of GDP and percentage point of inflation)

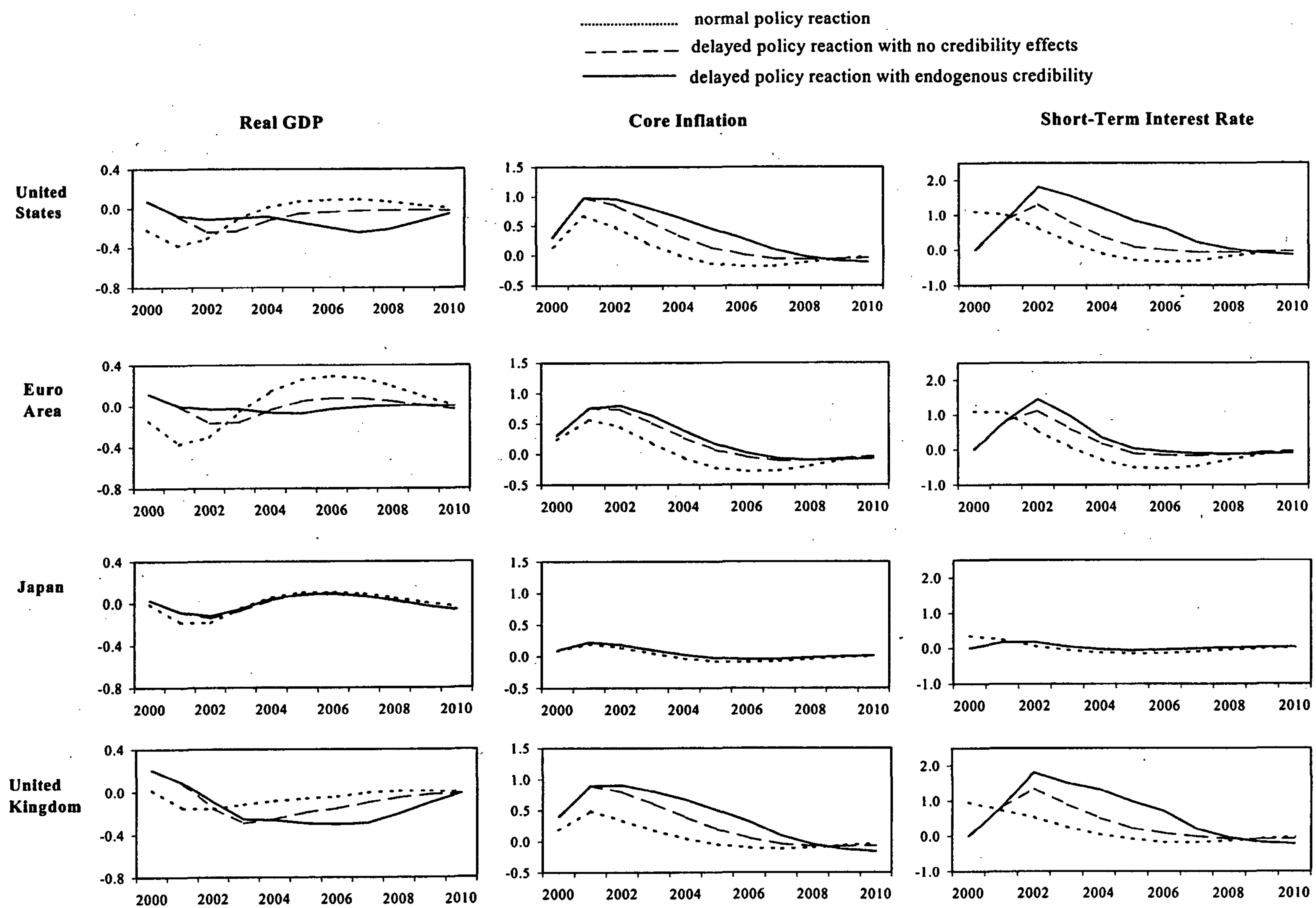

Table 6. The Effects of Persistent Oil Price Shocks
with a Delayed Policy Response – Asymmetric Real-Wage Catch-Up
(shock minus control)

			YEAR								
Country	Variable	Model	1	2	3	4	5	6	7	8	9
United States	GDP	V2a	-0.2	-0.4	-0.3	-0.1	0.0	0.1	0.1	0.1	0.1
		V2adr	0.1	-0.1	-0.2	-0.2	-0.1	-0.1	0.0	0.0	0.0
		V2adrec	0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2
	Core Inflation	V2a	0.1	0.7	0.5	0.2	0.0	-0.1	-0.2	-0.2	-0.1
		V2adr	0.3	1.0	0.9	0.6	0.3	0.1	0.0	-0.1	-0.1
		V2adrec	0.3	1.0	1.0	0.8	0.7	0.5	0.3	0.1	0.0
	Short-Term Interest Rate	V2a	1.1	1.0	0.6	0.2	-0.1	-0.3	-0.4	-0.3	-0.2
		V2adr	0.0	0.9	1.3	0.8	0.4	0.1	0.0	-0.1	-0.1
		V2adrec	0.0	0.9	1.8	1.6	1.2	0.8	0.6	0.2	0.0
Euro Area	GDP	V2a	-0.1	-0.4	-0.3	-0.1	0.1	0.3	0.3	0.3	0.2
		V2adr	0.1	0.0	-0.2	-0.2	0.0	0.0	0.1	0.1	0.0
		V2adrec	0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0
	Core Inflation	V2a	0.2	0.6	0.5	0.2	-0.1	-0.2	-0.3	-0.3	-0.2
		V2adr	0.3	0.8	0.8	0.5	0.3	0.1	0.0	-0.1	-0.1
		V2adrec	0.3	0.8	0.8	0.7	0.4	0.2	0.0	-0.1	-0.1
	Short-Term Interest Rate	V2a	1.1	1.1	0.6	0.1	-0.3	-0.5	-0.5	-0.5	-0.3
		V2adr	0.0	0.8	1.2	0.6	0.2	-0.1	-0.1	-0.2	-0.1
		V2adrec	0.0	0.8	1.5	1.0	0.4	0.1	0.0	-0.1	-0.1

Table Notes:

V2a Denotes model with core inflation effects from oil price shocks and asymmetric real-wage catch-up
dr Denotes delayed policy response
drec Denotes delayed policy response and endogenous credibility

Table 6 Continued. The Effects of Persistent Oil Price Shocks with a Delayed Policy Response – Asymmetric Real-Wage Catch-Up
(shock minus control)

			YEAR								
Country	Variable	Model	1	2	3	4	5	6	7	8	9
Japan	GDP	V2a	0.0	-0.2	-0.2	0.0	0.1	0.1	0.1	0.1	0.1
		V2adr	0.0	-0.1	-0.1	-0.1	0.0	0.1	0.1	0.1	0.0
		V2adrec	0.0	-0.1	-0.1	-0.1	0.0	0.1	0.1	0.1	0.0
	Core Inflation	V2a	0.1	0.2	0.1	0.0	0.0	-0.1	-0.1	-0.1	-0.1
		V2adr	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
		V2adrec	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
	Short-Term Interest Rate	V2a	0.4	0.3	0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
		V2adr	0.0	0.2	0.2	0.1	0.0	-0.1	0.0	0.0	0.0
		V2adrec	0.0	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
United Kingdom	GDP	V2a	0.0	-0.2	-0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0
		V2adr	0.2	0.1	-0.1	-0.2	-0.2	-0.1	-0.1	0.0	0.0
		V2adrec	0.2	0.1	-0.1	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2
	Core Inflation	V2a	0.2	0.5	0.3	0.2	0.1	-0.1	-0.1	-0.1	-0.1
		V2adr	0.4	0.9	0.8	0.6	0.4	0.2	0.1	0.0	-0.1
		V2adrec	0.4	0.9	0.9	0.8	0.7	0.5	0.3	0.1	-0.1
	Short-Term Interest Rate	V2a	1.0	0.7	0.5	0.3	0.1	-0.1	-0.2	-0.2	-0.1
		V2adr	0.0	0.8	1.3	0.9	0.5	0.2	0.1	0.0	-0.1
		V2adrec	0.0	0.8	1.8	1.5	1.3	1.0	0.7	0.2	-0.1

Table Notes:

V2a Denotes model with core inflation effects from oil price shocks and asymmetric real-wage catch-up
dr Denotes delayed policy response
drec Denotes delayed policy response and endogenous credibility

delayed, the interest rate is held unchanged (relative to the baseline path) for one and a half years, after which it reverts to the path dictated by the monetary policy reaction function.[28]

The results of delaying the policy response vary across countries. In Japan there is little effect on economic activity or inflation and very little need for subsequent policy action. In other countries, delaying the policy reaction—that is, holding the short-term nominal interest rate constant and allowing inflation expectations to rise—has expansionary effects on aggregate demand and GDP in the short run but leads to a much sharper interest-rate response by the third year, with subsequent contractionary effects on GDP. Interest rates are lowered as (forecast) inflation is brought under control, but both interest rates and output continue to cycle after oil prices revert (in year six) to the baseline level. The decline in interest rates—to levels below baseline in the simulations with exogenous credibility—reflects the decline in oil prices (beginning in year three) and the induced weakening of pressures on core inflation.

Table 7 presents summary statistics on the cumulative changes after ten years in output and price levels. For each country, comparisons of the entries in the first and second rows indicate the cumulative effects of delaying the policy response when policy credibility does not suffer. The cumulative loss of output in these cases is about 0.3 percentage points of GDP in the United Kingdom and smaller amounts elsewhere, while the cumulative effects on price levels range from 0.3 to 0.5 percent in Japan to about 2.5 percent in the United Kingdom. When credibility is endogenous, the cumulative output losses and price level increases are larger, as indicated by the differences between the first and third rows.

The most striking implications of endogenous credibility, however, are not the differences apparent in Table 7, but rather the interest rate implications shown in Figures 7 and 8 (and Tables 5 and 6). Under endogenous credibility, the efforts to restore macroeconomic stability (i.e., to steer economies back to baseline) after delaying policy responses for a year and a half result in short-term interest rates being pushed in the third year to levels about 2 percentage points above baseline in the United States and the United Kingdom and 1.5 percentage points in the Euro Area.[29] While sharp interest rate hikes might be regarded as successful in averting major cumulative costs in these hypothetical scenarios, in reality the scope for such an aggressive tightening of monetary policy is often constrained by political pressures. In the presence of such constraints, the costs of delay could be much larger than those summarized in Table 7.

[28] More precisely, the policy setting in the second year is the average of what would emerge from the case with a one-year delay and the case with a two-year delay, with the interest rate reverting in the third year to the path dictated by the policy reaction function.

[29] Short-term interest rates are pushed up slightly more in the case of a symmetric real-wage catch-up effect than in the asymmetric case, but short-rates also decline somewhat more gradually in the latter case. Long-term interest rates, which reflect projected short rates, tend to increase somewhat more in the asymmetric case.

Table 7. Summary Statistics from Delayed Policy Response Simulations
(Percentage Points)

	Cumulative Change After Ten Years					
	Real GDP		CPI		Core Price Level	
	Symmetric	Asymmetric	Symmetric	Asymmetric	Symmetric	Asymmetric
United States						
V2	0.2	-0.6	0.5	0.8	0.4	0.8
V2dr	0.1	-0.8	2.9	3.1	2.8	3.1
V2drec	-0.3	-1.3	4.2	4.6	4.2	4.5
Euro Area						
V2	0.7	0.2	0.3	0.4	0.2	0.3
V2dr	0.3	0.0	2.3	2.4	2.2	2.4
V2drec	0.2	-0.1	2.8	2.9	2.8	2.9
Japan						
V2	0.4	0.0	0.0	0.0	0.0	0.0
V2dr	0.5	0.0	0.3	0.5	0.3	0.5
V2drec	0.6	0.0	0.3	0.5	0.3	0.4
United Kingdom						
V2	-0.1	-0.6	0.6	0.8	0.6	0.8
V2dr	-0.4	-0.9	3.2	3.2	3.2	3.2
V2drec	-1.0	-1.5	4.6	4.6	4.5	4.5

E. Comparative Costs of Potential Policy Errors

Given that the optimal policy response to an increase in oil prices depends so heavily on how private agents respond, what should monetary authorities assume when they set policy? Is there a danger that the recent oil price increases will pass through into core inflation, or will the oil price shock simply result in a temporary increase in headline inflation? Hooker's (1999) evidence for the United States, based on empirical analysis in a reduced-form Phillips curve framework, suggests that oil price increases did not affect core inflation during the 1980s and 1990s. However, policymakers may want to interpret this evidence with caution because the positive oil price shocks that occurred during the last two decades were very short lived, and because any impacts on core inflation may have been mitigated by the response of policy.

It is broadly agreed that policymakers—in responding to oil prices increases, and in seeking to stabilize the economy more generally—should carefully monitor a wide range of indicators, and exploit the best analytic tools available, to try to reduce their uncertainties about economic behavior, including the pass-through effects of inflationary shocks. But even with the best analysis available, policymakers must make decisions based on very incomplete information about macroeconomic relationships. Should they base their responses to the recent increase in oil prices on the reduced-form Phillips curve evidence from the 1980s and 1990s; or should they respond as if there is potential for oil prices to influence core inflation? No matter what they assume, they are likely to be wrong to some degree. If the monetary authorities expect the inflationary consequences to be more persistent than turns out to be the case, then policy settings will initially be inappropriately tight, other things equal. If, on the other hand, the authorities initially underestimate the strength of the pass-through effects into core inflation, then policy may not be tightened enough to quickly stabilize inflation.

Our purpose in this section is to illustrate that the macroeconomic costs of these two types of policy errors are different orders of magnitude, and that the welfare-maximizing strategy is for policymakers to base their responses on high-side estimates of the degree of pass-through into core inflation, *other things equal.* We demonstrate this by using MULTIMOD to compare the effects on output and inflation of the persistent 50 percent increase in oil prices under two possible structures for the economy combined with monetary policy reactions based, alternatively, on correct and incorrect information about those structures. The first structure has no core inflation consequences of the oil price increase. Under the second structure, the oil price shock passes through into core inflation, workers behave asymmetrically in only resisting the declines in their real wages that result from changes in oil prices, and the credibility of inflation objectives is eroded when core inflation deviates significantly from target in association with policy behavior that does not provide an adequate response to the shock.

Four simulations are used to generate the estimated costs of making policy errors. In two of the simulations the policymaker correctly perceives the inflation process. In the remaining two simulations the monetary authorities misperceive the structure of the wage/price nexus for the first two years following the oil price shock, and policy during those years is based on a forecast of inflation that is generated using the incorrect model of the inflation process. The consequences of the policy errors are characterized by the additional macroeconomic variability that they cause, as measured by differences between the deviations of output and inflation from baseline in the simulations with policy errors minus the corresponding deviations from baseline in the simulations with the same structure of the economy and no policy errors. We define "error 1" as the case in which policymakers assume no pass-through into core inflation when the true structure of the economy includes the asymmetric real-wage catch-up effect and credibility is endogenous. "Error 2" is the case in which there is no pass-through into core inflation but policymakers base their reactions on the model of the economy that includes the asymmetric pass-through structure and endogenous credibility.

Figure 9 shows the simulated effects of the two hypothetical policy errors on real GDP, core inflation, and the short-term nominal interest rate, and Table 8 presents several summary statistics that characterize the estimated costs of the errors. The plots represent the additional changes that arise from the policy errors—i.e., the deviations from baseline under the policy error minus the deviations from baseline under the same structure of the economy with no policy error. Similarly, the first two columns of the table report the additional cumulative changes that arise from the errors. The third column of the table reports the loss that would arise under a quadratic loss function that equally weights the additional variability in real output and core inflation arising from the errors.[30]

The table shows that initially making the incorrect assumption that there are no core inflation effects (error 1) results in a permanent sacrifice of real output for the United States, the Euro Area and the United Kingdom. In these cases the slow response of policymakers implies that output must be permanently sacrificed to re-anchor inflation expectations at the target rate. These results reflect the relative importance of the estimated core inflation effects across the countries/blocks. In Japan, the core inflation effects are close to zero, reflecting MULTIMOD's estimates of insignificant pass-through effects; so neither policy error has very significant consequences. Under the second error, the initial declines in real output that arise from policy being set too tight are fully recovered once policymakers (after two years) recognize their error. The price level also exhibits more drift under the first policy error than it does under the second. And since both output and inflation show greater additional variability under the first error than under the second, the quadratic loss echoes the result that underestimating the strength of the pass-through effect is more costly than overestimating it.[31]

[30]The loss is calculated as the sum, over the first ten annual observations, of the square of the difference between the two deviations of real GDP from baseline, plus the square of the difference between the two deviations of core inflation from target (baseline).

[31] Applying a 5 per cent annual discount factor or including interest rate variability with a weight of 0.3 in the loss calculation does not alter the ranking of the costs of the two errors.

Figure 9. Simulated Effects of Policy Errors on GDP, Core Inflation, and the Policy Interest Rate

(in percent of GDP and percentage points of inflation and interest)

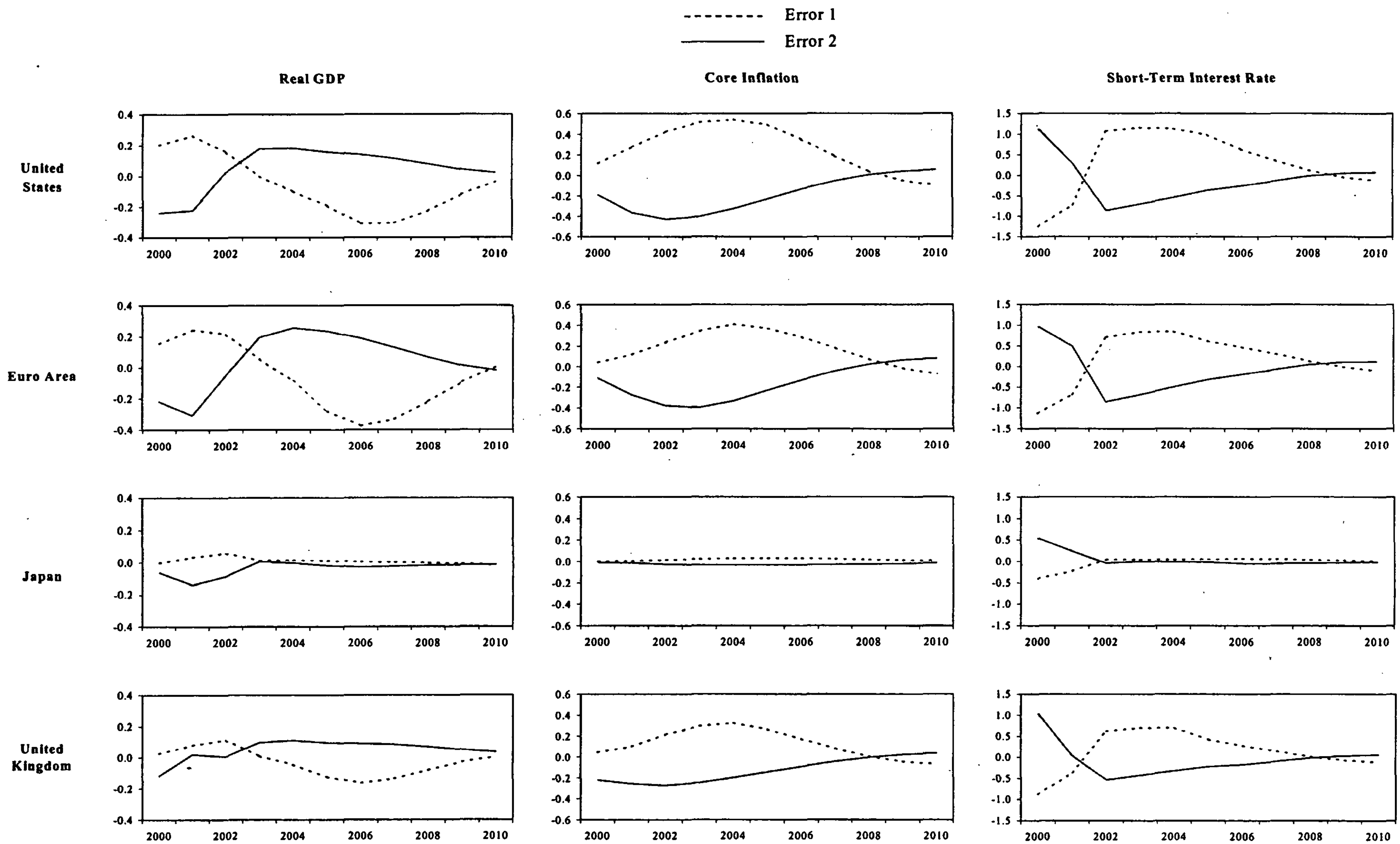

Table 8. Costs of Possible Policy Errors
Error 1 – erroneously believe no core inflation effects
Error 2 – erroneously believe core inflation effects

	Cumulative change after ten years (Percentage points)		Quadratic Loss (Inflation and Output Variance)
	Real GDP	Core Price Level	
United States			
Error 1	-0.4	3.0	5.4
Error 2	0.1	-1.9	0.8
Euro Area			
Error 1	-0.3	2.0	1.8
Error 2	0.1	-1.8	0.9
Japan			
Error 1	0.0	0.2	0.1
Error 2	-0.1	-0.3	0.1
United Kingdom			
Error 1	-0.5	1.5	3.1
Error 2	0.1	-1.0	0.2

V. Concluding Remarks

Oil price shocks posed major challenges for monetary policy during the 1970s. Subsequently, the price of oil exhibited fairly moderate variability during much of the 1980s and 1990s, but turned down sharply after the Asian financial crises erupted. Oil prices bottomed out at a 25-year low in February 1999, then tripled in the period through early September 2000, have since retreated moderately, but remain well above their average for the past two decades. The relatively high prevailing level has generated renewed interest in analyzing the expected macroeconomic consequences and risks associated with a rise in oil prices and the implications for how monetary policy should respond.

This paper has used MULTIMOD to address these issues. It has distinguished between the effects of temporary, more persistent, and permanent shocks and has suggested that even the effects of large permanent oil-price increases can be limited under forward-looking and well-chosen reactions by the monetary authorities.

The simulation analysis has developed several perspectives that are relevant for arriving at well-chosen monetary policy reactions and avoiding a repeat of the types of experiences that followed the oil shocks of the 1970s. Three perspectives deserve particular emphasis. First, experience during the 1980s and 1990s does not provide a valid basis for dismissing the risk that persistent oil-price increases will pass through into core inflation. Second, delay in responding to a persistent oil-price increase can have high macroeconomic costs if it leads to an erosion of monetary policy credibility. And third, in the face of significant uncertainties about behavioral relationships, monetary policymakers should interpret the data in a manner that errs in the direction of a more aggressive policy response to oil-price increases, *other things equal.*

These conceptual perspectives do not imply that monetary policy should always respond immediately and/or aggressively to oil price increases that are expected (based on futures prices) to be persistent. But they do underscore the importance of carefully monitoring a wide range of economic indicators to watch for signs that oil-price increases may be threatening to pass into core inflation, of looking and listening for any indications that market participants might be beginning to doubt the credibility of monetary policy, and of exploiting the best analytic tools available to help narrow uncertainties about the nature and parameters of key behavioral relationships.

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