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Oil price pass-through into inflation ☆

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ABSTRACT

This paper uses data from 19 industrialized countries to investigate oil price pass-through into inflation across countries and over time. A time-varying pass-through coefficient is estimated and the determinants of the recent declining effects of oil shocks on inflation are investigated. The appreciation of the domestic currency, a more active monetary policy in response to inflation, and a higher degree of trade openness are found to explain the decline in oil price pass-through.

1. Introduction

As documented in many studies, the dramatic rise in oil prices during the 1970s has been associated with subsequent economic downturns.[1] Although there is some debate as to whether oil shocks are the main cause of recession (see, e.g., Bohi, 1989), it is widely accepted that oil price shocks at least partially pass through into inflation. Understanding the empirical linkage between oil prices and inflation rates is then important as most monetary authorities attempt to keep inflation under control. Knowledge of the inflationary effects of oil price increases will then assist monetary authorities to conduct policy to accommodate these shocks.[2]

Fig. 1 plots the world average quarterly oil price from 1957:Q1 to 2006:Q4. Hikes in oil prices that have occurred since 1999 have attracted attention from macroeconomists. See Barsky and Kilian (2004) and Kilian (in press) for a thorough review. It has been widely observed in empirical studies that the statistical relationship between the oil price and the economy has weakened over time. Herrera and Pesavento (in press) estimate a quarterly structural vector autoregression (VAR) model for the U.S. economy, splitting their sample into two subperiods: 1959:Q1–1979:Q4 and 1985:Q1–2006:Q4. They find that oil price shocks have a larger and longer-lived effect on macroeconomic variables such as output growth, the aggregate price level, and inventory investment in the pre-Volcker period (1959:Q1–1979:Q4). Blanchard and Gali (2007) use data from industrialized economies (the U.S., France, the U.K., Germany, Italy, and Japan), and focus on the different effects of oil price shocks on inflation and economic activities across time. Their sample period is divided into two subperiods: pre-1983 and post-1984. A VAR analysis shows that the dynamic effects of oil shocks have decreased considerably over time. Then using a simple theoretical model, they examine the following four hypotheses to explain the increasingly mild effects of oil price shocks: the changing nature of oil shocks, the smaller share of oil in production, more flexible labor markets, and improvements in monetary policy. The calibrated results suggest that all four factors play an important role. As Blanchard and Gali (2007) argue, the time-varying impacts of oil prices on the economy may explain why previous studies provide mixed evidence on how oil shocks affect the economy.

A few studies focus exclusively on changes in the degree of oil price pass-through. Hooker (2002) estimates a Phillips curve model with quarterly data from 1962:Q2 to 2000:Q1. He identifies a structural break in the core U.S. inflation Phillips curve and finds that oil price pass-through has become negligible since 1980. LeBlanc and Chinn (2004) adopt a similar Phillips curve framework to analyze data from G5 countries, and obtain similar findings: current oil price increases are likely to have a modest effect on inflation in the U.S., Japan, and Europe. Gregorio et al. (2007) present evidence of a substantial decline in oil price pass-through using both a Phillips curve model and a rolling VAR model. They find that a decline in oil price pass-through is

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[1] See Hamilton and Herrera (2004) for a review of the literature.

[2] However, there is debate about the efficacy of monetary policy in eliminating the recessionary con- sequences of oil shocks. See Bernanke et al. (1997) and Hamilton and Herrera (2004).

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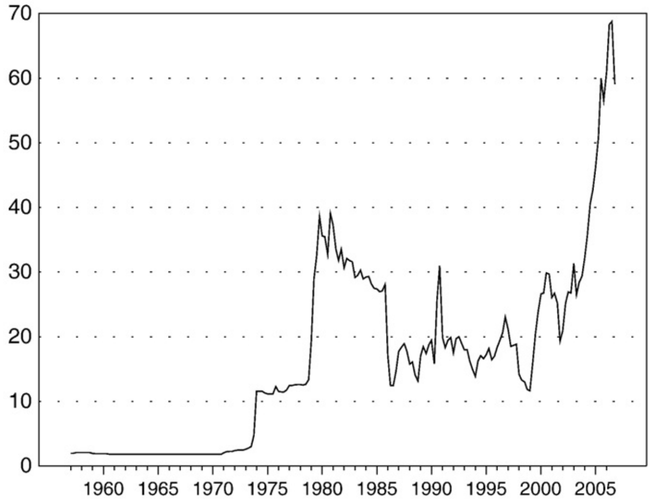

Fig. 1. Oil prices: world average.

a generalized feature of many of the 34 developed and developing countries considered. In addition, van den Noord and Andre (2007) conclude that the spillover effects of energy prices into core inflation (inflation excluding energy and food prices) are small in comparison with the effects of the 1970s. In summary, the extant literature focusing on pass-through into inflation has found that oil price pass-through has changed over time.

All of the above studies have considered a number of potential explanations for the changes in oil price pass-through. However, the evidence appears mixed. For instance, Hooker (2002) shows that declining energy intensity is not the major cause of declining pass-through in the U.S. economy, whereas Gregorio et al. (2007) using a similar specification for 24 industrial countries conclude that the fall in energy intensity helps explain the decline in average pass-through.

In this paper, I take a further step to investigate the variations in the degree of oil price pass-through using a state space framework. In contrast with most previous work, I construct the pass-through such that it changes gradually, rather than involving a one-off structural break. In addition, I formally estimate the effects of proposed explanatory variables and test their statistical significance. I examine three important questions: (1) how does oil price pass-through change over time, (2) is the declining pass-through a common feature in developed countries, and (3) what factors account for the change in pass-through? The contribution of the paper is twofold. First, rather than assuming a one-time change in pass-through, I estimate time-varying pass-through using the state space approach to account for gradual changes in oil price pass-through into the aggregate consumer price index (CPI) measure of inflation. Second, using a large panel dataset, I investigate the evolution of aggregate pass-through, and consider different explanations (hypotheses) for changes in pass-through. The empirical findings presented increase our knowledge of the changing effects of oil shocks. A clear understanding of the linkage between oil prices and inflation may then help policymakers to form a better understanding of inflation risk and take an appropriate monetary policy stance in response.

Using data from 19 industrial countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the U.K., and the U.S., it is found that the degree of oil price pass-through varies across countries and is positively correlated with energy imports. Moreover, the evidence supports an unstable pass-through coefficient over time. The appreciation of the domestic currency, a more active monetary policy in response to inflation, and a higher degree of trade openness are able to explain this evolution in oil price pass-through. Among these explanatory variables, trade openness in particular has statistically significant explanatory power.

The rest of the paper is organized as follows. Section 2 presents the data and conducts a preliminary investigation of oil price pass-through. Section 3 examines the evolution of the time-varying pass-through using a state space approach, and investigates the factors that potentially account for the changes in pass-through. Section 4 concludes the paper.

2. Data and preliminary investigation of pass-through

To estimate the degree of oil price pass-through, it is in generally useful to consider an augmented Phillips curve with the following structure:

$$\pi_t = \alpha + \sum_{i=1}^{k} \beta_i \pi_{t-i} + \gamma(y_{t-1} - \bar{y}_{t-1}) + \sum_{i=1}^{k} \theta_i \Delta o_{t-i} + \varepsilon_t, \quad (1)$$

where $\pi_t = p_t - p_{t-1}$ represents the CPI inflation rate calculated as the change in the log of the consumer price index (CPI). y_t is the log of output, and $\bar{y}_t$ is the Hodrick–Prescott filtered trend of y_t. Hence, $(y_t - \bar{y}_t)$ represents the output gap. The augmented term O_t is the log of oil prices in U.S. dollars. In Eq. (1), the short-run pass-through is given by the estimated coefficient θ_1. Long-run full pass-through is obtained by $\phi = \sum_{i=1}^{k} \theta_i / (1 - \sum_{i=1}^{k} \beta_i)$.

However, it is likely that oil prices, CPI, and output are cointegrated, i.e., a long-run equilibrium relationship between these variables may exist. To obtain long-run pass-through, the following empirical model is estimated:

$$p_t = \alpha + \beta_y y_t + \beta_0 o_t + \varepsilon_t. \quad (2)$$

Clearly, the long-run full pass-through is given by β_o. Moreover, to account for information concerning the long-run equilibrium relationship, I consider an error correction empirical model:

$$\pi_t = \alpha + \sum_{i=1}^{k} \beta_i \pi_{t-i} + \gamma(y_{t-1} - \bar{y}_{t-1}) + \sum_{i=1}^{k} \theta_i \Delta o_{t-i} + \varphi ECT_{t-1} + \varepsilon_t, \quad (3)$$

where ECT_t is the error correction term:

$$ECT_t = p_t - \beta_y y_t - \beta_o o_t.$$

I will let the data decide on which empirical model (Eq. (1) or Eq. (3)) should be applied. It is worth noting that under the error correction framework, total short-run pass-through is given by $\omega = \theta_1 + \varphi\beta_o$ while partial short-run pass-through is θ_1 (see Adolfson (2001)). While total short-run pass-through is investigated in this paper, the results are similar to partial short-run pass-through.

Quarterly data are used for 19 industrialized countries from 1970:Q1 to 2006:Q4. The series for the CPI, industrial production, and the world average price of oil are obtained from International Financial Statistics (IFS) published by the International Monetary Fund.[3] I first apply the Augmented Dickey–Fuller (ADF)–Generalized Least Squares (GLS) test proposed by Elliott et al. (1996) to investigate the time series properties of the CPI, industrial production, and the oil price, and find evidence that these series are integrated of order one, or I(1). I then apply the Johansen test for cointegration. In most cases, the maximum-eigenvalue test suggests a single cointegrating relationship at the 1% level of significance. For some countries (Australia, Italy, Sweden, and the U.S.), no cointegrating relationship is found using the maximum-eigenvalue test. However, trace tests suggest a cointegrating vector.[4] Guided by

[3] I employ industrial production rather than Gross Domestic Product (GDP) simply because the sample period available for real GDP is shorter for some countries, including Belgium, Denmark, Ireland, Italy, the Netherlands, Portugal, and Spain. However, the empirical results are qualitatively similar if I replace industrial production with real GDP for the remaining countries.

[4] To save space, the results of the ADF–GLS and Johansen tests are not provided, but are available upon request.

these findings, I use the error correction model (Eq. (3)) to estimate the degree of oil price pass-through. The optimal lag structure is found to be $k=4$ for sixteen countries as indicated by the Schwarz information criterion while different lag structures are suggested for Italy ($k=3$), the Netherlands ($k=1$), and the U.S. ($k=3$). For simplicity, while I select $k=4$ for all countries, the results are found to be robust to different lag structures.[5]

The estimates of the long-run oil price pass-through into inflation are provided in Table 1. Newey–West heteroskedasticity and auto-correlation consistent (HAC) standard errors are used with the Bartlett kernel. The truncation parameter is simply set to four but the results are similar when other parameter values are used. In most cases, the estimates of the long-run pass-through ($\hat{\beta}_o$) are statistically significant within conventional margins. An unweighted average across countries indicates that the average pass-through is 0.166170; this suggests that a 100% increase in the oil price is passed through as an increase of 17% in inflation over the long run.

The short-run dynamics for the error correction model are reported in Tables 2 and 3. First, it is obvious that most of the coefficient estimates for output gap in the augmented Phillips curve are positive and structurally plausible. Moreover, all of the coefficients for the error correction terms are negative. This suggests that the dynamic system will converge to a long-run equilibrium. Comparing Tables 1–3, it is clear that the long-run pass-through is higher than the short-run pass-through, as expected, in all countries except Portugal. The average pass-through is 0.004925 in the short run. That is, a 100% increase in the oil price is passed through as an increase of 0.5% in inflation one quarter later. Among G7 countries, Japan, Italy, and France have relatively higher short-run pass-through estimates (1.2%, 0.9% and 0.5%, respectively). The pass-through estimate for Germany is relatively lower (0.2%). As a consequence, the inflationary effect of oil prices varies across countries. Why then might the degree of oil price pass-through differ across countries? The dependence of each country on oil could be one explanation. Therefore, I plot the short-run and long-run pass-through coefficients for each country against their average net energy imports based on an average of the annual series from 1960 to 2004.[6] Fig. 2 presents clear evidence that a country with more energy imports tends to have larger pass-through. The correlations between energy imports and pass-through are 0.34 and 0.07 for the short-run and the long-run, respectively. Of course, dependence on imported energy is not the only explanation for any cross-country discrepancies. For instance, it is obvious that most European countries have higher pass-through than the U.S.. LeBlanc and Chinn (2004) argue that this may be the result of the more powerful labor unions and lower product market competition found across Europe.

Next, I investigate the stability of the pass-through coefficients. Using the tests of one-time structural breaks proposed by Andrews (1993) and Andrews and Ploberger (1994) in Table 4, I report the sup-LM and exp-LM statistics with asymptotic p-values computed by Hansen (1997)'s approximations. It is clear that only 5 of the 19 countries fail to reject the null hypothesis that there is no structural break. The estimated break date, $\hat{\tau}$, is also presented in Table 4. Based on the estimated break date, a dummy variable is constructed, as follows:

$$D_t = \begin{cases} 0 & \text{if } t<\hat{\tau} \\ 1 & \text{if } t\geq\hat{\tau} \end{cases}$$

Table 1
Long-run oil price pass-through into CPI inflation

	Constant	β_y	β_o
Australia	−5.617***	2.100***	0.219***
	(0.545)	(0.136)	(0.037)
Austria	0.371	0.855***	0.112***
	(0.271)	(0.072)	(0.027)
Belgium	−4.965***	1.990***	0.149***
	(0.744)	(0.181)	(0.037)
Canada	−2.916***	1.565***	0.152***
	(0.563)	(0.151)	(0.044)
Denmark	−3.320***	1.593***	0.214***
	(0.376)	(0.093)	(0.031)
Finland	−1.038**	1.099***	0.226***
	(0.427)	(0.115)	(0.052)
France	−14.374***	4.065***	0.094
	(1.678)	(0.403)	(0.069)
Germany	−2.334***	1.495***	0.096***
	(0.534)	(0.131)	(0.024)
Ireland	0.981***	0.545***	0.392***
	(0.220)	(0.067)	(0.056)
Italy	−14.194***	4.051***	0.114*
	(1.001)	(0.260)	(0.066)
Japan	0.429*	0.799***	0.161***
	(0.257)	(0.064)	(0.028)
Netherlands	−2.994***	1.557***	0.149***
	(0.933)	(0.236)	(0.046)
Norway	−1.368***	1.251***	0.097***
	(0.158)	(0.052)	(0.024)
Portugal	−10.838***	3.408***	−0.016
	(0.423)	(0.117)	(0.063)
Spain	−11.209***	3.416***	0.094
	(1.055)	(0.265)	(0.078)
Sweden	−8.738***	2.731***	0.254***
	(1.407)	(0.326)	(0.047)
Switzerland	−0.758*	1.084***	0.139***
	(0.403)	(0.099)	(0.026)
U.K.	−11.974***	3.397***	0.343***
	(0.923)	(0.221)	(0.038)
U.S.	−1.921***	1.329***	0.169***
	(0.361)	(0.094)	(0.029)

Note: The empirical model is $\pi_t=\alpha+\beta_y y_t+\beta_o o_t+\varepsilon_t$. The figures in parentheses are Newey–West HAC standard errors. β_o is the long-run pass-through coefficient.

Now, Eq. (3) is modified with a dummy interaction term:

$$\pi_t = \alpha + \sum_{i=1}^{k} \beta_i \pi_{t-i} + \gamma(y_{t-1}-\bar{y}_{t-1}) + \sum_{i=1}^{k} \theta_i \Delta o_{t-i} + \sum_{i=1}^{k} \delta_i (D_{t-i} \times \Delta o_{t-i}) + \varphi ECT_{t-1} + \varepsilon_t. \tag{4}$$

That is, I split the sample period into two subperiods using the break date endogenously determined by the data. The short-run pass-through coefficients in the first and second periods are respectively given as ω and $\omega+\delta_1$.

Table 5 shows the estimation results. Plainly, in most countries, the short-run coefficients in the post-break period are lower than in the pre-break period. The only exceptions are Canada, Norway, Spain, and Switzerland. That is, when considering an endogenous structural change, the evidence shows a decline in oil price pass-through. This finding is consistent with previous studies such as Hooker (2002), LeBlanc and Chinn (2004), Gregorio et al. (2007), and Blanchard and Gali (2007).

3. Time-varying pass-through

I have provided preliminary evidence that the degree of oil price pass-through may have changed since the 1970s. However, it is possible that the instability of the pass-through coefficients may be gradual rather than associated with a distinct point in time. In fact, it is more plausible to allow pass-through to change gradually as opposed to a particular point in time. More particularly, it would be difficult to believe that a sudden innovation or shock would exist that makes the degree of pass-through change dramatically. Moreover, if we would like to

[5] In place of the output gap, I also consider the unemployment gap (the deviation in the unemployment rate from the estimated NAIRU) as in Hooker (2002). The results are found to be similar and are available upon request.

[6] Data are obtained from the World Development Indicators (WDI) published by the World Bank.

Table 2
Oil price pass-through into CPI inflation: error correction model

	Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Ireland	Italy
constant	0.003**	0.001*	0.001	0.001**	0.002*	0.001	0.001*	0.001**	0.003*	0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
π_{t-1}	0.139	0.040	0.246***	0.374***	0.097*	0.259***	0.361***	0.162***	0.179**	0.461***
	(0.112)	(0.061)	(0.089)	(0.068)	(0.053)	(0.083)	(0.092)	(0.054)	(0.073)	(0.141)
π_{t-2}	0.201***	0.097**	0.173**	0.025	0.241***	0.045	0.123*	−0.045	−0.008	0.075
	(0.064)	(0.038)	(0.071)	(0.096)	(0.086)	(0.104)	(0.073)	(0.067)	(0.149)	(0.168)
π_{t-3}	0.197***	−0.019	0.079	0.191**	0.135	0.164**	0.139**	0.089	0.249**	0.133
	(0.064)	(0.060)	(0.097)	(0.097)	(0.107)	(0.078)	(0.067)	(0.055)	(0.096)	(0.105)
π_{t-4}	0.270**	0.694***	0.392***	0.285***	0.362***	0.416***	0.262***	0.591***	0.374***	0.219***
	(0.121)	(0.060)	(0.085)	(0.061)	(0.101)	(0.072)	(0.095)	(0.053)	(0.117)	(0.074)
$(y_{t-1}-\overline{y}_{t-1})$	0.076***	0.029*	0.041**	0.041***	0.039*	0.028	0.003	0.004	0.024	0.008
	(0.026)	(0.015)	(0.019)	(0.013)	(0.024)	(0.019)	(0.019)	(0.015)	(0.024)	(0.043)
ΔO_{t-1}	0.003	0.008***	0.009***	0.004*	0.002	0.008*	0.005	0.003	0.007	0.010***
	(0.004)	(0.003)	(0.003)	(0.002)	(0.006)	(0.004)	(0.003)	(0.002)	(0.006)	(0.003)
ΔO_{t-2}	−0.003	0.000	−0.000	−0.000	0.007	0.002	−0.000	−0.003	0.006	0.003
	(0.008)	(0.002)	(0.004)	(0.004)	(0.004)	(0.003)	(0.002)	(0.003)	(0.005)	(0.003)
ΔO_{t-3}	−0.004	0.007**	0.009***	0.001	0.006	0.001	0.004*	0.006**	0.005	0.009
	(0.004)	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)	(0.002)	(0.003)	(0.005)	(0.006)
ΔO_{t-4}	0.003	−0.001	−0.007**	−0.006**	−0.007	0.001	−0.005**	−0.006**	0.011	−0.004
	(0.003)	(0.003)	(0.003)	(0.002)	(0.004)	(0.004)	(0.002)	(0.002)	(0.009)	(0.005)
ECT_{t-1}	−0.007	−0.002	−0.003	−0.005	−0.004	−0.004	−0.006**	−0.012**	−0.005	−0.006
	(0.005)	(0.004)	(0.004)	(0.003)	(0.005)	(0.002)	(0.003)	(0.006)	(0.003)	(0.005)
SRPT	0.00137	0.00749	0.00869	0.00369	0.00155	0.00700	0.00484	0.00186	0.00483	0.00921

Note: The empirical model is $\pi_t = \alpha + \sum_{i=1}^{k}\beta_i\pi_{t-i} + \gamma(y_{t-1}-\overline{y}_{t-1}) + \sum_{i=1}^{k}\theta_i\Delta o_{t-1} + \varphi \mathrm{ECT}_{t-1} + \varepsilon_t$ The figures in parentheses are Newey–West HAC standard errors. $\mathrm{ECT}_t = p_t - \beta_y y_t - \beta_o o_t$ is the error correction term. $\mathrm{SRPT} = \theta_1 + \varphi\beta_0$ is the short-run pass-through coefficient.

Table 3
Oil price pass-through into CPI inflation: error correction model

	Japan	Netherlands	Norway	Portugal	Spain	Sweden	Switzerland	U.K.	U.S.
Constant	0.001	0.008***	0.001	0.003*	0.002	0.002*	0.001*	0.003**	0.002*
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
π_{t-1}	−0.011	0.055	0.183**	0.290***	0.045	0.102	0.192**	0.262***	0.531***
	(0.106)	(0.034)	(0.078)	(0.073)	(0.082)	(0.077)	(0.075)	(0.083)	(0.099)
π_{t-2}	0.315***	0.046	0.151**	0.139*	0.261***	0.100	0.062	0.119**	−0.303***
	(0.062)	(0.040)	(0.062)	(0.075)	(0.083)	(0.064)	(0.089)	(0.047)	(0.116)
π_{t-3}	0.134	0.071	0.112	0.094	0.215**	0.278***	0.062	−0.153	0.489***
	(0.141)	(0.045)	(0.074)	(0.112)	(0.089)	(0.064)	(0.096)	(0.096)	(0.108)
π_{t-4}	0.395***	0.062	0.439***	0.362***	0.343***	0.329***	0.491***	0.576***	0.134
	(0.083)	(0.042)	(0.097)	(0.076)	(0.106)	(0.090)	(0.104)	(0.104)	(0.089)
$(y_{t-1}-\overline{y}_{t-1})$	0.082**	−0.194	0.006	−0.067	−0.020	0.033	0.018	0.062	0.050***
	(0.039)	(0.184)	(0.025)	(0.059)	(0.035)	(0.028)	(0.018)	(0.045)	(0.013)
ΔO_{t-1}	0.015***	0.000	0.001	0.025***	0.008**	0.006	0.003	0.009	0.004*
	(0.004)	(0.008)	(0.003)	(0.007)	(0.003)	(0.004)	(0.005)	(0.008)	(0.002)
ΔO_{t-2}	−0.007	−0.026	−0.002	−0.009*	−0.009***	−0.000	−0.002	−0.002	−0.001
	(0.007)	(0.019)	(0.004)	(0.005)	(0.003)	(0.008)	(0.003)	(0.007)	(0.003)
ΔO_{t-3}	−0.000	−0.005	0.007*	0.007	0.010**	0.013*	0.008**	−0.009	0.004*
	(0.004)	(0.007)	(0.004)	(0.005)	(0.004)	(0.008)	(0.004)	(0.006)	(0.003)
ΔO_{t-4}	−0.010	−0.020	0.001	−0.021***	−0.004	−0.002	−0.012***	0.006	−0.007***
	(0.009)	(0.019)	(0.007)	(0.007)	(0.005)	(0.006)	(0.003)	(0.005)	(0.003)
ECT_{t-1}	−0.013	−0.112**	−0.011*	−0.018**	−0.007**	−0.003	−0.007	−0.017	−0.003
	(0.011)	(0.052)	(0.006)	(0.008)	(0.003)	(0.003)	(0.006)	(0.010)	(0.003)
SRPT	0.01260	−0.01629	0.00036	0.02485	0.00712	0.00529	0.00216	0.00324	0.00372

Note: The empirical model is $\pi_t = \alpha + \sum_{i=1}^{k}\beta_i\pi_{t-i} + \gamma(y_{t-1}-\overline{y}_{t-1}) + \sum_{i=1}^{k}\theta_i\Delta o_{t-1} + \varphi \mathrm{ECT}_{t-1} + \varepsilon_t$ The figures in parentheses are Newey–West HAC standard errors. $\mathrm{ECT}_t = p_t - \beta_y y_t - \beta_o o_t$ is the error correction term. $\mathrm{SRPT} = \theta_1 + \varphi\beta_0$ is the short-run pass-through coefficient.

investigate how pass-through changes over time along with the factors that may help explain the dynamic patterns, we need to use a specification including gradual changes as opposed to a one-off structural break. To provide evidence of the gradual change in pass-through, I first estimate a rolling regression and plot the estimates of the short-run pass-through in any 78-quarter rolling window period in Fig. 3. The first window period is from 1970Q1 to 1989Q3 while the last window period is from 1987Q3 to 2006Q4. I thus obtain 70 short-run pass-through coefficients. Clearly, in most countries, pass-through changes over different window periods rather than with a one-time break. This may give an idea that it is better to think of the dynamics of oil price pass-through as gradual changes. To obtain more concrete evidence from statistical tests, I implement the stability test proposed by Hansen (1992) to see if the change in pass-through is gradual. The test is approximately a Lagrange multiplier test of the null of constant parameters against the alternative that the parameters follow a martingale. The test results are reported in Table 6, and indicate that the evidence for 12 of the 19 countries supports time-varying pass-through.[7]

Motivated by this evidence, I now consider an augmented Phillips curve model with time-varying pass-through coefficients as follows:

$$\pi_t = \alpha + \sum_{i=1}^{k} \beta_i\pi_{t-i} + \gamma(y_{t-1}-\overline{y}_{t-1}) + \sum_{i=1}^{k} \theta_{it}\Delta o_{t-i} + \varphi ECT_{t-1} + \varepsilon_t, \quad \varepsilon_t \overset{\text{i.i.d.}}{\sim} N(0,\sigma_\varepsilon^2), \tag{5}$$

$$\theta_{it} = \theta_{it-1} + \eta_t, \quad \eta_{it} \overset{\text{i.i.d.}}{\sim} N(0,\eta_{\varepsilon i}^2), \quad i = 1, \ldots, k. \tag{6}$$

[7] However, it is worth noting that when conducting the Hansen (1992)'s test, it is not possible to discern whether the data displays a gradual change or a one-time break.

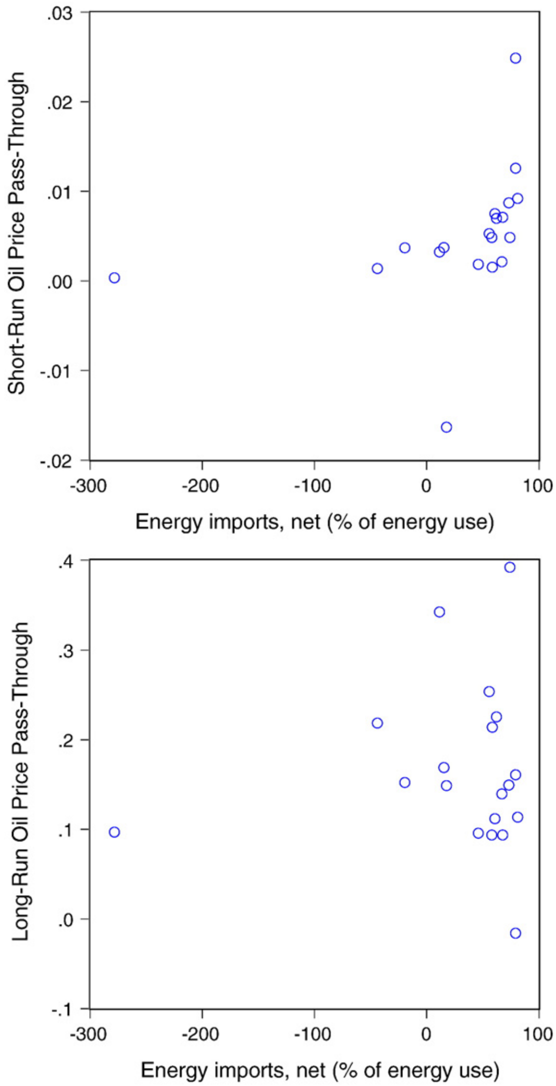

Fig. 2. Oil price pass-through and net energy imports.

The reason to estimate the time-varying pass-through using the state space method is two fold. First, we can discover how the degree of oil price pass-through changes over time. Second, we can employ the estimated time-varying pass-through coefficients to better understand the evolution of pass-through. We can then investigate the factors that may account for the changes in pass-through.

I plot the time-varying short-run coefficient in Fig. 4. We can see that although the short-run pass-through patterns evolve very differently in each country, overall there appears to be a downward trend, i.e., a gradual decline in pass-through in most countries. Indeed, among the 19 countries included, only Switzerland displays a gradual increase in short-run pass-through. If we simply compute the percentage decline of short-run pass-through as

$$\frac{\omega_{2006Q4}-\omega_{1970Q1}}{\omega_{1970Q1}},$$

we can assess if the change in the pass-through is significant. Table 7 provides the results. The average rate of decline in pass-through is 69.772%. Countries such as Belgium, Canada, Denmark, Finland, France, Germany, Japan, and the U.K. experienced a substantial decline over 100%. However, the percentage change in pass-through appears to be negligible in Norway, Australia, the Netherlands, Sweden, and the U.S.. For the case of the U.S., when compared to previous empirical results employing a one-time structural change (see, for instance, Hooker (2002)), a markedly different result is obtained here using the time-varying state space approach.

What is the explanation for the declining oil price pass-through documented in the previous section? A number of potential candidates have been proposed.

1. Low Inflation Environment: Taylor (2000) shows that regimes with lower inflation appear to have less persistent costs, and that the pricing power of firms is lower, thus decreasing the degree of pass-through.
2. The Share of Energy Consumption in the Economy: one argument is that a declining pass-through is related to the declining share of energy in consumption. In turn, lower energy intensity may result from more service-oriented economies, more energy-efficient technologies, and more diversified types of energy consumption.
3. The Role of Exchange Rate Movements: when exchange rate depreciation accompanies an oil price increase, the shock is more inflationary in domestic currency terms.
4. Trade Openness: trade openness stimulates an increasing flow of cheap goods from emerging economies into industrial countries, and this offsets the inflationary effects of oil price increases. See Pain et al. (2006).

Table 4
Andrews (1993)'s structural break tests

Country	sup-LM	*P*-value	exp-LM	*P*-value	Break date
Australia	32.05	0.02	13.06	0.01	2001Q1
Austria	36.30	0.00	14.12	0.00	1976Q4
Belgium	71.34	0.00	32.87	0.00	1976Q3
Canada	21.26	0.33	8.00	0.27	1984Q2
Denmark	35.93	0.01	15.60	0.00	1980Q2
Finland	39.77	0.00	16.44	0.00	1977Q3
France	39.66	0.00	17.48	0.00	1985Q2
Germany	22.74	0.24	8.85	0.17	1991Q3
Ireland	49.92	0.00	21.58	0.00	1976Q3
Italy	53.88	0.00	22.43	0.00	1980Q1
Japan	20.37	0.39	7.60	0.33	1981Q3
Netherlands	28.79	0.05	10.45	0.06	1976Q4
Norway	40.05	0.00	15.71	0.00	1977Q3
Portugal	50.94	0.00	22.74	0.00	1979Q3
Spain	24.40	0.16	10.06	0.08	2001Q2
Sweden	21.72	0.30	9.29	0.14	1991Q4
Switzerland	36.89	0.00	15.64	0.00	1978Q4
U.K.	44.78	0.00	18.27	0.00	1980Q2
U.S.	34.71	0.01	12.98	0.01	1981Q3

Table 5
Short-run pass-through: pre-break and post-break period

Country	Pre-break period ω	Post-break period $\omega+\delta_1$
Australia	0.00254	−0.01470
Austria	0.01361	0.00542
Belgium	0.01864	0.00491
Canada	0.00364	0.00395
Denmark	0.01718	−0.01062
Finland	0.02615	0.00047
France	0.01452	−0.00187
Germany	0.00442	−0.00663
Ireland	0.01618	0.00005
Italy	0.01511	0.00218
Japan	0.02883	0.00265
Netherlands	−0.01365	−0.01821
Norway	0.00009	0.00114
Portugal	0.05192	0.00682
Spain	0.00533	0.01622
Sweden	0.00783	−0.00531
Switzerland	−0.01870	0.00929
U.K.	0.02827	−0.00861
U.S.	0.00427	0.00277
Average	0.01190	−0.00053

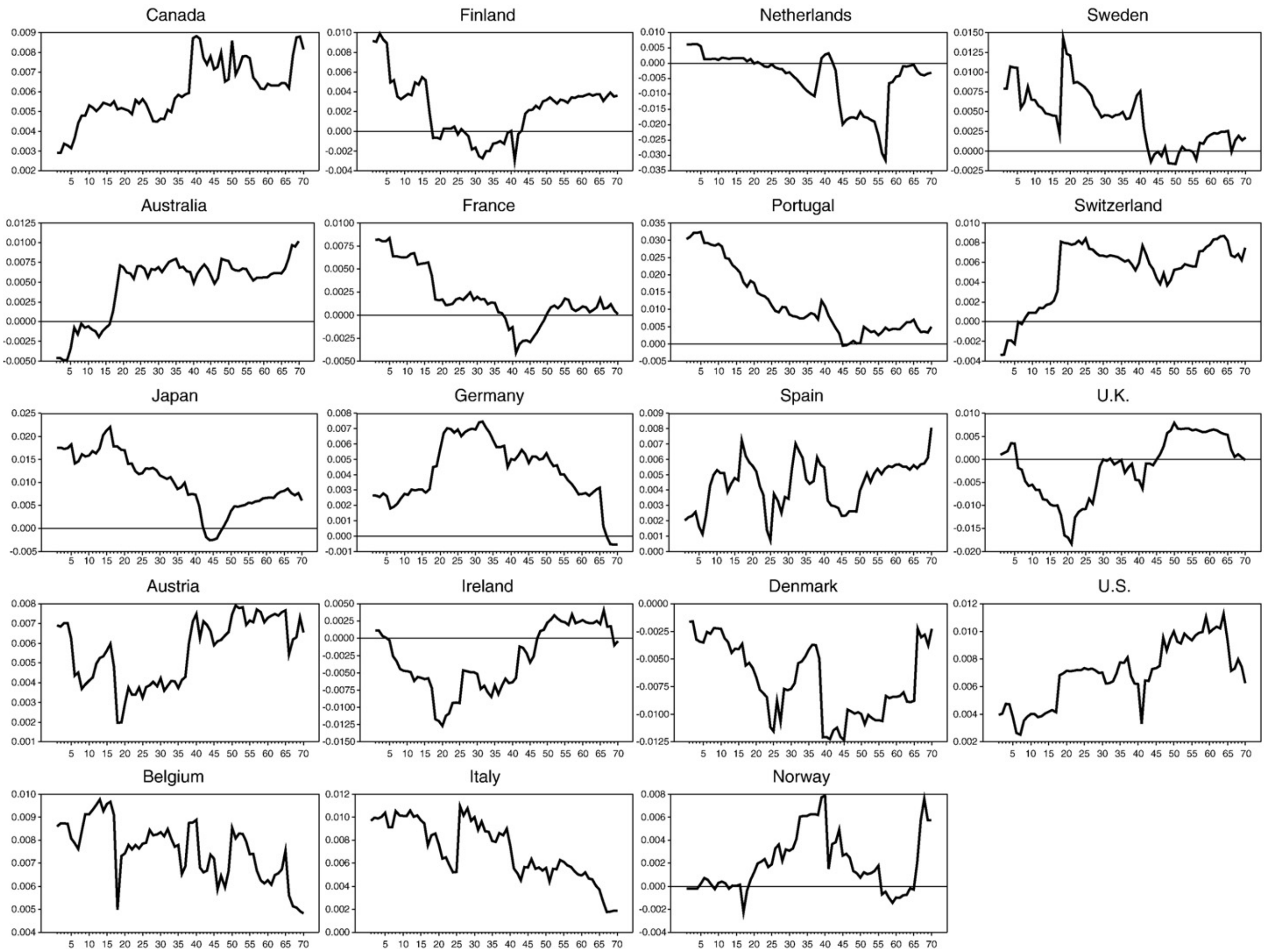

Fig. 3. Rolling estimates of the short-run oil price pass-through coefficient.

5. The Accommodative Role of Monetary Policy: another potential explanation for declining pass-through is that monetary authorities tend to actively commit to fighting inflation; for example, by adopting an inflation targeting policy. The monetary authorities may then respond to rising oil prices by increasing short-term interest rates, which dampens spending. Bernanke et al. (1997) demonstrate that economic downturns following oil shocks may take place because monetary authorities tighten monetary policy in response to oil price increases. The more active the central bank is then in fighting inflation, the lower the oil price pass-through.

Table 6
Hansen (1992)'s stability test

Country	Test statistic	P-value
Australia	1.92	0.38
Austria	2.34	0.15
Belgium	2.54	0.09
Canada	2.45	0.11
Denmark	2.23	0.19
Finland	3.84	0.00
France	3.37	0.01
Germany	2.39	0.13
Ireland	3.81	0.00
Italy	5.28	0.00
Japan	5.04	0.00
Netherlands	3.89	0.00
Norway	3.77	0.00
Portugal	3.15	0.01
Spain	1.88	0.42
Sweden	2.34	0.15
Switzerland	4.42	0.00
U.K.	3.37	0.01
U.S.	2.59	0.08

To investigate the evolution of aggregate pass-through and formally test the above hypotheses, I consider the following panel regressions assuming fixed effects:

$$Z_{jt} = \mu_j + \gamma_1 Z_{jt-1} + \gamma_2 \mathrm{INFLATION}_{jt} + \gamma_3 \log\mathrm{SHARE}_{jt} + \gamma_4 \log\mathrm{ER}_{jt} + \gamma_5 \log\mathrm{OPEN}_{jt} + \gamma_6 \psi_{jt} + \varepsilon_{jt}, \tag{7}$$

where $Z_{jt}=\hat{\omega}_{jt}$ is the short-run pass-through coefficient, $\mathrm{INFLATION}_{jt}$ is the CPI inflation rate, and SHARE_{jt} is the energy share in GDP, available from the U.S. Energy Information Administration (where energy intensity is defined as the total primary energy consumption per dollar of GDP). The series of energy intensity is annual from 1980 to 2005, and is converted into a quarterly series.[8] ER_{jt} is the exchange rate expressed in terms of U.S. dollars per unit for each of the national currencies. Thus, an increase in the ER reflects an exchange rate appreciation. OPEN_{jt} is the trade openness and is measured by (Export+Import)/GDP. Finally, ψ_{jt} is

[8] I employ the RATS procedure INTERPOL.SRC to convert the annual series into quarterly series. This procedure computes an interpolation of a series, changing the frequency to a higher value while maintaining the last value in each period.

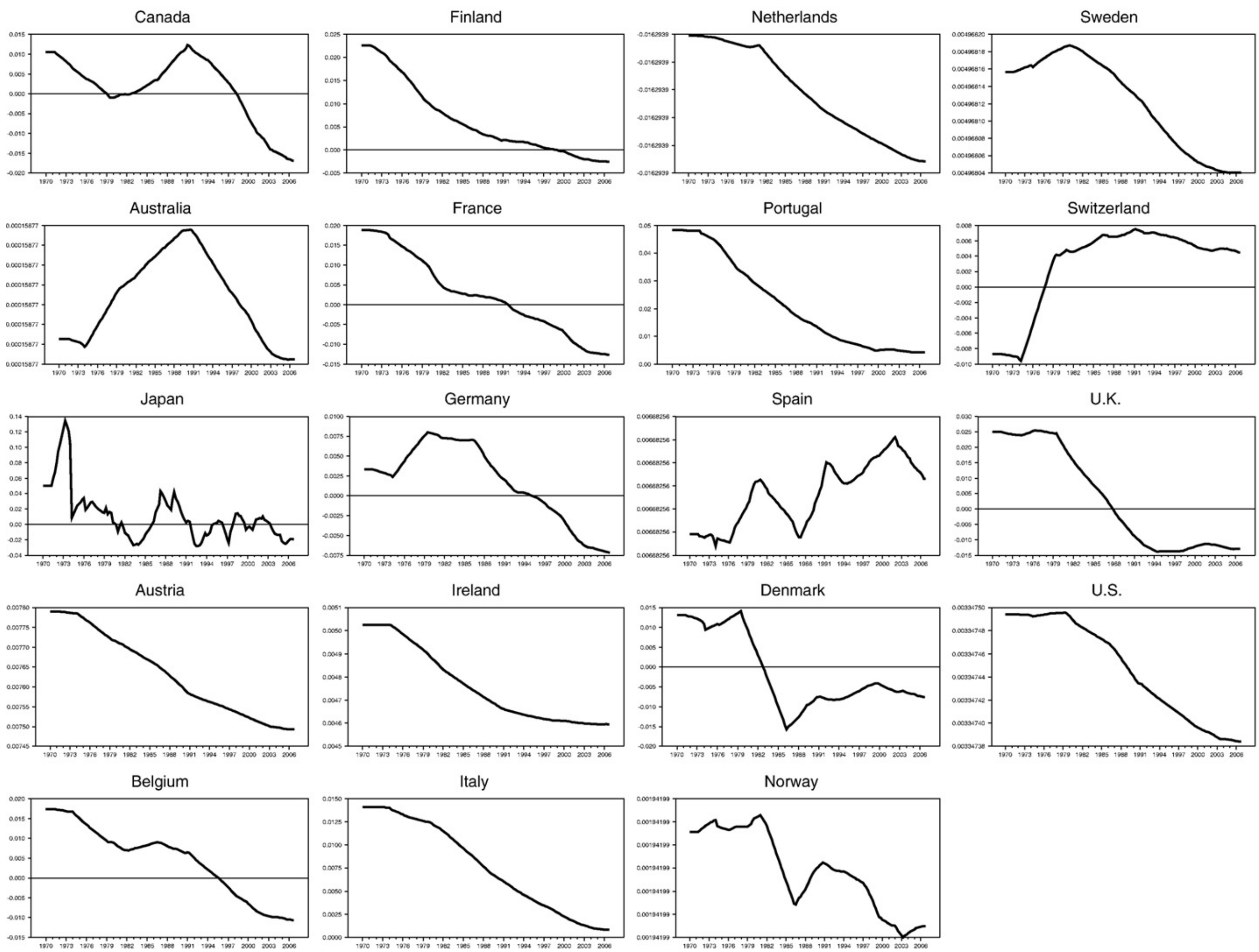

Fig. 4. Short-run time-varying oil price pass-through coefficient.

a measure of monetary policy stance, and is estimated using a time-varying Taylor Rule for each country:

$$\mathrm{INTRATE}_{jt} = \alpha_j + \psi_{jt}\mathrm{INFLATION}_{jt} + \lambda_j\left(y_{jt} - \bar{y}_{jt}\right) + v_{jt}, \tag{8}$$

where $\mathrm{INTRATE}_{jt}$ is the short-run interest rate.[9] Data for exports, imports, and GDP are obtained from Datastream. Nominal effective exchange rates and interest rates are from the IFS. The choice of interest rates is listed in Table 8.

Table 9 provides the estimation results in column (1). The connections between short-run pass-through and the explanatory variables are generally as expected. First note that when a country is more open to the world market, the degree of oil price pass-through declines, and the estimate is statistically significant. This may suggest a potential benefit of globalization. Additionally, a country that is more dependent on energy tends to have higher pass-through. Exchange rate movements have negative effects on the pass-through coefficient. Recall that an increase in exchange rates here implies an appreciation. Accordingly, this is consistent with the hypothesis that an oil price increase is less inflationary in domestic currency terms when the domestic currency appreciates. Regarding monetary policy, when it is more aggressive in response to inflation rates, the pass-through is lower, as expected. Finally, pass-through increases when a country has a lower inflation environment; this is inconsistent with Taylor (2000)'s argument.

In sum, the evidence from a large panel dataset suggests that an appreciation of the domestic currency, a more active monetary policy in response to inflation, and a higher degree of trade openness are major causes of the declines that have occurred in the oil price pass-through over time, particularly the long-run declines. However, it is worth noting that most of the estimates for short-run pass-through are not statistically significant, with the exception of the degree of trade openness. As a robustness check, I consider changes in short-run interest rates and changes in money aggregates (M2) as alternative measures of monetary policy. The results in columns (2) and (3) of Table 9 show that a significant coefficient estimate for the degree of trade openness remains.

4. Concluding remarks

The sharp and persistent increases in oil prices since 2004 have attracted attention from policymakers and macroeconomists alike and led to much research concerning the inflationary effects of oil price shocks. Although there is mixed evidence as to whether oil shocks cause economic downturns, it is widely accepted that oil price shocks at least partially pass through into inflation. Understanding the empirical linkage between oil prices and inflation rates is then

9 I would like to thank an anonymous referee for suggesting this measure of monetary policy.

Table 7
The percentage changes in pass-through from 1970:Q1 to 2006:Q4

Country	Short-run $100 \times \frac{\omega_{2006Q4}-\omega_{1970Q1}}{\omega_{1970Q1}}$ (%)
Australia	−0.000
Austria	−3.808
Belgium	−161.033
Canada	−260.488
Denmark	−157.276
Finland	−111.257
France	−167.014
Germany	−315.298
Ireland	−8.561
Italy	−94.132
Japan	−139.211
Netherlands	0.000
Norway	−0.000
Portugal	−91.113
Spain	0.000
Sweden	−0.002
Switzerland	151.909
U.K.	−151.433
U.S.	−0.003
Average	−79.406

Note: ω_t represents the short-run pass-through coefficient.

important as most monetary authorities attempt to keep inflation under control. Knowledge about the inflationary effects of oil price increases will then assist monetary authorities to adopt appropriate policy to accommodate these shocks.

Recent studies have documented a decline in the inflationary effects of oil price increases. That is, oil price changes have lower pass-through into aggregate CPI inflation in the 2000s than they did in the 1970s. In this paper, I use data from 19 industrial countries and a state space approach to estimate time-varying oil price pass-through coefficients and find evidence of declining pass-through for almost all of the countries considered. Further, I investigated some potential explanations for declining pass-through and conclude that an appreciation of the domestic currency, a more active monetary policy in response to inflation, and a higher degree of trade openness are major causes of the recent decline in oil price pass-through. Alternatively, energy intensity may have played a minor role in the evolution of pass-through over time. Finally, contrary to Taylor (2000)'s argument, I fail to find evidence that a lower inflation environment can lower pass-through.

Table 8
List of interest rates

Country	Interest rates
Australia	Average rate on money market
Austria	Government bond yield
Belgium	Treasury paper
Canada	Treasury bill rate
Denmark	Mortgage bond yield
Finland	Average cost of commercial bank debt
France	Government bond yield
Germany	Call money rate
Ireland	Deposits 5000–25,000 ass. banks
Italy	Government bond yield
Japan	Call money rate
Netherlands	Government bond yield
Norway	Government bond yield
Portugal	Government bond yield
Spain	Call money rate
Sweden	Commercial bank max deposit rates
Switzerland	Government bond yield
U.K.	Treasury bill rate
U.S.	Federal funds rate

Source: International Financial Statistics.

Table 9
Panel regression for the determinants of oil price pass-through over time

Explanatory variables	Short-run pass-through		
	(1)	(2)	(3)
$Z_{jt}-1$	0.9654***	0.9646***	0.9560***
	(0.0205)	(0.0199)	(0.0257)
Inflation	−0.0026	−0.0033	−0.0067
	(0.0055)	(0.0054)	(0.0069)
Share	0.0089	−0.0166	−0.0615
	(0.0680)	(0.0837)	(0.1017)
Nominal Effective Exchange Rates	0.0332	0.0394	0.0327
	(0.0919)	(0.0925)	(0.1021)
Openness	−0.1401**	−0.1219***	−0.1591**
	(0.0604)	(0.0463)	(0.0664)
Monetary policy			
(a) Taylor rule	−0.0025		
	(0.0032)		
(b) Change in Interest Rates		−0.0034	
		(0.0055)	
(c) Change in M2			0.000000259
			(0.000000217)
Adj. R^2	0.9701	0.9701	0.9660
No. of Observations	1548	1546	1306

Note: The figures in parentheses are Newey–West HAC standard errors.

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