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Oil price shocks and stock markets in the U.S. and 13 European countries

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ABSTRACT

Oil price shocks have a statistically significant impact on real stock returns contemporaneously and/or within the following month in the U.S. and 13 European countries over 1986:1–2005:12. Norway as an oil exporter shows a statistically significantly positive response of real stock returns to an oil price increase. The median result from variance decomposition analysis is that oil price shocks account for a statistically significant 6% of the volatility in real stock returns. For many European countries, but not for the U.S., increased volatility of oil prices significantly depresses real stock returns. The contribution of oil price shocks to variability in real stock returns in the U.S. and most other countries is greater than that of interest rate. An increase in real oil price is associated with a significant increase in the short-term interest rate in the U.S. and eight out of 13 European countries within one or two months. Counter to findings for the U.S. and for Norway, there is little evidence of asymmetric effects on real stock returns of positive and negative oil price shocks for oil importing European countries.

1. Introduction

Following the major oil price shocks of the 1970s a large literature developed on the relationship between oil prices and real economic activity. Work by Hamilton (1983) in particular, establishing oil price shocks as a factor contributing to recession in the U.S., stimulated study by many researchers on the

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connections between oil price and the macroeconomy.[1] Recent contributions finding significant effects of oil price shocks on macroeconomic activity for most countries in their samples include Cologni and Manera (2008) and Kilian (2008) on the G-7, Jimenez-Rodriguez and Sanchez (2005) for G-7 and Norway, and Cunado and Perez de Garcia (2005) for Asian countries. Despite the documentation that oil price shocks have significant effects on the real economy, relatively less work has appeared on the related question of the effect of oil price on the stock market. Jones and Kaul (1996) find that oil price increases in the post war period had a significantly detrimental effect on aggregate stock returns. Sadorsky (1999) reports that oil price increases have significantly negative impacts on U.S. stocks and that the magnitude of the effect may have increased since the mid 1980s. In contrast, Huang et al. (1996) do not find a significant connection between daily price of oil futures and general U.S. stock returns. Ciner (2001) concludes that a statistically significant relationship exists between real stock returns and oil price futures, but that the connection is non-linear.[2] In this paper we argue that if oil price shocks have effects on the real economy through consumer and firm behavior, then there should be observable effects of oil price shocks on world stock markets.

This study estimates the effects of oil price shocks and oil price volatility on the real stock returns of the U.S. and 13 European countries over 1986:1–2005:12. We argue that it is important to consider the effects of oil prices on stock prices in a number of countries in order to better identify effects that may be systematic across countries rather than country specific. It is also important to allow for the effect of uncertainty about oil prices when considering the effect of (linear and non-linear) transformations of movement in oil price on real stock returns since the effect of changes in the latter could be offset by increases in the former. The measure of volatility that we use, based on volatility of daily spot or futures crude oil price, has extreme values related to major political events concerning the Middle East and may reflect uncertainty about future oil supplies.

A multivariate VAR analysis is conducted with linear and non-linear specification of oil price shocks. Linear oil price shock is defined as the percentage change in the real price of oil and non-linear measures of real oil price shocks are scaled real oil price shock defined by Lee et al. (1995) and net oil price defined by Hamilton (1996). Oil price shocks have a statistically significant impact on real stock returns in the same month or within one month. Counter to the other countries, Norway as an oil exporter shows a statistically significantly positive response of real stock return to an oil price shock increase. The median result from variance decomposition analysis is that oil price shocks account for a statistically significant 6% of the volatility in real stock returns.

Generally, linear and non-linear measures of real oil price shocks calculated as world real oil price yield more cases of statistically significant impacts on real stock returns than do real oil price shocks measured as national real oil price. This result might indicate that markets anticipate significant effects of oil price in most economies and this effect is better captured by Brent (dollar index)/US PPI, than by a measure of real national oil price that reflects offsetting movement in the exchange rate. Net oil price does not have a statistically significant impact on real stock returns in as many countries as linear and scaled real oil price. The finding of statistically significant impact on real stock returns of oil price shocks for most countries is not sensitive to reasonable changes in the VAR model, such as variable order and inclusion of additional variables. For many European countries, but not for the U.S., increase in the volatility of oil prices significantly depresses real stock returns.

We find that the contribution of oil price shocks to variability in real stock returns in the U.S. is greater than that of the interest rate in all models. For somewhat less than half the European countries the reverse holds in that contribution of oil price shocks to variability in real stock returns is less than that of the interest rate. A one standard deviation increase in the world real oil price significantly raises the short-term interest rate in the U.S. and eight out of 13 European countries with a lag of one or two months. The null hypothesis of symmetric effects on real stock returns of positive and negative oil price shocks cannot be rejected for the oil importing European countries but is rejected for Norway and for the U.S. Differences

[1] Reviews of the literature on the relationship between oil and the macroeconomy are provided by Hamilton (2008), Huntington (2005) and Barsky and Kilian (2004). Examples of current work in the area include contributions by Gronwald (2008) on the impact of large oil price increases on GDP growth, by Lee and Chang (2007) on the relationship between demand for energy and real GDP, and by Balaz and Londarev (2006) on the role of oil in globalization.

[2] Recently papers have focused on the effect of oil price for stock market risk (Sadorsky, 2006).

between findings for the U.S. and a number of European countries, confirms the ongoing need to examine results on a country by country basis before arriving at conclusions concerning the effects of oil price shocks.

The remainder of this paper is organized as follows. In the next section the variables, the data, and the time series properties of the data are discussed. In Section 3 the measures of oil price shocks and the framework for the empirical analysis are presented. Sections 4 and 5 present result on the impacts of oil price shocks and of oil price volatility on the stock markets. A comparison of impacts of oil price and interest rate shocks on the stock market is given in Section 6. Section 7 concludes.

2. Variable and data description

2.1. Variables and data

In this paper we examine the effect of oil price shocks on real stock returns in the U.S. and in 13 European countries over 1986:1–2005:12. We will use a vector autoregressive model (VAR) to capture the complexities of the dynamic relations between these variables and other variables, including short-term interest rates, consumer prices, and industrial production, that may influence the connections between oil price shocks on real stock returns. At least since the formulation of Fama's (1981) hypothesis, measures of inflation and real activity have played a role in analysis of the behavior of real stock returns. In literature focused on oil price shocks, Sadorsky (1999) considers the effect of oil price shocks on real stock returns in the U.S. within a framework similar to that in this paper, and Jones and Kaul (1996) include industrial production as a proxy variable for cash flow in their analysis of oil and the stock market.

This study examines the monthly data available over 1986.1–2005.12 for stock prices, short-term interest rates, consumer prices, and industrial production for the U.S. and 13 European countries. Industrial production data are from OECD for the European countries and from FRED for the U.S. Short-term interest rates (usually Treasury-bill rates) are from IFS, IMF, for Germany, Belgium, Spain, Greece, Sweden, U.K., Finland, Italy, Denmark, and Norway. Short-term interest rates are from Main Economic Indicators, OECD, for Austria, from Bank of Netherlands, for the Netherlands, and from INSEE (National Institute for Statistics and Economic Studies) for France. For the U.S. the three month Treasury-bill rate is from FRED.

Stock price indices for European countries are from OECD, except that for Finland obtained from the IMF. The S&P 500 index for the U.S. is from COMPUSTAT. Nominal oil price is taken as an index in U.S. dollar price of U.K. Brent crude oil from IMF. Consumer price indices are from Main Economic Indicators, OECD, and

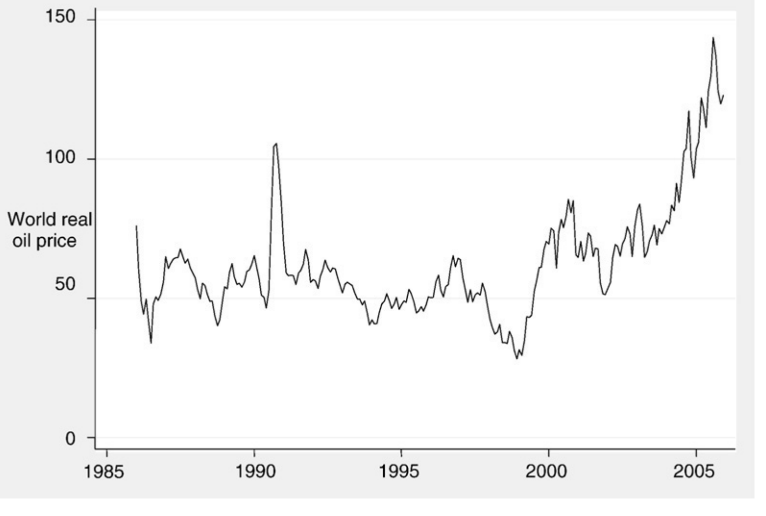


Fig. 1. World real oil price. (Dollar index of U.K. Brent/PPI for all commodities).

exchange rates in terms of the U.S. dollar are from FRED. Data and sources are described in detail in an Appendix A.

For each country, real stock returns are defined as the difference between the continuously compounded return on stock price index and the inflation rate given by the log difference in the consumer price index. World real oil price is calculated as the ratio of nominal oil price to the U.S. Producer Price Index for all commodities and is shown in Fig. 1. The world real oil price reflects a change in relative price of oil faced by firms. In the latter half of the sample the pattern of oil price behavior is interesting in that oil price increases are more frequent than oil price decreases. As an alternative to World real oil price on which to base measurement of oil price shocks, a national real oil price is obtained for each country using the exchange rate of and CPI of each country to adjust the nominal (dollar) price of oil.

In order to keep notation as simple as possible country suffices will be suppressed. The following notation will be employed:

r	first log difference of short-term interest rate
ip	first log difference of industrial production
rsr	real stock returns
op	first log difference of real oil price (world or national).

Table 1
PP unit root test results

	Real oil price				Interest rates			
	Log level		First log difference		Log level		First log difference	
Country	C	C&T	C	C&T	C	C&T	C	C&T
World	−2.186	−2.995	−13.152[a]	−13.155[a]				
U.S.	−2.392	−2.711	−12.998[a]	−13.012[a]	−1.394	−1.273	−8.982[a]	−9.000[a]
Austria	−2.183	−2.938	−12.921[a]	−12.926[a]	−0.279	−1.582	−11.073[a]	−11.137[a]
Belgium	−2.189	−3.003	−13.102[a]	−13.139[a]	−0.879	−1.924	−11.135[a]	−11.111[a]
Denmark	−2.646[c]	−3.250[c]	−13.062[a]	−13.092[a]	−0.730	−2.525	−12.483[a]	−12.419[a]
Finland	−2.030	−3.528[b]	−13.202[a]	−13.230[a]	−0.787	2.040	−10.372[a]	−10.348[a]
France	−2.303	−3.078	−12.920[a]	−12.927[a]	−0.672	−2.087	−13.099[a]	−13.074[a]
Germany	−2.093	−2.848	−12.920[a]	−12.927[a]	−0.920	−1.765	−14.078[a]	−14.077[a]
Greece	−2.867[b]	−3.011	−13.013[a]	−13.051[a]	0.536	−1.957	−11.629[a]	−11.716[a]
Italy	−2.559	−3.625[b]	−12.992[a]	−13.017[a]	−0.597	−2.060	−11.125[a]	−11.097[a]
Netherlands	−2.560	−3.145[c]	−13.057[a]	−13.083[a]	−0.679	−1.791	−16.980[a]	−16.970[a]
Norway	−2.422	−3.311[c]	−13.347[a]	−13.376[a]	−1.326	−2.690	−16.528[a]	−16.496[a]
Spain	−2.723[c]	−3.507[b]	−13.049[a]	−13.084[a]	−0.519	−2.527	−12.979[a]	−12.986[a]
Sweden	−1.885	−3.194[c]	−12.979[a]	−13.020[a]	−0.076	−2.026	−12.453[a]	−12.467[a]
U.K.	−2.974[b]	−3.171[c]	−13.421[a]	−13.453[a]	−1.369	−1.968	−9.188[a]	−9.181[a]

	Industrial production				Real stock returns	
	Log level		First log difference		(rsr)	
Country	C	C&T	C	C&T	C	C&T
U.S.	−0.439	−1.170	−14.286[a]	−14.260[a]	−15.427[a]	−15.42[a]
Austria	−0.204	−2.893	−27.118[a]	−27.218[a]	−13.645[a]	−13.674[a]
Belgium	−0.963	−4.755[a]	−29.321[a]	−29.253[a]	−9.872[a]	−9.840[a]
Denmark	−1.149	−6.383[a]	−19.804[a]	−19.760[a]	−12.580[a]	−12.605[a]
Finland	−0.093	−2.141	−23.928[a]	−23.894[a]	−10.631[a]	−10.616[a]
France	−0.837	−2.086	−23.965[a]	−23.936[a]	−12.801[a]	−12.775[a]
Germany	−0.634	−2.060	−22.957[a]	−22.919[a]	−14.537[a]	−14.510[a]
Greece	−1.406	−3.959[b]	−30.979[a]	−30.956[a]	−1.892[a]	−10.906[a]
Italy	−2.206	−2.245	−18.951[a]	−19.095[a]	−12.118[a]	−12.095[a]
Netherlands	−1.631	−9.042[a]	−35.235[a]	−35.144[a]	−10.445[a]	−10.423[a]
Norway	−1.929	−3.643[b]	−31.645[a]	−32.232[a]	−13.038[a]	−13.044[a]
Spain	−0.865	−2.522	−28.484[a]	−28.427[a]	−12.882[a]	−12.849[a]
Sweden	−0.423	−2.311	−18.812[a]	−18.769[a]	−10.404[a]	−1.383[a]
U.K.	−2.885[b]	−1.735	−22.986[a]	−23.852[a]	−12.151[a]	−12.137[a]

Notes: PP — Phillips and Perron (1988); C — constant; T — trend. World refers to the world real price of oil. Superscripts [a], [b], and [c], denote rejection of the null hypothesis of a unit root at the 1%, 5%, and 10%, level of significance, respectively.

Table 2
KPSS unit root test results

	Real oil price in log level				Real oil price in first log difference			
	Lag = 1		Lag = 4		Lag = 1		Lag = 4	
Country	L	T	L	T	L	T	L	T
World	3.16[a]	1.39[a]	1.37[a]	0.613[a]	0.132	0.0213	0.135	0.0220
U.S.	1.77[a]	1.45[a]	0.77[a]	0.632[a]	0.162	0.0242	0.162	0.0245
Austria	3.18[a]	1.39[a]	1.37[a]	0.605[a]	0.154	0.0249	0.151	0.0247
Belgium	3.36[a]	1.36[a]	1.44[a]	0.591[a]	0.151	0.0247	0.147	0.0244
Denmark	2.54[a]	1.56[a]	1.11[a]	0.683[a]	0.220	0.0271	0.217	0.0273
Finland	4.95[a]	1.33[a]	2.13[a]	0.591[a]	0.201	0.0269	0.202	0.0274
France	3.11[a]	1.61[a]	1.34[a]	0.702[a]	0.205	0.0256	0.205	0.0261
Germany	3.23[a]	1.44[a]	1.39[a]	0.623[a]	0.156	0.0252	0.153	0.0248
Greece	1.84[a]	1.74[a]	0.80[a]	0.756[a]	0.229	0.0260	0.230	0.0267
Italy	3.64[a]	1.34[a]	1.59[a]	0.597[a]	0.196	0.0269	0.197	0.0275
Netherlands	2.5[a]	1.50[a]	1.02[a]	0.658[a]	0.199	0.0268	0.197	0.0269
Norway	3.22[a]	1.44[a]	1.40[a]	0.636[a]	0.194	0.0245	0.203	0.0261
Spain	3.10[a]	1.56[a]	1.35[a]	0.689[a]	0.216	0.0266	0.217	0.0271
Sweden	4.67[a]	1.68[a]	2.00[a]	0.739[a]	0.226	0.0238	0.228	0.0244
U.K.	1.54[a]	1.39[a]	0.68[b]	0.615[a]	0.188	0.0234	0.193	0.0244

	Interest rate in log level				Interest rate in first log difference			
	Lag = 1		Lag = 4		Lag = 1		Lag = 4	
Country	L	T	L	T	L	T	L	T
U.S.	5.99[a]	0.766[a]	2.42[a]	0.314[a]	0.270	0.247[a]	0.158	0.145[c]
Austria	6.98[a]	1.180[a]	2.83[a]	0.483[a]	0.360[c]	0.140[c]	0.259	0.102
Belgium	9.89[a]	0.800[a]	4.02[a]	0.330[a]	0.088	0.087	0.071	0.070
Denmark	10.00[a]	0.732[a]	4.09[a]	0.310[a]	0.083	0.059	0.079	0.057
Finland	10.40[a]	0.741[a]	4.23[a]	0.308[a]	0.097	0.096	0.081	0.081
France	10.00[a]	0.853[a]	4.06[a]	0.354[a]	0.092	0.075	0.085	0.069
Germany	6.27[a]	1.360[a]	2.54[a]	0.556[a]	0.198	0.118	0.167	0.101
Greece	10.50[a]	2.680[a]	4.26[a]	1.090[a]	0.603	0.193[b]	0.045	0.148[b]
Italy	10.80[a]	1.560[a]	4.37[a]	0.645[a]	0.101	0.084	0.075	0.063
Netherlands	7.85[a]	0.895[a]	3.19[a]	0.366[a]	0.168	0.119[c]	0.139	0.099
Norway	7.90[a]	0.644[a]	3.23[a]	0.269[a]	0.056	0.056	0.048	0.048
Spain	10.50[a]	1.340[a]	4.26[a]	0.559[a]	0.186	0.113	0.135	0.083
Sweden	10.50[a]	1.060[a]	4.27[a]	0.443[a]	0.135	0.050	0.120	0.045
U.K.	9.02[a]	0.485[a]	3.67[a]	0.201[b]	0.106	0.090	0.074	0.063

	Industrial production in log level				Industrial production in first log difference			
	Lag = 1		Lag = 4		Lag = 1		Lag = 4	
Country	L	T	L	T	L	T	L	T
U.S.	11.9[a]	1.21[a]	4.81[a]	0.491[a]	0.290	0.284[a]	0.190	0.186[b]
Austria	11.7[a]	1.55[a]	4.74[a]	0.652[a]	0.0508	0.025	0.0994	0.0493
Belgium	10.8[a]	1.04[a]	4.42[a]	0.459[a]	0.0219	0.0191	0.0392	0.0341
Denmark	11.5[a]	0.64[a]	4.75[a]	0.357[a]	0.0133	0.0096	0.0261	0.0187
Finland	11.6[a]	1.65[a]	4.69[a]	0.684[a]	0.0872	0.0651	0.1370	0.1020
France	10.9[a]	0.933[a]	4.42[a]	0.385[a]	0.064	0.0639	0.0801	0.0796
Germany	9.45[a]	0.78[a]	3.87[a]	0.323[a]	0.0070	0.0698	0.0881	0.0825
Greece	9.56[a]	1.84[a]	3.93[a]	0.795[a]	0.026	0.0193	0.0579	0.0431
Italy	10.1[a]	0.999[a]	4.11[a]	0.420[a]	0.204	0.046	0.2210	0.0512
Netherlands	11.6[a]	0.799[a]	4.75[a]	0.405[a]	0.0179	0.0072	0.0387	0.0157
Norway	10.6[a]	2.49[a]	4.35[a]	1.090[a]	0.0618	0.0076	0.165	0.0208
Spain	11.0[a]	1.05[a]	4.46[a]	0.436[a]	0.0492	0.0498	0.0726	0.0735
Sweden	11.9[a]	0.98[a]	4.81[a]	0.412[a]	0.0607	0.0608	0.0816	0.0818
U.K.	10.0[a]	1.33[a]	4.09[a]	0.557[a]	0.389[c]	0.0595	0.566[b]	0.0943

(continued on next page)

Table 2 (*continued*)

Country	Real stock returns (rsr)			
	Lag = 1		Lag = 4	
	L	T	L	T
U.S.	0.143	0.081	0.160	0.091
Austria	0.225	0.125[c]	0.187	0.105
Belgium	0.098	0.091	0.092	0.085
Denmark	0.128	0.071	0.103	0.058
Finland	0.112	0.099	0.098	0.087
France	0.082	0.068	0.071	0.059
Germany	0.078	0.075	0.072	0.069
Greece	0.199	0.093	0.166	0.079
Italy	0.096	0.082	0.081	0.071
Netherlands	0.164	0.156[b]	0.141	0.134[c]
Norway	0.109	0.058	0.097	0.052
Spain	0.098	0.090	0.106	0.097
Sweden	0.091	0.086	0.075	0.071
U.K.	0.127	0.065	0.122	0.063

Notes: KPSS — Kwiatkowski et al. (1992); L — level stationarity; T — trend stationarity. World refers to the world real price of oil. Superscripts [a], [b], and [c], denote rejection of the null hypothesis at the 1%, 5%, and 10%, level of significance, respectively.

2.2. Time series properties

The outcome of PP (Phillips and Perron, 1988) and KPSS (Kwiatkowski et al., 1992) unit root tests of the log levels and first log differences of real oil price, the short-term interest rate, and industrial production, and of real stock returns are presented in Tables 1 and 2. In Tables 1 and 2 the null hypothesis that real stock returns has a unit root is rejected at 5% level for the PP and KPSS tests.

In Table 1 for the PP test for the interest rate, real oil price, and industrial production, the null hypotheses that the log level of each variable, has a unit root is not rejected at 5% level, and the null hypotheses that the first log difference of each variable has a unit root is rejected at 5% level. In Table 2, the KPSS test results with lag-truncation parameters of one and four, indicate that the null hypothesis that variables in log level are level and trend stationary is rejected at the 5% level, and the null hypothesis that variables in first log difference are level and trend stationary is not rejected at the 5% level. Thus, we accept that in log levels, the interest rate, real oil price, and industrial production are $I(1)$ processes, and that real stock returns (rsr) and in first log differences, the interest rate, real oil price, and industrial production are $I(0)$ processes.

Since the variables the interest rate, oil price, and industrial production in log level each contain a unit root, we conduct cointegration test (Johansen and Juselius, 1990) for common stochastic trend. The results reported in Table 3 show that null hypothesis of no cointegration is rejected only for the U.K. (at 5% level of significance with world oil price and at 1% level of significance with national oil price), for Italy (at 5% level of significance with world oil price), and for Finland (at 5% level of significance with national oil price). In Table 3 the null hypothesis of no cointegration is not rejected in 24 out of 28 cases. Given this outcome and the findings by Engle and Yoo (1987), Clements and Hendry (1995), and Hoffman and Rasche (1996) that unrestricted VAR is superior in terms of forecast variance to a restricted VECM at short horizons when the restriction is true, and by Naka and Tufte (1997) that the performance of unrestricted VARs and VECMs for orthogonalized impulse response analysis over short-run is nearly identical, we will run unrestricted VARs for all countries in what follows.

3. Oil price variables and model

3.1. Non-linear oil price variables

Two transformations of oil price data that have been widely used in the literature will be utilized in addition to first log difference of real oil price, op. These are scaled real oil price change due to Lee et al. (1995), SOP, and the net oil price increase due to Hamilton (1996), NOPI. Lee et al. (1995) argue that oil price

Table 3
Cointegration test results for 14 countries (variables: interest rate, real oil price, and industrial production in log levels)

Country	Hypothesis	$r=0$	$r=<1$	$r=<2$	Country	Hypothesis	$r=0$	$r=<1$	$r=<2$
World real oil price									
U.S.	Trace test	14.619	6.859	1.104	Greece	Trace test	28.273	6.032	0.025
	λ max test	7.760	5.754	1.104		λ max test	22.241[b]	6.007	0.025
Austria	Trace test	27.783	5.557	0.243	Italy	Trace test	30.902[b]	7.501	1.663
	λ max test	20.226	5.314	0.243		λ max test	23.402[b]	5.838	1.663
Belgium	Trace test	24.673	6.225	0.243	Netherlands	Trace test	17.129	7.814	2.186
	λ max test	18.449	5.982	0.243		λ max test	9.315	5.627	2.186
Denmark	Trace test	16.362	5.054	0.04	Norway	Trace test	26.353	7.527	1.683
	λ max test	11.308	5.054	0.04		λ max test	18.825	5.845	1.683
Finland	Trace test	27.601	8.682	0.404	Spain	Trace test	24.064	6.730	0.806
	λ max test	18.920	8.278	0.404		λ max test	17.333	5.924	0.806
France	Trace test	27.922	5.930	0.246	Sweden	Trace test	15.379	4.027	0.0004
	λ max test	21.992[b]	5.684	0.246		λ max test	11.352	4.020	0.0004
Germany	Trace test	16.477	6.850	0	U.K.	Trace test	41.936[b]	4.330	1.891
	λ max test	9.627	6.850	3.760		λ max test	37.606[b]	2.438	1.891
National real oil price									
U.S.	Trace test	14.469	7.070	1.201	Greece	Trace test	27.708	5.215	0.051
	λ max test	7.399	5.869	1.201		λ max test	20.494	5.164	0.051
Austria	Trace test	25.783	5.557	0.243	Italy	Trace test	27.404	8.794	1.155
	λ max test	20.226	5.314	0.243		λ max test	18.610	7.638	1.155
Belgium	Trace test	28.609	9.670	0.467	Netherlands	Trace test	18.388	9.714	3.355
	λ max test	18.933	9.201	0.476		λ max test	8.674	6.359	3.355
Denmark	Trace test	17.747	5.503	0.1	Norway	Trace test	24.520	8.517	2.152
	λ max test	12.244	5.403	0.1		λ max test	16.002	6.365	2.152
Finland	Trace test	29.819[b]	6.985	0.172	Spain	Trace test	23.654	7.848	0.316
	λ max test	22.839[b]	6.813	0.172		λ max test	15.806	7.532	0.316
France	Trace test	28.714	7.984	0.486	Sweden	Trace test	16.028	5.458	0.139
	λ max test	20.716	7.512	0.486		λ max test	10.570	5.319	0.139
Germany	Trace test	17.861	7.356	0.0001	U.K.	Trace test	38.322[a]	5.778	2.189
	λ max test	10.505	7.356	0.0001		λ max test	32.544[a]	3.589	2.189

Notes: Johansen and Juselius (1990) test statistic for cointegration. World real oil price — dollar index of U.K. Brent/PPI in log level, National real oil price — dollar index of U.K. Brent/[(dollar price national currency)(national CPI)] in log level. The number of cointegrating vectors is indicated by r. Superscripts [a] and [b] denote rejection of the null hypothesis at the 1% and 5% levels of significance, respectively.

shocks are more likely to have a significant impact in an environment in which oil prices have been stable than in an environment where oil price movements have been frequent and erratic.

For the Lee et al. (1995) oil price specification, a GARCH(1,1) model is estimated for world real oil price and for national real oil price for each country. This model is given by (country and world suffices suppressed)

$$\mathrm{op}_t = \alpha + \sum_{i=0}^{p} \alpha_i op_{t-i} + \sum_{i=0}^{q} \beta_i z_{t-i} + \varepsilon_t, \quad \varepsilon_t | I_{t-1} \sim N(0, h_t), h_t = \gamma_0 + \gamma_2 \varepsilon_{t-1}^2 + \gamma_2 h_{t-1}, \tag{1}$$

where op_t is first log difference in real oil price, ε_t is an error term, and $\{z_{t-1}:i \geq 1\}$ denotes an appropriately chosen vector contained in information set I_{t-1}. The lags p and q are selected optimally for world real oil price and national real oil price for each country. Scaled oil price is defined as (world and country suffices are suppressed):

$$\mathrm{SOP}_t = \hat{\varepsilon}_t \Big/ \sqrt{\hat{h}_t}. \tag{2}$$

Net oil price increase, introduced by Hamilton (1996), is designed to capture how unsettling an increase in the price of oil is likely to be for the spending decisions of consumers and firms. If the current price of oil is higher than it has been in the recent past, then a positive oil price shock has occurred. Hamilton (1996) measures net oil price (U.S. PPI for crude oil) increase in a quarter as the maximum of zero and the percentage difference of the value in the current quarter from the maximum value achieved during the previous four quarters. Hamilton (2003) more recently considers a 12-quarter rather than a 4-quarter horizon is the more appropriate for constructing a net oil price increase measure. In this paper data are at a monthly frequency and it is not possible to define net oil price increase exactly as Hamilton (1996, 2003). In this analysis with monthly data we define net oil price increase as:

$$\mathrm{NOPI}_t = \max\ (0,\ \log\ P_t - \max\ (\log\ P_{t-1} \ldots \log\ P_{t-n})), \tag{3}$$

where $\log P_t$ is the log of level of real oil price at time t (world and country suffices are suppressed) and n is 6.

3.2. VAR model

The empirical framework for investigating the complexities of the dynamic connections between oil price shocks and stock prices in this paper is an unrestricted vector autoregression (VAR) model. A VAR model has been frequently used to analyze the impact of oil price shocks on economic activity since work by Darby (1982) and Hamilton (1983). The main advantage of this model is the ability to capture the dynamic relationships among the economic variables of interest. A VAR model consists of a system of equations that expresses each variable in the system as a linear function of its own lagged value and lagged values of all the other variables in the system. For example, a VAR of order p, where the order p represents the number of lags, that includes k variables, can be expressed as:

$$\boldsymbol{y}_t = \boldsymbol{A}_O + \sum\nolimits_{i=1}^{p} \mathbf{A}_i \boldsymbol{y}_{t-i} + \boldsymbol{u}_t, \tag{4}$$

where $\boldsymbol{y}_t = [y_{1t} \ldots y_{kt}]'$ is a column vector of observation on the current values of all variables in the model, $\mathbf{A}_i$ is $k \times k$ matrix of unknown coefficients, $\boldsymbol{A}_O$ is a column vector of deterministic constant terms, $\boldsymbol{u}_t$ is a column vector of errors with the properties of $E(\boldsymbol{u}_t)=0$ for all t, $E(u_s u_t')=\boldsymbol{\Omega}$ if $s=t$ and $E(u_s u_t')=0$ if $s \neq t$, where $\boldsymbol{\Omega}$ is the variance–covariance matrix. Thus, $\boldsymbol{u}_t's$ are assumed to be serially uncorrelated but may be contemporaneously correlated and $\boldsymbol{\Omega}$ is assumed to have non-zero off-diagonal elements. All the variables, $\boldsymbol{y}_t = [y_{1t} \ldots y_{kt}]'$, in the model must have the same order of integration.

Our basic VAR model will have the four stationary variables, first log difference of short-term interest rate (r), real oil price (op), first log difference of industrial production (ip), and real stock returns (rsr). The basic model will be extended to allow for the possibility of spill over effects from the U.S. stock market to the European stock markets and in other ways, including the possible effect of the rate of inflation, on the relationship between oil prices and real stock returns. Here, country suffices are suppressed, and the oil price variable in different VAR systems will be either first log difference of world real or national real oil prices or non-linear transformations of real oil price changes defined as either scaled (SOP) or net (NOPI) real oil price variables (in Eqs. (2) and (3)). Lag length in Eq. (4), p, will be taken to be 6 for all VAR.[3]

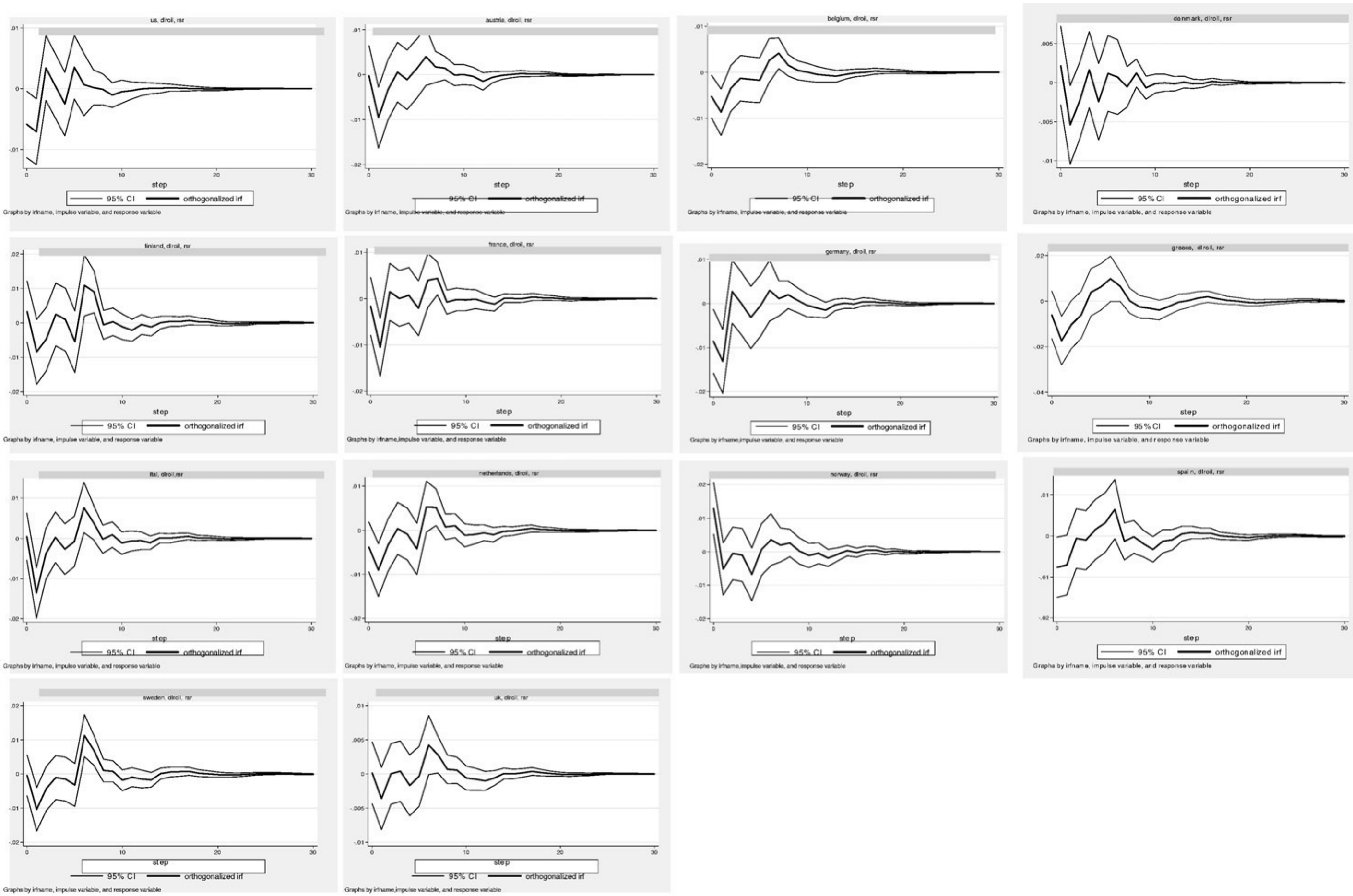
4. Impact of oil price shock on stock market

4.1. World real oil price shock

In this section we assess the impact of world real oil price shock on real stock returns by examining orthogonalized impulse responses. The orthogonal innovations, denoted by ε_t, are obtained by transforming the errors terms in Eq. (4) by $\varepsilon_t = \mathbf{q}\boldsymbol{u}_t$ such that $\mathbf{q}\boldsymbol{\Omega}q' = \mathbf{I}$, where $\mathbf{q}$ is any lower triangular matrix, $\mathbf{I}$ is an identity matrix, and $\boldsymbol{\Omega}$ is the covariance matrix of the residual $\boldsymbol{u}_t$. The orthogonal innovations $\boldsymbol{u}_t = \mathbf{q}\varepsilon_t$ then satisfy $E(\boldsymbol{u}_t u_t') = \mathbf{I}$.

The orthogonalized impulse responses of the variables in the model are obtained as a moving average representation of a four-variable VAR with variables placed in the following order: first log difference of short-term interest rate; first log difference of real oil price (world or national); first log difference of

[3] A check of optimal lag length based on LR, AIC, and BSIC criteria for the various VAR specifications across country and oil price variables yielded a range of results, with some less that 6 and some more than 6.



Notes : Figures are: first row - U.S., Austria, Belgium, Denmark; second row - Finland, France, Germany, Greece; third row - Italy, Netherlands, Norway, Spain; fourth row – Sweden, U.K. In VAR(r, op, ip, rsr), r, op, and ip, are the short-term interest rate, world real oil price, and industrial production in first log difference, and rsr is real stock return.

Fig. 2. World real oil price shocks: Orthogonalized impulse response function of real stock returns to linear oil price shocks in VAR(*r*, op, ip, rsr).

Table 4
Statistically significant orthogonalized impulse response of real stock return to real oil price shock: VAR(*r*, oil price shock, ip, rsr) (contemporaneously and/or with lag of one month)

	U.S.	AUS	BEL	DEN	FIN	FRA	GER	GRE	ITA	NET	NOR	SPA	SWE	U.K.
World real oil price	Sign of statistically significant effect on real stock returns of shock to world real oil price													
Shock to op	n	n	n	n	n#	n	n	n	n	n	p	n	n	
Shock to SOP	n	n	n	n	n#	n	n	n	n	n	p	n	n	n#
Shock to NOPI	n#	n#	n#				n	n	n	n#			n#	
National real oil price	Sign of statistically significant effect on real stock returns of shock to national real oil price													
Shock to op	n	n	n		n	n	n	n	n	n#	p		n	
Shock to SOP	n	n	n			n	n	n	n	n#	p		n	
Shock to NOPI	n	n#					n	n				n#	n	

Notes: n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock contemporaneously and/or a lag of one month. The superscript # indicates that statistic significance is at 10% level. In VAR (*r*, oil price shock, ip, rsr), *r* and ip are the short-term interest rate and industrial production in first log difference and rsr is real stock return. Oil price shock is measured as first log difference in world real oil price or in national real oil price or as non-linear transformations of these variables. SOP denotes scaled oil price change and NOPI indicates net oil price change. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities). National real oil price for country *i* — [(U.S. dollar index for U.K. Brent crude oil)(units of currency country *i* per U.S. dollar)]/(CPI for country *i*).

industrial production; and real stock returns. The order of variables in this VAR model is indicated by the notation VAR(*r*, op, ip, rsr). This order of variables was considered in Sadorsky (1999) for analysis of oil price shock on real stock returns for the U.S. With this order of variables, shocks to the interest rate, oil prices, and industrial production have possible contemporary effect on real stock returns, but not the other way around. Since the order of variables can sometimes have important effects on results, orthogonalized impulse responses from VAR systems with different ordering and additional variables including oil price volatility and inflation will be estimated and reported in later sections of the paper.

Orthogonalized impulse responses of real stock returns from a one standard deviation shock to oil price measured by the log first difference in real world oil price from the VAR(*r*, op, ip, rsr) are shown in Fig. 2. Results for 14 countries and 95% confidence bounds around each orthogonalized impulse response appear in Fig. 2. For the U.S. and for ten of thirteen European countries (the exceptions are Norway, Finland, and the U.K.) an oil price shock has a negative and statistically significant impact on real stock returns at the 5% level in the same month and/or within one month. In later months the orthogonalized impulse responses vary between being negative and positive, with some statistically significant effects in some months for some countries. Given that the effect being observed is for variable that is a (real) rate of return the orthogonalized impulse responses revert to zero (usually well within 12 months). A transitory effect on the real rate of return on stocks is expected. For Norway, an oil exporting country, oil price shock has a positive and statistically significant impact on real stock returns at the 5% level in the same month and a positive but statistically insignificant effect with a lag of one month.[4] For Finland, a negative and statistically significant impact on real stock returns with a lag of one month is obtained at the 10% level.

The first row of Table 4 summarizes the results in Fig. 2. In Table 4 an n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock contemporaneously and/or at lag of one month. The superscript # indicates that statistical significance is at 10% level. A summary of orthogonalized impulse response results for the impacts on real stock returns of shocks to the non-linear transformations of world real oil price, SOP and NOPI, from the models VAR(*r*, SOP, ip, rsr) and VAR(*r*, NOPI, ip, rsr), appear on lines 2 and 3 of Table 4. To economize on space, figures showing the orthogonalized impulse responses are not reported, but for the oil price shock measure SOP they are similar to those in Fig. 2 for the oil price shock measure op.

The second row of Table 4 shows that a one standard deviation increase in scaled world real oil price (SOP) significantly impacts real stock returns in all countries contemporaneously and/or with a one month lag. The results are negative with the exception of Norway, for which an oil price shock (SOP) significantly

[4] Oil prices increases are beneficial to Norwegian firms given the dependence of the economy on oil exports. Gjerde and Saettem (1999) also report a positive association between oil prices and Norwegian listed firm stock price and note that in the 1990s Norway exports were over 40% of GDP and dominated by exports of oil and natural gas.

raises real stock returns contemporaneously or within one month. Now, in contrast to the result for a shock to op, a positive shock to scaled world real oil price reduces U.K. real stock returns contemporaneously or within one month at the 10% level.[5]

In the third row of Table 4 results for the impact of net world real oil price (NOPI) on real stock return are summarized. Net world real oil price has a statistically significant impact on real stock returns for the U.S. and for 7 out of 13 of the European countries. The smaller number of statistically significant results with NOPI compared to linear or scaled world real oil price shocks may be due to the pattern of oil price increases and decreases in the period of study.

On concluding the discussion of this sub-section, it should be noted that inclusion of a non-linear variable, such as net oil price, on the left-hand side of the VAR system, the impulse responses may not adequately capture how the variable responds to the other variables in the system. An alternative approach is taken by Balke et al. (2002) with a near-VAR in which the regular version of the oil price variable is used on the left left-hand side, and the non-linear version of the oil price variable is generated with an identity. This procedure does substantially complicate the procedure for calculating the confidence bands for the impulse response functions.[6] We do not employ a near-VAR in this paper.

4.2. National real oil price shock

In rows four through six of Table 4 results are reported on the statistical significance of linear and non-linear measures of national real oil price shocks on real stock returns. Linear and SOP measures of national real oil price shocks have a statistically significant effect on real stock returns for the U.S. and for 10 and 9 European countries, respectively. NOPI national real oil price does not have a statistically significant impact on real stock returns in as many countries as does linear or scaled national real oil price. Generally, linear and non-linear measures of real oil price shocks measured as real world oil price yield more cases of statistically significant impacts on real stock returns than do real oil price shocks measured as national real oil price. This result regarding the more pervasive effect of the real world (US dollar) price of oil, we take to imply that markets anticipate that an oil price shock will have significant effects in most countries and markets, with implications for own firm circumstances that will not be offset by movement in own exchange rate that may serve to mitigate movement in the real world price of oil. For this reason, in what follows we will confine our attention to the impacts of linear and non-linear measures of world real oil price. This observation about the more pervasive effect of the real world price of oil than real national oil price on stock returns also serves to motivate discussion of the effect of possible stock market spillover effects between American and European markets in the next section.

4.3. Spillover effects from U.S. stock market

The U.S. equity markets account for a substantial fraction of global equity markets. It is therefore possible that the VAR models for Europe may be miss-specified in that they do not include a stock market index from the United States to account for stock market spillover effects between American and European markets.[7] The model that will now examine for each European country is given by VAR(r, op, ip, $\mathrm{rsr}_{\mathrm{us}}$, rsr), where $\mathrm{rsr}_{\mathrm{us}}$ represents real stock return for the U.S. (and other country suffices are suppressed in this

[5] An outcome for the U.K. intermediate between that for Norway and the other European countries is not surprising. The U.K. is a net oil exporter over 1980 to 2004 since oil production minus domestic consumption is positive over this period, but negative starting in 2005 (http://europe.theoildrum.com/story/2006/9/17/135527/399). The value of net oil exports never achieved the relative importance for the U.K. economy as that achieved in the Norwegian economy. Jimenez-Rodriguez and Sanchez (2005) also report a difference between results for the U.K. and Norway, in that a positive oil price shock significantly reduces output in the U.K. and increases output in Norway.

[6] We are grateful to a Referee for pointing out the potential limitation of impulse responses from VAR systems in the presence of complex non-linear variables. It is noted that a finding of weak exogeneity for both the linear and non-linear form of the oil price variable in the model will better justify the use of the non-linear oil price form in generating the impulse response functions. Results from the inclusion of lags of predicted values of the oil price shock variables in the regression equations for real stock returns (in addition to lags of the oil price shock variables) results in, for the most part, findings of statistical insignificance of the predicted oil price shock variables, supportive of weak exogeneity of the linear and non-linear oil price variables.

[7] We are grateful to a referee for suggesting that we examine results from a VAR specification that includes a U.S. stock market index in the VAR models for the European countries.

Table 5
Statistically significant orthogonalized impulse response of real stock return to real oil price shock given spillover from U.S.: VAR(r, oil price shock, ip, rsr_{us}, rsr) (contemporaneously and/or with lag of one month)

	AUS	BEL	DEN	FIN	FRA	GER	GRE	ITA	NET	NOR	SPA	SWE	U.K.
World real oil price	Sign of statistically significant effect on real stock returns of shock to world real oil price: VAR(r, op, ip, rsr_{us}, rsr).												
Shock to op	n	n	n#	n	n	n	n	n	n	p	n	n	n
Shock to SOP	n	n	n	n	n	n	n	n	n#	p	n	n	n
Shock to NOPI		n				n	n	n	n			n#	n#
National real oil price	Sign of statistically significant effect on real stock returns of shock to national real oil price: VAR(r, op, ip, rsr_{us}, rsr).												
Shock to op	n	n			n	n	n	n	n	p	n#	n	n#
Shock to SOP	n	n			n#	n	n	n	n#	p		n	n#
Shock to NOPI		n				n							

Notes: n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock contemporaneously and/or a lag of one month. The superscript # indicates that statistic significance is at 10% level. In VAR (r, oil price shock, ip, rsr_{us}, rsr), r and ip are the short-term interest rate and industrial production in first log difference, and rsr is real stock return in a European country. rsr_{us} is real stock return in the U.S. Oil price shock is measured as first log difference in world real oil price or in national real oil price or as non-linear transformations of these variables. SOP denotes scaled oil price change and NOPI indicates net oil price change. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities). National real oil price for country i — [(U.S. dollar index for U.K. Brent crude oil)(units of currency country i per U.S. dollar)]/(CPI for country i).

expression). This ordering allows for real returns in U.S. stock market index to contemporaneously affect real returns in European stock market indices and not the reverse.

In Table 5 an n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock contemporaneously and/or at lag of one month for the VAR (r, op, ip, rsr_{us}, rsr). The superscript # indicates that statistical significance is at 10% level. A summary of orthogonalized impulse response results for the impacts on real stock returns of shocks to the linear world real oil price and to the non-linear transformations of world real oil price, SOP and NOPI, appear on lines 1, 2 and 3, respectively, of Table 5. These results with inclusion of rsr_{us} in the VAR are similar to those reported in Table 4 without rsr_{us} in the VAR, with the main difference being that all three oil price shock measures now have statistically significant negative effects on stock prices in the U.K., contemporaneously and/or at a lag of one month. The only other notable change is that for Austria, with rsr_{us} in the VAR, NOPI does not have a statistically significant effect.

The effect of changes national real oil price shock measures on real stock returns with rsr_{us} in the VAR are reported in rows four through six of Table 5. As before, real oil price shocks measured as national real oil price real yield fewer cases of statistically significant impacts on real stock returns than do world real oil price shocks. The results for the U.K. are improved in that linear and SOPI national real oil price shocks have statistically significant negative effects with rsr_{us} in the VAR compared to insignificant effects with rsr_{us} is not included in the VAR model.

In summary, linear and SOPI measures of real world oil price shocks yield statistically significant impacts on real stock returns in all 13 European countries when allowance is made for the effect of real U.S. stock returns on real stock returns in European markets.

4.4. Alternative VAR specifications

As a robustness check the impact of an oil price shock on real stock returns from alternative VAR models are examined. The first alternative model, VAR(oil price shock, r, ip, rsr), places oil price shock ahead of the interest rate in the order of the variables and the second alternative model, VAR(r, oil price shock, ip, infl, rsr), has five variables with the introduction of inflation (infl) into the basic model. The focus is on whether the findings regarding the impact of linear and non-linear measures of world real oil price on real stock returns for the basic VAR model carry over for alternative specifications of the VAR.

In the first three rows of Table 6, results are presented for the impact on real stock returns of a one standard deviation increase in world real oil price, measured in turn by op, SOP, and NOPI, from the model VAR(oil price shock, r, ip, rsr). The results are essentially the same as that for the basic VAR shown in the first three rows of Table 4. Linear and SOP measures of world real oil price shocks have a statistically significant effect on real stock returns for the U.S. and for 12 and 13 European countries, respectively, either contemporaneously and/or with a lag of one month. NOPI yields the same statistically significant results

Table 6
Statistically significant orthogonalized impulse response of real stock return to real world oil price shock: alternative VARs (contemporaneously and/or with lag of one month)

	U.S.	AUS	BEL	DEN	FIN	FRA	GER	GRE	ITA	NET	NOR	SPA	SWE	U.K.
Sign of statistically significant effect on real stock returns in VAR(oil price shock, *r*, ip, rsr)														
Shock to op	n	n	n	n	n#	n	n	n	n	n	p	n	n	
Shock to SOP	n	n	n	n	n#	n	n	n	n	n	p	n	n	n#
Shock to NOPI	n#	n#	n				n	n	n#	n#			n	
Sign of statistically significant effect on real stock returns in VAR(*r*, oil price shock, ip, infl, rsr).														
Shock to op	n	n	n	n	n#	n	n	n	n	n	p	n	n	
Shock to SOP	n	n	n	n	n	n	n	n	n	n	p	n	n	
Shock to NOPI	n	n	n		n#		n	n	n	n			n	

Notes: n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock contemporaneously and/or a lag of one month. The superscript # indicates that statistic significance is at 10% level. infl, *r*, and ip are the consumer price index, short-term interest rate and industrial production in first log difference and rsr is real stock return. Oil price shock is measured as first log difference in world real oil price or as non-linear transformations of this variable. SOP denotes scaled oil price change and NOPI indicates net oil price change. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities).

placed first in the VAR as with the basic VAR when oil price shock is placed second in the model (there is some shift in significance level either up or down depending on the country).

For the VAR with inflation introduced as an additional variable, VAR(*r*, op, ip, infl, rsr), results for linear and non-linear (SOP and NOPI) world real oil price shocks on real stock returns are presented in the last three rows of Table 6. The difference from the results in Table 4 (apart from a few shifts in level of significance of statistically significant results) for the basic VAR(*r*, op, ip, rsr) are that oil price shocks measured by SOP are no longer statistically significant for the U.K. Thus, we conclude that the finding of statistically significant impact on real stock returns of oil price shocks contemporaneously and/or within one month for most countries is not sensitive to reasonable changes in the VAR model.

4.5. Asymmetric effects of oil price shocks

In the literature oil price increases have been found to have a greater influence in absolute value on the macroeconomic aggregates than have oil price decreases. This asymmetric effect has been documented by Mork (1989), Hooker (1996, 2002), Hamilton and Herrera (2004), Davis and Haltiwanger (2001), and Balke et al. (2002), among others for the U.S., by Lee et al. (2001) for Japan, by Huang et al. (2005) for Canada, Japan, and the U.S., and by Cunado and Perez de Garcia (2003) for most European countries. Hamilton (2003) for U.S. data reports non-linear oil price increases are much more important than non-linear oil price decreases in explaining U.S. GDP growth. An asymmetric effect is reported as a basic finding by Jones et al. (2004) in their survey of the literature on oil and the macroeconomy.[8] However, counter to this evidence Kilian (2007) reports that for component expenditures of consumption and investment there is little evidence suggesting asymmetric responses to positive and negative oil price shocks.

Following Mork (1989), the asymmetric effect of oil price shocks on real stock returns will first be considered by testing the null hypothesis that the coefficients of positive and negative oil price shocks are the same. In order to check for asymmetric effects of real oil price change, the first log difference in world real oil price, op_t, will be separated into positive and negative real oil price changes as in Mork (1989). The asymmetric effect of scaled oil price changes on real stock returns will also be examined. The positive and negative real oil price changes in linear and scaled oil price shocks are defined as:

$$\mathrm{opp}_t = \max\ (0, \mathrm{op}_t) \text{ and } \mathrm{opn}_t = \min\ (0, \mathrm{op}_t) \tag{5}$$

$$\mathrm{SOPP}_t = \max\ (0, \mathrm{SOP}_t), \text{ and } \mathrm{SOPN}_t = \min\ (0, \mathrm{SOP}_t). \tag{6}$$

In Eqs. (5) and (6) op is first log difference in world real oil price and SOP is world scaled oil price defined in Eq. (2). A 5 variable VAR will be estimated for each measure of oil price shock by splitting oil price

[8] A number of explanations for asymmetric effects of oil price shocks on real activity have been advanced in the literature, including adjustment costs and financial stress, but a consensus view does not seem to have emerged.

Table 7
Coefficient test of asymmetric effect of world real oil price shocks on stock returns: 1986–2005

$$\mathrm{rsr}_t=\alpha_o+\sum_{i=1}^{6}\alpha_{1i}r_{t-i}+\sum_{i=1}^{6}\alpha_{2i}\mathrm{OP}_{t-i}+\sum_{i=1}^{6}\alpha_{3i}\mathrm{ON}_{t-i}+\sum_{i=1}^{6}\alpha_{4i}\mathrm{ip}_{t-i}+\sum_{i=1}^{6}\alpha_{5i}\mathrm{rsr}_{t-i}+\boldsymbol{u}_t$$

$$\mathrm{rsr}_t=\alpha_o+\sum_{i=1}^{6}\alpha_{1i}r_{t-i}+\sum_{i=1}^{6}\alpha_{2i}\mathrm{OP}_{t-i}+\sum_{i=1}^{6}\alpha_{3i}\mathrm{ON}_{t-i}+\sum_{i=1}^{6}\alpha_{4i}\mathrm{ip}_{t-i}+\sum_{i=1}^{6}\alpha_{6i}\mathrm{rsr}_{\mathrm{us}t-i}+\sum_{i=1}^{6}\alpha_{5i}\mathrm{rsr}_{t-i}+\boldsymbol{u}_t$$

VAR model	Chi-square (χ^2) test results of H_0:$\alpha_{2i}=\alpha_{3i}$,$i=1,\ldots$ 6			
	No spillover: VAR(r, OP, ON, ip, rsr)		Spillover possible from $\mathrm{rsr}_{\mathrm{us}}$: VAR($r$, OP, ON, ip, $\mathrm{rsr}_{\mathrm{us}}$, rsr)	
Oil price shock	op (linear)	SOP (scaled)	op (linear)	SOP (scaled)
U.S.	10.2	14.36[b]		
Austria	2.30	0.64	5.39	3.81
Belgium	2.88	5.86	3.13	4.44
Denmark	8.13	6.94	7.06	5.88
Finland	3.42	4.60	4.12	6.75
France	4.54	1.72	3.49	1.31
Germany	1.40	3.56	3.32	8.50
Greece	6.35	5.92	5.29	7.35
Italy	9.68	7.86	7.12	6.10
Netherlands	6.42	10.04	6.11	10.22
Norway	8.32	10.65[c]	7.72	11.34[c]
Spain	7.07	8.09	6.74	8.08
Sweden	7.55	7.73	6.71	10.00
U.K.	7.02	7.65	5.76	5.32

H_0:$\alpha_{2i}=\alpha_{3i}$,$i=1,\ldots$ 6. $\mathrm{OP}_{t=i}$ and $\mathrm{ON}_{t=i}$ are positive and negative oil price shocks (either linear or scaled).
Notes: Oil price shock is measured as first log difference in world real oil price, op, or as non-linear transformation real world oil price, scaled oil price (SOP). r and ip are the short-term interest rate and industrial production in first log difference and rsr is real stock return. $\mathrm{rsr}_{\mathrm{us}}$ is real stock return in the U.S. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities). Superscripts [b] and [c] denote statistical significance at the 5% and 10% levels, respectively.

changes into oil price increases and oil price decreases: i.e. VAR(r, opp_t, opn_t, ip, rsr) and VAR(r, SOPP_t, SOPN_t, ip, rsr) will be estimated. VARs will also be estimated that includes $\mathrm{rsr}_{\mathrm{us}}$ as an additional variable. The test for asymmetry is a conventional Chi-square (χ^2) test of the null hypothesis that the coefficients of positive and negative oil price shocks in the VAR are equal to each other at each lag.

In the equations for real stock returns:

$$\mathrm{rsr}_t=\alpha_o+\sum_{i=1}^{6}\alpha_{1i}r_{t-i}+\sum_{i=1}^{6}\alpha_{2i}\mathrm{OP}_{t-i}+\sum_{i=1}^{6}\alpha_{3i}\mathrm{ON}_{t-i}+\sum_{i=1}^{6}\alpha_{4i}\mathrm{ip}_{t-i}+\sum_{i=1}^{6}\alpha_{5i}\mathrm{rsr}_{t-i}+u_t, \tag{7}$$

$$\mathrm{rsr}_t=\alpha_o+\sum_{i=1}^{6}\alpha_{1i}r_{t-i}+\sum_{i=1}^{6}\alpha_{2i}\mathrm{OP}_{t-i}+\sum_{i=1}^{6}\alpha_{3i}\mathrm{ON}_{t-i}+\sum_{i=1}^{6}\alpha_{4i}\mathrm{ip}_{t-i}+\sum_{i=1}^{6}\alpha_{6i}\mathrm{rsr}_{\mathrm{us}t-i}+\sum_{i=1}^{6}\alpha_{5i}\mathrm{rsr}_{t-i}+u_t \tag{8}$$

where $\mathrm{OP}_{t=i}$ and $\mathrm{ON}_{t=i}$ are positive and negative oil price shocks (in turn either linear or scaled), Chi-square (χ^2) test results of the null hypothesis H_0:$\alpha_{2i}=\alpha_{3i}$, $i=1,\ldots$ 6, against the alternative are reported in Table 7.

The results obtained by carrying out this test of pair-wise of equality of the coefficients on positive and negative oil price shocks are the following for Eq. (7) with the absence of spillover effects: for linear oil price shocks the null hypothesis of symmetry cannot be rejected for the European countries and for U.S.; and for scaled oil price shocks the null hypothesis of symmetry cannot be rejected for all countries except for the U.S. (the null hypothesis is rejected at the 5% level of confidence) and for Norway (the null hypothesis is rejected at the 10% level of confidence).[9] It is also reported in Table 7, that for Eq. (8) with allowance for spillover effects from the U.S. stock market to the European stock markets, the null hypothesis of

[9] Although the null hypothesis of symmetric effects of oil price shocks on real stock returns is not rejected for the European countries for the full sample, the null hypothesis is rejected in a few cases for sub-samples. The question of sub-samples is of some interest in that the pattern of oil price fluctuation changed in the mid 1990's, in that after this point oil price increases are more frequent than the oil price decreases and the magnitude of oil price increases is smaller than that of oil price decreases. For example, the null hypothesis of symmetry in effects of positive and negative oil price shocks on real stock returns is rejected for Spain and Germany over 1996:6–2005:12.

pair-wise of equality of the coefficients on positive and negative oil price shocks cannot be rejected for all countries for linear oil price shocks, and cannot be rejected for all countries except Norway (at the 5% level of confidence) for scaled oil price shocks. Thus, we conclude that there is no evidence for asymmetric effects of oil price shocks on European stock returns, with the exception of Norway.

The possibility of asymmetric effect of oil price shocks on real stock returns will also be examined by using the method in Balke et al. (2002). Balke et al. (2002) test whether Hamilton's (1996) normalized oil variable retains statistical significance in explaining aggregate U.S. economic activity when the first log difference in real oil price also appears in regression equations.[10] Balke et al. (2002) argue that if the coefficients on the lags of the normalized oil variable (NOPI) in the regression for the dependent variable of interest retain statistical significance in the presence of lags of the first log difference in real oil price (op), then oil price shocks have an asymmetric effect.

For the model VAR(r, NOPI, ip, rsr), it is noted in Table 4 that the orthogonalized impulse response in real stock returns to a one standard deviation shock in NOPI is statistically significant contemporaneously and/or with a lag of one month for the U.S., Austria, Belgium, Germany, Greece, Italy, Netherlands, and Sweden. For a model that includes two oil price shock variables, the percentage change in the real price of oil (op) and NOPI, i.e. for the VAR(r, op, NOPI, ip, rsr), the orthogonalized impulse response in real stock returns to a one standard deviation shock in NOPI is not statistically significant contemporaneously or with a lag of one month for any of these countries.[11]

In addition, the null hypothesis that the coefficients on the lagged terms in NOPI in the equation for real stock returns (that includes the linear oil price shock variable op) are all zero, cannot be rejected at the 10% level of confidence. The F-test statistic for the exclusion of NOPI, i.e. for H_0:α_{3i}=0, i=1,… 6, in the equation

$$\mathrm{rsr}_t = \alpha_0 + \sum_{i=1}^{6}\alpha_{1i}r_{t-i} + \sum_{i=1}^{6}\alpha_{2i}\mathrm{op}_{t-i} + \sum_{i=1}^{6}\alpha_{3i}\mathrm{NOPI}_{t-i} + \sum_{i=1}^{6}\alpha_{4i}\mathrm{ip}_{t-i} + \sum_{i=1}^{6}\alpha_{5i}\mathrm{rsr}_{t-i} + u_t, \tag{9}$$

is 1.46 for the U.S., 1.02 for Austria, 0.14 for Belgium, 1.15 for Germany, 1.26 for Greece, 0.44 for Italy, 1.17 for the Netherlands, and 1.11 for Sweden. An F-statistic of 1.90 would indicate statistical significance at the 10% level of confidence. Thus, the null hypothesis that NOPI has zero coefficients in the presence of op cannot be rejected, and we conclude that there is absence of evidence of asymmetric effect of oil price shocks. If the effect of spillovers from the U.S. stock market are considered (VAR(r, op, NOPI, ip, $\mathrm{rsr}_{\mathrm{US}}\mathrm{rsr}_{\mathrm{us}}$, rsr)), the null hypothesis that NOPI is statistically insignificant in the presence of op cannot be rejected with the exception of the result for the exclusion test for Greece that yields an F-test statistic 1.90, statistically significant at the 10% level of confidence.

In summary, there is some evidence for the U.S. for asymmetric effects on real stock returns of positive and negative scaled oil price shocks (at the 5% level of confidence) on real stock returns. Most of the evidence is that oil price shocks do not have asymmetric effects on real stock returns in the European countries, the exceptions are a finding that positive and negative scaled oil price shocks (at the 10% level of confidence) have asymmetric effects on Norwegian real stock returns, and that for Greece in a model that includes spillover effect from the U.S. stock market, NOPI has a statistically significant effect (at the 10% level of confidence) on real stock returns in Greece even in the presence of a linear oil price shock variable (op).

5. Oil price volatility

5.1. Definition of volatility

Increased volatility in energy prices can affect the present value of the discounted stream of dividend payments, through increasing uncertainty about product demand and by increasing uncertainty about the

[10] In contrast to the Hamilton (1996) measure of oil prices, Balke et al. (2002) report that several other measures of oil price change capturing unusual oil price behavior do not indicate asymmetric effects of oil prices on real activity.

[11] For the VAR(r, op, NOPI, ip, rsr), the impulse response in real stock returns to a one standard deviation shock in op remains statistically significant contemporaneously and/or at a lag of one month for countries except the U.K. as in Table 4. If the effect of spillovers from the U.S. stock market are considered (VAR(r, op, NOPI, ip, $\mathrm{rsr}_{\mathrm{US}}\mathrm{rsr}_{\mathrm{us}}$, rsr)), the impulse response in real stock returns to a one standard deviation shock in NOPI remain statistically insignificant contemporaneously or with a lag of one month for all of the European countries.

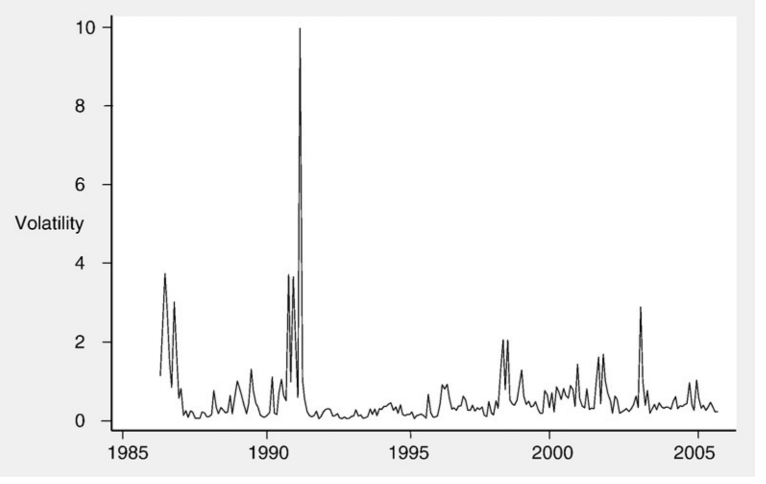


Fig. 3. Monthly oil price volatility. (Normalized sum of squared first log difference in daily spot crude oil price).

future return on investment. Bernanke (1983) and Pindyck (1991) argue that a firm faced with increased uncertainty may delay implementing investment in capital equipment. We will construct an indicator of uncertainty on the basis of daily data on oil prices. Measurement of monthly oil price volatility (following Merton 1980 and Andersen et al., 2003) will be given by the sum of squared first log differences in daily spot crude oil price:

$$\mathrm{Vol}_t = \sum_{d=1}^{s_t} \left(\mathrm{Log}\ \left(P_{t,d+1}/P_{t,d}\right)/\sqrt{s_t}\right)^2, \tag{10}$$

where $P_{t,d}$ is the spot price crude oil on day d of month t (obtained from NYMEX), and s_t is the number of trading days in month t. An alternative measure of oil price volatility could be given by the sum of squared first log differences in daily futures (1 month) crude oil price

$$\mathrm{Volf}_t = \sum_{d=1}^{s_t} \left(\mathrm{Log}\ \left(F_{t,d+1}/F_{t,d}\right)/\sqrt{s_t}\right)^2, \tag{11}$$

where $F_{t,d}$ is the futures crude oil price in day d of month t (obtained from NYMEX). However, since the correlation of Vol_t and Volf_t is 0.9586 and both measures yield very similar results we will present work using Vol_t only.

Vol_t is represented in Fig. 3. Vol_t is elevated at the time of the First Gulf War. The sharpest spike is in January 1991. On January 12, 1991 the Congress of the U.S. authorized military force to liberate Kuwait, on January 16, 1991 air strikes began against Iraq, and on January 17, 1991, Iraq fired scud missiles against Israel.[12] Volatility in oil price apparent over several months in 1986 may be due to the switch by Saudi Arabia in early 1986 from selling its oil at official prices to a market-based pricing system and thus changed from being a swing producer (with fluctuation in market share). As a result of this shift, Saudi Arabia recaptured market share from the rest of OPEC and spot prices fell from $28 per barrel in 1985 to $14 per barrel in 1986. The high level of volatility in oil price in March 2003 shown in Fig. 3 is presumably associated with the ongoing Iraqi disarmament crisis in early 2003 and the invasion of Iraq on March 20, 2003 by U.S. and other forces.[13]

[12] Iraq invaded Kuwait on August 2, 1990 (August 1990 is a spike in data on oil price volatility). A spike in oil price volatility in October 1990 might be associated, against the back drop of the Iraqi occupation of Kuwait, with an escalation in the Israeli–Palestinian conflict involving the Temple Mount in Jerusalem on October 8, 1990, and Syrian occupation of Mount Lebanon and ousting of the Lebanese government on October 13, 1990.

[13] Huntington (2005) has an interesting discussion of historic oil supply disruptions. The measure of volatility in this paper might be a proxy variable for market expectations of future supply disruptions.

5.2. Effect of oil price volatility

Several VAR models will be estimated with Vol_t included as a variable. In the first model volatility of oil price replaced oil price shock in the basic VAR model. Orthogonalized impulse response results of the response of real stock returns to a one standard deviation shock to Vol_t in the model VAR(*r*, Vol, ip, rsr) appears on the first line in Table 8. Oil price volatility has a significantly negative impact on the real stock returns in 9 out of 14 countries. In particular, for the U.K., where impact of oil price shocks except for the scaled oil price shock variable on real stock returns is not significant, volatility of oil prices depressed the stock market. Volatility does not significantly affect real stock returns for the U.S.

Volatility is now included in the basic model along with oil price shocks. Orthogonalized impulse response results of the response of real stock returns to a one standard deviation shock to Vol_t in the model VAR(*r*, op, Vol, ip, rsr), where op is linear oil price shock (real oil price shock in first difference), appears on the second line in Table 8. Orthogonalized impulse response results of the response of real stock returns to a one standard deviation shock to linear oil price shock in the same five variable model appears on line 3 of Table 8. The result for impact of linear oil price is essentially the same in this model as that found for the basic VAR(*r*, op, ip, rsr) and reported on line 1 in Table 4 with statistically significant orthogonalized impulse responses contemporaneously and/or with lag of one month for all countries except the U.K. Now however, real stock returns in the U.K respond significantly and negatively to Vol_t even with op in the model. For the other countries, inclusion of both op and Vol_t in the model only results in a significant and negative response to Vol_t in six cases.

The accumulated results of this section are that the effects of a shock to real world oil price on real stock returns are robust to the inclusion of a measure of oil price uncertainty in the model. Oil price shock is negatively related to real stock returns either contemporaneously or with a lag of one month. An increase in the volatility of oil prices is also negative related to real stock returns either contemporaneously or with a lag of one month in just over half the countries considered.

6. Oil price and interest rate shocks

6.1. Variance decomposition

Table 9 presents the forecast cast error variance decomposition of real stock returns due to the interest rate and oil price shocks. Each percentage shows how much of the unanticipated changes of real stock returns are explained by the variable indicated over a 24 month horizon. Results are presented based on four models for world real oil price; linear and scaled (SOP) oil price shock specifications and the basic VAR (*r*, oil price shock, ip, rsr) and alternative VAR(oil price shock, *r*, ip, rsr).

The contribution of oil price shock to the real stock returns over a 24 month horizon ranges from 3.0% for the U.K. to 10.3% for Sweden in case of linear oil price shock and basic VAR specification in column 2 of Table 9, with results being statistically significant in 12 out of 14 cases. The median result is that oil price shocks account for about 6% of the volatility in real stock returns. Results for the contribution of oil price

Table 8
Statistically significant orthogonalized impulse response of real stock return to oil price volatility and/or world real oil price (contemporaneously and/or with lag of one month)

	U.S.	AUS	BEL	DEN	FIN	FRA	GER	GRE	ITA	NET	NOR	SPA	SWE	U.K.
Sign of statistically significant effect on real stock returns in VAR(Vol, *r*, ip, rsr)														
Shock to volatility		n	n		n		n#	n	n	n			n	n
Sign of statistically significant effect on real stock returns in VAR(*r*, op, Vol, ip, rsr)														
Shock to volatility		n	n#					n	n	n			n	n
Shock to op	n	n	n	n	n#	n	n	n	n	n	p	n	n	

Notes: n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to Vol and/or oil price shock contemporaneously and/or a lag of one month. The superscript # indicates that statistic significance is at 10% level. Vol is oil price volatility — normalized sum of squares of first log difference in daily spot oil price. Oil price shock, op, is measured as first log difference in world real oil price. *r* and ip are the short-term interest rate and industrial production in first log difference and rsr is real stock return. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities).

Table 9
Variance decomposition of variance in real stock returns due to world real oil price and interest rate shocks

	Percentage of variation in real stock returns due to shocks interest rate or oil price (24 month horizon)							
VAR model	VAR(*r*, op, ip, rsr)		VAR(*r*, SOP, ip, rsr)		VAR(op, *r*, ip, rsr)		VAR(SOP, *r*, ip, rsr)	
Shock to	1	2	3	4	5	6	7	8
	Due to *r*	Due to op	Due to *r*	Due to SOP	Due to *r*	Due to op	Due to *r*	Due to SOP
U.S.	1.11	5.86[b]	1.17	4.41[c]	0.98	5.96[b]	1.14	4.44[c]
Austria	2.98	4.03[c]	2.93	3.31	2.95	4.06[c]	2.94	3.31
Belgium	2.33	8.50[b]	2.49	7.00[c]	2.01	8.79[b]	2.20	7.27[c]
Denmark	4.22[c]	2.92	4.28[c]	2.82	4.42[c]	2.72	4.43[c]	2.67
Finland	2.87	5.61[b]	2.74	4.66[b]	2.99	5.49[b]	2.75	4.65[c]
France	1.08	5.86[b]	1.21	4.80[c]	1.05	5.89[b]	1.20	4.81[c]
Germany	3.02	7.54[b]	2.63	6.90[b]	3.03	7.53[b]	2.61	6.91[b]
Greece	2.34	8.34[b]	2.14	8.70[b]	2.44	8.24[b]	2.27	8.57[b]
Italy	13.72[a]	9.69[a]	14.06[a]	9.38[a]	13.61[a]	9.81[a]	13.88[a]	9.56[a]
Netherlands	1.45	7.34[b]	1.49	6.56[b]	1.26	7.53[b]	1.26	6.79[b]
Norway	8.92[b]	5.96[b]	9.27[b]	5.09[c]	8.95[b]	5.93[b]	9.33[b]	5.03[c]
Spain	4.84[b]	4.67[c]	4.18[c]	4.75[c]	4.84[c]	4.67[c]	4.18[c]	4.75[c]
Sweden	9.91[b]	10.28[a]	9.57[b]	8.84[b]	9.91[b]	10.28[a]	9.62[b]	8.79[b]
U.K.	3.86	3.01	4.36	2.95	4.06	2.81	4.52[c]	2.79

Notes: Oil price shock is measured as first log difference in world real oil price, op, or as non-linear transformation real world oil price, scaled oil price (SOP). *r* and ip are the short-term interest rate and industrial production in first log difference and rsr is real stock return. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities). Superscripts [a], [b], [c], denote statistical significance at the 1%, 5%, 10% levels.

shocks to variability in real stock returns are similar across the four models reported in columns 2, 4, 6, and 8 of Table 9.[14] Allowance for spillover effects from the U.S. stock market on the European stock markets by estimating the model VAR(*r*, oil price shock, ip, $\mathrm{rsr}_{\mathrm{US}}\mathrm{rsr}_{\mathrm{us}}$, rsr), where $\mathrm{rsr}_{\mathrm{US}}$ $\mathrm{rsr}_{\mathrm{us}}$ is the real stock return for the U.S., also provides similar results (not reported to economize on space). Thus, variance decomposition suggests that oil price shocks are a significant source of monthly volatility in real stock returns and are a prime factor when considering real stock returns.[15]

We find that the contribution of oil price shocks to variability in real stock returns in the U.S. is greater than that of interest rate in all models. This result is consistent with the finding by Sadorsky (1999) for the U.S. after 1986 that the contribution of oil price shock is greater than that of interest rates on real stock returns. It is also consistent with finding by Davis and Haltiwanger (2001) that oil price shocks account for about twice the variation in plant level employment as interest rates.

These findings for the U.S. that oil price shocks have greater impact shocks to the interest are similar are also found for Austria, Belgium, Finland, France, Germany, Greece, and Netherlands. However, the interest rate contributes more to variability in real stock returns than oil price shocks for Denmark, Italy, Norway, and Sweden. For Spain the contribution of the interest rate and oil price shocks to variability in real stock returns are statistically significant and of about the same magnitude. Thus, for somewhat less than half the European countries considered the relative magnitude of oil price shocks and interest rate shocks as contributors to variability in real stock returns is different from that found for the U.S. and serves to reinforce the need to examine behavior in many countries.

[14] In results not reported models with variance compositions of real stock returns to oil price shocks at horizons of 6 and 12 months are very similar to those for the 24 month horizon in Table 9. Also not reported, we find that models with linear and SOP oil price specification show a bigger contribution of oil price shock to the real stock returns than models with NOPI oil price specification.

[15] In some cases it is possible to make a comparison with results obtained by other researchers. For example, for Norway, Gjerde and Saettem (1999) report 24 month horizon variance decomposition for real stock returns of 6.2% and 5.0% from oil price and interest rate shocks over 1974 to 1994, quite similar to results in Table 9 for 1986 to 2005. Papapetrou (2001) in a study for Greece over 1989:1 to 1999:6 report 24 month horizon variance decomposition for real stock returns of 12.5% and 5.2% from shocks to consumer price index for fuels deflated by the consumer price index and the interest rate, respectively, that are larger than effects for related variables in Table 9. The relatively small number of observations in the latter study may be part of the explanation for the difference in results.

Table 10
Statistically significant orthogonalized impulse response of interest rate to world real oil price (statistically significant effect of oil price shock at first and/or second lag)

Sign of statistically significant effect on interest rate of world oil price in VAR(r, oil price shock, ip, rsr)														
World real oil price	U.S.	AUS	BEL	DEN	FIN	FRA	GER	GRE	ITA	NET	NOR	SPA	SWE	U.K.
Shock to op	p#		p		p		p		p	p		p	p	p
Shock to SOP			p	n	p		p		p	p	n#	p		p
Shock to NOPI	p#	p	p	p	p		p		p			p	p	

Notes: n (p) indicates negative (positive) statistically significant orthogonalized impulse response at 5% level of real stock return to oil price shock at first and/or second lag. The superscript # indicates that statistic significance is at 10% level. Oil price shock is measured as first log difference in world real oil price, op, or as non-linear transformation real world oil price, scaled oil price (SOP) or net oil price change (NOPI). r and ip are the short-term interest rate and industrial production in first log difference and rsr is real stock return. World real oil price — (U.S. dollar index for U.K. Brent crude oil)/(U.S. PPI for all commodities).

6.2. Impact of oil price shocks on interest rate

A number of papers investigate the connection between monetary policy and oil price shocks. Bernanke et al. (1997) attribute the perceived association of oil price shocks and real growth to monetary authority behavior, a view recently qualified by Hamilton and Herrera (2004). It should be emphasized that in this paper, a rise in the interest rate following oil price increases should not be interpreted as monetary policy tightening. In the current analysis, ten of the thirteen European countries are members of the European Monetary Union and depend upon the European Central Bank for the conduct of monetary policy. In addition, the interest rate targeted by the Federal Reserve for the conduct of monetary policy is the over-night federal funds rate, not the three month T-bill rate, the interest rate used in the VAR for the U.S. (and for most of the other countries).

Despite the inability to directly associate change in interest rate with the direction of monetary policy in the analysis in this paper, it is appropriate to investigate whether oil price shocks have an impact on short-term interest rates in the countries included in the analysis. The impact of oil price shock on the interest rate in the basic VAR is reported in Table 10. Given the order of the VAR(r, oil price shock, ip, rsr) a one standard deviation oil price shock can only affect the interest rate with a lag. In Table 10 a positive (negative) statistically significant orthogonalized impulse response at 5% level of interest rate to oil price shock at a lag of one and/or two months is indicated by the letter p (n). The superscript # indicates that statistic significance is at 10% level. The first row of Table 10 indicates that a one standard deviation increase in the world real oil price significantly raises the short-term interest rate in the U.S. and eight out of 13 European countries with a lag of one or two months.[16]

The second row of Table 10 indicates that an increase in scaled oil price significantly raises the short-term interest rate in seven and lowers the interest rate in two of the European countries with a lag of one or two months. The negative response of the interest rate to SOP in two cases could be due to the fact that SOP captures not just oil price change but also uncertainty about oil prices. The last row of Table 10 indicates that an increase in net oil price significantly raises the short-term interest rate in the U.S. and in eight European countries.

7. Conclusion

The vast literature establishing robust results across many countries on the connection between oil price shocks and aggregate activity implies that connections should also hold between oil price shocks and stock markets. This study estimates the effects of oil price shocks and oil price volatility on the real stock

[16] A review of the literature on monetary policy and oil price shocks is provided by Cologni and Manera (2008). The finding of no significant connection between interest rates and oil prices has been reported for some countries and sample periods. Cologni and Manera (2008) report, on the basis of quarterly data over 1980Q1–2003Q3, that among the G-7 there is a monetary policy reaction of rising interest rates in response to higher oil prices for the U.S., but a tendency to the reverse for Canada, France and Italy. In this analysis stock price play no role.

returns of the U.S. and 13 European countries over 1986:1–2005:12 using a multivariate VAR analysis. We find that oil price shocks have a statistically significant impact on real stock returns in the same month or within one month and that this result is robust to reasonable changes in the VAR model of variable order and inclusion of additional variables. Linear and scaled measures of real oil price shocks calculated as world real oil price rather than national real oil price yield most cases of statistically significant impacts on real stock returns. Thus, statistically significant effect of oil price shocks is better captured by Brent (dollar index)/US PPI than by a measure of real national oil price that reflects offsetting movement in the exchange rate.

The finding that real oil price shocks calculated as world real oil price, rather than national real oil price, have a statistically significant impact on real stock returns across all countries, implies that markets anticipate significant and pervasive effects of oil price shocks in most countries and markets that will have implications for own firm circumstances reflected in stock price movement. When allowance is made for the effect of real U.S. stock returns on real stock returns in European markets, oil price shocks have a statistically significant impact on real stock returns in all European countries in the same month or within one month. When spillover effects are allowed for, all three oil price shock measures now achieve statistically significant negative effects on stock prices in the U.K. The median result from variance decomposition analysis is that oil price shocks account for a statistically significant 6% of the volatility in real stock returns.

Other results for the effect of oil price shocks on stock prices vary between countries, with the U.S. pattern varying between being an outlier and representing the majority outcome depending on issue addressed. For many European countries, but not for the U.S., increase in the volatility of oil prices significantly depresses real stock returns contemporaneously or within one month. For the U.S. and about half the European countries the contribution of oil price shocks to variability in real stock returns is greater than that of the interest rate. A one standard deviation increase in the world real oil price significantly raises the short-term interest rate in the U.S. and eight out of 13 European countries at a lag of one or two months. Finally, while there is some evidence of asymmetric effects on real stock returns of positive and negative oil price shocks for the U.S. and for Norway, there is little evidence of asymmetric effects for the oil importing European countries (the exception at a marginal level being for Greece in a model with spillover effects from the U.S. market). Additional research should be directed to investigating the mechanisms by which oil price and energy prices affect firm behavior and stock price.

Appendix A. Data sources

Monthly data over 1986.1 to 2005.12.

Countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Spain, Sweden, U.K., U.S.

Nominal oil price: IMF data from IFS. *U.K. Brent* (11276AADZF).

Real oil price of World: Nominal oil price deflated by the U.S. PPI.

Real oil price of each country: Product of nominal oil price and exchange rate (#/U.S. $)deflated by the CPI of each country.

U.S.

Consumer Price Index: FRED (Federal Reserve Economic Data). Consumer Price Index for All Urban Consumers All Items (CPIAUCSL), seasonally adjusted.

Industrial Production: FRED. Industrial Production Index (INDPRO, 2002 = 100), seasonally adjusted.

Share Prices: S&P 500 Index From COMPUSTAT NORTH AMERICA (I0002-S&P 500 comp-Ltd).

Short-term interest rate: FRED. 3 month Treasury-bill (TB3MS).

Producer Prices Index: FRED. Producer Price Indexes All commodities (PPIACO).

European countries

Exchange Rate: FRED. Number of units of currency per U.S. dollar.

Consumer Price Index: OECD. Data from Main Economic Indicators (2000 = 100), seasonally adjusted with X-11 procedure.

Industrial Production: OECD. Data from Main Economic Indicator (seasonally adjusted).

Share Price: OECD. Data from Main Economic Indicators, except for Finland from IMF (17262…ZF. industrial).

Short-term interest rate: IMF data from IFS for Germany, Belgium, Spain, Greece, Sweden, U.K. (Treasury Treasury-bill rate — line 60c), for Finland, Italy, Denmark, Norway (Money market rate — line 60 b). For Austria data are from OECD data from Main Economic Indicators. For Netherlands, data are call money rate from Bank of Netherlands. For France, data are money market rate from INSEE (National Institute for Statistics and Economic Studies).

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