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Oil and the Stock Markets

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ABSTRACT

We test whether the reaction of international stock markets to oil shocks can be justified by current and future changes in real cash flows and/or changes in expected returns. We find that in the postwar period, the reaction of United States and Canadian stock prices to oil shocks can be completely accounted for by the impact of these shocks on real cash flows alone. In contrast, in both the United Kingdom and Japan, innovations in oil prices appear to cause larger changes in stock prices than can be justified by subsequent changes in real cash flows *or* by changing expected returns.

THE DEPENDENCE OF THE world economy on oil was again reflected in the international reaction to Iraq's occupation of Kuwait. The maneuvers by Iraq to raise the world price of oil late in July 1990 and its invasion of Kuwait less than a week later led to a near doubling of oil prices (from $16.10 to $30.00 per barrel) in the second half of 1990. In fact, the 1990 oil price rise is comparable to even the notorious OPEC price hikes of 1973–1974 and 1979–1980.

There are two distinguishing features of oil in the postwar world economy. First, oil is a major resource that has been (and continues to be) extensively used around the world. For example, Figure 1 shows that even as late as 1988, energy expenditures as a proportion of gross national product were as high as 8.03 percent in the United States. The relative share of petroleum products alone was a nontrivial 3.7 percent of GNP. Second, oil price hikes in the postwar era appear to be dominated by shocks "exogenous" to the rest of the world economy. For example, Hamilton (1983, 1985) conducts a detailed analysis of oil price changes in the United States and concludes that ". . . the particular timing of changes in nominal crude oil price reflects largely *exogenous* developments specific to the petroleum sector." (italics added) In fact, based on his statistical and qualitative analyses, Hamilton argues that we must give a causal interpretation to the correlation between oil prices and macroeconomic phenomena. Similarly, the critical importance of oil to other

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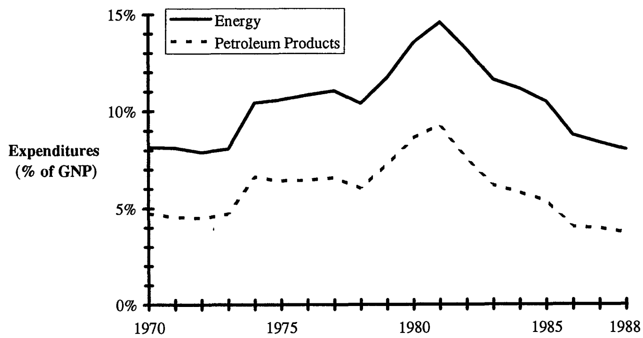

Figure 1. Share of Energy and Related Products in Gross National Product for the United States, 1970–1988. Annual U.S. energy expenditures (solid line) and expenditures on petroleum products (dashed line) as proportions of the gross national product.

countries is amply demonstrated in the studies by Helliwell, Sturm, Jarrett, and Salou (1986) and Rasche and Tatom (1981).

Given the importance of oil to the world economy, it is surprising that little research has been conducted on the effects of oil shocks on the stock market.[1] In this article, we conduct a detailed investigation of the effects of changes in oil prices on stock prices during the postwar period. Our main contribution is that we gauge whether the stock market rationally evaluates the impact of oil shocks on the economy. The peculiar characteristics of oil shocks, that is, their Granger-precedence with respect to other economic phenomena and their obvious importance to the world economy, provides us a unique opportunity to assess the stock market's ability to (rationally) evaluate the *causal* real effects of events that "exogenously" perturb the economy.[2]

Our detailed investigation of the reaction of the U.S. stock market to oil shocks shows that stock prices rationally reflect the impact of news on current and future *real* cash flows. We find no evidence of fads and/or market overreaction. While the Canadian stock market also appears to react rationally to oil shocks, the experiences of Japan and the United Kingdom are different. We are unable to completely explain these stock markets' reactions to oil price changes within the context of a rational asset pricing framework; oil shocks in Japan and the United Kingdom lead to changes in stock prices that appear to be substantially greater than can be justified by the effects of these shocks on subsequent real cash flows. Our attempts to account for changing expected

[1] Notable exceptions are a few recent studies that use oil prices as one of many risk factors that may be priced in the stock markets (see Chen, Roll, and Ross (1986), Ferson and Harvey (1993), and Hamao (1988)). The economic relevance of oil shocks is also reflected in their apparent significant importance in explaining the postwar negative relation between stock returns and inflation (see Hess and Lee (1994) and Kaul and Seyhun (1990)).

[2] We use the term Granger-precedence in the Granger (1969) causality sense. The expression that oil price changes Granger-precede implies that they are *not* Granger-caused by other variables in the system. Of course, if oil price changes are also weakly exogenous, then they will be "strongly exogenous" with respect to the variables in the system (see Engle, Hendry, and Richard (1983)).

returns also cannot help explain the effect of oil shocks on either stock market. Measurement errors in inflation and/or oil price variables and, more importantly, in our proxies for expected real cash flows also do not appear to affect our analysis. Therefore, we conclude that in the case of Japan and the United Kingdom either: (a) oil price shocks impact expected stock returns in a way that is not captured by our proxies for expected returns, or (b) these stock markets overreact to oil price shocks.

The remainder of this article is organized as follows. Section I contains a discussion of the theoretical basis for our tests of the rationality of stock prices. This section also contrasts our study with numerous recent attempts to gauge the efficiency of stock markets. Section II contains an analysis of the post-war experience of the United States, Canada, Japan, and the United Kingdom. Section III contains a brief summary and conclusions.

I. Oil Shocks and the Rationality of the Stock Market

We motivate our tests of whether stock prices react rationally, or overreact, to changes in oil prices using the standard cash-flow/dividend valuation model. Following Campbell (1991), the log real return on a stock in period t, RS_t, can be expressed as (see also Campbell and Shiller (1988))

$$\mathrm{RS}_t \cong \mathrm{E}_{t-1}(\mathrm{RS}_t) + (\mathrm{E}_t - \mathrm{E}_{t-1}) \sum_{j=0}^{\infty} \rho^j \Delta \mathrm{C}_{t+j} - (\mathrm{E}_t - \mathrm{E}_{t-1}) \sum_{j=1}^{\infty} \rho^j \mathrm{RS}_{t+j} \tag{1}$$

where E_t denotes the expectation formed at time t, C_t is the log of the real cash flow in period t, and ρ is a parameter close to but less than one.

Equation (1) simply states that stock returns vary through time due to changes in expected and unexpected returns. The unexpected return in period t has two sources of variation: (a) changes in current *and* expected future cash flows (given by the second term on the right hand side of equation (1)), and (b) changes in expected future returns (the last term in equation (1)).

A. Oil Shocks and Stock Prices

Our test of the rationality of the stock market is based on equation (1) and uses the effects of oil shocks to gauge whether stock prices overreact to new information that has real consequences for the economy. We gauge whether the reaction of stock prices to an oil shock can be fully explained by the effects of the latter on current and future real cash flows and/or current and future changes in expected returns. Specifically, we estimate a regression of the form:

$$\begin{aligned}\mathrm{RS}_t = {} & \mathrm{E}_{t-1}(\mathrm{RS}_t) + (\mathrm{E}_t - \mathrm{E}_{t-1}) \sum_{j=0}^{\infty} \rho^j \Delta \mathrm{C}_{t+j} \\ & - (\mathrm{E}_t - \mathrm{E}_{t-1}) \sum_{j=1}^{\infty} \mathrm{RS}_{t+j} + \sum_{s=0}^{k} \theta_s \mathrm{OIL}_{t-s} + \eta_t\end{aligned} \tag{2}$$

where OIL_t is the percentage change in oil prices in period t, and k is some arbitrarily chosen parameter.

The basic implication of the rationality of the stock market for equation (1) is that the coefficients of the oil price variables, θ_ss, should be jointly indistinguishable from zero. This follows because, given equation (1), oil shocks are relevant for changes in stock prices *only* to the extent that they affect current and future real cash flows and/or expected returns. (Of course, oil shocks are clearly not the sole determinants of cash flows or returns.) Conversely, however, if the stock market overreacts to oil shocks, then the joint insignificance of θ_ss should be rejected.

It is important to note that lagged oil price variables are included in equation (2) because past oil shocks could affect current expected returns ($E_{t-1}(RS_t)$ in equations (1) and (2)). Of course, if expected returns are constant then the first (and third) term of (1) and (2) would disappear and, therefore, any correlation between stock returns, RS_t, and lagged oil price variables would be direct evidence of market inefficiency. Given the growing evidence of time-variation in expected returns (see, for example, Fama and French (1989), Fama (1990), Keim and Stambaugh (1986), and Schwert (1990)), it appears natural to design our tests based on equation (2), which allows for oil shocks to affect expected stock returns.

B. A Comparison to Previous Studies

In recent years there have been numerous studies which argue that stock prices not only reflect changes in current and future cash flows and expected returns, but are also determined by speculative dynamics, that is, fads, investor sentiment, and/or overreaction to news. Many researchers claim that the strong predictability of stock returns over various horizons is evidence of such fads. In an attempt to gauge whether the predictability of stock returns is rational, several recent studies test whether imposing a "factor structure" on returns (using Capital Asset Pricing Model (CAPM) or a more general asset pricing model like the Arbitrage Pricing Theory (APT)) can eliminate or explain their predictability. If factors and/or their associated risks can explain the predictability of stock returns then the market is rational, and vice versa (see, for example, Cutler, Poterba, and Summers (1991), Fama and French (1989), Ferson and Harvey (1991), Ferson and Korajczyk (1995), Morck, Shleifer, and Vishny (1990), and Sentana and Wadhwani (1991)).

For illustrative purposes, consider the basic approach adopted by Ferson and Korajczyk (1995), who estimate a regression similar to:

$$R_{it} = \alpha_{i0} + \sum_{p=1}^{L} \alpha_{ip} Z_{pt-1} + \sum_{j=1}^{k} \beta_{ij} F_{jt} + u_{it} \tag{3}$$

where R_{it} is the *excess* return on a security (portfolio), Z_{pt-1} is the value of the predetermined variable p at time $t - 1$, and F_{jt} is the value of factor j in month t.

If the stock market is rational (irrational) then we should be unable to reject (accept) the joint hypothesis that α_{i0} and α_{ip}s are equal to zero in equation (3) for all assets. The problem with such an approach is that since irrationality is a valuation problem, the use of endogenous financial variables (or functions thereof) to determine the rationality (or irrationality) of stock prices may not lead to convincing inferences. In particular, the predictor variables, Z_{pt-1}, which are typically past stock returns, dividend yields, treasury bill returns, etc., are endogenous valuation variables with no (theoretically) established *causal* real effects on the economy or the stock market. Therefore, the correlation(s) between these variables and stock returns, R_{it}, could be entirely driven by common fads. More importantly, the factors, F_{jt}, on the right-hand side of equation (3), are also usually endogenous valuation variables (such as the market return, the default spread, the term spread, etc.), or functions thereof, and can therefore be subject to the same fads that potentially infect the left-hand side (portfolio) returns in equation (3). Consequently, it may eventually be impossible to distinguish rational from irrational stock-price movements using such an approach.

We attempt to circumvent some of the drawbacks of previous studies. First, note that we consider the impact of oil price changes, which econometrically precede (or Granger-cause) virtually all economic time series. These oil shocks have documented economically significant *real* effects on the economy and are unlikely to suffer from fads because they are dominated by a few sharp movements induced by "exogenous" events such as wars and OPEC embargoes (see Hamilton (1983, 1985), Hess and Lee (1994), and Kaul and Seyhun (1990)).[3] Unlike previous studies, therefore, we study the causal effects of economically important events like oil shocks on the economy and real cash flows, and we gauge the stock market's ability to evaluate the impact of these shocks.

To determine whether the stock market's response is rational (irrational), we adopt a two-step approach that should, at least partially, circumvent the problems associated with earlier studies. In the first step, we abstract from potential changes in expected returns and test whether the effect of oil shocks on stock returns can be completely explained by *real* measures of cash flows in equation (2). The major advantage of using current and future *real* cash flow variables alone is that if their inclusion in equation (2) is sufficient to neutralize the effects of oil shocks on stock returns (i.e., render $\theta_s = 0\ \forall s$), then we can conclude that the stock market is efficient. This conclusion follows because, unlike the "factors" used in most previous studies (see equation (3)), *real* cash flow measures are unlikely to suffer from fads. Conversely, however, if real cash flow measures are unable to "explain" the effects of oil shocks on stock returns, we cannot conclude that the stock market is inefficient. Changes in

[3] Ideally we would like to measure "real supply shocks." However, due to data availability considerations, we use oil price changes to proxy for supply shocks. Given the exogenous causes for most major oil price changes in the postwar period, it may be reasonable to presume that oil prices are not subject to fads (or at least not the fads that potentially infect the stock market).

expected returns could also help explain the effects of oil price changes on stock prices. Therefore, our second step in explaining the effects of oil shocks on stock returns involves conditioning stock returns on these shocks, real cash flows, *and* expected return variables. However, a major problem with accounting for changes in expected returns is that well-accepted proxies for them—the term spread, the default spread, dividend yields, etc.,—are all financial variables that could be subject to the same fads as stock returns. Consequently, as in previous studies that impose a factor structure on asset returns, our second step in explaining the effects of oil shocks on stock prices suffers from problems; any correlation between real stock returns and proxies of expected returns could be spurious and fad-driven. Nevertheless, our two-step procedure of *separately* evaluating the impacts of real cash flow variables and changing expected returns could provide new insights into the rationality of the stock-valuation process.

II. The Evidence

A. Data Description

We study the experiences of four countries—the United States, Canada, Japan, and the United Kingdom—to gauge the effects of oil shocks on different economies. The effects of oil shocks are likely to vary considerably across different countries depending on their production and consumption of oil reserves. For example, ceteris paribus, net exporters (importers) of oil are likely to benefit (suffer) from the several price hikes in the postwar period. An analysis of the experience of different countries is also important to gauge the ability of various stock markets to rationally assess the impact of unpredictable "events." Apart from studying the United States, the experiences of Canada, Japan, and the United Kingdom should provide a wide variety of evidence for countries in different parts of the globe, with presumably different institutional and regulatory environments. The specific choice of innovations in oil prices as the "event" is justified by the findings of Hamilton (1983, 1985), Helliwell, Sturm, Jarrett, and Salou (1986) and Rasche and Tatom (1981), who show that oil shocks have permanent detrimental effects on output in most countries.

The empirical analysis is limited to the postwar period largely because of data availability considerations. The sources of the data and a description of the particular variables used in our empirical analysis are presented in Appendix A. Therefore, here we briefly describe only some of the more important features of the data. Since we are interested in determining the real impact of oil prices on stock markets, we use real stock returns throughout our analysis (although we do check the sensitivity of our results to the use of nominal stock returns). We measure the real rate of return on common stock, RS_t, as the difference between the continuously compounded return on a country's market index (e.g., S&P 500 for the United States) and the inflation rate calculated using the consumer price index. We measure oil prices using the producer price indices for oil, which vary slightly across the countries: the index for the United States is for fuels and related products and power; for Canada and Japan the indices measure prices of petroleum and coal products, while the series for the United Kingdom measures all fuel prices. To measure oil-price shocks, we first calculate the percentage change in oil prices and then prewhiten these series. The prewhitening is conducted to remove any serial correlation induced by the averaging of nonsynchronously measured components of the overall price index (see Working (1960)). This procedure has the advantage of removing any spurious statistical significance of lagged oil price variables in estimates of equation (2).

Our measure of aggregate cash flows is the (seasonally adjusted) index of industrial production (IIP). We calculate the growth rate of output (or equivalently the percentage change in real cash flows) as the first difference of the logarithm of the index, and denote it by IP_t. We use quarterly data on all variables as a compromise between the measurement errors in monthly data and the lack of sufficient annual observations. Finally, Granger (1969)-causality tests for all countries reveal that, with the exception of the United Kingdom, oil prices Granger-precede both stock returns and output. These results confirm Hamilton's (1983, 1985) conclusion that the episodic volatility of oil prices in the postwar period may be regarded (at least statistically) as exogenous events vis à vis the rest of the world economy.[4]

B. Rationality of the Stock Market: The Case of Cash Flows

We evaluate the rationality of the stock market in two distinct steps; first allowing for the effects of oil shocks on real cash flows alone, followed by an analysis that also accounts for potential variations in expected returns induced by changes in oil prices. Before testing for rationality using a regression similar to equation (2), we establish two important empirical facts: (a) stock returns in all countries are correlated with current and future changes in expected cash flows, and (b) oil shocks have a significant impact on each of the four stock markets under consideration. Specifically, we estimate the following two regressions:

$$\mathrm{RS}_t = \alpha_1 + \sum_{s=0}^{4} \beta_{1s}\mathrm{IP}_{t+s} + \eta_{1t}, \tag{4}$$

and

$$\mathrm{RS}_t = \alpha_2 + \sum_{s=0}^{4} \theta_{1s}\mathrm{OIL}_{t-s} + \eta_{2t}. \tag{5}$$

[4] Detailed evidence on the causality tests can be obtained from the authors.

To test for the significance of the relations in equations (4) and (5), we conduct two sets of tests on the slope coefficient of each regression: an F-test of whether the *sum* of the slope coefficients is zero, and an F-test for the hypothesis that *each* of the slope coefficients is zero. The first test, therefore, tests whether the net effect of a variable is statistically significant, while the second one tests for the significance of the effects of individual independent variables. Under the assumption that the independent variables are mutually uncorrelated, the two tests should provide identical inferences unless the signs of the coefficients are not the same. We also report the (adjusted) R^2 of the regressions as a measure of the overall strength of the various relations. Finally, due largely to sample size considerations, we use four leads and/or lags in estimating regressions (4) and (5).

It is important to note that in equation (4), we use actual future realizations of industrial production, rather than expected values as dictated by theory (see equation (2)). In Appendix B we show that the ordinary least squares (OLS) estimator of the coefficient of the actual future growth rate of production will be inconsistent and biased toward zero, and the R^2 of a regression using realized future growth rates will provide a lower bound on the "true" explanatory power of the independent variables. More importantly, measurement errors in the cash flow variables also have implications for our tests of the rationality of the stock market (see discussion below).

The estimates of regression (4) are reported in Table I.[5] The evidence shows that stock returns have a strong positive relation with current and future cash flows in all four countries. Both the null hypotheses for the cash-flow coefficients, that is, $\sum_{s=0}^{4} \beta_{1s} = 0$ and $\beta_{1s} = 0 \; \forall s$, are strongly rejected; both F-statistics have p-values equal to zero in most cases, with the highest p-value being 0.005. The $\bar{R}^2$'s of the regressions range between 10 percent and 18 percent. These results are particularly noteworthy because the use of actual (versus expected) cash flows leads to bias toward zero in the coefficients and an attenuation in the $\bar{R}^2$s of estimates of regression (4).[6]

Table II contains estimates of regression (5) that measure the effects, if any, of oil shocks on stock returns. The only difference in the formats of Tables I and II is that we report more hypothesis tests conducted on the regression coefficients in the latter. We report two sets of F-statistics for tests of both the

[5] All reported F-statistics have not been corrected for heteroskedasticity since White's (1980) specification tests could not reject the null hypotheses of homoskedasticity for virtually all the estimated regressions. We nevertheless also calculate heteroskedasticity-adjusted χ^2 statistics for the significance of the slope coefficients of all regressions ((4) and (5) and (6)). These tests do not significantly alter our inferences.

[6] Previous researchers find that future output explains much larger proportions (up to 60 percent) of return variations of longer (one year) returns compared to shorter (monthly, quarterly) returns (see, for example, Fama (1981, 1990), Kaul (1987), and Schwert (1990)). The same pattern is revealed by the R^2s of equation (4) when estimated over different horizons. This difference probably occurs because information about cash flows is spread over many periods and hence affects stock returns of many previous periods (see Fama (1990)). Consequently, quarterly cash flow variables contain more "noise" (in a relative sense) than do corresponding annual variables.

Table I

Regression Analysis of the Relation Between Real Stock Returns and Real Cash Flows Using Quarterly Data for the United States, Canada, Japan, and the United Kingdom

This table contains estimates of regression (4):

$$\mathrm{RS}_t = \alpha_1 + \sum_{s=0}^{4} \beta_{1s}\mathrm{IP}_{t+s} + \eta_{1t}$$

where RS_t = real stock return in quarter t measured as the difference between the continuously compounded nominal stock return, S_t, calculated from a country's stock market index and the inflation rate, I_t, computed as the logarithmic difference in the consumer price index (CPI); and IP_t = growth rate of industrial production in quarter t calculated as the logarithmic difference in the (seasonally adjusted) index of industrial production. The hypotheses tests, H_1 and H_2, are conducted using standard F-statistics; the p-values of these statistics are reported in parentheses.

Country	α_1	$\sum_{s=0}^{4} \beta_{1s}$	$\bar{R}^2$	H_1: $\sum_{s=0}^{4} \beta_{1s} = 0$	H_2: $\beta_{1s} = 0\ \forall s$
United States	−0.008	1.835	0.174	21.651	8.158
(1947–1991)				(0.000)	(0.000)
Canada	−0.016	1.853	0.174	12.588	5.961
(1960–1991)				(0.001)	(0.000)
Japan:	−0.008	2.618	0.180	14.618	4.476
(1970–1991)				(0.000)	(0.001)
United Kingdom:	−0.013	3.730	0.104	13.925	3.585
(1962–1991)				(0.000)	(0.005)

summed and individual coefficients. The first set of tests for each basic hypothesis (H_1 and H_3) include all current and lagged coefficients. To distinguish the current versus lagged effects of oil shocks on stock returns, we also report F-tests (see H_2 and H_4) which consider *only* the lagged coefficients. The separation of the lagged from the contemporaneous oil effects helps us determine the relative importance of these two effects on stock returns and consequently also provides some idea of the effects of oil shocks on current expected versus unexpected returns (see equations (1) and (2)).

The evidence in Table II shows that oil price hikes in the postwar period have had a significant, and (on average) detrimental effect on the stock market of each country. Unlike the stock return-cash flow relation, and presumably due to varying dependence of the countries on oil, there is a substantial difference in the *extent* of detrimental effects of oil on the different stock markets. For example, the negative impact of oil-price hikes is most dramatic in the case of Japan. The p-values for all F-tests are less than 0.004, and the $\bar{R}^2$ is over 25 percent! In contrast, the relation between oil shocks and stock returns is much weaker for Canada, with only the sum of the θ_{1s}s being significantly different from zero at conventional significance levels and a low $\bar{R}^2$ (about 3 percent).

The results for both the United States and the United Kingdom, although not as extreme as Japan or Canada, show the substantial negative impact of oil

Table II

Regression Analysis of the Effects of Oil Shocks on Real Stock Returns Using Quarterly Data for the United States, Canada, Japan, and the United Kingdom

This table contains estimates of regression (5):

$$RS_t = \alpha_2 + \sum_{s=0}^{4} \theta_{1s} OIL_{t-s} + \eta_{2t}$$

where RS_t = real stock return in quarter t measured as the difference between the continuously compounded nominal stock return, S_t, calculated from a country's stock market index and the inflation rate, I_t, computed as the logarithmic difference in the consumer price index (CPI); and OIL_t = prewhitened percentage change in the oil price in quarter t computed as the logarithmic difference in the producer price indices for fuels and related products and power for the United States, for petroleum and coal products for Canada and Japan, and for fuel for the United Kingdom. All hypotheses tests, H_1 through H_4, are conducted using standard F-statistics; the p-values of these statistics are reported in parentheses.

Country	α_2	$\sum_{s=0}^{4} \theta_{1s}$	$\bar{R}^2$	H_1: $\sum_{s=0}^{4} \theta_{1s}=0$	H_2: $\sum_{s=1}^{4} \theta_{1s}=0$	H_3: $\theta_{1s} = 0\ \forall s$	H_4: $\theta_{1s} = 0\ \forall s > 0$
United States	0.008	−1.009	0.069	12.323	7.732	3.529	2.905
(1947–1991)				(0.001)	(0.006)	(0.005)	(0.023)
Canada	0.002	−0.992	0.028	6.911	6.434	1.672	1.904
(1960–1991)				(0.009)	(0.013)	(0.147)	(0.115)
Japan	0.019	−1.531	0.260	17.475	8.985	6.563	6.352
(1970–1991)				(0.000)	(0.004)	(0.000)	(0.000)
United Kingdom	0.003	−1.107	0.122	5.366	0.327	4.071	0.948
(1962–1991)				(0.023)	(0.569)	(0.002)	(0.439)

shocks on stock returns. Finally, with the exception of the United Kingdom, stock returns of each country are negatively affected by *both* current and lagged oil price variables. In regressions of current stock returns on lagged oil price variables alone, we also find that the latter have a statistically significant effect on the former, again with the sole exception of the United Kingdom. We do not report estimates of these regressions; they provide identical inferences to the ones based on estimates in Table II because changes in oil prices are prewhitened.[7] It is important to emphasize that, to the extent that all macroeconomic variables (including oil prices) contain measurement errors, the "true" effects of oil shocks on stock returns are likely to be even stronger. Specifically, the arguments in Appendix B for the attenuation of the R^2s of regression (4) because of (obvious) measurement errors in real cash flow variables also applies to estimates of regression (5) if oil prices are also measured with error.

[7] Although we do not report the results for brevity, we also find that oil shocks have had a significant negative impact on the current *and* future cash flows of each of the four countries in the postwar period.

The evidence of statistically significant lagged effects of oil prices on stock returns suggests that either (a) oil shocks induce some variation in expected stock returns, or (b) the stock markets are inefficient. One intriguing aspect of the results for all countries, except the United Kingdom, is that the magnitudes of the effects of oil price changes at lags 2 and 3 (and even at lag 4 for Canada) are usually larger than the effect of contemporaneous oil price changes on stock returns.[8] At first glance, this may suggest that the stock markets are inefficient because the current oil price variable should have a larger effect than past oil price variables on current stock returns. From (1) note that in an efficient market past oil shocks can only affect the current expected return component, $\mathrm{E}_{t-1}(R_t)$, of returns, while the contemporaneous oil shock affects all future expected stock returns, $(\mathrm{E}_t - \mathrm{E}_{t-1}) \sum_{j=1}^{\infty} \rho^j \mathrm{RS}_{t+j}$. This line of reasoning, however, may be misleading because the estimated coefficient of the contemporaneous oil price variable in equation (5), $\hat{\theta}_{20}$, reflects not only the effects of the current oil shock on all future expected stock returns but also the (conceivably opposite) effects of the shock on all future changes in real cash flows. In fact, there is some evidence to suggest that past oil prices proxy for expected returns in the United States and Canada (see Section II.*C* and footnote 9 for details).

However, given the nontrivial nature of the effects of current versus lagged oil price changes on stock returns, without a more explicit model for stock returns (both expected and unexpected) we cannot determine whether the estimates of equation (5) in Table II conclusively imply that the stock markets are efficient, or vice versa. Since developing such a model is beyond the scope of this paper, we study the *combined* effects of oil price changes (past and current) on stock returns and test whether this effect can be rendered insignificant by conditioning stock returns on real cash-flow and/or expected return variables.

To directly gauge whether the significant negative effects of oil shocks on real cash flows are *correctly* evaluated by the stock market, we estimate an appropriately parameterized version of model (3), which we rewrite as:

$$\mathrm{RS}_t = \alpha_3 + \sum_{s=0}^{4} \theta_{2s}\mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_{2s}\mathrm{IP}_{t+s} + \eta_{3t}. \tag{6}$$

If the stock market rationally reflects the effects of oil shocks on current and anticipated future cash flows, then the slope coefficients of the oil price variables in equation (6), θ_{2s}s, should be jointly indistinguishable from zero using both the F-tests proposed earlier. Also, comparisons of the estimates of (6) with estimates of equations (4) and (5) result in some interesting inferences. The

[8] The estimated coefficients of the contemporaneous oil price variable, $\hat{\theta}_{20}$, and the four lagged oil price variables, $\hat{\theta}_{21}$ to $\hat{\theta}_{24}$, in (5) are: −0.272, −0.063, −0.343, −0.362, and 0.031 (for the United States); −0.089, −0.223, −0.064, −0.373, and −0.244 (for Canada); −0.555, 0.065, −0.261, −0.838, and 0.057 (for Japan); and −0.124, 0.059, −0.020, −0.117, and −0.092 (for the United Kingdom).

difference between the $\bar{R}^2$s of regressions (6) and (4) provides an economic measure of the extent of overreaction (or irrational response) of stock prices to oil shocks conditional on expected returns being constant. Similarly, a comparison of the $\hat{\theta}_s$ coefficients in equations (5) and (6) reveals the extent to which current and future cash flows neutralize the effects of oil shocks on stock returns.

Measurement errors entailed in the use of actual versus expected real cash flows in equation (6), however, could lead to problems in interpreting the regression estimates. In Appendix B we show that if current *and/or* lagged oil shocks are correlated with "true" expected cash flows, measurement errors in actual cash flows will (a) bias the coefficients of oil price changes away from zero; and (b) spuriously accentuate the difference between the $\bar{R}^2$s of regressions (6) and (4). Consequently, measurement errors in real cash flows used in equation (6) may lead to a rejection of the null hypothesis of market efficiency even when the market is efficient. If, therefore, we find that inclusion of actual future cash flows in equation (6) renders the oil effects insignificant, and there is no difference between the $\bar{R}^2$s of equations (4) and (6), we can conclude that the stock market rationally evaluates the impact of oil shocks. Conversely, if the oil effects remain significant in equation (6) and there is a substantial difference between the $\bar{R}^2$s of regressions (4) and (6), then the market may or may not be efficient depending upon the extent of measurement errors in cash flows and/or the extent to which oil shocks affect expected returns. Therefore, in Section III.*A* we conduct an investigation of the potential effects of measurement errors on our tests.[9]

Estimates of regression (6) are reported in Table III. The evidence for the United States and Canada provides support for the hypothesis that the stock markets of both these countries correctly assess the impact of oil shocks. First, note that all F-tests conducted on the oil price coefficients, the θ_{2s}s in equation (6), cannot reject the hypothesis that these coefficients individually or collectively, whether lagged or contemporaneous, are indistinguishable from zero. The lowest p-value for all the hypotheses tests is 0.123 for the United States and 0.427 for Canada. Second, the estimate of $\sum_{s=0}^{4} \theta_{2s}$ in regression (6) is less than half (one-third) its magnitude in regression (5) for the United States (Canada). On the other hand, the estimated effects of the cash flow variables are only marginally altered by the inclusion of oil price variables, and for both the United States and Canada these effects remain strongly significant (see H_5 and H_6). Finally, the $\bar{R}^2$s of regressions (6) and (4) are virtually identical for the United States—17.7 percent versus 17.4 percent—and for Canada the $\bar{R}^2$ of regression (6) is actually slightly less than the $\bar{R}^2$ of regression (4).

The experiences of Japan and the United Kingdom, however, provide a sharp contrast to the United States and Canadian results. Perhaps the most startling evidence is for Japan over the 1970–1991 period. Both H_1: $\sum_{s=0}^{4} \theta_{2s}=0$ and H_3: $\theta_{2s} = 0\ \forall s$ in equation (6) are rejected at conventional levels of

[9] In Appendix B we show that if oil prices also contain measurement errors, then the effects of errors in real cash flows on our analysis will actually be mitigated.

Table III

Regression Analysis of the Effects of Oil Shocks on Real Stock Returns Conditional on Cash Flows Using Quarterly Data for the United States, Canada, Japan, and the United Kingdom

This table contains estimates of regression (6):

$$\mathrm{RS}_t = \alpha_3 + \sum_{s=0}^{4} \theta_{2s}\mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_{2s}\mathrm{IP}_{t+s} + \eta_{3t}$$

where RS_t = real stock return in quarter t measured as the difference between the continuously compounded nominal stock return, S_t, calculated from a country's stock market index and the inflation rate, I_t, computed as the logarithmic difference in the Consumer Price Index (CPI); IP_t = growth rate of industrial production in quarter t calculated as the logarithmic difference in the (seasonally adjusted) index of industrial production; and OIL_t = prewhitened percent change in the oil price in quarter t computed as the logarithmic difference in the producer price indices for fuels and related products and power for the United States, for petroleum and coal products for Canada and Japan, and for fuel for the United Kingdom. All hypotheses tests, H_1 through H_6, are conducted using standard F-statistics; the p-values of these statistics are reported in parentheses.

Country	α_3	$\sum_{s=0}^{4} \theta_{2s}$	$\sum_{s=0}^{4} \beta_{2s}$	$\bar{R}^2$	H_1: $\sum_{s=0}^{4} \theta_{2s}=0$	H_2: $\sum_{s=1}^{4} \theta_{2s}=0$	H_3: $\theta_{2s} = 0\ \forall s$	H_4: $\theta_{2s} = 0\ \forall s > 0$	H_5: $\sum_{s=0}^{4} \beta_{2s}= 0$	H_6: $\beta_{2s} = 0\ \forall s$
United States	−0.006	−0.465	1.559	0.177	2.401	0.768	1.132	0.711	12.765	5.331
(1947–1991)					(0.123)	(0.327)	(0.338)	(0.586)	(0.001)	(0.000)
Canada	−0.013	−0.317	1.612	0.154	0.635	0.525	0.465	0.556	7.230	4.365
(1960–1991)					(0.427)	(0.470)	(0.801)	(0.695)	(0.008)	(0.001)
Japan	0.002	−1.042	1.719	0.328	6.116	3.345	4.238	4.728	5.453	2.476
(1970–1991)					(0.016)	(0.072)	(0.002)	(0.002)	(0.002)	(0.040)
United Kingdom	−0.009	−0.606	2.892	0.189	1.387	0.081	3.208	1.413	7.028	2.758
(1962–1991)					(0.242)	(0.777)	(0.010)	(0.235)	(0.009)	(0.022)

significance, potentially implying that the stock market does not rationally react to oil shocks. And the hypothesis tests conducted only on lagged values of the oil variable, H_2 and H_4, have p-values of 0.072 and 0.002. Also note that $\sum_{s=0}^{4} \hat{\theta}_{2s}$ in (6) is -1.042, which remains large relative to $\sum_{s=0}^{4} \hat{\theta}_{1s} = -1.531$ in equation (5). Even conditional on future cash flows, therefore, a one percent increase in oil prices leads to a one percent decrease in real stock returns. On the other hand, there is a significant decrease in the effect of future cash flow variables in (6) compared to (4); $\sum_{s=0}^{4} \hat{\beta}_{2s} = 1.719$ in equation (6) compared to $\sum_{s=0}^{4} \hat{\beta}_{1s} = 2.618$ in equation (4), although these effects remain statistically significant (see H_5 and H_6). The obvious inability of real cash-flow measures to explain the effects of oil shocks on the Japanese stock market is best reflected in the substantial increase in the $\bar{R}^2$ of (6) relative to (4); the increase from 18 to 33 percent is over 80 percent!

The estimate of regression (6) for the United Kingdom also shows that the effects of oil shocks on stock returns are not completely accounted for by the real cash flow variables. The sum of the $\hat{\theta}_{2s}$s in equation (6) remains relatively large in absolute magnitude (-0.606 versus -1.107 in regression (5)), although (unlike Japan) there is only a contemporaneous effect of oil shocks on stock returns. Similar to the Japanese experience, however, the increase in the $\bar{R}^2$ of (6) relative to (4) is also over 80 percent. Therefore, the experiences of Japan and the United Kingdom suggest that the volatility in postwar stock prices generated by oil shocks cannot be explained by the impact of these shocks on real cash flows. And this conclusion appears to be robust to measurement errors in oil prices and real cash-flow variables (see Section III.*A*).

C. Rationality of the Stock Markets: Variations in Cash Flows and Expected Returns

The preceding empirical analysis has been conducted without accounting for any changes in expected returns induced by oil price changes. Given the growing evidence of time-varying expected returns (see, for example, Fama and French (1989), Fama (1990), Keim and Stambaugh (1986), and Schwert (1990)), we need to account for the potential effects of oil shocks on expected returns. However, a major problem with accounting for changes in expected returns is that well-accepted proxies for expected returns—the term spread, the default spread, dividend yields, etc.,—are themselves *financial* variables. Therefore, any correlation between real stock returns and proxies of expected returns could be spurious and fad-driven. This problem is unlikely to be of significance for the United States and Canada, because in these countries the inclusion of future cash flow variables is sufficient to eliminate the effects of oil shocks on stock returns, in spite of measurement errors in the cash flow variables. Also, Fama (1990) shows that current and future growth rates of real output subsume most of the information contained in the expected return variables (see also Schwert (1990)). Since real output is unlikely to be subject to fads, any correlation between ex ante expected returns (and shocks to expected returns) and real cash flows is also unlikely to be induced by fads (see also Cochrane (1990)).

The case of Japan and the United Kingdom, however, is more complicated. Our evidence for both countries shows that the response of stock prices to oil shocks cannot be justified by current and future real cash flows. If conditioning on ex ante expected returns and changes in expected returns eliminates the effects of oil shocks, it may not imply that these stock markets are efficient; the correlation between proxies of expected returns and stock returns may be partly or entirely fad-induced. If, however, in spite of the inclusion of these proxies the effects of oil shocks on stock returns remain significant, the evidence would be consistent with market overreaction, although changes in equilibrium expected returns not captured by our proxies and/or measurement errors in real cash flows cannot be completely ruled out as sources of any "excess" volatility generated by oil shocks.

In order to gauge the role of changing expected returns, we estimate the following regression for all four countries:

$$\mathrm{RS}_t = \alpha_4 + \sum_{i=1}^{5} a_i X_{it} + \sum_{s=0}^{4} \theta_s \mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_s \mathrm{IP}_{t+s} + \eta_{4t}, \tag{7}$$

where X_{it} are well-accepted proxies for expected returns and shocks to expected returns (see, for example, Fama (1990) and Schwert (1990)), that is, $X_{1t} = \mathrm{DY}_{t-1}$ = dividend yield measured at time $t - 1$, the average of monthly dividend yields on the country's market index for the past twelve months, $X_{2t} = \mathrm{DEF}_{t-1}$ = default spread measured at time $t - 1$, the difference between the annual yield on a portfolio of corporate bonds (CBY_{t-1}) and the yield on a portfolio of long-term government bonds (GBY_{t-1}), $X_{3t} = \mathrm{TERM}_{t-1}$ = term spread measured at time $t - 1$, the difference between the annual yield on a portfolio of long-term government bonds (GBY_{t-1}) and the yield on a short-term Treasury bill (TBY_{t-1}), $X_{4t} = \mathrm{SDEF}_t$ = shocks to the default spread at time t, the residual from a first order autoregressive model for DEF_t, and $X_{5t} = \mathrm{STERM}_t$ = shock to the term spread at time t, the residual from a first order autoregressive model for TERM_t. The data are obtained from the Citibase database for the United States, and from *Financial Statistics* (an OECD publication) for the other countries (see Appendix A for details).

Before analyzing the estimates of equation (7), we briefly discuss the relations between stock returns and the expected return variables, X_{it}. Estimates of the regressions of RS_t on X_{it} alone (not reported) show strong evidence of time variation in expected returns in all countries. The $\bar{R}^2$s of these regressions range between three and 16 percent. The F-statistics for the joint significance of the a_is have p-values of less than 0.01 for all countries except the United Kingdom. In spite of the strong relation between the X_{it}s and real stock returns, however, the information in these proxies for expected returns is typically subsumed by the real cash flow variables (IPs) for all countries, with the sole exception of Japan. This evidence is similar to the findings of Fama

(1990) and is consistent with the production-based asset pricing model of Cochrane (1990) in which expected returns depend on expected output growth and unexpected returns are dependent on unexpected output growth.

Estimates of regression (7) are reported in Table IV. The format of this table is similar to Table III; the only difference between the estimates reported in the two tables is the inclusion of expected return variables, X_{it}, in the latter regressions. Since we are only interested in the combined importance of the X_{it}s, we do not report the $\hat{a}_i$ coefficients (see equation (7)) but instead report an F-statistic that evaluates their joint significance. Finally, the numbers in parentheses in the $\bar{R}^2$ column are the $\bar{R}^2$s of regressions (not reported) that project stock returns on the expected return, X_{it}, and the real cash flow, IP_t, variables alone. The differences in the two sets of $\bar{R}^2$s provide a measure of the extent of overreaction, once stock returns are conditioned on real cash flow *and* expected return variables.

The results in Table IV show that the effects of oil shocks are eliminated by the inclusion of the real cash flow and expected return variables for the United States and Canada, which is not surprising given that current and future cash flows alone are sufficient to account for the effects of oil shocks in both countries.[10] The results for Japan and the United Kingdom, however, remain puzzling. Conditioning on X_{it}s does eliminate the significance of the combined effect of all oil variables for Japan (see H_2 and H_3); but the hypotheses tests on the individual coefficients of the oil variables, whether contemporaneous or lagged, continue to have low p-values. The p-values for H_4 and H_5 are 0.058 and 0.032. The continued significance of oil shocks is also reflected in the difference in $\bar{R}^2$s of 0.361 versus 0.303; that is, the oil variables add nontrivial explanatory power to regressions of stock returns on *both* cash flow and expected return variables. The Japanese evidence is therefore consistent with the findings of French and Poterba (1991) who are unable to isolate either changes in required returns or growth expectations that are large enough to explain recent Japanese stock price movements. The experience of the United Kingdom is even more perplexing than the case of Japan. Inclusion of the expected return variables has virtually no effect on the significance of the (contemporaneous) oil variable, and the difference in $\bar{R}^2$s of 0.236 versus 0.151 remains large.

Clearly, measurement errors in future cash flow variables could explain the apparent "excess" volatility generated by the postwar oil shocks in the United Kingdom and Japan. However, attempts to account for the effects of measurement errors (see discussion in Section III.*B*) again have virtually no impact on the results reported in Table IV.

[10] However, there is evidence that oil shocks affect expected returns on stocks. For example, the mere inclusion of the expected return variables (that is, without the cash flow variables in (7)), eliminates the individual and combined effects of the *lagged* oil price variables in the United States and Canada.

Table IV

Regression Analysis of the Effects of Oil Shocks on Real Stock Returns Conditional on Cash Flows *and* Expected Returns Using Quarterly Data for the United States, Canada, Japan, and the United Kingdom.

This table contains estimates of regression (7):

$$\mathrm{RS}_t = \alpha_4 + \sum_{\iota=1}^{5} a_\iota \mathrm{X}_{\iota t} + \sum_{s=0}^{4} \theta_s \mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_s \mathrm{IP}_{t+s} + \eta_{4t}$$

where RS_t = real stock return in quarter t measured as the difference between the continuously compounded nominal stock return, S_t, calculated from a country's stock market index and the inflation rate, I_t, computed as the logarithmic difference in the consumer price index (CPI); IP_t = growth rate of industrial production in quarter t calculated as the logarithmic difference in the (seasonally adjusted) index of industrial production; OIL_t = prewhitened percentage change in the oil price in quarter t computed as the logarithmic difference in the producer price indices for fuels and related products and power for the United States, for petroleum and coal products for Canada and Japan, and for fuel for the United Kingdom; and $X_{\iota t}$ = proxies for expected returns and shocks to expected returns, where X_{1t} = dividend yield measured at time $t-1$, DY_{t-1}, is the average of monthly dividend yields on the country's market index for the past twelve months, X_{2t} = default spread measured at time $t-1$, DEF_{t-1}, is the difference between the annual yields on portfolios of corporate bonds, CBY_{t-1}, and long-term government bonds, GBY_{t-1}, X_{3t} = term spread measured at time $t-1$, TERM_{t-1}, is the difference between the annual yields on a portfolio of long-term government bonds, GBY_{t-1}, and on the a short-term Treasury bill, TBY_{t-1}, X_{4t} = shocks to the default spread at time t, SDEF_t, is the residual from a first order autoregressive model for DEF_t, and X_{5t} = shock to the term spread at time t, STERM_t, is the residual from a first order autoregressive model for TERM_t. We report the intercepts and the *sum* of the coefficients of independent variables. For brevity, we do not report the coefficient of the expected return variables, $X_{\iota t}$, but we do report the F-test (see H_1) for their joint significance. All hypotheses tests, H_1 through H_7, are conducted using standard F-statistics; the p-values of these statistics are reported in parentheses. The numbers in parentheses in the $\bar{R}^2$ column are the $\bar{R}^2$s of the regressions of RS_t on the expected return, X_{it}, and the real cash flow, IP_{t+s}, variables alone.

Country	α_4	$\sum_{s=0}^{4} \theta_s$	$\sum_{s=0}^{4} \beta_s$	$\bar{R}^2$	H_1: $a_i = 0\ \forall i$	H_2: $\sum_{s=0}^{4} \theta_s=0$	H_3: $\sum_{s=1}^{4} \theta_s=0$	H_4: $\theta_s = 0\ \forall s$	H_5: $\theta_s = 0\ \forall s > 0$	H_6: $\sum_{s=0}^{4} \beta_s=0$	H_7: $\beta_s = 0\ \forall s$
United States	−0.055	−0.351	1.279	0.189	1.478	0.923	0.367	0.759	0.609	7.866	3.978
(1947–1991)				(0.195)	(0.200)	(0.338)	(0.546)	(0.581)	(0.657)	(0.006)	(0.002)
Canada	−0.061	−0.853	1.359	0.206	2.410	3.174	2.945	0.850	1.005	2.053	2.477
(1960–1991)				(0.211)	(0.041)	(0.078)	(0.089)	(0.518)	(0.408)	(0.155)	(0.037)
Japan	0.033	−0.658	1.917	0.361	1.727	1.659	1.107	2.267	2.815	5.915	2.080
(1970–1991)				(0.303)	(0.141)	(0.202)	(0.297)	(0.058)	(0.032)	(0.018)	(0.079)
United Kingdom	−0.162	−0.755	3.494	0.236	2.240	2.079	0.008	3.245	1.825	8.567	2.548
(1962–1991)				(0.151)	(0.056)	(0.153)	(0.928)	(0.010)	(0.130)	(0.004)	(0.033)

III. Additional Issues

Our results show that the effects of oil shocks on the U.S. and Canadian stock markets can be completely explained by their effects on contemporaneous and future real cash flows. In the case of Japan and the United Kingdom, however, real cash flows and expected return proxies cannot explain the detrimental effects of oil shocks on their respective stock markets. In this section, we address some potential biases that may be present in our empirical analyses.

A. The Impact of Measurement Errors

Measurement errors plague virtually any empirical analysis. However, the use of macroeconomic data, and particularly the use of actual versus expected future real cash flows, makes our inferences particularly vulnerable to such errors.

A.1. Measurement Errors in Inflation

From an economic perspective, it is obvious that the real impact of oil shocks on stock markets should be gauged by regressing real stock returns on proxies for oil shocks. Consequently, in our entire empirical analysis we use real stock returns, RS_t, measured as the difference between nominal stock returns and the inflation rate, that is $\mathrm{RS}_t = S_t - I_t$ (see Appendix A and Section II.*A*). Note that random measurement errors in our measures of inflation (first differences in the logarithm of the consumer price index) should cause no biases in the regression estimates because RS_t is the dependent variable in all our tests. However, since oil price shocks are also measured using nominal price series, some potential biases may be induced in estimates of the regression coefficients of oil price variables in equations (4), (6), and (7).

To determine the potential implications of the use of real stock returns in our analysis, we reestimate all the regressions and conduct all hypotheses tests using nominal stock returns, S_t. For brevity, we do not report the results, which are qualitatively similar to those reported in the paper. For all the countries, use of nominal stock returns attenuates the measured effects of oil shocks on the stock markets, but it also attenuates the statistical relation between stock returns and real cash flows. Consequently, it is not surprising that our main inferences remain qualitatively unchanged. Most importantly, our puzzling inability to explain the strong negative effects of oil shocks on the Japanese and the U.K. stock markets has virtually no relation to the use of real stock returns in the empirical analysis.

A.2. Measurement Errors in Oil Prices

Since oil prices used in this study are producer price indices, the constituent prices of which are sampled, they may contain measurement errors. However, if these measurement errors exhibit classical properties (that is, are random and uncorrelated with the other variables used in the analysis), the measured effects of oil shocks in regression estimates of equation (5) will actually *underestimate* the true effects of these shocks on stock returns (see Appendix B). Hence, the strong negative impact of oil shocks on the Japanese and the U.K. stock markets shown in Table II, which we are unable to explain using real cash flows and expected returns, actually underestimate the true effects of these shocks on the two stock markets.

We explicitly attempt to deal with one particular effect of measurement errors on the oil price indices. Working (1960) shows that the average of nonsynchronously sampled components of an index can lead to serial correlation in the first differences of the index. Consequently, our entire analysis is based on prewhitened first differences of the (logarithm) of oil price indices, where the prewhitening is accomplished by fitting parsimonious time-series models to the first differences and using the residuals from these empirical models as the proxies for oil shocks.

A.3. Measurement Error in Cash Flows

In Appendix B we show that measurement errors in future cash flow variables will bias the coefficient(s) of real cash flows in regression (4) toward zero. More importantly, however, these errors will affect our main inferences about the rationality of stock markets that are based on regression (6). Specifically, we show that coefficients of oil, $\hat{\theta}_{2s}$, in estimates of (6) will be biased away from zero, and the difference between the $\bar{R}^2$s of regressions (6) and (4) will be magnified, even under the null hypothesis that $\theta_{2s} = 0 \ \forall s$. The same effects will be observed for the estimated coefficients of oil shocks and the $\bar{R}^2$s of regression (7). Therefore, measurement errors could be the cause of our inability to explain the effects of oil shocks on the stock markets of Japan and the United Kingdom. However, in Appendix B we also show that if *both* real cash flows and oil prices contain measurement errors, then the effects of measurement errors in real cash flows on our analysis will be mitigated. Nevertheless, since our real cash flow measures surely contain measurement errors (because we use actual versus expected variables), we concentrate on the biases caused by them.

To evaluate the potential impact of measurement errors in real cash flows on estimates of equations (6) and (7), we first use the innovative approach of Kothari and Shanken (1992) to purge these regressions of the effects of measurement errors. Specifically, we estimate the following augmented versions of (6) and (7):

$$\mathrm{RS}_t = \alpha_3 + \sum_{s=0}^{4} \theta_{2s}\mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_{2s}\mathrm{IP}_{t+s} + \sum_{s=1}^{4} \gamma_{2s}\mathrm{RS}_{t+s} + \eta_{3t}, \tag{6a}$$

and

$$\mathrm{RS}_t = \alpha_4 + \sum_{i=1}^{5} a_i X_{it} + \sum_{s=0}^{4} \theta_s\mathrm{OIL}_{t-s} + \sum_{s=0}^{4} \beta_s\mathrm{IP}_{t+s} + \sum_{s=0}^{4} \gamma_s\mathrm{RS}_{t+s} + \eta_{4t}. \tag{7a}$$

Note that future realized stock returns are included as additional regressors in (6a) and (7a) because they are proxies for the measurement errors in the future realized cash flow variables used in (6) and (7). In an efficient market, information about future real cash flows is revealed after time t, and should therefore be reflected in stock prices after the time interval $\{t-1, t\}$ (see also equation (4)). Thus returns over the future four quarters are chosen as proxies for the measurement errors in the realized future cash flow variables used in equations (6) and (7). In each case, a single augmented regression of the form (6a) or (7a) is used because a two-stage procedure of regressing real cash flows (IPs) on real stock returns (to purge the measurement errors) and then using the estimated residuals in equations (6) or (7) would lead to biased estimates of the coefficients of real cash flows and potentially misleading standard errors (see Kothari and Shanken (1992)).

For brevity, we do not report the detailed estimates of regressions (6a) and (7a). Our results for the United States and Canada show that estimates of θ_{2s} in (6a) and θ_s in (7a), individually and jointly, are again indistinguishable from zero. This is not surprising, because even without any corrections for measurement errors, the effects of oil shocks are insignificant in estimates of equations (6) and (7). The surprising and important evidence, however, is that the inferences for the United Kingdom and Japan based on equations (6a) and (7a) also remain largely unaltered. For both countries, the $\hat{\theta}_{2s}$s and $\hat{\theta}_s$s remain, either individually and/or jointly, significantly different from zero. Also, the differences in the $\bar{R}^2$s of regressions (6a) and (4) are quite similar to the differences in $\bar{R}^2$s of regressions (6) and (4) in Table III, as are the differences in the $\bar{R}^2$s in the $\bar{R}^2$ column of Table IV constructed based on estimates of (7a).

To confirm the robustness of our results based on equation (6a), we also calculate the *extent* of measurement error(s) in realized cash flows (i.e., IPs) needed to explain the apparent "excess" volatility in the Japanese and the U.K. stock markets (see appendix for details). Based on annual estimates of equations (4) and (6), we show that the extent of noise to variation in "true" expected real cash flows would have to be to the order of 1.38 and 1.22 for Japan and the United Kingdom. Therefore, between 55 and 60 percent of the variation in realized real cash flows would have to be "unexpected." These estimates appear to be quite high, especially given the estimates of regression (6a) and (7a) and the fact that annual stock returns *alone* can predict large proportions of the variation in future annual real cash flow variables (see, for example, Fama (1990)). Finally, note that measurement errors in real cash flow variables may not play an important role in our analysis because current and lagged oil price variables already have a significant impact on current stock returns without the inclusion of these variables (see estimates of equation (5) in Table II).

Our results therefore suggest that measurement errors alone cannot explain the apparent "excess" volatility in stock returns in the United Kingdom and Japan, at least in tests that condition stock returns on oil shocks and real cash flow variables alone.

B. Sensitivity to Subperiod Analysis

Due to data availability considerations, the sample periods for the four different countries analyzed in this study cover substantially different time periods. The U.S. sample covers the entire postwar period, while Japan covers only the post-1970 period and the Canadian and the U.K. samples include the post-1960 period.

To uncover the sensitivity of our inferences to the use of different periods, we estimate all regressions for all countries for the same 1970–1991 period. We estimate all regressions separately for each country, and we also estimate all of them jointly using a Seemingly Unrelated Regression model (see Zellner (1962)). The results are qualitatively similar to those reported in the paper. We do not further subdivide our sample because this would lead to statistically unreliable evidence since the 1970–1991 quarterly data already contain less than 100 observations.

IV. Conclusion

In this article, we show that changes in oil prices that Granger-precede most economic series have a detrimental effect on output and real stock returns in the United States, Canada, Japan, and the United Kingdom during the postwar period. More importantly, the Granger-precedence of oil prices and the use of *real* cash flow variables provides a natural opportunity to test whether the world's stock markets are rational or they overreact to new information. The evidence suggests that the U.S. and Canadian stock markets are rational: the reaction of stock prices to oil shocks can be completely accounted for by their impact on current and expected future real cash flows alone. In contrast, however, the evidence for Japan and the United Kingdom is puzzling. In both countries, we are unable to explain the effects of oil price shocks on stock returns using changes in future cash flows and/or financial variables that are often used to proxy for changes in expected returns. These results appear to be robust to measurement errors in oil prices, inflation, and real cash flow variables used in this study. We also find it difficult to envision a rational model in which oil shocks change expected returns in a way that is unrelated to future cash flows, as well as default spreads, term premia, and other expected return variables used in our study. Consequently, we conclude that the postwar oil shocks appear to have generated volatility in the Japanese and U.K. stock markets that is in "excess" of what can be explained by existing rational models.

Appendix A

Data Sources and Description

This appendix contains a detailed description of the various sources of data used in this study. We also describe the specific transformations conducted on the raw data to obtain the variables used in the empirical analysis.

Appendix A

Variables	Raw Data Series	Transformations Used	Sources of Raw Data: United States	Canada	Japan	United Kingdom
1) Real Cash Flows (IP)	Index of Industrial Production	First differences in the logarithms of the index	Citibase (1978) database; Series: IP (base = 1987; SA)	Citibase (1978) database; Series: IPCAN (base = 1987; SA)	Citibase (1978) database; Series: IPJP (base = 1987; SA)	Citibase (1978) database; Series: IPUK (base = 1987; SA)
2) Inflation (I)	Consumer Price Index	First Differences in the logarithms of the index	Citibase (1978) database; Series: PZUNEW (base = 1982–84; NSA)	Main Economic Indicators; Series: Consumer Prices (All items) (various bases; NSA)	Main Economic Indicators; Series: Consumer Prices (All items) (various bases; NSA)	Main Economic Indicators; Series: Consumer Prices (All items) (various bases; NSA)
3) Oil Shocks (OIL)	Producer Price Index of Oil and Related Products	Prewhitened first differences in the logarithms of the index	Citibase (1978) database; Series: PWFUEL (base = 1982; NSA)	Main Economic Indicators; Series: Producer Prices of Petroleum and Coal Products (various bases; NSA)	Main Economic Indicators; Series: Producer Prices of Petroleum and Coal Products (various bases; NSA)	Main Economic Indicators; Series: Producer Prices of Fuel (various bases; NSA)
4) Stock Returns (S)	Aggregate Stock Market Indexes	First differences in the logarithms of the index	Citibase (1978) database; Series: FPS6US (S&P500) (base = 1967; NSA)	Citibase (1978) database; Series: FPS6CA (base = 1967; NSA)	Citibase (1978) database; Series: FPS6JP (base = 1967; NSA)	Citibase (1978) database; Series FPS6UK (base = 1967; NSA)
5) Real Stock Returns (RS)	[see (2) and (4)]	RS = S − I	[see (2) and (4)]	[see (2) and (4)]	[see (2) and (4)]	[see (2) and (4)]

Appendix A—*Continued*

Variables	Raw Data Series	Transformations Used	Sources of Raw Data: United States	Canada	Japan	United Kingdom
6) Dividend Yield (DY)	Dividend Yields on the Stock Indices	12-month moving averages	Citibank (1978) database; Series: FSDXP (S&P500 Dividend Yield; NSA)	Financial Statistics; Series: Industrial Dividend Yield (NSA)	Financial Statistics; Series: Industrial Share Yield (NSA)	Financial Statistics; Series: Industrial Ordinary Share Yield (NSA)
7) Corporate Bond Yield (CBY)	Yields on Long-Term Corporate Bonds	Annualized Yields	Citibase (1978) database; Series: FYAI (Moody's: Corporate Industrial A bonds; NSA)	Financial Statistics; Series: Industrial Bond Yield (NSA)	Financial Statistics; Series: Industrial Bond Yield (NSA)	Financial Statistics; Series: Corporate Bond Yields (20-year) (NSA)
8) Government Bond Yields (GBY)	Yields on Long-Term Government Bonds	Annualized Yields	Citibase (1978) database; Series: FYGT10 (U.S. Treasury 10-year constant maturity; NSA)	Financial Statistics, Series: Federal Government, 10-year and over bonds (NSA)	Financial Statistics; Series: Central Government Bonds (NSA)	Financial Statistics; 20-year government bonds (NSA)
9) Short-Term Treasury Yields (TBY)	Yields on Short-Term Treasury Securities	Annualized Yields	Citibase (1978) database; Series: FYGM3 (U.S. Treasury 3-month bills; NSA)	Financial Statistics; Series: 3-month Treasury bills (NSA)	Financial Statistics; Series: 2-month Treasury bills (NSA)	Financial Statistics; Series: Treasury bills (NSA)
10) Default Spread (DEF)	Ex ante ($t-1$) data [see (7) and (8)]	$DEF_{t-1} = CBY_{t-1} - GBY_{t-1}$	[see (7) and (8)]	[see (7) and (8)]	[see (7) and (8)]	[see (7) and (8)]

Appendix A—*Continued*

Variables	Raw Data Series	Transformations Used	Sources of Raw Data: United States	Canada	Japan	United Kingdom
11) Term Spread (TERM)	Ex ante ($t-1$) data [see (8) and (9)]	$\text{TERM}_{t-1} = \text{GBY}_{t-1} - \text{TBY}_{t-1}$	[see (8) and (9)]	[see (8) and (9)]	[see (8) and (9)]	[see (8) and (9)]
12) Shock to Default Spread (SDEF)	Unexpected Component of Default Spread between time $t-1$ and t [see (10)]	Residual from first-order autoregressive model fit to DEF_t [see (10)]	[see (10)]	[see (10)]	[see (10)]	[see (10)]
13) Shock to Term Spread (STERM)	Unexpected component of term spread between time $t-1$ and t [see (11)]	Residual from first-order autoregressive model fit to TERM_t [see (11)]	[see (11)]	[see (11)]	[see (11)]	[see (11)]

Appendix B

Econometric Consequences of Errors in Variables

In this appendix we discuss the econometric consequences of using *actual*, in lieu of *expected*, changes in future cash flows in our regressions. For convenience, assume that all variables have zero means, and let y = current real stock returns, x = expected change in future cash flows, and z = current change in oil prices, where $x = \gamma z + \eta$ (i.e., expected change in future cash flows is *partly* determined by the current change in oil prices). Though oil price changes are assumed to be measured without error, expected future cash flows (x) are unobservable and are proxied by actual changes, $X = x + u$, where u = unexpected component of future cash flows given all current information. The use of actual versus future cash flows in our regressions not only biases the OLS coefficient estimator of expected cash flows, but it also biases the coefficient estimator of oil price changes in the multiple regression (6) and the *difference* in the R^2s of regressions (4) and (6), which is our measure of the extent of excess volatility generated by oil shocks.

To simplify our econometric analysis, we do not use multiple leads and lags of variables as in (4)–(6). Instead we assume that x measures all future expected cash flows, and z contains all information about oil price changes relevant to current changes in stock prices. Specifically, let us suppose that the "true" relation between stock returns and expected changes in cash flows is given by

$$y = \beta x + \varepsilon \tag{B1}$$

Since x is unobservable, in (B1) we replace x by $X = x + u$, i.e.,

$$y = \hat{\beta} X + e = \hat{\beta}(x + u) + e. \tag{B2}$$

Under the assumption that expected stock returns are constant through time, $\mathrm{Cov}(e, u) = 0$ and the OLS $\hat{\beta}$ suffers from the well-known errors in variables bias toward zero (see Greene (1993)):

$$\mathrm{plim}(\hat{\beta}) = \frac{\beta}{1 + \sigma_u^2/\sigma_x^2}.$$

It can also be shown that the R^2 of regression (B2) will be downward biased. As in the case of the bias in $\hat{\beta}$, the downward bias in the R^2 depends on the ratio σ_u^2/σ_x^2. Also, it is important to note that this "errors in variables" analysis applies to *any* simple regression in which the regressor is measured with error. Specifically, if oil prices are measured with error, then in equation (5) the estimated effects of oil shocks on stock returns will be attenuated, and the R^2 of this univariate regression will also be downward biased.

Now consider the simplified version of the regression of real stock returns on actual future changes in cash flows and current changes in oil prices, under the assumption that oil prices are measured without errors (see equation (6)):

$$y = \hat{\theta}_0 z + \hat{\theta}_1(x + u) + h. \tag{B3}$$

It can be shown for this special case that, given $x = \gamma z + \eta$,

$$\mathrm{plim}(\hat{\theta}_0) = \frac{\beta\gamma\sigma_u^2/\sigma_\eta^2}{1 + \sigma_u^2/\sigma_\eta^2} \tag{B4}$$

and

$$\mathrm{plim}(\hat{\theta}_1) = \frac{\beta}{1 + \sigma_u^2/\sigma_\eta^2}. \tag{B5}$$

From equation (B5) it is clear that the OLS estimator of the coefficient of changes in future cash flows in the multiple regression (B3) is also biased toward zero as in the simple regression (B2). However, the bias in $\hat{\theta}_1$ will be larger than the bias in $\hat{\beta}_1$ unless $\gamma = 0$ (i.e., unless x and z are orthogonal). More importantly, however, (B4) implies that even under the null hypothesis of $\theta_0 = 0$, the OLS estimator $\hat{\theta}_0$ will be biased away from zero. (Note that if the stock market is efficient the true coefficient of oil price changes in (B3) or (6) will be zero.) Again, the strength of the bias will depend on the relation between the true expected changes in future cash flows, x, and current changes in oil prices, z. In our case, $\gamma < 0$, therefore $\hat{\theta}_0$ will be negative, and its absolute value will be larger the more the noise in measured X (i.e., the larger is σ_u^2) and/or the stronger the relation between x and γ (i.e., the smaller is σ_η^2). Note that this analysis applies to current *and* lagged oil price variables as long as the oil variable is correlated with the future output variable(s).

Also, the difference in R^2s between regressions (B2) and (B3) will be positive. Using $\mathrm{plim}(\hat{\beta})$, and rearranging (B1) and (B2), we can write the variances of the disturbances of regressions (B2) and (B3) as:

$$\mathrm{Var(e)} = \mathrm{Var}(\varepsilon) + \beta^2\left[\frac{\sigma_u^2\sigma_x^2}{\sigma_u^2 + \sigma_x^2}\right] \tag{B6}$$

and

$$\mathrm{Var(h)} = \mathrm{Var}(\varepsilon) + \beta^2\left[\frac{\sigma_u^2\sigma_\eta^2}{\sigma_u^2 + \sigma_\eta^2}\right]. \tag{B7}$$

Since $\sigma_x^2 \geq \sigma_\eta^2$, $\mathrm{Var(e)} \geq \mathrm{Var(h)}$, and thus adding the additional variable z does increase the R^2 of regression (B3) relative to regression (B2). Note that this occurs even under the null hypothesis that oil price changes do not affect stock returns once the latter are conditioned on expected changes in future cash flows x. Hence, since x is measured with error, we will tend to falsely reject the null hypothesis of an efficient stock market because $\mathrm{plim}(\hat{\theta}_0) \neq 0$ and the R^2 of regression (B3) is greater than the R^2 of regression (B2). A similar econometric analysis applies to regression (7) under the assumption that both oil prices and expected return proxies are measured without error.

However, if oil price shocks are also measured with error, the biases noted above will be *attenuated.* Specifically, suppose that oil price changes are measured with error v, so that we observe $Z = z + v$. Then the estimated regression of stock returns on oil shocks and real cash flows becomes

$$y = \breve{\theta}_0(z + v) + \breve{\theta}_1(x + u) + h. \tag{B8}$$

where the measurement error v has variance σ_v^2 and is independent of all other variables. The measurement error v is simply an additional source of noise in regression (B3), in which only cash flows are measured with error. A consequence of this additional "noise" is that the coefficient of the mismeasured variable is driven toward zero in the usual way. That is,

$$\text{plim}(\breve{\theta}_0) = \frac{1}{k}\,\text{plim}(\hat{\theta}_0), \qquad k = 1 + \frac{\sigma_v^2(\sigma_x^2 + \sigma_u^2)}{\sigma_z^2(\sigma_\eta^2 + \sigma_u^2)}. \tag{B9}$$

More importantly, the bias in the estimator of θ_1 in equation (B5) is similarly mitigated:

$$\text{plim}(\breve{\theta}_1) = \text{plim}(\hat{\theta}_1) + \text{plim}(\hat{\theta}_0)\frac{\gamma\sigma_v^2}{k(\sigma_\eta^2 + \sigma_u^2)}. \tag{B10}$$

Thus, additional measurement error in oil shocks partially *reverses* the effects of errors in measuring expected cash flows. To the extent that oil prices are measured with error, measurement errors become a less likely source for the significance of oil shocks in regression (6).

Potential Importance of Measurement Errors for Japan and the United Kingdom

Note that the difference in the R^2s of (B2) and (B3) is a function of unknown parameters β, σ_x^2, σ_u^2, and σ_η^2. This difference will be zero under the null hypothesis of no overreaction if (a) there is no measurement error in X, i.e., $\sigma_u^2 = 0$, and/or (b) if x and z are orthogonal, i.e., $\sigma_x^2 = \sigma_\eta^2$. Our evidence clearly suggests that neither of these two conditions is met, and therefore the extent of the upward bias in the difference in R^2s remains an empirical issue. Although we do not know each of the unknown parameters β, σ_x^2, σ_u^2, and σ_η^2, we can use the OLS point estimates of $\hat{\beta}$, $\hat{\sigma}_y^2$, $\hat{\sigma}_X^2$ (i.e., $\hat{\sigma}_x^2 + \hat{\sigma}_u^2$), and $\hat{\sigma}_z^2$ to calculate the degree of measurement error in expected versus actual cash flow changes (i.e., $\hat{\sigma}_u^2$) that could "explain" the *observed* differences in R^2s of regressions (4) and (6).

In order to be consistent with the above econometric analysis, and given that we use four quarters of lead and/or lag variables in equations (4) and (6), we use annual estimates of (B2) and (B3) to calculate the $\hat{\sigma}_u^2$s that would be required to explain the large differences in R^2s observed for Japan and the

United Kingdom. We find that the extent of noise in actual cash flows relative to the "true" value of expected cash flows, that is, σ_u^2/σ_x^2, has to be very large to explain the differences in observed R^2s for both Japan and the United Kingdom. Specifically, $\hat{\sigma}_u^2/\hat{\sigma}_x^2$ for Japan and the United Kingdom are 1.38 and 1.22, respectively, implying that the variance of the noise in actual future cash flows is substantially greater than the variance of expected cash flows. These estimates suggest that the extent of excess volatility generated by oil shocks in Japan and the United Kingdom is unlikely to be spuriously driven by statistical biases induced by measurement errors (see Section III.*B*).

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