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Commodities and the Market Price of Risk

Shaun K. Roache

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Commodities and the Market Price of Risk

Prepared by Shaun K. Roache[1]

Authorized for distribution by Miguel A. Savastano

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Abstract

Commodities are back following a stellar run of price performance, attracting financial investor attention. What are the fundamental reasons to hold commodities? One reason is the exposure offered to underlying risk factors. In this paper, I assess the macro risk exposure offered by commodity futures and test whether these risks are priced, using Merton's (1973) intertemporal capital asset pricing model for a sample of commodity prices covering the period January 1973 – February 2008. I find that commodity futures offer a hedge against lower interest rates and that investors are willing to accept lower expected returns for this position. Although some commodities are also a hedge against U.S. dollar depreciation, this risk is not priced.

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Author's E-Mail Address: sroache@imf.org

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I. INTRODUCTION

Commodities have remerged as an attractive asset class in recent years following a stellar run of price performance (Figure 1). Although controversy surrounds the precise causes of this rally, there is mounting evidence that financial investors—from short-term speculators to long-term institutions—have raised their exposure.[2]

Rising prices attract investor attention, but what are the fundamental reasons for investors to hold commodities? One reason is that financial assets provide investors with exposure to underlying risk factors. For example, an investor buying an individual stock in the industrials sector is effectively buying exposure to risk factors such as the overall stock market, the performance of the industry, and the company that pays the dividend.

For a financial investor, commodity futures contracts are similar to other financial assets. Commodity futures fulfill many roles, including to allow producers and consumers to hedge their long and short exposures, but they may also provide exposure to factors such as inflation, real interest rates, and exchange rates. This exposure may be very different from other widely-held asset classes, such as equities, allowing investors to diversify their portfolios through commodities. Much of the commodity-specific risk may be diversified away and investors should expect to be rewarded only for holding the macro, or systematic, risk exposure offer by each commodity.

In this paper, I assess the macro risk exposure offered by commodity futures and test whether these risks are priced, using Merton's (1973) intertemporal capital asset pricing model (ICAPM) as a theoretical framework. This model predicts that investors seek protection against states of the world in which their wealth declines. Investors should accept lower expected returns from assets that perform well during the "bad times", in much the same way as consumers are willing to pay insurance policy premiums (and vice versa). Investors assess whether they are in a poor state, or more likely to enter one, by observing variables known as factors.

The paper proceeds as follows: section II outlines the ICAPM; section III provides a brief review of the risk-pricing literature relevant to commodities; section IV describes the data used; section V discusses estimation options; section VI presents the results; and section VII provides concluding remarks.

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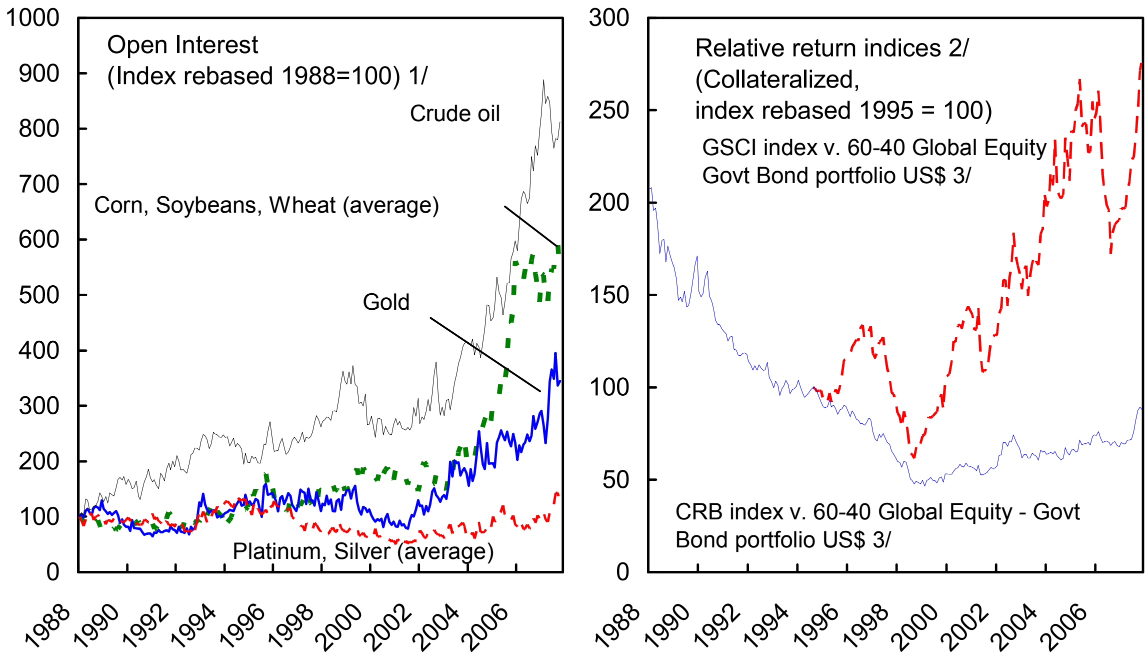
[2] For example, a recent survey indicates that the proportion of UK pension funds with direct commodity exposure has doubled since 2006 (Pensions and Investments (2008)). There is also evidence that long-term institutions, including pension funds in Europe and the United States, are also raising exposure to commodities (Pensions and Investments (2007)). Recent research also indicates that more than a third of investors in commodities have been active in these markets for less than three years (Greenwich Associates (2008)).

Figure 1. Commodity Futures Contracts: Open Interest and Relative Returns (1988–2008)



Source: Thomson Datastream, author's estimates.

[1] A rebased index of the total number of futures contracts or option contracts that have not yet been exercised, expired, or fulfilled by delivery.

[2] The illustrative 60-40 portfolio provides a comparison against an asset allocation that has been favored by long-term investors such as pension funds.

[3] The S&P GSCI commodity index is a production weighted composite of 24 products. The Reuters/ CRB index is an equally-weighted index of 17 products.

II. Merton's ICAPM Risk-Pricing Model

A. Deriving the Risk-Pricing Equation

A simple version of Merton's (1973) intertemporal capital asset pricing model (ICAPM), based on an exposition provided by Campbell and Viciera (2002), is presented below. To keep things simple, I consider only one risky asset—which could be a commodity future, a stock, or a bond. Assume the instantaneous return on this single risky asset is dY/Y, where the possibility of dividends has been ignored. The return on an instantaneously riskless asset is given by dB/B. There is also a single state variable S that follows a stochastic process and which partly drives the dynamics of the investment opportunity set. It is further assumed that the returns and the state variable follow stationary Itô processes:

$$dY_t / Y_t = \mu(S,t)\,dt + \sigma(S,t)\,dZ_{Yt} \tag{1}$$

$$dB_t / B_t = B_t r(S,t)\,dt \tag{2}$$

$$dS_t = \mu_S(S,t)\,dt + \sigma_S(S,t)\,dZ_{St} \tag{3}$$

The term μ is the drift for the risky asset, σ is the standard deviation, and dZ is a Weiner process. The correlation between the returns on the risky asset and the change in the state variable is given by:

$$dZ_{Yt}dZ_{St} = \rho_{YS}(S,t)\,dt \tag{4}$$

To simplify the exposition, dependence of the drift μ, volatility σ, riskless return r, and correlation ρ on time t and the state variable S is ruled out. With time-separable preferences and initial wealth $W_0 > 0$, the optimal portfolio and consumption problem for the investor is to maximize the expected present value of utility by adjusting consumption C and the share of wealth held in the risky asset α.

$$\max_{C,\alpha} E_0\left[\int_0^\infty U(C,t)\,dt\right] \tag{5}$$

This maximization is subject to the usual intertemporal budget constraint, which states that the change in wealth dW is determined by the expected portfolio return $\alpha\,(\mu - r) + r$, less consumption, plus any unexpected risky asset return.

$$dW_t = \left[\left(\alpha_t(\mu_Y - r) + r\right)W_t - C_t\right]dt + \alpha_t W_t \sigma_Y dZ_{Yt} \tag{6}$$

Other constraints include conditions on wealth and consumption, $W > 0$ and $C > 0$.

Let $J(W, S, t)$ denote the maximized indirect utility function, or value function. The Bellman principle then implies that, at the optimum, the expected rate of increase of this function must be zero.

$$0 = \max_{C,\alpha}\left\{U(C,t) + \frac{1}{dt}E_t\left[dJ(W,S,t)\right]\right\} \tag{7}$$

Expanding the term for the total differential of the value function J then requires an application of Itô's lemma.

$$dJ(W,S,t) = J_W dW + J_S dS + J_t dt \;+ \tfrac{1}{2}J_{WW}(dW)^2 + J_{WS}dWdS + \tfrac{1}{2}J_{SS}(dS)^2 \tag{8}$$

Substituting this expression, together with the expected values of the stochastic differential equations (1), (2), and (3) into (7) yields:

$$0 = \max_{C,\alpha}\{U(C,t) + J_W[(\alpha(\mu_Y - r) + r)W - C] + J_S\mu_S \\ + J_t + \tfrac{1}{2}J_{WW}\alpha^2W^2\sigma_Y^2 + J_{WS}\alpha W\sigma_Y\sigma_S\rho_{YS} + \tfrac{1}{2}J_{SS}\sigma_S^2 \tag{9}$$

For a convergent value function, it is also necessary to impose a transversality condition:

$$\lim_{t\to\infty} E_0[J(W,S,t)] = 0 \tag{10}$$

The first order conditions with respect to the decision variables, C and α, then provide a pair of expressions for consumption and portfolio choice as a function of wealth W:

$$U_C = J_W \tag{11}$$

$$\alpha^* = \frac{1}{-J_{WW}W/J_W}\left(\frac{\mu_Y - r}{\sigma_Y^2}\right) - \frac{J_{WS}}{J_{WW}W}\left(\frac{\sigma_S}{\sigma_Y}\rho_{YS}\right) \tag{12}$$

The equilibrium risk premium on the risky asset is then recovered from rearranging the first-order condition (11):

$$(\mu_Y - r) = \left(-\frac{J_{WW}W}{J_W}\right)\alpha^*\sigma_Y^2 - \frac{J_{WS}}{J_W}(\sigma_S\sigma_Y\rho_{YS}) \tag{13}$$

This can be written as:

$$(\mu_Y - r) = \gamma_0 \operatorname{cov}(r_Y, r_P) + \gamma_1 \operatorname{cov}(r_Y, dS) \tag{14}$$

Where $\gamma_0 = - J_{WW} / J_W W$ is the Arrow-Pratt coefficient of relative risk aversion, $r_Y = dY/Y$ is the return on the risky asset, and r_P is the return on the portfolio (for which all of the variance is determined by the portfolio share α and variance σ_Y of the risky asset).

The equilibrium return, according to equation (14), is function of two components. First, the product of the investor's relative risk aversion γ_0 (or the "price of risk") and the covariance of the risky asset with changes in wealth, proxied by the aggregate portfolio return (or the "quantity of risk"). This is the traditional CAPM result of Sharpe (1964). Second, the product of a term that describes the impact on the marginal utility of wealth from a change in the state variable γ_1 (or the "price of state variable risk") and the covariance of risky asset returns with changes in the state variable (or the "quantity of state variable risk").

B. Identifying State Variables

Up to this point, the model is firmly grounded in theory, but the choice of state variables introduces a more subjective element. The ICAPM indicates that state variables, when they change, affect the marginal utility of wealth. Previous literature has tended to express this in terms of variables that could affect the investment opportunity set, or provide some indication as to the level of future returns. In either case, the researcher obtains little guidance as to what to include as a state variable.

An alternative way to approach the risk-pricing question is the Arbitrage Pricing Theory (or APT) of Ross (1976). This more general model suggests that any factor additional to the market portfolio may be legitimately included if it is priced. Since Fama and French (1992) revealed that firm-size is priced by the equity market, there has been a proliferation of papers that have included an increasingly diverse range of factors, including exposure to commodity prices. For this paper, I have chosen to follow Ferson and Harvey (1991) in the choice of macro state variables—or additional factors in an APT context. (See section IV).

III. Brief Review of the Literature

Despite a voluminous empirical risk pricing literature, little attention has been paid to so-called “alternative” asset classes, which includes commodities. The focus has mainly been on equities and assessing whether the CAPM, in its various forms, is a valid model. This brief review of relevant studies focuses instead on direct applications of risk-pricing models to commodities.

One definition of the commodity future risk premium is the difference between the current futures price and the expected spot price at the time of delivery. Two alternative theories have been developed to explain this form of risk premium. First, according to Keynes (1930), we should anticipate a positive risk premium if investors are providing insurance to producers hedging their physical long positions. For some commodities, this risk premium may be negative if consumers hedging their underlying short positions is more prevalent. Second, there is the theory of storage costs, convenience yield, and the opportunity costs of foregone interest income—see Kaldor (1939), Working (1949), and Brennan (1958). For example, if the commodity is expected to be relatively scarce today compared to the future, the spot price and convenience yield will be high, and the risk premium low.

Fama and French (1987) find evidence in support of both models, with basis variation in response to storage costs and interest rates; risk premia also varied through time for some agricultural commodities with a range of between 1–2 percent. Kaminsky and Kumar (1990) also find some commodities offering positive risk premia, influenced by macro U.S. variables. Longstaff and Wang (2004) study day-ahead electricity contracts and establish a link between positive risk premia and measures of economic risk faced by market participants. Gorton and Rouwenhorst (2006) use a 45-year sample to show that the collateralized commodity futures risk premium has been equal in size to that of stocks. Kolos and Ronn (2008) find that futures prices are biased predictors of spot energy prices, indicating a non-zero risk price with the sign likely dependent upon the relative balance of hedging investors that are either long or short.

Far fewer studies have tested the more general ICAPM framework of risk pricing with commodities. Jagannathan (1985) tested the consumption-based ICAPM and the value of the coefficient of relative risk aversion with corn, soybean, and wheat futures. Although the range of estimates was consistent with earlier results using equity returns, they were not statistically significant, even when the sample period or combinations of the dependent variables were changed.

Bessembinder (1992) tests risk pricing integration across asset markets for 22 futures contracts, including six agricultural and five mineral contracts. Risk factors included the U.S. stock market index and six macroeconomic variables similar to those used by Chen, Roll, and Ross (1986), among them unexpected U.S. inflation and the change in real U.S. short-term interest rates. The risk exposure of commodity futures was low and there was very little evidence of non-zero risk pricing, although each commodity's idiosyncratic risk—conditional on net hedging—had explanatory power for expected returns, consistent with Keynes' postulation.

Khan, Khoker, and Simin (2008) model the expected return of four commodity futures—oil, natural gas, copper, and gold—as a linear function of systematic risk and two commodity specific factors, hedging pressure and a proxy for the scarcity of the commodity. The beta-pricing model they estimate suggests that macroeconomic factors have predictive capability for the commodity-specific factors—for example, business conditions may affect inventory holdings (the scarcity proxy). They conclude that the effect of macroeconomic variables on commodities may not only be direct, but indirect through their influence on commodity-specific factors such as hedging pressure.

IV. Data

Prices for 17 commodity futures contracts are taken from the Commodities Research Bureau (CRB) database—see www.crbtrader.com. These prices are for a position that is continuously rolled over into the nearest-future—i.e., the closest to delivery. The data are provided on a month-end basis for each component of the CRB index and cover the period January 1973 to February 2008. Returns on commodity futures contracts are customarily measured on a collateralized basis. This represents the return of a position in a risk-free instrument—e.g., the one-month Treasury bill—plus a long position in the futures contract. The excess return, measured over the risk-free rate, is then simply the change in the value of the position in the future. Summary statistics are presented in Table 1.

The state variables used in the estimation include:

- Global equity market total returns in U.S. dollars, acting as a proxy for the "market portfolio" that plays a key role in the CAPM. The broad equity market is typically included in risk price estimations.

- Inflation shocks, which could be a source of economic risk if they have real effects and investors regard some commodities as an effective inflation hedge. The shocks were calculated as the residuals of an ARIMA(2,2,3) model applied to the U.S. consumer price index (CPI).

Table 1. CRB Commodity Index Components: Summary Statistics of Log Returns Jan-1973 to Feb-2008 (Percent unless otherwise specified) 1/

	Annualized		Sharpe	Max.	Min.		
	Return	Volatility	ratio 2/	return	return	Skew	Kurtosis
Gold	7.7	20.3	**0.38**	25.5	**-24.4**	0.6	6.8
Silver	6.5	32.4	0.20	45.9	-61.7	-0.4	10.5
Copper	5.5	27.1	0.20	33.5	-31.6	0.1	5.0
Platinum	7.9	27.3	0.29	34.7	-49.7	0.0	8.6
Crude oil	9.6	31.7	0.30	**85.3**	-35.1	**1.8**	**21.7**
Corn	3.5	26.3	0.13	37.7	-37.7	0.0	6.6
Soybeans	3.2	29.2	0.11	45.6	-39.8	0.1	7.9
Wheat	4.2	27.2	0.15	30.9	-29.9	0.2	4.2
Live cattle	2.1	20.6	0.10	19.6	-25.1	-0.2	4.2
Lean hogs	0.7	33.8	0.02	34.5	-51.7	-0.3	4.9
Cocoa	3.8	32.3	0.12	32.3	-33.0	0.2	3.8
Coffee	2.7	38.0	0.07	46.6	-36.4	0.5	4.8
Sugar	1.2	**43.7**	0.03	65.0	-29.8	0.9	5.7
Cotton	2.1	30.6	0.07	33.7	-76.1	-1.6	16.9
Orange juice	3.2	31.1	0.10	54.9	-25.0	1.2	8.6
Heating oil	9.0	34.8	0.26	52.4	-57.1	0.0	9.6
Natural gas	**10.7**	42.9	0.25	39.4	-53.8	-0.2	5.8

Source: CRB, Author's estimates

[1] Maximum statistic for the group in bold, minimum underlined.

[2] Ratio of excess return sample mean divided by sample standard deviation.

- Real short-term interest rates, measured using the U.S. three-month treasury bill yield and CPI inflation over the previous 12 months. Much of the previous literature has used the interest rate as a variable indicating the state of investment opportunities. For example, when real interest rates are low, it is assumed that opportunities are scarce, encouraging investors to accept a lower return for holding risk-free instruments.

- The change in the slope of the yield curve, measured as the yield gap between the U.S. three-month T-bill and the U.S. 10-year Treasury note. Yield curve shifts may be triggered by a large number of unidentifiable factors, including but not limited to a rise in long-term inflation expectations, expectations of aggressive short-term interest rate changes, or shifting risk appetite more broadly.

- The U.S. dollar nominal effective exchange rate against major currencies, as calculated by the Federal Reserve.[3] Adler and Dumas (1983) were among the first to posit that exchange rate risk may be priced by stock markets, particularly if there exist deviations from purchasing power parity, and subsequent work has supported this claim—e.g., Roache (2006). There is also a widespread perception in financial markets that some commodities act as a hedge against U.S. dollar weakness.

V. Estimating the Quantities and Prices of Risk

A. The Macro Risk Exposure of Commodities

How much macro risk exposure do commodity futures offer? In other words, to what extent does a change in any one macro factor drive commodity returns? Perhaps the simplest way to find out is to estimate simple regressions of each commodity on each of the macro factors over the entire sample period. Table 2 presents the results of these regressions for each commodity in our sample. The risk quantity coefficients will be termed "betas", as is standard in the asset pricing literature. A number of results stand out.

First, the R-squared statistics for almost all commodities, with the exception of gold, are very low. While it might be true that commodities offer exposure to macroeconomic and financial factors, other factors appear to be much more important in determining their price.

Second, a group of commodities, among them precious metals and energy, have provided statistically significant exposure to real interest rates and the U.S. dollar index. In fact, all 17 commodities are inversely related to U.S. real interest rates. The coefficient on the stock market, while statistically important to the same grouping, is quite low.

Third, there are three commodity clusters which correlate closely together, after controlling for the influence of the macro and financial factors (Tables A1 and A2 in the appendix). These clusters are defined as having a correlation to another greater than 0.5 and are shown below with their average within-group correlation:

- precious metals—gold, silver, and platinum (0.66);
- agricultural—corn, soybeans, and wheat (0.57);
- energy—crude oil and natural gas (0.62).

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[3] Commodities are often viewed as a hedge against U.S. dollar depreciation versus other major currencies with large financial market-related turnover, such as the yen, the euro and the pound sterling. Compared to the broader IMF nominal effective exchange rate index, the narrower coverage of the Federal Reserve's exchange rate index provides cleaner exposure to these currencies.

Table 2. Full Sample Commodity Factor Exposures Jan-1973 to Feb-2008 1/ 2/

	Inflation shocks	Stock market	Real 3-month T-bill yield	Yield curve change	U.S. dollar trade-wtd index	R squared
Gold	3.1 ***	0.2 ***	-0.005 ***	0.009	-1.0 ***	0.19
Silver	3.0 *	0.4 ***	-0.006 ***	0.013	-0.4 *	0.08
Copper	-0.6	0.5 ***	-0.002	0.012 *	-0.7 ***	0.10
Platinum	3.1 **	0.5 ***	-0.004 **	0.018 **	-0.7 ***	0.13
Crude oil	7.8 ***	-0.1	-0.003 **	-0.001	-0.2	0.05
Corn	-2.1	0.0	-0.001	0.002	0.3 *	0.01
Soybeans	-0.8	0.0	-0.002	0.010	0.0	0.01
Wheat	-0.8	0.0	-0.001	0.013 *	-0.2	0.01
Live cattle	-2.2	0.1	-0.001	0.003	0.1	0.01
Lean hogs	-2.7	0.2	-0.002	0.013	0.2	0.02
Cocoa	2.9	0.0	-0.001	0.003	-0.7 ***	0.03
Coffee	3.0	0.1	-0.003	0.010	0.4	0.02
Sugar	4.5	0.0	-0.005	-0.015	-0.6	0.03
Cotton	0.6	0.2 **	-0.001	-0.007	0.0	0.01
Orange juice	-0.1	-0.1	0.000	-0.003	0.3	0.01
Heating oil	4.9 *	0.0	-0.002	-0.009	-0.4	0.02
Natural gas	1.5	0.2	-0.003 *	-0.016 *	-0.7 **	0.02
Average	1.5	0.1	-0.002	0.003	-0.2	0.04

Source: Author's estimates.

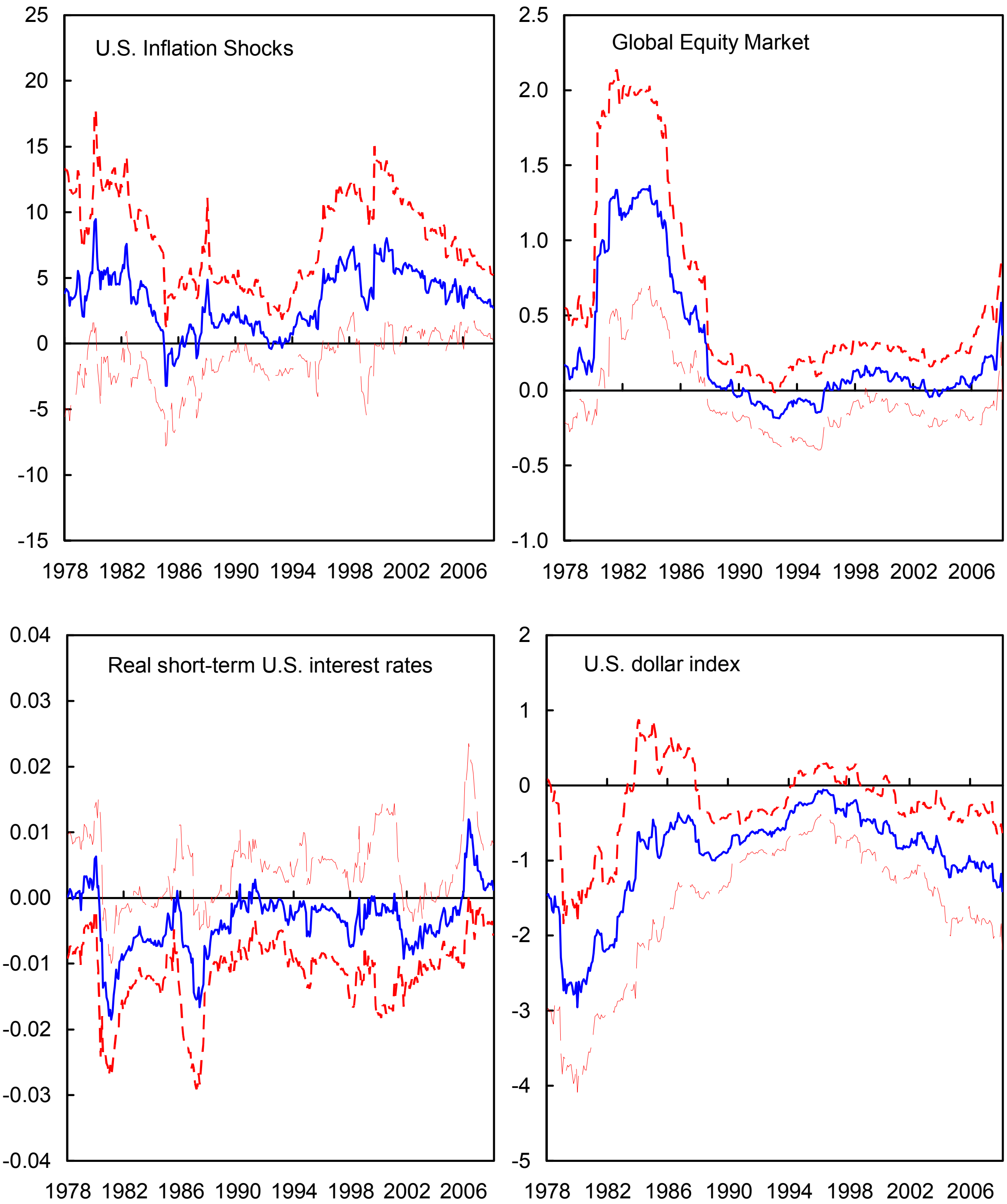
[1] Coefficients from regressions run from January 1973 to February 2008 using monthly data.

[2] Significance at the 1, 5, and 10 percent levels denoted by ***, **, and * respectively, based on Newey-West standard errors.

One possible drawback of this approach is that macro risk exposures might change. For some financial assets, there are fundamental reasons why exposures might change. Take the example of an stock for a company that changes its product lines or its geographic focus; these fundamental shifts in the drivers of the dividend stream should be reflected in the influences that macro factors might have on the firm's dividends.

For commodities there is less of a "fundamental" story to changing macro risk exposure. It has become conventional market wisdom that commodities can, in some circumstances, provide effective hedge positions against some macro risks, such as U.S. dollar depreciation or inflation. Why might these hedging properties change over time? Could changes be the result of self-fulfilling prophecies regarding their value as hedges? Without speculating on why risk exposures might change, Figure 2 plots rolling betas for the gold price, which shows a common pattern for CRB components—risk exposures change significantly over time and similar patterns are observed for other commodities.

Figure 2. Gold Futures: Rolling Regression Beta to Macro Factors, 1978–2008 1/



Source: Author's estimates.

[1] Coefficients from rolling 60-month regressions of gold futures excess returns on macro factors, with two standard error bounds.

B. Market Prices for Macro Risk

Ideally, the estimation method should allow for time-varying betas and risk-prices. A number of methods have been developed, with some recent work focusing on the simultaneous estimation of both sets of parameters, often using GMM or maximum likelihood (ML) techniques (e.g., see the multivariate GARCH-in-mean approach described in de Santis and Gerard (1997)). Simultaneous ML estimation, assuming the model is well-specified, provides asymptotically efficient estimators and avoids the errors-in-variables problems associated with multi-stage regressions.

One common alternative is the well-known Fama-MacBeth (1973) two-step approach. The first stage is to estimate the risk quantities β for each individual commodity using rolling 60-month regressions of excess returns r on the macro factors f:

$$r_{it} = \alpha + \sum_{j=1}^{K} \beta_j f_{jt} + e_{it} \tag{15}$$

The second stage is to estimate the regression of the cross-sectional returns for all commodities on the estimated betas for each sample period:

$$\mathbf{r} = \gamma_0 \boldsymbol{\iota} + \boldsymbol{\beta\gamma} + \boldsymbol{\upsilon} \tag{16}$$

In this representation, $\mathbf{r}$ is an (N x 1) vector of excess commodity returns at some time t, $\boldsymbol{\beta}$ is the (N x K) matrix of K risk quantities for each commodity, and $\boldsymbol{\gamma}$ is the (K x 1) vector of risk prices. The (N x 1) vector $\gamma_0\, \boldsymbol{\iota}$ represents the common intercept for the cross-section. Most asset pricing models, including ICAPM, predict that this term should be zero, but in small homogenous samples such as commodity futures, it might reflect a common risk premium that is determined only by membership of the asset class.[4] The (N x 1) vector $\boldsymbol{\upsilon}$ denotes the idiosyncratic residuals, or the pricing errors.[5]

The risk premia $\boldsymbol{\gamma}$ and pricing errors $\boldsymbol{\upsilon}$ are then estimated as the average of the cross-sectional regressions:

$$\hat{\boldsymbol{\gamma}} = \frac{1}{T}\sum_{t=1}^{T} \hat{\boldsymbol{\gamma}}_t \qquad\qquad \hat{\boldsymbol{\upsilon}} = \frac{1}{T}\sum_{t=1}^{T} \hat{\boldsymbol{\upsilon}}_t \tag{17}$$

Standard errors for these estimates of the sample means are given by:

[4] For example, the backwardation theory of Keynes (1930) mentioned earlier.

[5] Pricing errors may be defined differently, to include the common intercept term.

$$\sigma^2(\hat{\boldsymbol{\gamma}}) = \frac{1}{T^2}\sum_{t=1}^{T}(\hat{\boldsymbol{\gamma}}_t - \hat{\boldsymbol{\gamma}})^2 \qquad \sigma^2(\hat{\boldsymbol{\upsilon}}) = \frac{1}{T^2}\sum_{t=1}^{T}(\hat{\boldsymbol{\upsilon}}_t - \hat{\boldsymbol{\upsilon}})^2 \tag{18}$$

Joint tests of whether all the pricing errors are zero may then be conducted, as suggested by Cochrane (2001, p.246) using:

$$\hat{\boldsymbol{\upsilon}}' \operatorname{cov}(\hat{\boldsymbol{\upsilon}})^{-1} \hat{\boldsymbol{\upsilon}} \sim \chi^2_{N-1} \tag{19}$$

Although Fama-MacBeth is an old technique, it is tried and tested, more robust to misspecification and has been shown to compare favorably to other approaches in terms of bias and inference—see Shanken and Zhou (2007). Perhaps its most obvious drawback is the reliance upon estimated betas, which biases estimates of the standard errors downward; to account for this effect, I use the adjustment proposed by Shanken (1992).

VI. RESULTS

Table 3 presents results from a range of specifications, which include: multivariate models with and without intercepts; and bilateral models estimated for each commodity and the stock market index.

A. Real Interest Rate Risk is Priced

Of all the macro factors, only real interest rate risk is priced. The coefficient on real interest rates is both statistically and economically significant, averaging about 0.5 percent per month across specifications, notwithstanding its significant time variation (Figure 2). To illustrate how this might translate into annual expected returns, I use the estimates for gold. The average beta of the gold future on the real interest rate is about -0.005 and the annual risk premium for bearing interest rate exposure is 12 x 0.6 = 7.2 percent. Together the quantity and price of interest rate risk imply a negative expected annual excess return of -0.005 x 7.2 = - 3.6 percent.

This result supports the ICAPM theory by suggesting that investors are willing to *pay* a premium in order to hedge themselves against poor states of the world. Real interest rates are a proxy for the state of investment opportunities, with lower interest rates pointing to a scarcity of profitable investments in the broader economy and lower wealth in the future as a consequence. Commodities, due to their negative beta to the real interest rate, pay off in these poor states and act as a form of insurance.

How reliable is the negative beta of commodities to real interest rates? Table 2 showed that full sample betas were negative for all commodities and significant for five, including gold and oil. More fundamentally, Frankel (2006) has offered three reasons why real commodity prices fall as real interest rates rise:

- the present value of future revenues would tend to fall, increasing the incentive for extraction today rather than tomorrow and boosting supply;

- the opportunity cost of carry would rise, encouraging a reduction in inventories and addition to current supply; and
- the return offered on competing financial instruments, most obviously treasury bills, would increase, leading to a decline in commodity demand.

Table 3. Commodity Risk Price Estimates: Fama-MacBeth Regressions 1973–2008

	Constant term	Inflation shocks	Stock market	Real 3-month T-bill yield	Yield curve change	U.S. dollar trade-wtd index
				Unrestricted - nonzero intercept		
Bivariate model		0.3212	-	0.3212	-0.0757	-0.0019
		(0.1)		(1.4)	(-0.8)	(-1.1)
		0.4711		*0.1654*	*0.4071*	*0.2550*
Multivariate model	0.0045 **	-0.0001	0.0037	0.4915 **	-0.0431	-0.0023
	(2.5)	(-0.3)	(0.8)	(2.0)	(-0.6)	(-1.1)
	0.0122	*0.7405*	*0.3976*	*0.0423*	*0.5389*	*0.2814*
Pricing error test χ^2 4/	4.30					
				Arbitrage pricing theory restriction imposed $\gamma_0 = 0$		
Bivariate model		0.0003	-	0.4853 **	-0.0545	-0.0026
		(1.0)		(2.1)	(-0.8)	(-1.1)
		0.2990		*0.0370*	*0.4071*	*0.2550*
Multivariate model		0.0002	0.0064	0.6197 **	0.0036	-0.0026
		(0.7)	(1.5)	(2.4)	(0.0)	(-1.2)
		0.4640	*0.1401*	*0.0154*	*0.9620*	*0.2156*
Pricing error test χ^2 4/	5.40					

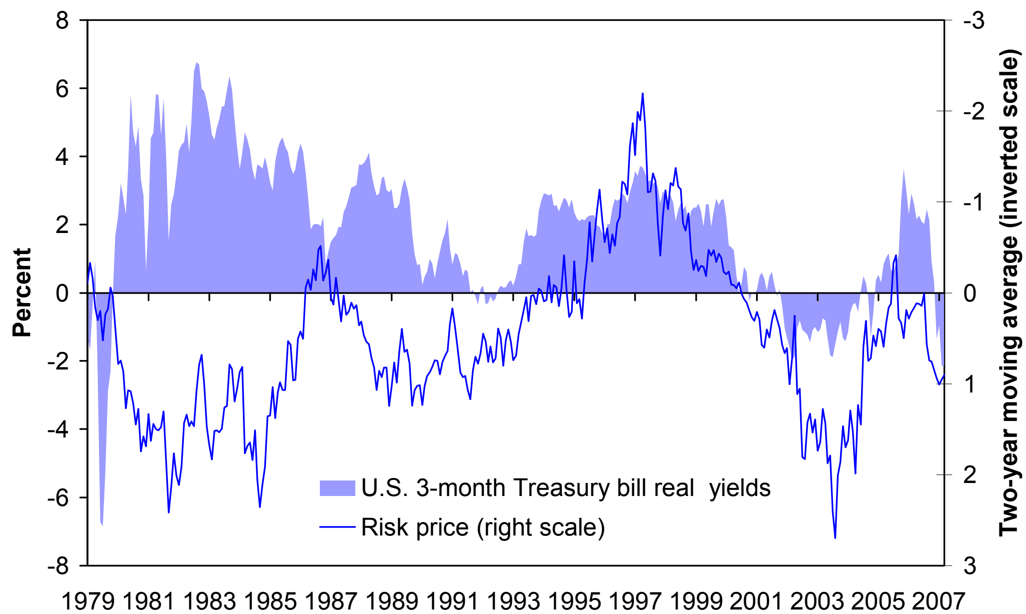
Source: Authors' estimates.
[1] Bivariate model estimated using equity market and the other orthogonalized variable as factors.
[2] t-ratios in parantheses and p-values in italics.
[3] Significance at the 1, 5, and 10 percent levels denoted by ***, **, and * respectively, using Shanken (1992) adjusted standard errors.
[4] The null hypothesis is that the pricing errors are all jointly equal to zero in the multivariate model. The test statistics is distributed as chi-squared with N - 1 degrees of freedom.
Significance at the 1, 5, and 10 percent levels denoted by ***, **, and * respectively.

B. The Time-Varying Cost of Interest Rate Insurance

The interest rate risk premium on commodity futures varies over time and in recent years has been inversely correlated with interest rates levels. In other words, as real interest rates decline (rise), the cost of insurance against low rates increases (falls).

The ICAPM model offers no predictions on how risk premia may vary; it does however indicate that the marginal effect of the state variable on the utility of wealth can cause the premia to change. In other words, investors appear willing to pay more for insurance in poor states of the world.

Figure 3. Real Interest Rates and the Risk Price, 1979–2008



Source: Author's estimates.

C. Evidence for a Commodity-Specific Risk Premium

The intercept in this model may be interpreted as the risk premium associated with holding a commodity future. For all specifications including an intercept, it was possible to reject the hypothesis that its value was zero. The premium was also economically significant, contributing an annualized 5.4 percent to the expected return to the asset class.

This result is consistent with Keynes' suggestion that futures should offer a positive risk premium for speculators that are effectively selling price insurance to risk-averse producers; however, for some commodities, consumer hedging may predominant, which would argue for a negative premium. Arbitrage pricing theory (APT) is also inconsistent with this result, since commodity asset class risk could be diversified away in a broad portfolio.

D. Model Fit

An intuitive test for model fit is to test the null that all the pricing errors are jointly zero—see equation (19); it was not possible to reject this null at the 1 percent level. However, this does not mean that this is a useful model for forecasting commodity returns, a purpose for which it is not designed; the model aims to shed light on asset class equilibrium pricing. With R-squared values for the full sample beta equations so low (Table 2), it is clear that there are many other factors that drive excess returns to each commodity; these factors are likely to be commodity-specific and are not addressed here.[6]

VII. Conclusion

Commodity futures offer some macro risk exposure, but the exposure varies across the asset class. Precious metals, copper, and energy, perhaps the commodities most traded by financial investors, are influenced by interest rate and currency movements; agricultural commodities tend to be less sensitive.

Perhaps surprisingly given these risk exposures, exchange rate risk is not priced. Investors should not expect to receive, or pay, a premium for holding an asset class that can covary strongly with the U.S. dollar. In theory, exchange rate risk may be priced if purchasing power parity (PPP) does not hold and the home price index-deflated returns of an asset varies across countries—see Adler and Dumas (1983). That said, the easier it is to hedge currency exposure using alternatives with less basis risk, the less we should expect to uncover currency risk premia in assets such as commodity futures.

Interest rate risk is priced and, rather than a simple hedge against bond markets, this result may be interpreted as evidence of a general insurance policy against bad times. Commodities perform well during periods in which other investment opportunities are scarce and expectations of future wealth gains are reduced. This insurance policy pays off with a higher degree of probability for those contracts that exhibit a strong and reliably inverse relationship with interest rates.

Long-term investors moving into the commodity asset class may need to continuously update and refine their estimates of macro risk exposure and pricing. So far, this topic has not been well explored in the literature and many questions remain unanswered. Are commodities exposed to macro risk emanating from specific regions? Are global interest rates more important than U.S. interest rates? And perhaps most importantly, will commodities behave more like a homogenous asset class should large well-diversified financial investors continue to raise their exposure?

[6] Other factors include macro factors in particular regions, with an relevant example being the growth of commodity demand in the largest emerging market economies.

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APPENDIX

Table A1. Correlation Matrix of Excess Returns, Jan-1973 to Feb-2008 1/

	Gold	Silver	Copper	Platinum	Crude oil	Corn	Soybeans	Wheat	Live cattle	Lean hogs	Cocoa	Sugar	Cotton	Orange juice	Heating oil	Natural gas
Silver	**.70**															
Copper	**.34**	**.37**														
Platinum	**.66**	**.67**	**.39**													
Crude oil	**.19**	**.14**	.07	**.13**												
Corn	.09	**.17**	.09	.09	-.03											
Soybeans	**.19**	**.17**	**.16**	**.19**	-.05	**.63**										
Wheat	.09	**.17**	**.14**	**.14**	.05	**.49**	**.36**									
Live cattle	.02	.05	.05	**.15**	-.03	**.14**	**.16**	**.13**								
Lean hogs	.04	**.12**	.03	.09	.03	**.14**	**.16**	**.14**	**.30**							
Cocoa	**.17**	**.19**	**.17**	**.16**	.03	.06	**.10**	.01	-.04	-.02						
Sugar	.05	.06	.09	.09	-.00	**.15**	**.18**	**.11**	-.02	-.06	**.14**					
Cotton	**.16**	**.16**	**.17**	**.21**	.04	**.12**	**.13**	**.14**	-.01	-.06	.06	.08				
Orange juice	.01	.06	**.13**	.09	-.02	**.24**	**.17**	**.15**	.03	.08	.07	.01	-.00			
Heating oil	-.06	-.04	-.02	-.04	-.02	**.10**	.07	-.02	-.07	-.06	.03	.03	.02	-.07		
Natural gas	.09	.05	.05	.05	**.62**	-.05	.01	**.11**	.02	.03	.04	-.01	-.00	-.02	-.05	
Average	**.18**	**.20**	**.15**	**.20**	.08	**.16**	**.17**	**.15**	.06	.06	.08	.06	.08	.06	-.01	.06

Source: Author's estimates.
[1] Figures in bold are statistically significant at the 95 percent level.

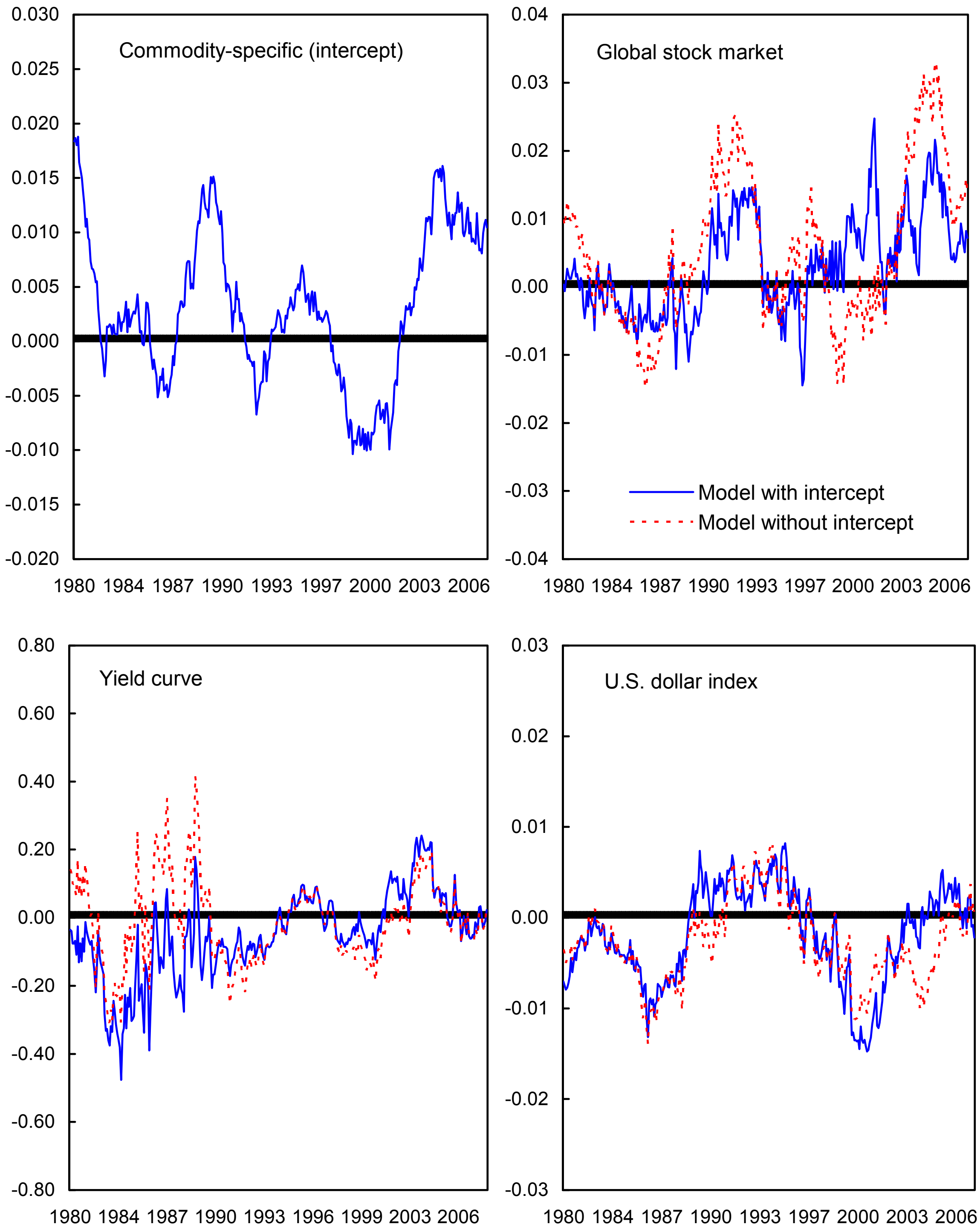
Table A2. Correlation Matrix of Residuals from Five-Factor Beta Models, Jan-1973 to Feb-2008 1/

	Gold	Silver	Copper	Platinum	Crude oil	Corn	Soybeans	Wheat	Live cattle	Lean hogs	Cocoa	Sugar	Cotton	Orange juice	Heating oil	Natural gas
Silver	**.70**															
Copper	**.29**	**.34**														
Platinum	**.65**	**.63**	**.33**													
Crude oil	**.19**	**.14**	.07	**.12**												
Corn	.09	**.15**	**.10**	.08	-.01											
Soybeans	**.12**	**.13**	**.16**	**.16**	-.03	**.64**										
Wheat	.09	**.17**	**.14**	**.12**	.04	**.50**	**.41**									
Live cattle	-.01	.02	.05	**.13**	-.01	**.10**	**.14**	**.13**								
Lean hogs	.02	**.10**	-.00	.06	.06	.09	**.13**	**.13**	**.26**							
Cocoa	.09	**.17**	**.16**	**.13**	.03	.03	.05	.01	-.06	-.05						
Sugar	.02	.01	**.10**	.05	-.01	**.13**	**.15**	**.11**	-.02	-.07	**.16**					
Cotton	**.12**	**.14**	**.20**	**.21**	.01	**.12**	**.14**	**.15**	-.02	-.06	.04	.08				
Orange juice	-.00	.06	**.13**	.08	-.04	**.25**	**.20**	.08	.03	.09	.08	.01	-.00			
Heating oil	-.04	-.03	-.02	-.03	-.02	.09	.08	-.02	-.07	-.07	.04	.03	.03	-.06		
Natural gas	.06	.03	.05	.03	**.62**	-.05	.02	**.11**	.02	.04	.02	-.02	-.03	-.03	-.05	
Average	**.16**	**.18**	**.14**	**.18**	.08	**.15**	**.17**	**.14**	.05	.05	.06	.05	.07	.06	-.01	.05

Source: Author's estimates.

[1] Figures in bold are statistically significant at the 95 percent level.

Figure A1. Estimated Risk Prices, 1979–2008



Source: Author's estimates.