Macroeconomic Fundamentals to the Commodity Risk Premium

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Abstract

This chapter aims to build a connection between commodities' price movements and the growth level in industrial production in different economic regions. Commodities should only be incorporated in a diversified strategy as long they either have a poor correlation to standard assets such as equities, or offer an attractive risk premium. We demonstrate that the part of commodity return not attributed to the roll yield is related to economic activities in the U.S. and China. 40 to 50% of variation in commodities returns are explained by industrial production growth in those both regions. The slow-down of economic activity implies lower excess returns on commodities. Similar to the risk premium on equities and credit, the commodity risk premium is dependent on the economic enviornment. This finding casts doubt on both commodities' diversification potential, and investor's interest in this asset class in terms of expected risk premium, given the current low world structural growth.

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1 Introduction

Since 2005, commodities are increasingly incorporated in multi-asset allocation strategies, driven by their documented low correlation to standard asset classes such as equities and bonds (e.g., Gorton and Rouwenhorst (2006), Erb and Harvey (2006), Kat and Oomen (2006), Kat and Oomen (2007), Lummer and Siegel (1993), Kaplan and Lummer (1998), Greer (2000), Jensen et al. (2000), Jensen et al. (2002), Laws and Thompson (2007), Roache (2008)). Combining uncorrelated assets in a portfolio helps to reduce the total volatility of the portfolio, a desired objective of many asset managers and hedge funds around the world with the objective to deliver positive returns with a limited drawdown. To exploit commodities' potential to reduce total portfolio volatility, commodities need to be particularly uncorrelated with standard asset claases over periods of market downturns. A low correlation during positive equity performance periods, and a high and positive correlation over periods of market collapse would actually be detrimental to any portfolio's performance over both periods. Is the low correlation a sufficient justification to advocate for the inclusion of raw materials through futures in a portfolio? A classic way of evaluating this is to determine the ability of commodities to generate a risk premium, especially since commodities are usually assets with higher volatilities than that of government bonds. Replacing bonds in a portfolio by commodities increases risk. Standard financial theory would therefore require a risk premium to justify this replacement. In the case of equities, for example, part of the compensation for risk comes from the revenue associated to each stock, i.e., the dividends. In the case of commodities, however, there is no such thing as a revenue, e.g., holding a future contract on oil delivers no explicit revenue to its owner, unlike the coupon attached to a credit bond. This chapter evaluates if there is a statistically positive return corresponding to investing in commodities over the long run, i.e., whether investors are rewarded for their risk-taking, and the relation of this risk premium and the economic environment.

The influence of the economic environment on commdities performance is on the back of the head of many investment managers. Since 2011, the prices of numerous commodities have seen a diminishing trend with uncanny consistency. Apart from the rumored financialization of commodities, and among of the various factors that are used to explain this prolonged co-variation of commodities prices, the switch from an investment-led to a consumption-led economy in China is another hypothesis explaining the commodities price trend that receives lots of attention. In spite of the large number of press articles on this thesis, there has been little empirical investigation using econometric tools. The plausibility of the Chinese economy's transition as an explanation to the observed commodities price trend is based on two key beliefs. First, the investment community is increasingly considering commodities as a unique asset class, which implies that common factors to this asset class would explain an increasing share of the behavior of single commodities. Second, macroeconomic evolutions influence the course of commodity prices. This is at odds with a significant portion of the theoretical literature on commodities that rely on idiosyncratic factors, such as stock levels, storage costs or hedging pressures. While empirical investigations before the 2008 financial crisis suggest idiosyncratic factors explain a large proportion of commodities price variation, the returns on commodities post-2008 tell a different story, when co-movements account for the bulk of price variations in raw materials.

To assess the realized return of commodities, we overcome its dependence on the start and end dates of the investment by following Boon and Ielpo (ming). Alleviating the dependence of realized return on the holding period is essential because a holding period beginning in December 2008 has a drastically different realized returns as compared to a holding period starting before the oil boom in 2003, for example. We randomly sample the realized return in four commodity markets - energy, agriculture, industrial metals and precious metals - and their aggregate over fixed holding periods ranging from a month to twelve years. This block sampling method also allows us to relate the realized returns on each randomly sampled block to the coincident economic situation, as measured, for example, by the industrial production over the same period. We then estimate linear regressions of the sampled returns for a given holding period on the underlying fundamentals in our attempt to connect the performance of commodities indices, and the economic situation in the U.S., member countries of the Organization for Economic Co-operation and Development (OECD), the Eurozone and China. We determine to which economic region does commodity returns relate best. Upon identifying the economic region with the cycle that best explains the variation of the commodity indices, we discuss the performance of these four markets and their aggregate on the level of economic activity, as proxied by the industrial production of the relevant economic zone. Our approach builds on the results presented in Bjornson and Carter (1997), who show that when interest rates, inflation and economic growth are high, the returns on commodities are usually at their lowest. Additionally, our analysis is also related to Nguyen and Sercu (2011)'s proposal to combine business cycle indicators and monetary policy regimes in order to underscore the relation between commodity markets and major macroeconomic variables. They evaluate commodity markets during three phases of expandionary and recessionary period (i.e., early, middle and late). They conclude that an investor should invest in commodities when monetary policy is restrictive over the middle and late stages of expansion phases, during recession and when monetary policy is expansive over boom periods, i.e., during recovery periods. Chevallier and Ielpo (2013) and Chevallier et al. (2014) highlight that over stressed economic periods, commodity markets tend to react more to economic news than over calmer periods. Instead of focusing on each regime phase, this chapter focuses on relating the actual level of economic activity with the performance of commodity markets. We are interested in the impact of a prolonged, low Chinese industrial production growth on the return of commodities. We identify the economic zone that has the greatest influences on each commodity market over the past fifteen years, then relate the returns to the industrial production growth rate of that particular economic region. We conclude that industrial and precious metals, and agricultural commodities are mostly influenced by Chinese economic activity. The energy sector is mainly influenced by the U.S. economic activity. We find that industrial production growth explains up to 50% of the returns on commodities. For non-energy commodities, we estimate that Chinese industrial production of 5% per year are unlikely to generate positive returns, a claim that is consistently with the market evolution since 2011. In the case of energy markets, we estimate that a 2% growth in the U.S. industrial production is necessary to attain rising energy prices. As China and the U.S. are both experiencing a structural slowdown in recent years that is likely to persist, this chapter's analysis should be carefully considered when making prospective investments.

The organization of the chapter unfolds as follows: we discuss the methodology used to compute realized returns by holding periods in Section 2. Then we establish the relation between commodity sectors and economic activities in Section 3. In Section 4, we present and discuss the implication of the estimated regressions between industrial growth rates and the performance of commodity sectors.

2 Realized Returns per Holding Period: Making the Case for a Commodity Risk Premium

The rationale for investing in any asset class that is not a government bond is the fact that the asset class rewards investor for takng risk. Most of the standard assets generate a risk premium, as they deliver an uncertain return, e.g., as a coupon or a dividend, to investors. Commodities, however, do not deliver such a *revenue*. Commodities' lack of appeal is further worsened by a typically upward sloping future curve, as rolling a future position to maintain an investment in these markets entails a cost that is proportional to the steepness of the future curve. If commodities provide a risk premium of any kind, it should be investigated from realized returns excluding roll cost, as is done in Gorton and Rouwenhorst (2006) and Erb and Harvey (2006), i.e., the expected return of an asset class delivering no revenue can be inferred from past returns. Others investigated the dependence of commodity expected returns on bottom-up metrics associated to the stock market, inventory costs or market positioning. For example, Stoll (1979), Hirshleifer (1988), Hirshleifer (1989) and De Roon et al. (2000) assess the impact of systematic factors and hedging pressure on single commodity futures. Drawing on the theory of storage (Working, 1949), Gorton et al. (2012) analyze the relation between commodity inventory levels and commodity futures' expected returns. Acharya et al. (2013) present an equilibrium model of commodity markets based on capital constraint on speculators and a hedging demand stemming from producers. Daskalaki et al. (2014) test a large number of potential models and factors, covering brokerage houses' leverage and monetary policy related factors, or commodity hedging pressure variables. They find little evidence that commodity markets are affected by such factors. Gorton et al. (2012) find that inventories have a high explanatory power over the 'basis' of many commodities, i.e., the difference between the first future and the spot price of each commodity, where the net position of traders has more limited explanatory power. Here, we approach this issue from a different angle, focusing on the macroeconomic factors that can explain movements in the cross-section of commodity sectors' indices.

We perform our analysis on weekly Bloomberg Commodity Index performance by sector, from 1999 to 2015. Figure 1 is a plot of the indices' performance over this period, normalized to 100 at their 1999 levels. Descriptive statistics under the "Global" column in Table 1 suggest the existence of tail events (i.e., negative skewness). Furthermore, the indices tend to have larger negative returns than positive ones (i.e., the kurtosis is greater than three) - a characteristic shared also by equities and credit. Thus, commodities' diversification potential are weak according to these summary statistics.

In order to evaluate the existence of realized risk premium, a key challenge is to mitigate the dependence of commodities performance on the time period considered. For example, an investment in energy yields an annualized excess return[1] of 71.6% between January to July 2008, with a standard deviation of 27.6%. At 2.6, the Sharpe ratio of investments in energy over this period suggests a lucrative risk premium. If instead, the investor invests in energy between July 2008 for a year, she receives an annuallized excess return of -123.4% at an annualized standard deviation of 45.5%. The devastating Sharpe ratio of -2.71 implies no realized risk premium for an investment over this period. These marked differences in the realized risk premiums for other commodity sectors. Therefore, our inference on the realized risk premium depends on the outcome over a the portion of history that is

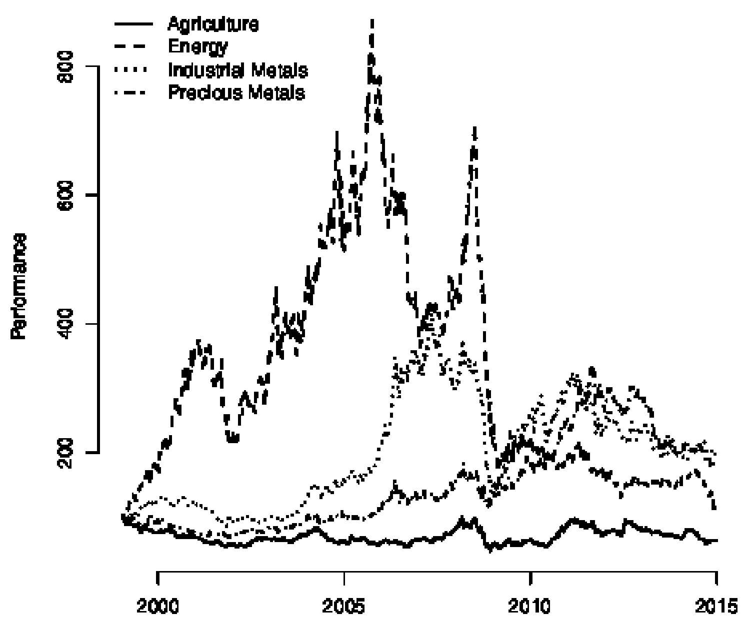
[1]The risk-free rate is the 3-month U.S. Treasury Bond.

focused upon. Relying on the series of realized return in Figure 1 is insufficient to determine whether the realized risk premiums are positive.

To overcome the dependance of the realized risk premiums on the holding period, we randomly draw, with replacement, 100,000 intervals of consecutive weekly return for one-month to six-year holding periods, from the sample of commodity sector excess returns. This method of block-sampling, as advocated in Lin and Chou (2003), preserves the serial dependency that the data exhibit, and is in contrast to independent sampling of returns as carried out by Hodges et al. (1997). If investors are rewarded with higher returns by assuming higher risk, the realized risk premiums from our random draws would be positive.

Table 1 presents statisics to the annualized performance of the randomly drawn porfolio. For a one year holding period, most of the Sharpe ratio are either negative or close to zero, with the exception of precious metals. The Sharpe ratios for all sectors excluding energy are positive for longer investment horizons. The precious metals' Sharpe ratio is considerably high for long term investors, and is monotonically increasing in the holding period. This observation suggests that precious metals are probably the only commodity that should be included in a diversified "risk-premium-chasing" strategy. Across the holding periods considered, maximum Sharpe ratio is attained for a holding period of four years for agriculture, six months for energy, and six years for industrial and precious metals.

Figure 1: Performance of the Bloomberg Commodity Index by Sectors



This figure plots the evolution of the commodity indices by sector, when the price level in 1999 is normalized to 100. The time period is January 1^{st} 1999 to December 25^{th} 2015.

Table 1: Performance Statistics of Randomly Block-Sampled Portfolio by Sector and Investment Horizon

AGRICULTURE

	Global	1 month	3 months	6 months	9 months	12 months	18 months	24 months	36 months	48 months	60 months	72 months
Avg. return (%)	-2.82	-2.1	-3.49	-2.35	-1.49	-1.32	-1.09	-0.48	0.32	0.99	0.81	0.49
Std.dev. (%)	19.73	64.73	42.29	30.29	25	19.99	14.7	12.76	7.04	4.63	4.31	4.26
Sharpe ratio	-0.14	-0.03	-0.08	-0.08	-0.06	-0.07	-0.07	-0.04	0.05	**0.21**	0.19	0.11
Skewness	-0.34	0.02	-0.56	-0.1	-0.01	0.16	0.38	0.29	0.02	0.12	0.12	0.2
Kurtosis	5.52	5.03	5.69	4.11	3.93	3.04	2.51	2.19	2.73	2.55	2.1	1.84

ENERGY

	Global	1 month	3 months	6 months	9 months	12 months	18 months	24 months	36 months	48 months	60 months	72 months
Avg. return (%)	-0.18	1.02	0.37	1.90	-0.20	0.15	-0.31	-1.91	-3.15	-3.00	-4.28	-5.42
Std.dev. (%)	30.54	99.04	66.36	51.17	43.88	37.84	29.48	24.37	20.33	19.51	17.95	16.30
Sharpe ratio	-0.01	0.01	0.01	**0.04**	0.00	0.00	-0.01	-0.08	-0.16	-0.15	-0.24	-0.33
Skewness	-0.53	-0.37	-1.04	-1.30	-1.10	-0.56	0.01	0.13	0.04	0.06	0.29	0.64
Kurtosis	4.62	3.73	5.75	6.24	5.46	3.63	2.97	2.98	2.02	1.84	1.66	2.03

INDUSTRIAL METALS

	Global	1 month	3 months	6 months	9 months	12 months	18 months	24 months	36 months	48 months	60 months	72 months
Avg. return (%)	4.05	5.23	3.48	4.81	3.67	3.54	3.70	4.15	4.76	6.38	7.16	7.13
Std.dev. (%)	23.19	74.46	50.86	39.33	34.30	29.00	23.78	21.55	16.16	13.07	11.14	9.74
Sharpe ratio	0.17	0.07	0.07	0.12	0.11	0.12	0.16	0.19	0.29	0.49	0.64	**0.73**
Skewness	-0.60	-0.40	-1.39	-0.99	-0.76	-0.28	-0.05	0.11	0.56	0.75	0.33	-0.36
Kurtosis	5.46	6.23	8.87	6.68	5.38	3.84	2.94	2.24	2.05	2.30	2.17	2.04

PRECIOUS METALS

	Global	1 month	3 months	6 months	9 months	12 months	18 months	24 months	36 months	48 months	60 months	72 months
Avg. return (%)	3.84	2.75	3.59	4.84	4.76	4.99	5.22	6.31	7.91	9.08	9.57	9.58
Std.dev. (%)	20.65	63.33	35.29	25.00	21.08	18.11	15.58	13.67	9.84	6.60	4.96	4.46
Sharpe ratio	0.19	0.04	0.10	0.19	0.23	0.28	0.34	0.46	0.80	1.38	1.93	**2.15**
Skewness	-0.58	-0.25	-0.26	-0.17	-0.14	0.01	-0.12	-0.28	-0.48	-0.44	-0.52	-0.27
Kurtosis	5.61	3.94	4.04	3.24	2.90	2.47	2.23	2.54	2.86	2.78	2.20	2.69

This table provides the annualized mean and standard deviation of excess returns, Sharpe ratio, skewness and kurtosis, of 100,000 randomly block-sampled time periods by commodity sector and by investment horizon. In the “Global” column, the statistics correspond ot those over the full sample period. The risk-free rate is the yield on three-month U.S. Treasury bills. The maximum Sharpe ratio across the holding periods considered is in bold font.

3 Commodity Sector Performance and Economic Activity

The analysis on commodity sectors' realized risk premium in Section 3 implies that over the long run, commodities besides energy deliver a risk premium. However, the maximum Sharpe ratio is not necessarily attained with a longest investment horizon considered for all sectors. A better understanding of the underlying factors that drive these risk premiums would allow the investor to better capture the risk premium. As commodities are inputs to production processes, a plausible candidate for such an underlying factor is the world economic growth. In Boon and Ielpo (ming), the economic environment, is shown indeed to drive global risk premium across a variety of asset classes.

While economic growth can be proxied through consumption-related variables or through production-related ones, given the role of commodities to production processes, it is likely that producer-related variables serve as a more appriopriate proxy. Gorton et al. (2012) highlight that various production bottom up variables affect the price of commodities. Of the global economic powers, we identify four economic zones to most likely have an influence on commodity prices, namely, the U.S., representative countries of developed economies (i.e., member countries of the OECD), countries in the Eurozone, and China.

A straightfoward correlation analysis between any measure of economic growth in these regions and the return on commodities does not effectively reveal the relation between them because both series have a differenct scale, and commodity prices are much more volatile and the economic growth measure. Such a correlation analysis implies weak to no relation between economic cycles and commodity prices. A way around this situation consists of computing returns and volatilities per phase in each economy. In a two-regime setting (i.e., expansion and recession), the distance between these moments across the regimes can help us identify the most relevant economic region. The geographical zone that is the most related to the asset price variations is the one that yields the largest distance in asset performance in its expansionary and recessionary periods.

We use business cycle dates from the St. Louis Federal Reserve's Federal Reserve Economic Data (FRED). For each economic regime, we compute the annualized excess return, standard deviaton and Sharpe ratio by in its expansionary and recessionary periods. The measure of the economic regions' explanatory power on commodity performance is the absolute difference in Sharpe ratio between expansionary and recessionary periods (ΔSharpe Ratio).

Table 2 presents the ΔSharpe Ratio by economic region and by business cycles for the commodity sector considered. reveals that for agriculture, the Eurozone has the largest ΔSharpe Ratio. For industrial and precious metals, the Chinese economy yields the largest ΔSharpe Ratio. As energy, the corresponding economic region with the largest ΔSharpe Ratio is the U.S.. Therefore, the prices of agricultural products seemingly follow economic activity in the Eurozone, the price variation of industrial and precious metals adhere most closely to the Chinese economic activity, while the prices of energy is most influenced by evolution in the U.S. economy.

Table 2: Excess Return, Volatility and the Sharpe Ratio of the Commodity Indices by Sector, Economic Region and Business Cycles

	Geographical Zone	Business Cycle	Avg. Return (ann., %)	Volatility (ann., %)	Sharpe Ratio	ΔSharpe Ratio
Agriculture	U.S.	Recession	-17.24%	32.40%	-0.53	0.55
		Expansion	0.36%	18.60%	0.02	
	OECD	Recession	-5.75%	22.79%	-0.25	0.25
		Expansion	-0.08%	20.02%	0	
	China	Recession	-15.47%	22.99%	-0.67	1.3
		Expansion	11.38%	18.17%	0.63	
	Eurozone	Recession	-13.82%	23.45%	-0.59	**0.85**
		Expansion	4.98%	19.26%	0.26	
Energy	U.S.	Recession	51.01%	-44.22%	1.15	**1.45**
		Expansion	-8.16%	-27.72%	-0.29	
	OECD	Recession	-9.37%	36.55%	-0.26	0.44
		Expansion	5.11%	27.51%	0.19	
	China	Recession	-10.45%	32.51%	-0.32	0.69
		Expansion	10.66%	29.24%	0.36	
	Eurozone	Recession	-6.20%	36.34%	-0.17	0.31
		Expansion	3.87%	27.40%	0.14	
Industrial Metals	U.S.	Recession	-24.47%	37.06%	-0.66	1.09
		Expansion	8.63%	20.10%	0.43	
	OECD	Recession	-15.06%	26.57%	-0.57	1.25
		Expansion	14.30%	20.81%	0.69	
	China	Recession	-14.35%	25.24%	-0.57	**1.71**
		Expansion	22.55%	19.83%	1.14	
	Eurozone	Recession	-15.30%	26.99%	-0.57	1.35
		Expansion	15.67%	20.10%	0.78	
Precious Metals	U.S.	Recession	-0.02%	27.75%	0	0.24
		Expansion	4.29%	18.23%	0.24	
	OECD	Recession	-0.70%	20.66%	-0.03	0.35
		Expansion	6.04%	19.25%	0.31	
	China	Recession	-6.93%	21.95%	-0.32	**1.17**
		Expansion	14.33%	16.76%	0.86	
	Eurozone	Recession	-5.94%	21.52%	-0.28	0.79
		Expansion	9.46%	18.45%	0.51	

Descriptive statistics of factor portfolio performance during recessionary and expansionary periods, by economic region and by commodity sector. Dates for the economic cycles are from the Federal Reserve Bank of St. Louis' FRED Database, available at `https://research.stlouisfed.org/fred2/release?rid=242`. ΔSharpe Ratio is the difference in Sharpe Ratios between the expansion and the recession regime. For example, in the case of Agriculture, with the U.S. regime indicator, the recession Sharpe ratio is -0.53 and the expansion's is 0.02. The absolute difference between the two of them is therefore 0.55. This measure is meant to gauge the explanatory power of each economic region's business cycle. The larger the ΔSharpe Ratio, the stronger is the association of the returns on the factor portfolio with the region's economic cycle. The largest ΔSharpe Ratio across economic regions is in bold.

4 Projected Commodity Returns from Industrial Production Growth

To quantify the relation between the performance of factor portfolios with economic activity, we select as our economic indicator, industrial production (IP). IP is a measure of industrial output from all facilities located in the economic region concerned, in manufacturing, mining, and electric and gas utilities. As IP constitutes the most volatile part of a business cycle,[2] and contains information about future economic fundamentals, it is a good proxy for real activity. We obtain monthly IP data for the U.S. from FRED, and quarterly Chinese IP data from the National Bureau of Statistics of China. As the commodity sectors' returns data is of weekly frequency, we merge the returns data with the quarterly Chinese IP data to the corresponding quarter of the week, and with the monthly U.S. IP data to the correponding month of the week. The merged data is used in subsequent analysis. We report only annualized statistics to reconcile the different data frequencies.

We postulate a linear relationship between IP and commodity sector performance as follows:

$$Y^{(s)}_{t_k,\, t_k+h} \quad = \quad \alpha_h + \beta_h \Delta IP^{(s)}_{t_k,\, t_k+h} + \epsilon_{t_k,\, t_k+h} \tag{1}$$

h is the holding period in number of weeks, t_k is starting date of the k^{th} random sample. $Y^{(s)}$ is either the excess return of the factor portfolio, its volatility, or its Sharpe ratio for factor $s \in$ {Agriculture, Energy, Industrial Metals, Precious Metals}. ΔIP is the variation of industrial production, with $s \in$ {Agriculture, Industrial Metals, Precious Metals} corresponding to the Chinese IP, and $s \in$ {Energy} referring to the IP for the U.S.. ϵ is the residual term. h ranges from a month to six years, as measured by the number of weeks. Eq. (1) is estimated on a block bootstrapped sample of size 100,000, indexed by k, $k = 1,\, 2,\, \ldots,\, 100,000$. The rationale and construction of this random sample is outlined in Section 3.

Table 3 report the estimates for β, and the R^2 for the commodities sector. IP growth explains between 30% and 49% for an eighteen-month investment horizon. The signs of $\hat{\beta}$ are consistent with intuition: returns are positively correlated with variation in IP, whereas volatility generally has the opposite correlation with IP growth. Furthermore, almost all $\hat{\beta}$ is statistically significant, underscoring the presence of a relation between the commodity prices and economic activities. Commodity volatility is largely unexplained by the IP growth, except when it concerns Energy. Finally, IP explains between 20% and 50% of the asset class's Sharpe ratios over the investigated history for an eighteen-month holding period. These results highlight the strong connection between industrial production cycles and the commodity asset class: it is an essential piece of evidence that should matter to any cross-asset or commodity only investor. For agriculture, energy and precious metals, the R^2 attains its maximum value for the investment horizons of eighteen-month, but for industriai metals, the highest R^2 is reached at six-year, the maximum holding period considered.

[2] In contrast, real consumption growth is known to be smooth. In the U.S., for instance, annualized standard deviation for seasonally adjusted real consumption growth in the 1980s-1990s is 1.1% (**?**).

Table 3: Relation between the Return Statistics and the Relevant Economic Region's Industrial Production Growth by Commodity Sector and Investment Horizon

AGRICULTURE						
Dependent Variable	Return		Volatility		Sharpe Ratio	
Statistic	R^2	β	R^2	β	R^2	β
1 month	0.03	3.55*	0	-0.15*	0.04	26.13*
3 months	0.09	3.88*	0.02	-0.35*	0.1	21.08*
6 months	0.14	3.59*	0.03	-0.34*	0.15	18.83*
9 months	0.19	3.56*	0.02	-0.32*	0.21	18.65*
12 months	0.23	3.3*	0.01	-0.21*	0.27	17.99*
18 months	**0.3**	**2.95***	0	-0.02	0.35	17.48*
24 months	0.21	2.3*	0	0.01	0.26	14*
36 months	0.13	1.18*	0	-0.03	0.17	7.5*
48 months	0.01	0.2*	0.01	-0.26*	0.02	1.95*
60 months	0.02	0.36*	0.04	-0.56*	0.04	2.72*
72 months	0.07	0.82*	0.08	-0.81*	0.1	5.08*

ENERGY						
Dependent Variable	Return		Volatility		Sharpe Ratio	
Statistic	R^2	β	R^2	β	R^2	β
1 month	0.04	4.89*	0.13	-1.13*	0.02	13.39*
3 months	0.12	5.19*	0.23	-1.08*	0.06	11.59*
6 months	0.18	5.05*	0.28	-1.1*	0.1	11.56*
9 months	0.26	5.55*	0.33	-1.17*	0.16	12.5*
12 months	0.31	5.46*	0.38	-1.24*	0.19	12.6*
18 months	**0.32**	**5.01***	0.39	-1.34*	0.2	12.1*
24 months	0.26	4.27*	0.39	-1.41*	0.16	10.27*
36 months	0.2	4.1*	0.37	-1.43*	0.14	10.21*
48 months	0.3	6.09*	0.28	-1.34*	0.26	17.05*
60 months	0.44	9.27*	0.1	-0.85*	0.41	27.47*
72 months	0.7	15.74*	0.05	0.58*	0.69	48.82*

INDUSTRIAL METALS						
Dependent Variable	Return		Volatility		Sharpe Ratio	
Statistic	R^2	β	R^2	β	R^2	β
1 month	0.06	5.26*	0.02	0.45*	0.06	34.97*
3 months	0.14	5.88*	0.02	0.4*	0.17	27.05*
6 months	0.19	5.36*	0.02	0.39*	0.22	23.61*
9 months	0.27	5.8*	0.04	0.5*	0.31	24.5*
12 months	0.32	5.61*	0.05	0.61*	0.38	24.31*
18 months	0.4	5.57*	0.1	0.84*	0.51	26.04*
24 months	0.45	5.74*	0.11	0.93*	0.57	27.02*
36 months	0.57	5.73*	0.09	0.89*	0.65	26.45*
48 months	0.62	5.75*	0.05	0.73*	0.63	25.16*
60 months	0.59	5.59*	0.01	0.36*	0.52	22.48*
72 months	**0.65**	**5.78***	0	0.05	0.54	22.41*

PRECIOUS METALS						
Dependent Variable	Return		Volatility		Sharpe Ratio	
Statistic	R^2	β	R^2	β	R^2	β
1 month	0.05	4.05*	0	0.06	0.09	45.75*
3 months	0.15	4.2*	0	-0.07*	0.19	26.48*
6 months	0.22	3.69*	0	-0.08*	0.24	21.34*
9 months	0.33	3.95*	0	-0.09*	0.33	21.48*
12 months	0.4	3.94*	0	-0.04	0.41	21.54*
18 months	**0.49**	**4.02***	0	0.1*	0.53	22.14*
24 months	0.48	3.77*	0.01	0.2*	0.54	20.6*
36 months	0.41	2.95*	0.01	0.16*	0.51	15.96*
48 months	0.26	1.9*	0	0	0.39	10.66*
60 months	0.22	1.52*	0.01	-0.21*	0.36	8.54*
72 months	0.27	1.7*	0.03	-0.45*	0.42	8.97*

Estimates of β and the R^2 of Eq. (1) by commodity sector. For example, a one-year investment horizon yields an R^2 of 23% for excess returns. $*$ indicates 5% statistical significance. The independent variable is industrial production (IP) growth of China for Agriculture, Industrial and Precious Metals, whereas for Energy, it is IP growth for the U.S.. The holding period with the highest estimated R^2 is highlighted in bold.

Estimates of Eq. (1) reveals a convincing relation between the Chinese IP growth with the variation of prices in agriculture, industrial and precious metals, as well as a relation between U.S. IP growth with energy prices. Furthermore, the estimates of Eq. (1) allows us quantify the relation of excess returns, volatility, and the Sharpe ratio for any level of industrial production growth. In Table 4, we present expected returns, volatilities and Sharpe ratios based on estimates of Eq. (1), for fixed levels of IP growth, and a holding period of eighteen-month. The levels of IP growth is fixed between 6-8% for China, and -8% to 8% for the U.S. to reflect the trend and outlook for IP growth in these economic regions. In parenthesis, we have a Nadaraya-Watson non-parametric estimate of the same quantity.

In the U.S., an IP growth stagnation is estimated to be detrimental of returns on Energy, and only an IP growth of around 2.7% would result in positive excess returns . In China, IP growth below 14% is insufficient to see long-term positive excess returns on agriculture, industrial and precious metals. The National Bureau of Statistics of China expects a 4.8% growth in the Chinese IP for 2020, and the Federal Reserve expects a 1.94% growth in the U.S. IP for the same year. With these forecasts, commodities appear to be less appealing than they may have been in the past.

Table 4: Expected Returns, Volatility and Sharpe ratio by the Level of Industrial Production for an Investment Horizon of 18-month

			AGRICULTURE				
Chinese Industrial production	Growth=6%	Growth=8%	Growth=10%	Growth=12%	Growth=14%	Growth=16%	Growth=18%
Returns	-0.23 (-0.13)	-0.17 (-0.11)	-0.11 (-0.12)	-0.05 (-0.1)	0.01 (0.11)	0.07 (0.05)	0.13 (0.07)
Volatility	0.19 (0.14)	0.19 (0.14)	0.19 (0.17)	0.19 (0.24)	0.19 (0.22)	0.19 (0.17)	0.19 (0.17)
SR	-1.34 (-0.91)	-1 (-0.8)	-0.65 (-0.74)	-0.3 (-0.37)	0.05 (0.59)	0.4 (0.27)	0.75 (0.38)
			ENERGY				
US Industrial production	Growth=-8%	Growth=-5.3%	Growth=-2.7%	Growth=0%	Growth=2.7%	Growth=5.3%	Growth=8%
Returns	-0.45 (-0.53)	-0.32 (-0.35)	-0.18 (-0.16)	-0.05 (0.13)	0.08 (0.03)	0.22 (0.14)	0.35 (0.03)
Volatility	0.42 (0.42)	0.38 (0.38)	0.35 (0.34)	0.31 (0.32)	0.27 (0.27)	0.24 (0.26)	0.2 (0.25)
SR	-1.08 (-1.26)	-0.76 (-0.86)	-0.44 (-0.44)	-0.12 (0.4)	0.21 (0.04)	0.53 (0.42)	0.85 (0.05)
			INDUSTRIAL METALS				
Chinese Industrial production	Growth=6%	Growth=8%	Growth=10%	Growth=12%	Growth=14%	Growth=16%	Growth=18%
Returns	-0.37 (-0.04)	-0.26 (-0.07)	-0.15 (-0.1)	-0.04 (-0.16)	0.07 (0.04)	0.19 (0.22)	0.3 (0.28)
Volatility	0.16 (0.13)	0.18 (0.14)	0.2 (0.18)	0.21 (0.26)	0.23 (0.26)	0.25 (0.22)	0.26 (0.25)
SR	-1.75 (-0.3)	-1.23 (-0.45)	-0.71 (-0.55)	-0.19 (-0.59)	0.33 (0.2)	0.85 (1.02)	1.37 (1.13)
			PRECIOUS METALS				
Chinese Industrial production	Growth=6%	Growth=8%	Growth=10%	Growth=12%	Growth=14%	Growth=16%	Growth=18%
Returns	-0.24 (-0.16)	-0.16 (-0.18)	-0.08 (-0.12)	0 (0.04)	0.08 (0.2)	0.16 (0.12)	0.24 (0.14)
Volatility	0.2 (0.19)	0.2 (0.19)	0.2 (0.18)	0.2 (0.24)	0.2 (0.22)	0.21 (0.19)	0.21 (0.21)
SR	-1.4 (-0.87)	-0.96 (-0.94)	-0.52 (-0.69)	-0.08 (0.09)	0.37 (0.96)	0.81 (0.67)	1.25 (0.69)

The table shows the expected returns, volatilities and Sharpe ratio by the level industrial production, for an investment horizon of 18 months. The numbers are obtained from the regression of each of those quantities on the industrial production level across the randomly drawn sub-samples. For example, at the Chinese industrial production growth of 6% per year, Agriculture is forecast to deliver an excess return of of -23% per year, for a volatility close to 19%, that is a Sharpe ratio of -1.34. An equivalent non-parametric estimate is given in parentheses. This estimate is obtained from a Nadaraya-Watson estimator, with a bandwidth parameter chosen to be equal to $\frac{1.8\sigma}{n^{1/5}}$, where σ is the standard deviation of the industrial production indicator and n the number of observation in the sample.

5 Conclusion

Our analysis reveals that there is a risk premium associated to investment in Agriculture, Industrial and Precious Metals. Moreover, the reward in terms of excess return generally increases in the length of the investment horizon. For Energy, however, we find little evidence of the existence of risk premium apart from short investment horizons lasting one- to six- month.

We hypothesize that economic activity drives the realization of risk premium, and identify the Chinese economic cycle to most appriopriately reflect price variation of Agriculture, Industrial and Precious Metals. As for Energy, its price evolution adheres most closely to the U.S. business cycle. Using industrial production as a proxy for economic activity, we estimate a linear relationship between excess return, volatility and the Sharpe ratio with industrial production growth. At the level of forecasts for growth rates in industrial production for China and the U.S., our estimates suggests negative risk premium for commodities.

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