
In this paper, we introduce a model for understanding the short- and medium-term price movements between gold and currency. Solving for gold in US Dollars, we find that the majority of price movements can be explained by just a few key drivers: real interest rate expectations, central bank policy and changes in long-term energy prices. We offer the reader our insights as to why these drivers matter, and why other drivers like “fear and sentiment” are less significant than commonly attributed.

Gold is a crucial component of savings and wealth preservation the world over. Held by individuals and institutions in every country, spanning every income segment, the monetary stock of gold is currently equivalent to many trillions of US Dollars. Markets calibrate on the value of this stock every day, yet, there are very few analytical frameworks that in our view adequately explain the trends and fluctuations between gold and currency. Solving for a finite measurement of gold priced in dynamic systems of floating currencies proves quite challenging, which leads to a multitude of anecdotes and explanations for daily fluctuations.

However, when removing the currency denomination of gold and instead comparing gold over time to the market value of energy or grams of protein, we
find that gold’s value is remarkably stable over hundreds of years regardless of currency or political regime. As we discuss later in this report, the math of this function proves that gold is a store of value, making it money by one sense of the definition, even if no longer an official unit of account (since 1971) or medium of exchange (though this last feature is being reinvented by Goldmoney.com with the advances in mobile payments and FinTech). Recognizing gold as a store of value in an energy and commodity context is critical for understanding the monetary utility of gold. The consequence of this recognition is that it doesn’t need Malthusian thinking or the notion of “fear and sentiment” in markets to explain the demand and utility of gold as money stock.

Adding currencies back into the equation, currencies being dynamic systems of debt, it becomes important to understand the link between real interest rates and the relative value of currencies. Changes in real interest rates changes the monetary demand (store of value or portfolio demand) for gold relative to a currency. In other words, changes in the macro environment impact the denominator and not just gold itself.

Exhibit 1: Forward energy prices (and not spot energy prices) drive gold replacement costs or ‘proof of value’ over longer technology cycles
$/bbl (LHS), $/oz (RHS)

Exhibit 2: The FED decision not to hike impressively demonstrates the short-term real interest rate-gold relationship
17 September 2015
10-year TIPS yield, % (LHS); $/oz (RHS)

Source: Bloomberg, NYMEX, University of Michigan, St. Louis FED, Goldmoney Research
Bringing the fundamentals of commodity-money and fiat currency together, we develop a real interest rate-energy price model to help frame market fluctuations and trends.

While our model produces a very good predictive fit, it is important to note that we do not seek to forecast gold (or currency), but instead, provide a framework for understanding the relative drivers in a dynamic, multi-variable system. Adding a long-term energy price variable to the real interest rate framework is an important contribution and helps explain why gold-USD has declined in recent years (though, not against many other currencies) despite rising asset prices, real interest rates stuck at very low levels, elevated volatility and banking risks in many economies, and central banks maintaining extraordinary experimental policies.
Approach and Results

There are two common approaches to valuing gold: through exchange rate analysis relative to other forms of money and currency, or modeled as a commodity applying changes in supply, demand, marginal costs and inventories as explanatory variables. Analyzed independently, we find that both approaches have shortcomings which ignore the fundamental characteristics of gold and currency.

1) Modeling gold as a commodity turns out to be inadequate because gold is not an input good that is consumed over time; it is money (demanded as a store of value). Changes in aboveground stocks, the main driver for fluctuations in input commodity prices, are nearly irrelevant for gold prices. Commodities are produced, used and depleted in their basic form. Gold is produced and used over and over again (in economic calculation as a result of it being money) with almost no marginal cost of reuse and never drawing down significant inventories.

2) Modeling gold based on exchange rates of fiat currencies ignores that gold is the only money that costs something to be produced, a commodity-money with a tangible replacement cost. It takes labor, energy and time to get gold out of the ground which could be used to produce other goods and services. Furthermore, gold is not backed by a central bank and its value relative to other commodities over time is not affected by a country’s financial or political stability, which are drivers of the relative values of fiat currencies.

If gold is money, then monetary demand for gold relative to fiat currencies should be the main driver for the price. In other words, when changes in the macro environment lead to a change in the size of the monetary stock of gold, it should have an effect on the price. We find that that the monthly change in the price of gold is primarily a function of monetary demand and supply for gold (COMEX net speculative positions, ETF and Central Bank net sales) and changes in energy prices, consistent with the view that gold is money. The first 3 factors impact gold prices because they directly affect the price of currency and demand for gold in a portfolio, while energy feeds into production and replacement costs and derives its monetary proof of value.
Our findings are similar to what other researchers have determined in analyzing short-term price fluctuations, particularly the link between COMEX and ETF positioning and real interest rates, which we will discuss in more detail below. However, the established view is that changes in ETF and COMEX positioning reflect changes in market expectations of supply. The argument suggests that real interest rates impact gold mine supply to which market participants react by positioning themselves accordingly via COMEX and ETFs. This is consistent with a view of gold as a commodity. However, because gold is money, we think it is more reasonable for the link between real interest rates and COMEX and ETF positions to be one of monetary demand. Further, we find that the standard gold price model can be extended and further improved by introducing an energy price component that relates to gold’s proof of value.

Exhibit 3: Our model explains monthly changes of USD-gold with just a few variables
$/oz.

Table 1: The model helps explain nearly 60% of the monthly price movements since 1996
LN monthly gold price change in , flows in million oz., oil price as LN monthly change

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Source: Bloomberg, NYMEX, University of Michigan, St. Louis FED, Goldmoney Research
Gold as a Store of Value

We see gold primarily as money: a counterparty free, tangible store of value. This is also what gold has been for most of human history. This is not surprising since gold has all the physical properties to be an ideal unit of account and store of value.

First of all, it is a metal, which seems better suited to be money then, for instance, a gas or something liquid. It is hard and not easily deformed, but still malleable and ductile and can be minted into a coin, which was important for most of human history. And it is rare. Its rarity in the earth’s crust ensures that mining absorbs substantial amounts of labor and energy. This is key, as we find later in our analysis. Furthermore, it must not pose any health risks for people, which rules out elements like uranium or cadmium. If being a metal, rare and safe are necessary prerequisites for a natural medium of exchange, what qualifies?

As it turns out, only a handful of elements: ruthenium, rhodium, palladium, silver, osmium, iridium, platinum, and gold. These metals are known as noble metals and they are resistant to corrosion and oxidation, a very useful attribute for something that is being used as a store of value. Of those metals, ruthenium, rhodium, osmium and iridium are simply too rare to be a suitable medium of exchange as not enough people have any. This leaves just platinum, palladium, silver and gold as suitable candidates. While platinum and palladium make a good store of value, their commercial production only started in the early 1900s and is very unequally distributed; South Africa alone accounts for 75% of today’s global platinum production and together with Russia for 77% of the world’s palladium production. One company, Norilsk Nickel, accounts for roughly 40% of the world’s palladium mine output, and much is produced as a co-product or by-product which introduces other value factors. This leaves gold and silver to be employed as money more broadly and, unsurprisingly, they have been used as money for thousands of years. Gold has some store of value advantage over silver in that it is less reactive, rarer and never had significant industrial application that creates short term demand volatility, but silver still acts as a store of value (and in fact demanded for its unique marginal cost step function, which we will explain in further reports). Given these factors, it is therefore quite obvious why gold naturally became the world’s premier money.
We also believe it is important to note that gold ascended as money through thousands of years of independent experiments, not by theory or creed. We only learned the details of its relative physical properties, economic frameworks, and mathematical proofs later. This is important to understand in that, even now, after being de-monetized officially, gold has mathematically performed as the elite store of value regardless of prevailing sentiments or top-down economic policy. While silver and other commodity monies, or well-managed currencies and other savings assets, may outperform gold for short periods within certain business cycles, no other form of money has outperformed gold over the average savings cycle of a human lifetime (we will further explore the proof of this statement in upcoming reports).

(A more detailed examination of the physics and anthropological explanation for gold as money can be found at https://www.goldmoney.com/why-gold)

**Gold and Currencies**

Because gold is money, its price in a currency is simply the exchange rate to that currency. If the exchange rate of that currency changes, it also changes its relative value vs gold. For example, a decrease in value of the USD against the Euro, the Yen and the Chinese Yuan should result in a decrease vs gold. Thus, a gold pricing model that tries to explain changes in the price of gold in one currency could simply use exchange rates between fiat currencies as explanatory variables. However, with this approach, some important characteristics of gold are being ignored.

- Fiat currencies do not cost anything to produce in a direct sense (coins may be rather costly to make but they constitute a very small share of most currencies in circulation); hence production costs have no impact on a currency’s value. Gold, however, will necessarily have to reflect its extraction costs such as labor, energy and other raw materials going into the production process. Energy is an important factor of the production costs of gold; hence, gold should reflect the market’s expectation of future energy costs as will be illustrated further along. This, from our point of view, plays an important role in why gold can maintain its buying power for energy and goods that require energy as large portion of
their production cost (as opposed to services and downstream marketed-products). The labor, energy and time that go into the production of gold could be used to make something else: a house, a car, or even food commodities. Therefore, the production of gold comes always at the expense of something else (but unlike gold, everything else depreciates or deteriorates over cycles without a maintenance cost, and therefore has a different long-term value or utility).

- Another important differentiation is that fiat currency is tied to a country’s financial soundness. Arguably, a fiat currency’s relative value should reflect this over time, but with gold it is different. Gold is not backed by a central bank; there is no Treasury behind it, and its value is not affected by a country’s financial or political stability. Thus, there is more to the price of gold than just other currencies’ performance.

- Explaining the move in gold prices by fluctuations in currencies gives little information to investors. The concept that gold in USD goes up when the USD goes down does not help anybody to get a better understanding of what underlying drivers are.

**Gold as a Commodity**

A different way to look at changes in gold prices is to look at it as a commodity. Commodities, in the narrow sense, are raw materials that are used as inputs in a production process. Commodities might slightly differ in quality but are generally standardized and interchangeable. Examples are crude oil, soybeans and copper. Gold is mined like other metals, often by the same companies. It is an element which is clearly standardized, probably more so than any other commodity and, thus, it might be reasonable to model gold prices like other commodities. Commodity prices can typically be modeled in a two-step process: longer-dated prices are driven by the marginal cost of future supply and set the anchor point around which spot prices fluctuate. The spread between longer date and spot prices – the shape of the curve – are then a function of inventory levels. This will be explained in more detail below.
Long term prices…

Future production costs of a commodity act as an anchor point for pricing. Long-term prices should reflect long-term production costs plus some return for the producer. The world’s future production capacity is dependent on three factors: the current capacity, the expected decline rate of the current capacity, and incremental supply from new projects. The first two are more or less given: current capacity is fixed, while decline rates are a function of geology. Decline rates can fluctuate with prices, but only when prices reach extreme levels. The reason for this is that commodity production is typically characterized by large capital costs and relatively low operating costs. For example, building an oil platform is expensive, but once it is built, operating it is inexpensive. When output at a mine or an oil well starts declining, producers can spend more or less money to manage decline rates. Yet, overall decline rates are determined by geological conditions more than anything. Only when prices fall to very low levels and remain there for a prolonged time, commodity producers will stop spending money on maintenance of existing infrastructure, which will lead to an acceleration of decline rates. Hence, the third factor – incremental supply from new projects – is normally the most important driver for future supply. Incremental supply from new projects depends on how much companies invest, which is a function of price and cost expectations. Production companies will only invest in those projects that are economically viable in the future. Therefore, the forward price has to be at a level at which enough projects are sanctioned to meet the expected future demand. This can be illustrated in a diagram where cumulative future supply is displayed at the horizontal axis and costs at the vertical axis.

As longer-dated prices increase, more and more projects become economically viable and cumulative future supply increases. The longer-term price has to be at a level where future supply meets the expected demand (see Exhibit 4). The longer-term price is typically much more stable than the spot price of the commodity (see Exhibit 5).
This is because the drivers of longer-term prices – technological changes, changing expectation for longer-term input costs and changes in the longer-term demand outlook – typically change only slowly over time. Spot prices, on the other hand, are primarily driven by inventories (as will be discussed in more detail in the next paragraph), which can fluctuate significantly in the short run.

...and inventories

The second step in the process of modeling commodity prices is to get from longer-dated prices to the spot price. In commodity markets, one can buy the physical commodity at spot, or one can buy it forward. A forward contract (or a future, for simplicity) allows one to buy or sell a particular commodity or financial instrument at a pre-determined price at a specific time in the future. Forward prices can be lower or higher than the spot price, for reasons that will be explained later. The forward curve consists of a series of forwarded prices plotted together (see Exhibit 6). Consequently, to get from the long-dated price to the spot price, we need to understand what drives the shape of the forward curve. In our view, the shape of a commodity forward curve is simply a function of inventories. A consumer of a commodity, for instance an airline that consumes
jet fuel, is willing to pay a premium for immediate delivery when inventories are really low. The alternative is to run out of the commodity (the jet fuel), which will lead to a shutdown of the business (planes stay on the runway). A shutdown is extremely costly for any business and needs to be avoided at almost any cost. Hence, for a commodity with low inventories there is willingness by consumers to pay a premium for instant delivery rather than for delivery at some point in the future. However, consumers will assume that a current shortage will be alleviated over time as high prices will trigger a supply response (refiners will shift the yield towards producing more jet fuel). Thus, in an environment of very low inventories, spot prices tend to be the highest and the curve gradually declines; the commodity is said to trade in Backwardation.

A commodity with high inventories typically shows a different shaped futures curve. In the absence of any risk that the input good would run out, consumers are unwilling to take immediate delivery. Storing a commodity costs money in the form of storage, insurance and opportunity costs. Consumers, therefore, need an incentive in the form of a discount to accept immediate delivery and pay for storage themselves. In such an environment, spot prices tend to be lower than longer-dated prices; the curve is said to trade in Contango. In exceptional cases, when inventories are very high and supply continues to exceed demand, the Contango can reach extreme levels as there is now a risk that existing storage capacity will be insufficient. The discount of near-dated prices will reach a level where producers begin to shut in production as prices fall below cash operating costs.

Hence, the level of inventories determines the discount/premium to the long-term price (see Exhibit 6). The higher the inventories, the larger the discount required and vice versa. This relationship between inventories and the shape of the forward curve is one of the strongest across most commodities (see Exhibit 7). Over the entire curve, shapes can also change, from Contango to Backwardation and vice versa. This is more typical for commodities with seasonal variations in either supply or demand.
Exhibit 6: Contango and Backwardation in commodity forward price curves
$/bbl

Exhibit 7: For most commodities, changes in stocks drives changes in the forward curve
$/bbl, Brent crude oil, year-over-year change (LHS); Million barrels, year-over-year change (RHS)

So, why not model gold prices just like a commodity? In our view, gold prices share one aspect with other commodities. The cost of production should be reflected in the price. If the price of gold is below production costs, mines will eventually close and gold supply will decline until supply and demand find a new equilibrium. If gold is priced well above current production costs, investment will flow into the development of new mines and eventually supply will catch up. However, inventories, the main driver for fluctuations around the longer-term price for commodities, are normally not important to the price of gold. (We will discuss the role of mine supply and marginal cost dynamics in more detail in a later report, as we believe this market also functions in some different ways from input commodities.)

Unlike most commodities, gold is not really consumed. According to the World Gold Council, gold demand in the first 6 months of this year was 2100 tonnes. Jewelry – whether possessed for adornment or store of value reasons – accounted for 56% of that amount, demand from Exchange Traded Funds (ETFs) together with demand for bars and coins was 22% and central banks absorbed a further 12%. Only 8% was used in tech-products such as electronics, and much of that will later be recycled. If we assume that these percentages generally reflect how
the aboveground gold stock is put to use, it means that the vast majority of the
world’s gold production ends up in liquid inventories that are easily saleable (In
India, the world’s largest importer of gold, gold jewelry is a very important form
of savings. Gold jewelry is simply another form of inventories). As a result, most
of the gold mined throughout history comprises its aboveground stock (about
170,000 tonnes by common estimates), most of which is still readily available for
sale at what its owner believes to be the right price depending on currency values,
savings horizons, or other asset prices. Aboveground stocks, therefore, only
change with new mine output, which is about 8 tonnes per day. It becomes
rather obvious why changes in aboveground stocks have a very limited impact on
the price of gold. This is a major difference to a commodity like oil, where in the
long run, inventories neither build nor draw and all oil produced is irrevocably
consumed and disappears as it is either burned as fuel or turned into plastics.
Gold does not disappear; it is accumulated, which is the fundamental human
action that substantiates gold as money.

This highlights an important differentiation between an input commodity and
gold. Commodities are produced, transported, stored, consumed and then
disappear (or have some recycling/repurposing cost relative to their use cost).
Gold is produced and used over and over again (in economic calculation as a
result of it being money) with almost no marginal cost of usage, little
maintenance or holding cost, and never disappears. Gold is accumulated because
of its usefulness as money (a store of value relative to other commodities that are
used and disappear). So, while commodities and gold share the common trait of
both being a tangible asset with a marginal cost of replacement, this is where the
comparison ends from a pricing model perspective

Proposing a gold pricing model

As illustrated above, changes in aboveground gold inventories are not a major
driver of gold prices. The traditional commodity pricing model (longer-term
price set by production costs while the shape of the curve is driven by
inventories) is, therefore, inadequate to explain changes in the price of gold. If
gold is money, then monetary demand for gold should be the main driver for the
price. In other words, when changes in the macro environment lead to a change
in the size of the monetary stock of gold, it should have an effect on the price. We find that the **monthly change in the price of gold is primarily a function of monetary demand and supply for gold (COMEX net speculative positions, ETF and Central Bank net sales) and changes in energy prices** (see Exhibit 8 and table 2), consistent with the view that gold is money. Thus, the bulk of changes in the price of gold are driven by changes in demand and supply of gold relative to changes in the demand and supply of the currency being used to measure the gold price. It is only the monetary demand and supply that matters. This is different from commodities, where prices are a function of inventories and fluctuations in inventories are the result of aggregate demand and supply.

Further, we find that the main drivers of changes in the monetary stock are real interest rates and central bank policy such as Quantitative Easing (QE) and gold sales.

Our findings are similar to what other researchers have concluded, particularly the link between COMEX and ETF positioning and real interest rates, which we will discuss in more detail below. However, the established view is that changes in ETF and COMEX positioning reflects changes in market expectations of supply. The argument suggests that real interest rates impact gold mine supply to which market participants react by positioning themselves accordingly via COMEX and ETFs. This is consistent with a view of gold as a commodity. However, because gold is money, we think it is more reasonable that the link between real interest rates and COMEX and ETF positions is one of monetary demand. Further, we find that the standard gold price model can be extended and further improved by introducing an energy price component.

The model we propose does not predict a price level, but simply helps to understand how prices will change if the underlying parameters change. For example, we find that the near $100/oz decline in the price of gold over the past 12 months can be largely be attributed to the sharp drop in longer-dated oil prices. It is also useful to do the reverse, determining how the underlying parameters have to change in order for gold to increase or decrease by a certain amount. In an upcoming report, we will show what has to happen for gold to drop below certain levels and discuss how likely this is.
Exhibit 8: Gold prices follow COMEX and ETF positions, CB net sales and oil prices
$/oz.

Table 2: The model explains nearly 60% of the monthly moves
LN of monthly gold price change in, flows in million oz., oil price as LN monthly change

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Source: Bloomberg, NYMEX, University of Michigan, St. Louis FED, Goldmoney Research

The drivers

As we outlined above, gold price moves are mainly driven by changes in COMEX net speculative positions, ETF holdings, central bank net sales and longer-dated oil prices. The first 3 factors reflect monetary demand and supply for gold. There is also non-monetary demand and supply for gold: demand can come from the tech sector and jewelry (though jewelry can also be seen as a store of value), supply can come from recycled metal and from the mining sector. However, we find that changes in these factors do generally not impact the price of gold. In fact, jewelry buyers and recycled metal sellers are simply reacting to the price rather than setting it. The last factor is energy. Gold is money, but unlike fiat currencies it is a commodity money. It costs something to produce, and energy is a major factor. This means in reverse that energy prices in gold will remain stable over time. We will discuss each driver below.
As you probably noticed, one source of demand is missing from the above analysis: gold’s role as currency. Gold in circulation as currency does not create demand for gold, but increasing its use as currency would. While gold has never stopped being a store of value, it’s importance as a medium of exchange and unit of account has declined over decades. Arguably, demand for gold coins is and has been strong for years, but their purchase reflects savings demand. After all, money can be spent or saved, and gold coins have become a savings vehicle - and not expected to be used as a means of payment in commerce. But as our clients know, we are working hard to improve and enhance gold’s usefulness as currency.

COMEX demand

We find that changes in the net positioning of non-commercial traders (often referred to as net specs) at the Commodity Exchange Inc. (COMEX) are one of the main drivers for changes in the gold price. Our analysis shows that changes in net spec positioning is one of two market mechanisms that bring information about changes in real interest rate expectations into the price of gold. Real interest rates are nominal interest rates minus inflation, and we will explain this in more detail later. It is also a mechanism that brings information about central bank policy such as Quantitative Easing (QE) into the gold price. Historically, gold prices and real interest rates have traded almost 1:1 (see Exhibit 9). However, this relationship broke down over the past couple of years. More specifically, gold prices have increased less than what real interest rates would have implied. The reason for this breakdown lies in the FED’s Quantitative Easing program.

The FED announced on November 25, 2008 that it will initiate a program to purchase up to $600bn in Mortgage backed securities, which was extended by a further $1050bn in March 2009. QE2 was announced on November 3, 2010 and involved buying $600bn of US Treasuries. After QE2 “Operation Twist” followed in September 2011. Operation Twist was different from QE1&2 in that it did not require expanding the FED’s balance sheet. Instead, the FED sold short-term Treasury bills and bought long-term Treasury bonds, which pressured long-term bond yields downward. Finally, a third round of quantitative easing, “QE3”, was
announced on September 13, 2012, which started a $40 billion per month, open-ended MBS purchasing program. This was later increased to $85bn in December.

Exhibit 9: COMEX non-commercial net length follow real rates but QE led to a level shift
Million oz. (LHS), % TIPS yield (RHS)

Source: Bloomberg, University of Michigan, St. Louis FED, Goldmoney Research

2012. On June 19, 2013, FED chairman Ben Bernanke announced that the FED could start tapering the program, contingent upon continued positive economic data. Purchases finally halted on October 29, 2014. At that point, the FED’s balance sheet had accumulated $4.5 trillion in assets, from about $700-800bn before the QE programs began.

We can build a model which predicts COMEX non-commercial net long positions with a regression using 10-year TIPS yields as well as inputs for the various QE measures (see Exhibit 10 and table 3). The QE inputs capture the announcement and the size of QE measures, not the flows. Such a regression explains COMEX spec levels quite well. Both the QE3 and the Taper announcement variables show lower statistical significance. The FED’s communication in regards to QE3 and tapering was much more ambiguous than when QE1&2 was announced. For QE3, the FED simply stated that it would
purchase $40bn of assets a month, but gave no ending date, which made it impossible for the market to estimate the whole impact of the program at the time of announcement. When the FED announced it would taper, it was somewhat similar. Initially, FED chairman Ben Bernanke simply stated that the FED could begin tapering later that year (2012) if its forecasts for inflation and unemployment are correct. This vague language persisted in subsequent communication with the result that the market only gradually changed its forward view. While QE3 and tapering probably had an impact on COMEX positioning and gold pricing, the way the information fed into the market, makes it difficult for a model to capture.

ETF demand

Changes in ETF holdings are another important driver for changes in gold prices. A 1 million oz. of sale / purchase by ETFs impacts the price of gold by about 0.83%. ETFs are relatively new when compared to gold trading at the exchanges, and initially, ETF demand was uncorrelated to any macro drivers. But more recently ETF positioning is also following real rates and similar to COMEX net

Exhibit 10: COMEX net spec positions are driven by TIPS yields as well as QE announcements

Table 3: COMEX net spec positions regression model output
spec positioning, where QE led to a level shift. This means that the QE announcement had a larger impact on real interest rates than COMEX net spec and ETFs. But after the announcement, they moved in tandem again, just from a different level.

We can again use a regression with TIPS yields and QE as input variables and get a reasonable fit (see Exhibit 11). Hence, there are two mechanisms – COMEX net spec length and ETF holdings – through which information about changes in real interest rates and other central bank policy are transferred into the gold price.

Exhibit 11: Similar to COMEX net spec length, gold ETF holdings are primarily driven by real rates and FED policy such as QE

Million oz. (LHS), % TIPS yield (RHS)

Source: Bloomberg, University of Michigan, St. Louis FED, Goldmoney Research

Why real interest rates matter

As we have illustrated earlier, both COMEX net speculative positions and ETF holdings are driven primarily by real interest rates. To recall, real interest rates are measured as nominal interest rates minus inflation expectations. It is the
expected real yield of a 10-year Treasury note. In other words, what is the expected purchasing power of that investment in 10 years? The easiest way to track real interest rates is via Treasury Interest Protected Securities (TIPS). TIPS pay a nominal interest, but the principal increases with inflation and decreases with deflation. TIPS are traded and, thus, changes in nominal interest rates or inflation expectations should be reflected in TIPS yields. However, the inflation measure utilized to adjust the principal is the Consumer Price Index (CPI). Whether or not the CPI is tracking inflation accurately is a hotly debated subject, and we will dive into this in future reports. For this framework, we used TIPS to measure real rates, being well aware of the potential shortcomings.

The important relationship between real interest rates and gold prices has been highlighted by researchers preceding us, but we would like to provide some alternative ways to explain why real rates matter. One of the proposed explanations was that producers may react to falling real interest rates by mining less gold and vice versa. Higher real interest rates would lead producers to discount the future more heavily and, thus, trying to extract as much gold now as possible. In an environment of low real rates, producers discount the future less and, therefore, have more incentive to leave the gold in the ground. While mine supply data does in fact show that gold production and real rates move in tandem over very long cycles, this explanation is somewhat counter-intuitive. If real rates drive up gold prices, intuitively, one would think that gold miners will seize the opportunity and produce as much gold as they can when prices are high. Also, if prices are high and financing is cheap, one would expect miners to invest a lot in future production. Low real rates should lead to more future production and the market should be able to factor that in.

Our first alternative suggested explanation is that investors and savers have something like a natural allocation to gold in their portfolio. For the purpose of this explanation, we assume that this is on average 10%. If people hold gold in the portfolio, not just for diversification but for safety, they will not lend that gold out. However, holding gold and not lending it out generates no interest. Interest can only be achieved by taking a risk. For example, your bank pays interest on your money in your savings account, but it can only do that because it lends your money out at a higher interest rate. As a consequence, the interest on your money in the bank comes at the risk that your bank will not be able to repay you when you ask for your money to be returned. One can also generate interest on
gold by lending it out, but that interest is earned by accepting counter-party risk. Therefore, holding gold in a portfolio and not lending it out comes at a cost. A small fraction of that overall cost is for storage and insurance, but the main apparent cost is opportunity costs for foregone interest. This opportunity cost is larger, the higher real interest rates are. Hence, investors are less willing to hold a lot of gold when real rates are high, but would be likely to increase their holdings closer to their natural allocation of 10% when real rates are low. Importantly, if on aggregate people want to increase their gold allocation, there is nobody there to buy from. On aggregate, it is not possible to increase the amount of gold (in grams) in all portfolios at the same time as gold must come from somewhere. The only way that the entire population can increase their aggregate gold allocation is for gold prices to rise relative to all other assets in the portfolio. In other words, the quantity of grams does not change, but a rise in the price of grams increases the value of gold measured as a percentage of the portfolio’s total value. This is consistent with our view that gold is money and that the price of gold should, therefore, be driven by monetary supply and demand for gold.

The second alternative suggested explanation is to look at it from a currency perspective. Falling real interest rates should, in theory, lead to a weaker currency and thus reduce demand for that currency. For example, when real interest rates fall in the US, the USD should become weaker relative to other currencies and monies, including gold. With emphasis on “in theory” as in reality, exchange rates are driven by a whole host of factors including the perceived financial and political stability of that country, its trade balance and more. Again, this approach is consistent with the view that gold is money and, therefore, the price of gold should be driven by monetary supply and demand.

Central bank net sales

In our view, changes in central bank gold holdings are often politically or ideologically driven and are not correlated to specific changes in the near-term macro environment. Central banks were net sellers of gold until around 2008 (see Exhibit 12). These sales came predominantly from developed nations. Since 2008, central banks have been net buyers of gold as developing countries began to accumulate gold while developed countries stopped selling. Central bank
purchases do have an impact on the price of gold, but less so than private portfolio demand. According to the results of our regression analysis, a net sale of 1 million oz over 1 month impacts the price of gold by just about 0.1%. However, of all the parameters we identified that drive gold, net sales by central banks was statistically by far the weakest, and it only mattered when we measured changes over 2 months rather than 1.

Exhibit 12: Starting in 2008, emerging market central banks started buying gold, reversing the trend
Million oz.

Source: Bloomberg, IMF, Goldmoney Research

This could be due to the nature of the reported data. Central banks tend to keep their cards close to their chest and, thus, sales and purchases are often reported with a significant time delay or sometimes not at all. Purchases by the Chinese central bank over previous years are a prime example. As every central bank has different interests and reports differently, the 1-month lagged variable we introduce does an insufficient job capturing this accurately, but is the best we could do with published reporting shortcomings. Due to the nature of the data, our model is likely to understate the true impact of changes in central bank stocks.
As outlined earlier, there is also non-monetary supply and demand; jewelry demand and demand from the tech sector as well as supply of recycled material and mine supply. We find that these factors normally do not impact the price of gold.

**Jewelry demand**

Jewelry buyers are typically price takers not price setters. Jewelry demand and prices inversely correlate. Obviously, that does not mean that higher demand from jewelry buyers depresses the price, it is the other way around; higher prices are likely to depress jewelry demand. It works the same way in the other direction as well; lower prices generate jewelry demand. Hence, jewelry demand acts more like a cushion, offsetting other drivers that push the price in one direction. Further, while jewelry itself is often purchased as a store of value, the largest markets for these purchases are typically markets where purchases are not timed specifically as a reaction to short term fluctuations in currency. Jewelry demand has, therefore, no explanatory value for the changes in gold prices.

**Mine supply**

We find that mine supply stands out from other supply and demand sources. Short-term changes in mine supply do not seem to affect the price of gold. Fluctuations in production from one month to the next are natural and not something the market is overly concerned about. Again, this is very different from other commodities. In the petroleum sector for example, an unexpected shutdown of a refinery can have a huge impact on the pricing of petroleum products such as gasoline and diesel, even if the refinery is offline for just a few weeks. The reason is, again, that commodity prices are primarily driven by the level of inventories. Because the ratio of commodity stocks to production is so much lower than it is for gold, short-term disruptions in production matter.

However, changes in supply could matter if the disruption in gold production is part of a broader issue, for example, if a major accident occurred in a large mine,
leading to the permanent closure of the mine, or war breaks out in a major gold producing region. These events could alter the long-term supply outlook for gold at current prices (or to be precise, at current forward prices), or shift the replacement cost of gold. In order to achieve the same supply in the future, some projects that have so far been uneconomical at current prices will have to become economical in order to replace the lost future supply. The impact from longer-term supply disruptions could, therefore, feed into the price via the future marginal supply cost curve (similar to how longer-term oil prices change with changes in the marginal cost curve of future supply) and not via flows. Unfortunately, this is something that is very difficult to measure. While we can track central bank gold sales or ETF demand with simple time series, the same cannot be resolved for how the market reassesses a long-term supply disruption.

As a result, the effect of these permanent supply shocks cannot be captured by our model. What we do know, however, is that these shocks rarely work to the downside. In other words, it does not happen very often that we find a very prolific source of gold that substantially shifts the overall marginal future supply cost curve downward. The last bonanza gold discovery occurred in the 19th century.

Recycled supply

Fashions change, hard times force the sale of jewelry, and electronic products are recycled rather than sent to the dump. Yet, sellers of recycled gold are also price takers, rather than price setters. Recycled supply increases when prices go up and decreases when prices go down. In that respect, it is the equivalent of jewelry demand on the supply side. Thus, recycled supply tends to cushion price declines and temper price increases rather than being the driver of it. We, therefore, do not use recycled supply as input parameter in the model. Again, this is an example of gold prices not being a function of short-term inventory changes as seen in other input commodities.
Energy prices

The last piece in the puzzle is energy prices. Our model shows that longer-term oil prices – we used the 3-year forward price for WTI crude oil in order to have an adequate time series – are significant. This comes as no surprise to us as energy is the dominant production cost for gold (both direct and indirect), which also helps define its proof of value. The labor, energy and time that go into the production of gold could be used to make something else. However, unlike the alternative input-commodity, when energy goes into producing gold this commodity-money can be reused over and over with very little marginal transaction cost, giving it very high utility as a monetary stock over time. This usefulness, from our point of view, plays an important role in why gold can maintain its buying power for energy and goods that require energy in the production process (see Exhibit 13 and 14). As an example, 1 barrel of oil in 1921 cost on average 2.6 grams of gold, the same as 2014. In US dollars, however, one barrel of oil went from $1.73/bbl in 1921 to $98.95/bbl in 2014, an increase of almost 6000%.

Exhibit 13: Unlike for USD, oil priced in gold did not change much in almost 100 years
$/bbl and gold/bbl (indexed to USD oil price in 1920)

Exhibit 14: The price of oil in gold has been remarkably stable over time (even smoother if forward prices used instead of spot prices)
Grams/bbl (3-year moving average)

Source: Bloomberg, BP, Goldmoney Research,

Source: Bloomberg, BP, Goldmoney Research,
Arguably, petroleum is not the most important energy cost factor for a gold mine, electricity is. Unfortunately, electricity price data is not as straightforward as oil.

Firstly, a global price for electricity does not exist. Oil has the benefit that the same quality of oil has roughly the same price anywhere on the planet. Price differentials at retail level for refined products such as diesel and gasoline are mostly a consequence of taxes and local distribution of products. Oil can be moved relatively easily and inexpensively and any arbitrage opportunity would be quickly exploited. Electricity is fundamentally different as it can only be moved through power lines. As a result, there is a myriad of domestic power prices which make it impossible to track “the price” of electricity.

Secondly, gold production is relatively concentrated by structural geological conditions and production happens mainly in emerging markets, as for example China, which is the largest producer at this time. Electricity prices in these countries are hard to observe and subsidies, often hidden, make it virtually impossible to measure and compare prices between countries. Fortunately, oil still does a decent job tracking power prices.

Coal, which is the main source of fuel for power production, is often moved by trains running on diesel and bulk carriers that burn bunker fuel to move seaborne coal. Mining coal is also in itself oil intensive. Further, as oil has the highest energy density and easily transported, futures prices tend to settle the short term arbitrages of many local power markets. Hence, fluctuations in the price of oil correlate well with other energy and electricity prices, particularly over time.

Our regression of monthly changes in the price of gold shows that longer-dated oil prices are a statistically significant factor to explain monthly changes in gold prices. However, while significant, the coefficient is relatively low, roughly 10. This means that a 10% change in the long-term price of oil moves gold by only 1%. Yet, this is probably due to the fact that changes in energy prices require time to feed into the gold mining cost curve. Analyzing month-over-month changes cannot capture this. We, therefore, ran a regression on year-over-year changes using the same input variables. In this regression, longer-term oil prices show a higher statistical significance with a coefficient of 22 (see Exhibit 15 and table 4).
This means that every 10% increase in the price of oil pushes gold prices 2.2% higher. The 35% decline in the price of longer-dated oil over the past 12 months has, thereupon, impacted gold prices by 11% or roughly $135/oz.

Exhibit 15: Changing the analysis from month-over-month to year-over-year changes...
% change year-over-year (LN)

Table 4: ...better captures the importance of long-dated oil prices on gold prices
LN of monthly gold price change in %, flows in million oz., oil price as LN monthly change

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<thead>
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<th>Coefficients</th>
<th>t-Stat</th>
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<td>Intercept</td>
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<td>COMEX</td>
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<td>CB net sales</td>
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<tr>
<td>ETF</td>
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<tr>
<td>Previous year price change (squared)</td>
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<td>LT oil price</td>
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<td>R Square</td>
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<td>Adjusted R Square</td>
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<td>Standard Error</td>
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<td>Observations</td>
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</table>

Source: Bloomberg, University of Michigan, St. Louis FED, Goldmoney Research

This correlation holds an important implication. If energy costs feed directly through into the price of gold, and gold can be used again and again with very low maintenance or holdings costs, then gold can act as store of value that protects the purchasing power of savings against all other goods requiring energy. If gold prices increase with energy prices, then gold will retain its purchasing power for goods that require energy to be produced, which is basically everything. Gold is the only form of money that achieves this consistent purchasing power naturally, defined by the physics and geology of earth’s crust, independent of any political or fiat currency system and independent of centralized economic planning. In an upcoming report we plan to dive deeper into the importance of energy for the price of gold as it is an important building block to understand why gold maintains its purchasing power in the long run.
Aboveground stocks have so far not mattered

As we highlighted earlier, gold is different from a commodity in that it is not consumed. Gold is produced and used over and over again and never disappears, which is why aboveground stocks only grow. Unlike other commodities, short-term fluctuations in aboveground stocks do not impact the price. But do gold inventories not matter at all? We find one particular type of stock, COMEX registered inventories, do have an impact on price. So far, it was small, but it could potentially be larger.

As for other commodities, there is an active futures market for gold. COMEX is the largest futures market, and gold can be traded as far as 5 years out. While the shape of the forward curve for most commodities is simply a function of stocks, for COMEX gold it is mainly interest rates and to a much lesser extent stocks. More specifically, under normal circumstances, spreads between long-dated gold prices and the front month can largely be explained by US interest rates as measured by the rate on 1- and 10-year Treasury bills. Near end spreads, however, such as 1-2 month forward spreads are also driven by COMEX registered stocks.

Intuitively, the first finding makes sense. Forward rates should reflect the differential between nominal interest rates and interest paid on lending gold (lease rates), otherwise there would be an arbitrage opportunity. Simply speaking, if one can borrow money for 2% and lend gold out at 1%, the 12-month forward gold price should trade 1% over spot. If the forward price for gold is much higher than that, for instance 5% over the spot price, one could borrow $100 at 2%, use the money to buy gold at the spot market, lend it into the market for 12 months and sell gold 12 months forward. In 12 months, that person would first receive the gold back plus the 1% lending fee, of $10, deliver the gold against the short forward position (receiving $105) and use the proceeds to repay the loan plus interest ($102). The result would be a risk free return of 4% or 4% with no capital required.

In the example above, the buying of spot gold and selling of forward gold would put upward pressure on spot prices and downward pressure on future prices until both are in equilibrium. The shape of the gold forward curve should therefore be a function of the spread between gold lending rates and borrowing costs. We find that the longer-dated spread between the two is itself driven

*The commonly used term for lending gold is leasing, and lending rates are referred to as lease rates. However, as we view gold as money, we prefer the term lending and lending rates and will use this terminology throughout the report.
mainly by nominal interest rates. When nominal interest rates rise, the spread rises and therefore the Contango in the gold forward curve steepens. The relationship between the spread of the 5-year time spread (measured by 5-year swap rate) and interest rates can be evaluated with a regression analysis. The results of this analysis, as presented in Exhibit 16 and table 5, show that 1-year and 10-year Treasury bill rates can explain 90% of the spread.

Exhibit 16: The spread between the 5-year forward and the 1-month forward gold price...
% premium of the 5y over 1m forward price

Table 5: ...can largely be explained by nominal interest rates

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<th>Coefficients</th>
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<td>1-year T-bill rate</td>
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<tr>
<td>10-year T-note rate</td>
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<td>R Square</td>
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<td>Adjusted R Square</td>
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<tr>
<td>Standard Error</td>
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<td>Observations</td>
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Source: Bloomberg, COMEX, Goldmoney Research

In a preliminary regression, we also used COMEX stocks as an input variable. However, COMEX stocks had limited explanatory value to predict the longer-term spread. This changed when we looked at near-dated spreads. 1-2-month, 1-3-month and 1-12-month time-spreads (COMEX future contracts) are still mainly driven by the 1-year Treasury bill. But unlike the longer-dated spreads, COMEX registered stocks turn out to be important. The result of this regression are shown in Exhibit 17 and Table 6.

This outcome also makes intuitive sense. The risk for a COMEX short position to be unable to deliver at expiry increases with lower inventories. This has a direct impact on the nearest-dated futures contract, and potentially on other near-dated contracts as well. But further out the curve, low inventory is less of a
problem, and the market expects that it will be resolved by the time these contracts approach expiry. Given how much gold inventory there is available outside of COMEX registered stocks (by re-melting bullion or recycling from non-COMEX sources and delivering in after a few months), the market has no reason to believe that low stocks are a sign of any structural issues. Instead, the market will normally assume that a near-term shortage of COMEX registered inventories will be overcome by a rising gold price that eventually is high enough to induce owners to sell their metal and hold USD instead. This is different from other commodities, where low stocks reflect structural issues that need some time to be resolved (via supply increase or demand destruction).

Exhibit 17: Near-dated spreads are driven by COMEX registered stocks and 1-year T-Bill rates…% premium of the 5y over 1m forward price

Table 6: …as low stocks increase the risk for COMEX short positions

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<td>COMEX registered stocks</td>
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<td>Standard Error</td>
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<td>243</td>
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Source: Bloomberg, COMEX, Goldmoney Research

The takeaway from this analysis of aboveground stocks is that for gold pricing, inventories normally play a minor role. Only COMEX registered stocks matter and they only matter for the short end of the forward curve.

The traditional commodity model tries to predict spot prices as a function of the forward curve. In other words, the spread between the spot and very long-dated forwards matter. Because gold stocks only drive the very short end of the curve, and as changes in these spreads have been relatively small compared to the
overall volatility in the gold price in the past, inventories cannot explain larger moves in the gold price. This can be shown with the results of our regression analysis. In a regression analysis of 1-12-month gold time-spreads against 1-year T-Bills and COMEX registered inventories, COMEX stocks are still statistically significant with a t-value of -13.00 and a coefficient of -0.71. This means that a change of COMEX registered stocks of 1 million oz. changes the spread between the 1-month and the 12-month forward price by 0.71%. To put this into context, at today's price, a 1 million oz. decrease in COMEX registered stocks today would increase the price by only $7.84/oz. The regression model explains the shape of the gold curve reasonably well. However, intuitively, changes at very low stock levels might matter much more than at high levels. For example, 50,000 oz. drop when stocks are at 100,000 oz. is a much larger drop in percent than when stocks are at 1 million oz. We, therefore, ran a second regression analysis on the year-over-year change in the 1-12m time-spread (natural log) vs year-over-year changes in 1-year T-bill rates and COMEX registered stocks. The coefficient for changes in COMEX stocks is 0.86. This implies that drop of COMEX stocks by 50% from currently 0.16m to 0.08m would increase the 1-12m time-spread by about $5/oz and push the 1-12m spread into Backwardation. This would be unprecedented from a spread perspective, but from a flat price perspective, a $5/oz move is still not that large compared to overall price moves.

However, even this second analysis may fail to predict potential explosive moves in spreads when stocks reach ultra-low levels. More specifically, when inventories drop to levels where short positions struggle to get gold for delivery, there could be a situation where front month gold prices spike sharply. This has happened in other commodity markets, but we lack any historical examples for the gold futures market. For example, until recently, the maximum backwardation in COMEX 1-2-month futures was 0.3% over the past 30 years. As for comparison, the highest recorded backwardation in oil was 16.9%, in natural gas 45.5% and in corn 49.5%. More recently, COMEX registered stocks have fallen to extremely low levels, which has pushed the very near end of the curve into Backwardation. Moreover, COMEX registered stock to non-commercial short positions has risen to record levels (see Exhibit 18). While this has all sorts of implications for the gold market, the current Backwardation is still relatively small and the overall effect on prices still negligible at this point.
Unfortunately, because there are no historical examples where ultra-low stocks led to a wider Backwardation in gold futures, aboveground stocks cannot be incorporated in our gold price framework. The COMEX gold market is arguably different from other commodity markets such as oil or gas. For example, while registered stocks are very low, eligible stocks are very high. Eligible COMEX stocks and ETF holdings show very similar patterns (albeit ETF holdings are far larger), indicating that large parts of eligible stocks are held by ETFs. Hence, there are stocks available, but COMEX shorts might have to convince ETF holders to sell it to them. Therefore, it cannot be foreseen how spreads react if we suddenly have a real shortage at hand. Yet, aboveground stocks, or particularly COMEX registered stocks, could be one of those factors that do not matter, until they suddenly do.

**Exhibit 18: The ratio between COMEX non-commercial short positions and registered stocks has reached unprecedented levels**
Registered stocks in oz./ non-commercial short position in oz.

*Source: Bloomberg, University of Michigan, St. Louis FED, Goldmoney research*

**Bringing it all together**
We believe that we have developed an original framework and price model to analyze the relative movements in the USD gold price. While others before us have identified the short term correlations and rationale for gold prices tracking real interest rate markets, many of these existing real interest rate models have not explained why gold prices have come off trend while real rates are stuck at very low levels. We believe the key to understanding these longer term trends is found in an energy “proof of value” framework, and understanding the role of gold stock as a store of value. Further, in the gold-currency relationship, fundamentals are changing in both the numerator and denominator (real interest rate expectations, QE shifts, and energy technology), and a price model needs to help differentiate relative drivers.

In upcoming framework reports we will dive further into gold priced in other currencies, energy prices and currency relationships, look at prices and “real”, real interest rates, and the fundamentals of mining in our proof of value framework.

Ultimately, we believe that the indisputable relationship between gold and energy prices, independent of currency, holds an important implication. As energy costs feed directly through into the price of gold, and gold can be used again and again with very low maintenance or holding cost (low marginal transaction cost of money), gold can act as store of value that protects the purchasing power of savings against all other goods requiring energy. If gold prices increase with energy prices, then gold will retain its purchasing power for goods that require energy to be produced, which is basically everything. Gold is the only form of money that achieves this consistent purchasing power naturally, defined by the physics and geology of earth’s crust, independent of any political or fiat currency system and independent of centralized economic planning or policy.