

PRE-FINANCING OIL IMPORTS WITH GOLD²

Given that US dollar purchasing power has been diminishing against both Oil and Gold in the past hundred years, we examine the extent to which Germany could decrease its import costs by pre-financing oil with gold for the period 2005-2023. To account for this the study develops five models (M1, M2, M3, M4, M5) of pre-financing strategies. The research proposes the most effective model that decreases oil import both in terms of costs and volatility. The findings suggest that both costs and volatility in monthly import values decrease across all models. Results show that the most capital-efficient is the model, which has an initial lump sum pre-financing of three times the yearly oil demand prior to the start date. M3 achieves to reduce costs by 25% and volatility by 35%. This paper reiterates gold nature – acting as a safe haven and hedge against inflation.

Keywords: pre-financing; import; crude oil; gold; costs reduction; volatility

JEL: E2; E27; F37; Q02

1. Introduction

Gold is known to be a safe haven during times of economic instability, as it can buffer against oil price swings. Investments in gold are considered as a hedge against oil price volatility (Li & Umair, 2023). Other studies have questioned whether gold is a hedge or a safe haven against oil prices. (Reboredo, 2013) suggests there is a positive and significant average dependence between gold and oil, which would indicate that gold cannot hedge against oil price movements, but it can act as an effective safe haven against extreme oil price movements. Reboredo based on the copulas method confirms previous results of Baffes indicating that when oil prices remain high other commodities (including gold) prices boom, as oil is necessary for the economy from the production of commodities to their transportation (Baffes, 2007). General price levels tend to rise and spillovers are transferred to financial assets.

Gold is seen as a safe haven asset or store of value, meaning investors tend to buy gold when worried about the economy or other financial markets. As a result, the price of gold can rise significantly during periods of economic uncertainty. Various factors influence oil prices,

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including global economic growth, OPEC production quotas, and geopolitical tensions. Some factors that can affect the price of gold include interest rates, inflation, and the US dollar exchange rate.

This study aims to evaluate the effectiveness of a gold-based strategy for purchasing oil and why it would benefit countries to buy oil with gold. Additionally, it recommends the most optimal strategy for countries to use. The study begins with the results in Chapter 2, where a gold-based strategy is recommended in analyzing different models. Chapter 3 discusses the materials and methods. The study ends with a general conclusion in Chapter 4. For the rest of the introductory chapter, the motivation, objectives, and the models of the study are discussed.

1.1. Motivation for the study

Some countries have announced their intentions to use gold payments for their oil purchases. Ghana is one of the countries that proclaimed they will adopt gold purchasing of oil instead of US dollars. This move could help them reduce the country's reliance on the US dollar and improve its economic stability because it aims to address diminishing foreign currency reserves and the demand for dollars by oil importers, affecting the local currency. Ghana has implemented a strategy to improve the country's balance of payments and reduce currency depreciation (“Gold Will Replace U.S. Dollars in Ghana’s Oil Purchases – GlobalData,”). As part of this strategy, on January 15, 2023, Ghana received its first shipment of gold for the oil trade model. The country leaders anticipate that this move will lead to a significant reduction in fuel prices (“Ghana’s Gold for Oil Policy & Payment Model: A Problem in Search of a Solution,”).

China also intended to use gold as payment for oil in 2017 but the idea has not yet materialized fully (“China sees new world order with oil benchmark backed by gold – Nikkei Asia,” n.d.). In 2023 the country settled its first digital yuan cross-border crude oil payment (“China Completes First Cross-Border Crude Oil Settlement in Digital Yuan – Global Times,”).

There have been rumours about India and Iran negotiating a deal to trade oil for gold. (“The Petrodollar, Iran, and Gold—What You Need to Know | Financial Sense,” n.d.). Russia also stated that it is considering selling its oil for gold. (“Credit Suisse’s Pozsar: Gold Price Could Double to \$3,600 in This Case – Noor Trends,”).

However, out of all the rumours surrounding countries interested in buying oil with gold, Ghana is the only one that has successfully implemented its strategy.

Gold is a relatively stable asset, so trading oil for gold can help countries protect themselves from currency fluctuations, thus it is appealing to trade oil for gold (Madani and Ftiti, 2022). Another apparent reason is bypassing sanctions. If a country is under sanctions, it may be difficult to use US dollars (Agpaytech 2023) to trade oil. Gold can be convenient to bypass sanctions and continue to trade with other countries. This study explores the other benefits of holding gold in a country's reserves.

However, trading oil for gold is not without its risks. For example, gold prices can be volatile, and countries may need to store and transport large amounts of gold, which could be expensive. There are many factors to consider. The scope of the study will focus only on a basic gold-backed oil buying strategy without considering other factors. The study does not consider gold storage, transportation or conversion fees, insurance, security, or accessibility.

1.2 Objectives

This study explores the possibility of using gold instead of USD to purchase crude oil, with the primary objectives being to reduce volatility and absolute cost. The paper examines two lines of reasoning: first, hedging against the volatility of oil prices, and second, providing safe haven protection from the erosion of USD purchasing power (store of value). Purchasing power refers to the goods and services that can be purchased with money. By converting USD to gold, importer countries can maintain their purchasing power and lower the overall cost of crude oil imports.

The study aims to answer whether an oil-importing country would pay almost the same as in previous years for crude oil if they periodically purchased gold to finance their future oil payments instead of USD and if this move would protect them against oil price spikes.

1.3. Model Development and Evaluation

The simulation model keeps track of various variables to simulate the gold-based oil purchasing strategy, described in more detail in the Model Framework section. Ultimately, the study evaluates the performance of this strategy and recommends a model based on the simulation. To test whether the volatility and cost could be reduced, the study proposes five models (M1 – M5). The models simulate financing crude oil imports with a lump sum purchase of gold amounting between one to five times the yearly oil demand (prior to the start date), followed by monthly oil purchases. The simulated model's oil import values in USD are then compared to the direct (actual) import values. Statistical measures, such as standard deviation and variance, are used to determine the volatility of the models and compare them to the volatility of direct oil imports.

The oil-to-gold ratio is a measure that divides the price of crude oil per barrel by the price of one troy ounce of gold. This ratio helps to determine how much one barrel of oil costs in terms of gold. Another analysis of the oil-to-gold ratio involves comparing Germany's oil imports for a specific period to see if they could have been purchased with gold. This analysis assumes that the country stocked gold at the beginning of 2006 and used it to purchase oil. The goal is to evaluate whether gold can reduce the cost of oil imports and assess the effectiveness of gold as a safe haven asset. The volatility analysis aims to determine whether gold can protect against oil price spikes during economic uncertainties. Lower variance and standard deviation indicate less volatility and greater resilience to oil price movements caused by global events.

The expected outcomes of the study are:

- the potential for reducing volatility,
- the effectiveness of gold as a hedge against oil price volatility when purchasing crude oil using gold,
- the effectiveness of gold as a safe haven to prevent USD purchasing power erosion.

The research aims to test the properties of gold and recommend a gold-based oil replenishment model that is most effective in preserving purchasing power and protecting against price uncertainties. The results will contribute to a deeper understanding of the potential advantages of gold-based transactions in the oil market.

1.4 Challenges

1. Why not other commodities? Why not all commodities? Why not all goods and services?
 - We chose Crude oil since it is considered the blood of the modern economy. Crude oil is the top export product for many countries including the United States, Canada, Russia, Belarus, Kazakhstan, Turkmenistan, Iran, Norway, Finland, Saudi Arabia, UAE, Venezuela, Bolivia, Ecuador, Columbia, India, Myanmar, Egypt, Libya, Algeria, Sudan, Angola, Yemen, Oman, Iraq, Kuwait, Qatar, Bahrain. All these countries are dependent on the United States dollar and the US banking system to trade their oil and receive income from international markets. While it's true that for the United States trade is direct in its national currency is sensible, for other countries the USD acts as an intermediary instrument. This incurs additional costs on the trade of oil. While some of the above-mentioned exporters enjoy being paid in USD, others might want to have an alternative. A major concern is that the issuer of the USD can cut out political opponents from the banking system, as was the case with Russia. That is why an alternative to the dollar has been a hot topic around the world.
 - Oil has the largest market share in the commodities markets and due to the above reasons has been historically a reason for overthrowing of governments, starting revolutions, and even wars. Oil is a limited resource unlike soya, corn, wood, animals, and machinery. This makes it very valuable. As gold is not mined in one single country trading crude in Gold could democratize the international trade of oil and reduce its political influence.
 - Crude oil can be extremely volatile. Measured in gold, oil volatility could be reduced over time.
2. Volatility: while gold is generally stable over the long term, its price can be quite volatile in the short term due to market sentiments, speculative trading, and changes in demand. This volatility can complicate the pricing of commodities.
 - The proposed model is a mix between lump-sum investment and Dollar-cost averaging strategies. It manages risk by spreading the total purchases over time – in this way, it reduces the short-term volatility of gold by smoothing out price fluctuations and averaging the cost basis of the investment. The highest risk is

associated with the purchase of the initial lump sum of gold. With a long-term vision, this risk spreads out.

- Even though gold is volatile, it is less volatile than oil and the study shows that it evens out oil volatility. The recent debasement of many once-stable currencies and the current state of the US economy raise concern over the future of the US Dollar. These reasons make gold an attractive option.
 - Depending on the scale of the application of the model the price of gold could increase significantly or not. In the scenario where this model is used by a small share of players, the impact would not be significant. The impact of such conversion is to be the subject of further study. The long-term effect of the application of the model as an individual investment strategy is an obvious decrease in volatility from a portfolio perspective, which is seen by the results. That is why it should be first tested at a small-scale level as part of individual portfolio management.
3. Liquidity and Market Depth: The market for commodities priced in USD is vastly larger and more liquid. A shift to gold pricing would require substantial changes in market infrastructure and could initially lead to reduced liquidity.

A solution to increase liquidity could be the tokenization of gold. Tokenized real-world assets can help increase liquidity, speed up settlement and the velocity of the gold. Tokenization reduces the logistics burden and allows divisibility of the assets to the tiniest parts that would not be physically possible. That would increase gold price and gold market capitalization. In a world where gold has a significantly larger market cap, it would be easier to imagine (tokenized and fragmented) that it could service international trade in larger volumes than it is currently possible.

On the other hand, not all market participants need to use gold, and not all markets need to be in gold. But there should be an alternative for those who want to try it, even if it is less liquid.

4. Operational Issues: Most global trade and finance infrastructure is built around fiat currencies, particularly USD. Contracts, accounting, taxation, and other logistics would face significant upheavals if commodities were traded in gold.

While it's true that implementing a gold-based trading system presents practical challenges, such as the operational concerns mentioned above, these challenges can be mitigated through proper planning and adaptation. The transition to a gold-based system would require gradual adjustments to market infrastructure, but the long-term benefits of stability and resilience far outweigh the short-term inconveniences.

Additional research in this field could calculate these costs.

5. Economic Impact: Pricing commodities in gold could have unintended economic consequences, including impacts on monetary policy and inflation control, which are typically managed through currency manipulation.

On the one side, the main idea of the publication is the limited use of gold – not its imposition as a universal monetary unit.

On the other side, the current system, relying on macroprudential policies and fiat currencies like the USD, provides governments and central banks with excessive control over monetary policy. History is replete with examples where such control has led to disastrous consequences. Loose monetary policies have created depreciation of currency and economic chaos. Expansionary policies have achieved economic growth in the past. This growth, however, is not sustainable and has seriously harmed the planet.

Examples of a harmful central bank and government policies can be witnessed in the US (1775-1871, 1861-1865, 1929-1930s, 1937, 1941-1945, 1955-1975, 2007-2008, 2013), Germany (1921), Yugoslavia (1990s), Southeast Asia (1997-1975), Zimbabwe (2000-ongoing), Argentina (2001-2002, 2018-ongoing), Venezuela (2017- ongoing), Bulgaria (1996, 2008), Lebanon (2020-ongoing), Turkey (2021-ongoing) and other countries.

Milton Friedman (Friedman 1990), Saifedean Ammous (Ammous 2018) , and other economists believe the Federal Reserve has been harmful longer period of its existence compared to useful. Central banks managing the economy is a form of planned economy, which has also shown to be ineffective and harmful.

Money printing has fueled multiple wars. An early example in American history is when the Continental Congress overissued continental currency to finance the war effort which led to rapid depreciation of currency and economic hardship in 1775-1781. Later, during the American Civil War, the Federal Government issued greenbacks not backed by gold or silver, which once again led to significant depreciation of currency and economic dislocations. In Europe the Weimar Republic in 1921 undertook massive printing of money to finance war reparations leading to currency becoming worthless, the collapse of the economy and social unrest.

The opposite Federal policy was not always a success either – the Federal Reserve during the Great Depression did a sharp contraction in money supply and exacerbated deflationary pressures. This wrong monetary policy exacerbated the economic downturn, widespread bank failures, and economic hardship.

In 1934 the Federal Reserve prohibited US citizens from investing and holding gold. A restriction on individual freedom, which took 4 decades to be finally reversed.

In 1937 the Fed increased interest rates and reduced the money supply, which exacerbated the economic downturn once again, and led to a sharp contraction in economic activity and unemployment.

During World War II the US Government borrowing and money creation financed the war effort, increased government debt, increased inflationary pressures, and created economic dislocations.

Fed's expansionary monetary policy fueled the Vietnam War (1955-1975). Increased government deficit spending and debt led to stagflation and economic instability.

Glass-Steagall Act reversal in 1999 by the US Congress is said to have also contributed to the financial crisis of 2008. The Taper Tantrum of 2013 started by the Federal Reserve was a policy of tapering quantitative easing program that led to market volatility, a rise

in long-term interest rates, and global financial markets disruption. The current high worldwide inflation is a product of the massive money printing during the COVID crisis.

In South America Argentinian central bank pursued a fixed exchange rate regime pegged to the U.S. dollar, which became increasingly unsustainable given Argentina's deteriorating economic fundamentals. The consequence was a default on sovereign debt and a sharp devaluation of the peso (2001-2002).

Irresponsible fiscal and monetary policies including money printing around the world led to hyperinflations in Yugoslavia (the 1990s), Zimbabwe (2000-ongoing), Argentina (2018-ongoing), Venezuela (2017- ongoing), Bulgaria (1996), Lebanon (2020-ongoing), Turkey (2021-ongoing) and other countries.

During the 2010-s the European Sovereign Debt Crisis took place, where the European Central Bank had reluctance to intervene decisively to support struggling eurozone economies and stabilize financial markets, which exacerbated the crisis. This contributed to prolonged recessions, high unemployment, and social unrest in Greece, Portugal, and Spain.

Governments tend to benefit from inflation, as they are often the main debtor in the economy. Inflation helps reduce their debt. Increased spendings by the government allow for broader control over the population. It also allows taxing the entire population without prior approval of the population via legislation and parliament voting, as laws normally require. Taxation used to be imposed one-sidedly by the king until the birth of the Magna Carta in 1215. Since then taxes need to be voted and agreed upon prior, where the voice of the ones being taxed is heard. Inflation is a hidden tax that often hits the hardest the ones with the lowest income, who do not possess financial assets. Inflation also hits much harder the ones who receive the newly printed money last.

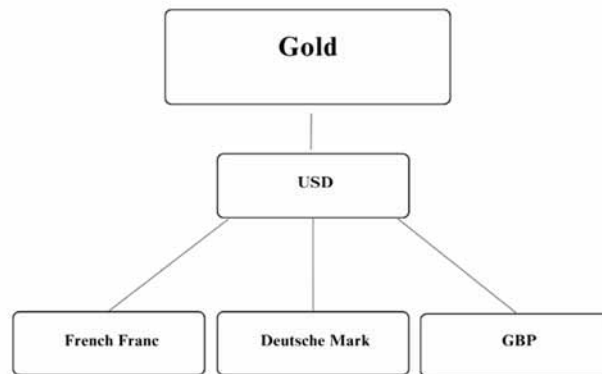
6. Why did the world abandon the gold standard more than 50 years ago?

Gold has the longest track record of being money – over 5,000 years. The characteristics of gold are the reason governments and people used it as money.

It is crucial to understand that the abandonment of the gold standard was not solely due to its rigidity but also due to the mismanagement and manipulation of currencies by governments and central banks. This period saw instances of hyperinflation, economic crises, and currency devaluation, highlighting the risks associated with a fiat currency system.

The USD intermediates global crude trading due to its historical position as a global reserve currency which was established based on its connection to gold. The USD was chosen as the reserve currency due to the largest golden reserves the US had after World War II compared to other countries.

The relationship between Gold/USD was not just abandoned but was one-sidedly suspended by the party supposed to guard the peg. The United States practically defaulted on its obligation to maintain a peg between the USD and gold. Since the rest of the currencies were pegged to the USD as an intermediary to gold and the USD was no longer pegged to gold, other currencies also depegged from USD and started floating.



It is understandable stagflation caused gold to be underpriced during the gold standard and thus the Federal Reserve was not able to maintain the peg. The global demand for USD was higher due to larger economic output compared to the circulating gold. That is why most economists nowadays believe that a gold standard is not plausible.

The research does not propose money to be pegged to gold. History has shown us that this has not worked well in the past. The article focuses on the possibility for an investment strategy on one side and, on the other side – a democratization of international crude trade by direct exchange between gold and crude oil for a limited number of market participants, who wish to take advantage of such trade.

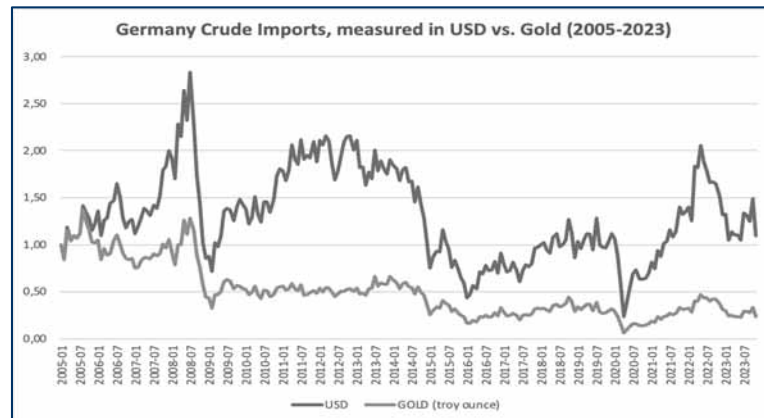
2. Results and Discussion

2.1 Reducing volatility of crude oil import costs

The research proposes a novel model to determine the optimal amount of gold required to fulfil oil demand, minimizing financial risks and uncertainties. The aim of the model is to examine the optimal gold-based purchasing of oil. It seeks to find whether the volatility of imports, measured in gold, is less than that of imports measured in US dollars. In other words, whether gold-based oil replenishments are less susceptible to oil price volatility. In addition, this model can serve as a measurement of how a country can manage its gold reserves and make informed decisions regarding its oil reserves. The primary objectives are to develop a model that accurately simulates the value of oil imports based on gold reserves and to compare its performance against direct import value data using statistical measures.

Would the volatility in the import cost of crude oil decrease or increase if it was measured in Gold? The standard deviation of German monthly crude oil import, measured in USD, is 0,47. Where the same import measured in Gold simulation – standard deviation is 0,28. This leads us to the notion that volatility would decrease for the importer country.

Figure 1. Comparison of normalized imports measured in USD versus measured in Gold troy ounce



Source: Indexmundi ("Gold – Monthly Price – Commodity Prices – Price Charts, Data, and News – IndexMundi," n.d.), OPEC ("OPEC : OPEC Basket Price," n.d.) and EUROSTAT ("Statistics | Eurostat," n.d.)³

The chart shows the normalized import value of crude oil in Germany in USD compared to the normalized gold needed to buy the same number of barrels from 2005 to 2023. The normalized import value is the total crude oil imports divided by the 2005 value. We visualize that the normalized crude oil imports in gold are declining over time, while the normalized oil imports in USD are increasing. This suggests that gold preserves its purchasing power, and it can also mean that Germany is spending a smaller proportion of its economy on crude oil imports than it was in the past. The value of oil imports has decreased relative to gold in the long term. This means it takes fewer ounces of gold to buy the same or less oil. There are several possible explanations for this, including:

- Increased supply of oil. The increase in oil production has increased oil supply and driven down prices.
- Decreased demand for oil. The global economy has become more energy-efficient in recent years, reducing the oil demand.
- Weaker US dollar⁴. The US dollar has weakened against other currencies making oil more expensive for buyers outside the US.
- Investment in gold as a safe-haven asset. Its price tends to increase in times of economic uncertainty. Investors have been buying gold in recent years to hedge against inflation and preserve purchasing power.

³ 1 troy ounce is equal to 31,1 grams. Monthly average price of gold troy ounce in USD, daily price of OPEC Basket is converted to monthly average, Germany's monthly import in barrels.

⁴ Since its peaks in 1985 (DXY 160.41) and 2002 (DXY 120.28) till January 2024 (DXY 103.96) – https://www.tradingview.com/symbols/TVC-DXY/?utm_source=androidapp&utm_medium=share.

An important caveat to mention is that there might be also other factors at play that affected the importing of oil for Germany in the model due to COVID-19 and the economic slowdown that it caused on the global economy. The COVID measures contributed to lower oil consumption due to the lack of travelling of people. This does not prevent the appliance of our model though.

One possible explanation for this trend might be that Germany is becoming more energy efficient and uses less crude oil to produce the same economic output. We can notice a declining trend in the number of barrels. Another possibility is that Germany is switching to other energy sources, such as renewable energy. Either way, if we compare it to the US dollar-based oil imports, we can see a difference in the outlook, meaning that the oil-to-gold ratio is declining compared to the US dollar-based oil imports. With the same amount of gold, Germany can buy the same or even more barrels of crude oil than it did in the past. The price of oil is becoming cheaper relative to the price of gold.

The fluctuations in the chart for the USD or Gold are due to several factors, including changes in oil supply and demand, economic conditions, and geopolitical events. Even though volatility is persistent in both series, oil imports in USD have a higher standard deviation of 0.47 than imports valued at 0.28 in gold. It shows that purchasing oil with gold over time protects the country from price swings in oil prices. Overall, the value of oil imports has decreased relative to gold in the long term, with the primary factor being global investments in gold.

Figure 2. Comparison of oil in USD terms against oil in Gold terms

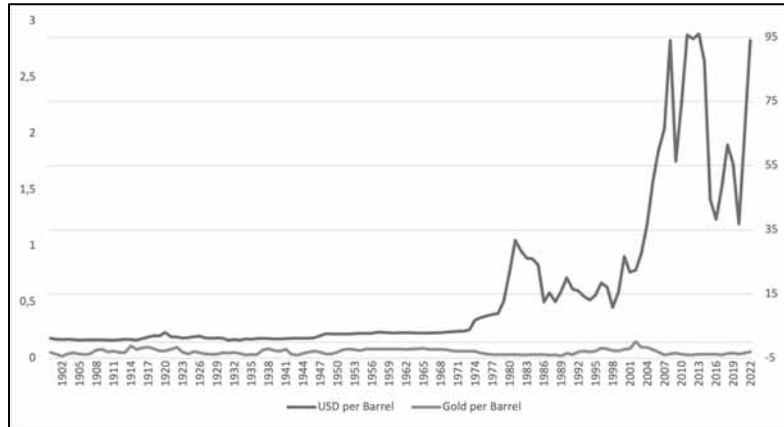


Figure 2⁵ is similar to Figure 1, as it is a normalized price comparison, and it shows the comparison of oil price per barrel and the oil price in ounces of gold (measuring the purchasing power of gold) for the time period from 1900 to 2022.

⁵ Yearly closing prices of gold and the First Annual Purchase Price (Dollars per Barrel) for oil. Oil import data: U.S. Energy Information Administration ("U.S. Crude Oil First Purchase Price (Dollars per Barrel)," n.d.), Gold price data: OnlyGold ("200 years of prices – Only Gold," n.d.)

In the beginning of the chart one barrel was trading 1.19 USD per barrel which was equal to 0.057571 ounces, and in 2022 one barrel was trading at 93.97 or equal to 0.051640 ounces. This is a 10% difference in purchasing power for 120 years. Almost the same weight of gold 120 years ago buys the same unit of oil.

Figure 3. Comparison of oil in USD terms against oil in Gold terms (Logarithmic Scale)



On the logarithmic chart, the stable nature of the purchasing power of gold is more visible. The gold needed to purchase one barrel stays in a predictable price range (light line). The price of oil in terms of gold stays relatively stable if we compare it to the price of oil in US dollars (dark line).

Table 1. Import Value of Crude Oil in the different models and Standard Deviation, thousands of USD

Model	Standard Deviation	Reduction
Direct	\$ 1,495,688	0%
M1	\$ 1,254,129	-16%
M2	\$ 1,058,227	-29%
M3	\$ 973,127	-35%
M4	\$ 933,882	-38%
M5	\$ 915,536	-39%

Table 2. Import Value of Crude Oil in the different models and Variance, thousands of USD

Model	Variance	Reduction
Direct	\$ 2,237,081,396,181	0%
M1	\$ 1,572,840,652,183	-30%
M2	\$ 1,119,844,357,866	-50%
M3	\$ 946,975,315,283	-58%
M4	\$ 872,136,247,669	-61%
M5	\$ 838,205,648,527	-63%

We can see from the data in Table 1 and Table 2 that the standard deviation and variance are significantly reduced in the simulated oil import value in US dollars compared to the direct import value. The standard deviation of the simulated import value is 16%-39% lower than the standard deviation of the direct import value for all five models. This suggests that the simulated import value is less volatile than the direct import value. This positive finding suggests that the model can reduce volatility. This allows the model to evaluate how to use gold to hedge a country's oil imports. The reduction in volatility is significant and consistent over time.

Table 3. Absolute Monthly changes in USD and percentage reduction, thousands of USD

	Standard Deviation		Variance	
	Absolute	Reduction	Absolute	Reduction
Direct	\$ 533,682	0%	\$284,816,052,170	0%
M1	\$ 473,644	-11%	\$224,338,545,807	-21%
M2	\$ 429,768	-19%	\$184,700,360,290	-35%
M3	\$ 398,375	-25%	\$158,702,403,105	-44%
M4	\$ 375,790	-30%	\$141,218,440,555	-50%
M5	\$ 359,132	-33%	\$128,976,064,139	-55%

The absolute change in Table 3 is the difference between the current month and the previous month for the import value for Direct, and each simulated five years of gold holding (month-to-month changes in oil import value in US dollars). The standard deviation of absolute change measures the volatility of the month-to-month changes in oil import value in US dollars. The standard deviation and the variance are significantly lower for the simulated values (M1 to M5) than for the direct value. This standard deviation reduction ranges from 11% for M1 to 33% for M5, and the variance reduction ranges from 21% for M1 to 55% for M5. The reduction in volatility is consistent across all periods.

A lower standard deviation of absolute change indicates that the month-to-month changes in the import value are less volatile and, therefore, more predictable, which results in better planning for a country's monthly oil reserves and, thus, its economies. Another way of interpreting the results is, that the lower the standard deviation of the absolute change, the less volatile the import value, making the simulated values less prone to experiencing large price swings in oil from one month to the next. The lower the variance of the absolute change, the more predictable the import value is.

The conclusion from Table 3 suggests that holding gold reduces the volatility of the monthly changes in oil import value in US dollars.

2.2 Gold as a hedge against oil price volatility

Our study suggests that gold cannot play the role of a hedge against oil price volatility when purchasing crude oil using gold, due to their positive correlation. For the period 2005 – 2023, the monthly average prices of Gold (Indexmundi) / Crude Oil (OPEC Basket) correlation has a positive value of 0,32. The correlation is not strong but has a relatively positive value. On a longer timeframe – the correlation between gold and crude oil yearly prices becomes extremely strong. The correlation value is 0,90. The 0,90 correlation is based on the annual

first purchase price in USD per barrel from EIA, while gold price data considers the Annual Closing price and is taken from OnlyGold.

To be a useful hedge the two assets should have a negative correlation. Commodities such as gold and oil almost always tend to have a reverse relationship with the US dollar. The stronger the US Dollar the cheaper the commodities and vice versa. This is due to the fact that these commodities are denominated in dollars (their central markets are priced in US dollars).

Thus, this study believes that gold can be used as a hedge against inflation but cannot hedge against oil price spikes in standard terms.

2.3 Gold as a safe haven to prevent USD purchasing power erosion

Would the importer country pay less for crude oil if they periodically purchased gold and financed the payment with gold, instead of USD? The results are positive in Table 4 we can witness that Model 5 brings a reduction with 1/3-rd of the cost.

Table 4. Cost, reduction, and required investment, thousands of USD

Model	Cost	Abs. reduction	Reduction	Initial investment
Direct	\$ 876,481,341	\$ 0	0%	\$ 0
M1	\$ 776,333,345	\$ 100,147,996	-11%	\$ 52,812,625
M2	\$ 703,477,139	\$ 173,004,201	-20%	\$ 105,625,249
M3	\$ 650,610,591	\$ 225,870,749	-26%	\$ 158,437,874
M4	\$ 612,410,906	\$ 264,070,435	-30%	\$ 211,250,498
M5	\$ 584,032,530	\$ 292,448,811	-33%	\$ 264,063,123

The statistics output in Table 4 aims to present insights for decision-making regarding oil import strategies and highlights the potential of using gold as a safe-haven asset (store of value).

Table 4 demonstrates that the simulated models (M1 to M5) offer significant cost reductions compared to the Direct model, meaning that the longer a country holds onto its gold the better cost reduction benefits for its oil imports.

The percentage reduction in cost for each simulated model compared to the Direct model increases progressively from M1 to M5. M5 has the highest percentage reduction of 33%, indicating a substantial cost reduction compared to the Direct model.

However, the initial investment required for the simulated models should be considered and it is noticeably higher than the Direct model. It's essential to consider both the cost reduction and the required investment when choosing a model.

M5 might be the most attractive option even with the highest initial investment, as it offers the most significant cost reduction (33%) over the long term. On the other hand, it has the highest initial investment of \$264B., which needs to be considered when deciding on its use.

The cost decreases progressively for the simulated models (M1 to M5), with M5 having the lowest cost of \$584B, a reduction of \$292B, compared to Direct. The initial investment increases progressively for the simulated model (M1 to M5).

The fact that the reduction in volatility is consistent across all time periods suggests that the gold model is robust. This means that the model is effective at reducing volatility even when the underlying data is subject to change.

The most significant reduction in standard deviation is noticed in M2 or M3 (M3 -35%) compared to the other models. M3 is optimal for managing oil import costs. The benefits from the other models are not that significant. M2 and M3 show the most considerable increase and difference compared to direct imports. It means that a country, to reap the benefits of the properties of gold, needs to buy and hold its gold for two or three years and use it to support its oil purchases.

- M3 exhibits the most significant reduction in standard deviation (35%) compared to the other simulated models. This indicates that M3 effectively smooths out fluctuations in oil import costs, making it a more stable option for managing these costs.
- M3 shows a substantial increase in the difference compared to direct imports. This suggests that M3 effectively captures the benefits of holding gold for oil import management, leading to significant cost reductions.

Holding gold for two or three years is necessary to reap the full benefits of M3. This is an important consideration for countries implementing this model, as it requires a longer-term commitment to gold accumulation.

It is important to note that the gold-based oil purchasing model is a simplified model and does not take into account all of the factors that could affect the price of gold or other assets from storage and transportation fees to global events like wars and geopolitical shifts of powers. However, the model can be a useful tool for making informed decisions about whether or not to invest in gold-based assets.

3. Materials and Methods

3.1 Research Design

The research employs a quantitative approach, utilizing a simulation model to evaluate the effectiveness of gold-based oil purchasing in mitigating oil price volatility. The model simulates the value of oil imports based on gold reserves and compares its performance against direct import value data using statistical measures.

For the analysis of the purchasing power of gold, the study uses a couple of analyses: the oil-to-gold ratio and the absolute monthly reduction in oil costs. Additionally, to evaluate the effectiveness of gold as a hedge against oil trade volatility, the study conducts a standard deviation analysis on various models with different gold holding periods.

One of the analyses performed to study the store-of-value properties of gold is calculating the ratio between oil and gold for 120 years. This ratio is calculated by dividing the price of crude oil per barrel by the price of one troy ounce of gold, measuring how much one barrel

costs in terms of gold. The study collected yearly closing prices of gold and the First Purchase Price (Dollars per Barrel) for oil.

3.2 Model framework

The results of the gold model this paper provides simulate the amount of gold needed to store to satisfy the oil demand of a country. The model works by tracking the following variables:

- **Beginning of Period (BOP):** The amount of gold available at the beginning of each period.
- **New Purchases:** The amount of gold purchased in each period.
- **Actual Demand:** The amount of gold used to finance oil imports in each period.
- **End of Period (EOP):** The amount of gold available at the end of each period.

The model calculates the following variables:

- **Average price of gold held at the beginning of the period (Avg\$GOLD (BOP)):** The average price of the gold owned at the beginning of each period.
- **Average price of gold owned after new purchases (Avg\$GOLDpostNewPurchase):** The average price of the gold owned after new purchases are made in each period.
- **Simulated import value in USD (Simulated Import Value USD):** The simulated value of oil imports in US dollars in each period.
- **Absolute Change (AbsChange):** The absolute change in the simulated value of oil imports in US dollars from the previous period.
- **Comparison of Standard Deviations (StDev) and Variance (Variance) for oil imports in dollars (Direct) and Simulated import value in US dollars (M1, M2, M3, M4, M5):** This comparison shows how the standard deviation and variance of the simulated import value compares to the direct import value.

The model works by first calculating the beginning of the period gold balance (BOP). This is equal to zero in the first period, and equal to the end-of-period gold balance (EOP) of the previous period in subsequent periods.

$$BOP_1 = 0 \quad (1)$$

$$BOP_2 = EOP_1 \quad (2)$$

$$BOP_n = EOP_{n-1} \quad (3)$$

Next, the model calculates the new purchases for each period. This is equal to the actual demand for the previous period in the first period and equal to the simulated import value in USD of the previous period in subsequent periods.

$$New\ Purchases_1 = \sum ImportGOLD_{past\ 12\ months} \quad (4)$$

$$\text{New Purchases}_n = \text{Actual Demand}_{n-1} \quad (5)$$

The actual demand for each period is equal to the amount of gold needed to finance oil imports for the period. This is calculated by multiplying the monthly oil import value in dollars by the average price of gold held after new purchases for the period.

$$\text{ImportGOLD}_n = \frac{\text{\$Import}_n}{\text{\$GOLD}_n} \quad (6)$$

The end-of-period gold balance (EOP) for each period is equal to the beginning-of-period gold balance (BOP) plus new purchases for the period minus actual demand.

$$\text{EOP}_n = \text{BOP}_n + \text{New Purchases}_n - \text{Actual Demand}_n \quad (7)$$

The average price of gold held at the beginning of the period (Avg\$GOLD (BOP)) is equal to the average price of the gold owned after new purchases for the previous period in the first period, and equal to the average price of the gold owned after new purchases for the current period in subsequent periods.

$$\text{Avg\$GOLD(BOP)}_1 = 0 \quad (8)$$

$$\text{Avg\$GOLD(BOP)}_n = \text{Avg\$GOLD(postNewPurchase)}_{n-1} \quad (9)$$

The average price of gold owned after new purchases (Avg\$GOLDpostNewPurchase) is calculated by dividing the total value of gold owned after new purchases by the total amount of gold owned after new purchases

Avg\$GOLDpostNewPurchase =

$$\left(\frac{\text{BOP}}{\text{BOP} + \text{New Purchase}} \right) \times \text{Avg\$GOLD(BOP)} + \left(\frac{\text{New Purchase}}{\text{BOP} + \text{New Purchase}} \right) \times \text{\$GOLD} \quad (10)$$

The simulated import value in USD (Simulated Import Value USD) is calculated by multiplying the actual demand for the period by the average price of gold held after new purchases for the period.

$$\text{Simulated Import Value} = \text{Actual Demand} \times \text{Avg\$GOLDpostNewPurchase}. \quad (11)$$

The absolute change in the simulated value of oil imports in US dollars from the previous period (AbsChange) is calculated by subtracting the simulated import value in USD of the previous period from the simulated import value in USD of the current period.

$$\text{AbsChange}_2 = \text{Simulated Import Value}_2 - \text{Simulated Import Value}_1 \quad (12)$$

$$\text{AbsChange}_n = \text{Simulated Import Value}_n - \text{Simulated Import Value}_{n-1} \quad (13)$$

The comparison of standard deviations (StDev) and variance (Variance) for oil imports in US dollars (Direct) and simulated import value in US dollars (M1 to M5) shows how the standard deviation and variance of the simulated import value compares to the direct import value. They measure how spread out the data is from the mean. In the context of comparing direct and simulated import values, it is expressed by the standard deviations in the same units as the data – US dollar terms. The variance is calculated by squaring the differences from the mean, which can make the effect of outliers less pronounced. Outliers have a heavier impact on standard deviation than on variance and it can be used for identifying outliers.

Using both standard deviation and variance gives the study a more complete picture. A lower variance and standard deviation indicate that the simulated import value is less volatile, and therefore more accurate.

3.3 Data Collection and Sources

The study explores historical data on oil imports, gold prices, and exchange rates to calibrate and test the simulation models. The data is sourced from reputable economic databases and covers a comprehensive timeframe to ensure the robustness of the analysis.

The raw dataset for our model covers the period 2005 – 2023 and consists of the monthly average price of gold troy ounce in USD (“Gold – Monthly Price – Commodity Prices – Price Charts, Data, and News – IndexMundi,” n.d.), daily price of OPEC Basket (“OPEC : OPEC Basket Price,” n.d.), Germany’s monthly import of oil barrels (“Statistics | Eurostat,” n.d.). Data is collected and reported respectively by Indexmundi, OPEC and EUROSTAT.

For the oil-to-gold ratio and their correlation, the study uses yearly closing prices of gold and the First Purchase Price (Dollars per Barrel) for oil from 1900 to 2022. Oil import data: U.S. Energy Information Administration (“U.S. Crude Oil First Purchase Price (Dollars per Barrel),” n.d.), Gold price data: Only Gold (“200 years of prices – Only Gold,” n.d.) It was necessary to use different sources, as data was not available for such a long period in Indexmundi and OPEC archives. For the longer time frame, Gold did not have monthly data available, thus our research for the long frame compares the yearly values.

4. Conclusions

The study explores crude oil imports and financing opportunities. The aim is to use gold/crude oil correlation to: 1) reduce crude oil import volatility; 2) hedge against oil spikes; 3) use gold as a safe haven. The main question is whether an oil-importing country (in our case Germany) would pay less for crude oil if it invested in gold in a lump sum, followed by periodic purchases.

The developed simulation model evaluates the effectiveness of gold-based oil purchases, mitigating oil cost volatility and preserving purchasing power. Overall, the results suggest that the developed model M3, which has an initial lump sum investment of three times the yearly oil demand prior to the start date, offers the most promising approach for managing oil import costs due to its significant reduction in volatility, substantial cost savings compared to direct imports, and alignment with the long-term benefits of gold ownership.

On the other hand, our test shows a positive correlation between gold and crude oil, thus we do not advise their composition in a common portfolio as a hedge against each other.

The results show that gold-based oil purchasing can significantly reduce the volatility of oil import costs and achieve substantial cost savings for countries that implement this strategy for optimally three years.

The model is robust and can be used to evaluate the effectiveness of different gold-based purchasing strategies for other commodities like gas, and copper. The model is a simplified version of what can be accomplished by accumulating and holding gold without taking into consideration other factors.

The article can navigate governments and large corporations wishing to purchase regularly crude oil to plan their costs and investments.

Data Availability Statement

Used data can be found in an Excel sheet on the following link <https://drive.google.com/drive/folders/1a3UXj8z96ChGYhpNwwOiGKtnov15R2Yk?usp=sharing>.

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