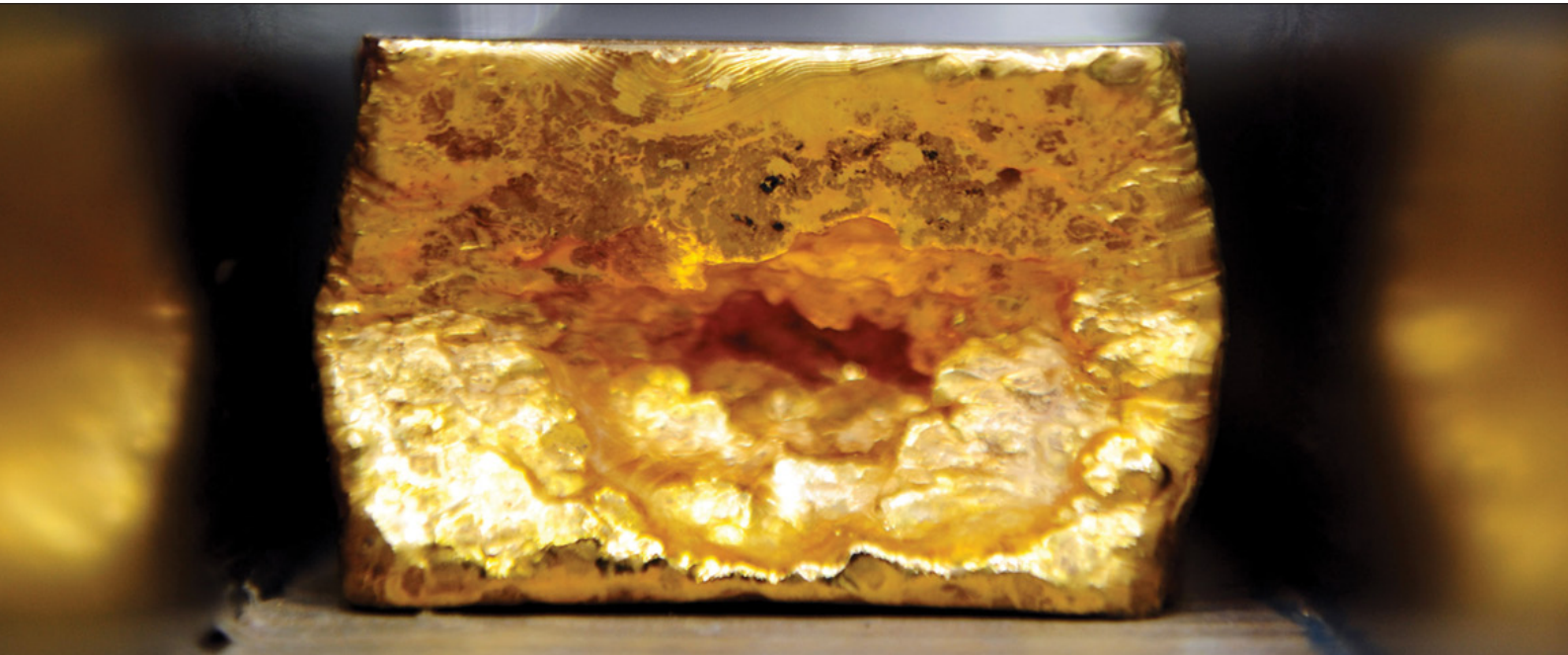


The Science of Gold & Other Precious Metals

Walt Sosnowski



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The Science of Gold & Other Precious Metals

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Introduction

There is frequent debate about the valuation of any asset or asset class. Sometimes the debate is fierce, and few investment topics evoke as much passion and controversy as gold — especially among professional investors. Many believe that gold is useless as a commodity and are sceptical of its alleged monetary value. For those that have legitimate doubts about the value of gold, this paper is an attempt to address some of those doubts.

Precious metals have been reliably used as money for thousands of years. Over the course of many centuries, silver and gold served as the money of choice in major economies around the world. Why did this happen? Was it solely due to tradition — or are there compelling reasons why precious metals have been used as money? Over the next few pages, I will attempt to explain some of the science behind gold as money and as an investment. Many of the concepts also apply to the other precious metals — silver, platinum, and palladium. In order to keep this short, however, the focus will be on gold.

Background

Before we get to the science of precious metals, we first need to cover some basics about money.

Money performs three basic functions:

1. Medium of exchange — money facilitates transactions of goods and services in an economy (unless we want to live in a barter society).
2. Unit of account — money provides a common measure of the value of goods and services being exchanged.
3. Store of value — money needs to hold its value over time.

While there are many things that could be used as money, I hope you would agree that the best money in the world would have the following characteristics:

- Divisible — each unit must be precisely divisible into smaller units.
- Uniform — each unit must be precisely uniform and consistent.
- Valuable — it must be a reliable store of value over long periods of time.
- Portable — it must be easy and inexpensive to transport in large values.
- Storable — it must be easy and inexpensive to store in large values.

In general, there are two potential types of money: physical currencies and fiat currencies. For those of you not familiar with the term, a fiat currency, such as the US dollar, is a currency that derives its value solely from government regulation or law. The term is derived from the Latin word fiat, which means “let it be done.” Additionally, the physical currencies can be further divided into two categories: elements and other commodities. Here are some examples of each:

Type	Examples
Fiat currencies	US dollars, euros, yen, etc.
Physical currencies	
Non-element commodities	Land, diamonds, oil, corn, cattle, etc.
Elements	Gold, silver, copper, zinc, etc.

Fiat currencies possess many of the attractive features of money. They are perfectly divisible. They are perfectly uniform. They are portable. They have low storage costs. But fiat currencies have one major flaw: they don’t do a good job of holding value over time. While they can hold value for years and sometimes even decades, they tend to lose value over time. This is because it is easy to create more fiat currency. By creating more, the fiat currency is diluted or debased. This debasement causes the value to decrease. From time-to-time, governments and central banks can be responsible and resist diluting the currency, but over time, the value of fiat currencies always ends up eroding at best — or completely failing at worst.

Now let’s consider potential physical currencies, and let’s start with physical things that aren’t elements. Non-element commodities can potentially serve as currencies, but they also have some fatal flaws. They aren’t perfectly uniform and divisible, and they are typically not portable. For instance, consider a barrel of oil. While oil is a commodity, there are many different variations such as West Texas Intermediate or North Sea Brent just to name two. Additionally, a barrel of oil isn’t very portable, and storage can be costly. Land is also a possibility. While land can be an excellent store of value, it clearly lacks uniformity. An acre of land in New York City has a very different value than an acre in the Mojave Desert. Plus, land isn’t very portable.

The Science of Precious Metals

Since most non-element commodities have shortcomings as money, the need for perfect uniformity and divisibility leads us to evaluate the elements for their utility as money. Therefore, let’s review the periodic table. As you will recall from your high school or college chemistry class, here is the typical way that most of us are taught to think about all the different elements in the universe:

Exhibit 1: Periodic Table of the Elements

hydrogen 1 H 1.0079																	helium 2 He 4.0026	
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180	
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948	
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80	
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29	
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [260]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	unbibium 112 Uub [277]	ununquadium 114 Uuq [289]					
* Lanthanide series		lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04			
** Actinide series		actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [288]	nobelium 102 No [259]			

Source: Wikipedia

Couldn't any of the elements be used as money? Not really. Theoretically, any of the elements could serve as money. Practically, however, there are limitations on which elements can serve as money and which can't. The limitations are as follows:

- It must be scarce:** This eliminates most of the 100+ elements.
- It must be a solid:** While it is theoretically possible to have a gas or a liquid be money, it is not very practical.
- It must not be harmful:** Many of the elements are radioactive or toxic, which would preclude their use as money.
- It must be durable:** This eliminates many elements that are brittle or corrosive.

So which of the elements in the periodic table would be the best form of money? In order to answer that question, we need to first determine which elements are the most rare. So instead of grouping the elements by atomic number, we need to re-sort the elements from *most* abundant to *least* abundant. While there are some differences between various scientific studies on the subject, for the purposes of this analysis we will use the list found in the *CRC Handbook of Chemistry and Physics, 92nd Edition 2011-2012*. Please note that abundance is measured in parts per million. For details, please see Exhibit 2 on the next page.

Exhibit 2: Elements Sorted by Abundance in the Earth's Crust

Element	Symbol	Parts per Million	Element	Symbol	Parts per Million
oxygen	O	461,000.000	ytterbium	Yb	3.200
silicon	Si	282,000.000	caesium	Cs	3.000
aluminium	Al	82,300.000	hafnium	Hf	3.000
iron	Fe	56,300.000	beryllium	Be	2.800
calcium	Ca	41,500.000	uranium	U	2.700
sodium	Na	23,600.000	bromine	Br	2.400
magnesium	Mg	23,300.000	tin	Sn	2.300
potassium	K	20,900.000	europium	Eu	2.000
titanium	Ti	5,650.000	tantalum	Ta	2.000
hydrogen	H	1,400.000	arsenic	As	1.800
phosphorus	P	1,050.000	germanium	Ge	1.500
manganese	Mn	950.000	holmium	Ho	1.300
fluorine	F	585.000	tungsten	W	1.250
barium	Ba	425.000	molybdenum	Mo	1.200
strontium	Sr	370.000	terbium	Tb	1.200
sulfur	S	350.000	thallium	Tl	0.850
carbon	C	200.000	lutetium	Lu	0.800
zirconium	Zr	165.000	thulium	Tm	0.520
chlorine	Cl	145.000	iodine	I	0.450
vanadium	V	120.000	indium	In	0.250
chromium	Cr	102.000	antimony	Sb	0.200
rubidium	Rb	90.000	cadmium	Cd	0.150
nickel	Ni	84.000	mercury	Hg	0.085
zinc	Zn	70.000	silver	Ag	0.075
cerium	Ce	66.500	selenium	Se	0.050
copper	Cu	60.000	palladium	Pd	0.015
neodymium	Nd	41.500	bismuth	Bi	0.009
lanthanum	La	39.000	helium	He	0.008
yttrium	Y	33.000	neon	Ne	0.005
cobalt	Co	25.000	platinum	Pt	0.005
scandium	Sc	22.000	gold	Au	0.004
lithium	Li	20.000	osmium	Os	0.002
niobium	Nb	20.000	ruthenium	Ru	0.001
nitrogen	N	19.000	rhodium	Rh	0.001
gallium	Ga	19.000	tellurium	Te	0.001
lead	Pb	14.000	iridium	Ir	0.001
boron	B	10.000	rhenium	Re	0.001
thorium	Th	9.600	krypton	Kr	0.000
praseodymium	Pr	9.200	xenon	Xe	0.000
samarium	Sm	7.050	protactinium	Pa	0.000
gadolinium	Gd	6.200	radium	Ra	0.000
dysprosium	Dy	5.200	actinium	Ac	0.000
argon	Ar	3.500	polonium	Po	0.000
erbium	Er	3.500	radon	Rn	0.000

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You will notice that the precious metals are not the scarcest elements on the planet. If scarcity is so important, then why shouldn't one of the more scarce elements be a better form of money than gold or silver? As you can see from the exhibit below, 20 of the 24 rarest elements have problems that prevent them from being money. If an element is radioactive or toxic, then it is clearly removed from the competition. Liquids or gases are not very practical, so we can throw those out as well. We can also remove solids that are brittle, corrosive, or hard to work with.

Exhibit 3: Details of the 24 Scarcest Elements

Element	Symbol	Parts/Million	Reasons not good as money
antimony	Sb	0.200	Toxic
cadmium	Cd	0.150	Toxic
mercury	Hg	0.085	Liquid and toxic
silver	Ag	0.075	
selenium	Se	0.050	Under certain conditions, can be toxic.
palladium	Pd	0.015	
bismuth	Bi	0.009	Brittle, unremarkable appearance, often confused with lead & tin.
helium	He	0.008	Gas
neon	Ne	0.005	Gas
platinum	Pt	0.005	
gold	Au	0.004	
osmium	Os	0.002	Brittle, difficult to work with, and can form osmium tetroxide which is toxic
ruthenium	Ru	0.001	Brittle, difficult to work with, and poor oxidation resistance.
rhodium	Rh	0.001	Difficult to work with due to high melting point & poor malleability.
tellurium	Te	0.001	Brittle and mildly toxic.
iridium	Ir	0.001	Brittle, difficult to work with, and iridium dust may ignite in the air.
rhenium	Re	0.001	Radioactive in natural state. Rhenium salts can be toxic.
krypton	Kr	0.000	Gas
xenon	Xe	0.000	Gas
protactinium	Pa	0.000	Radioactive and toxic
radium	Ra	0.000	Radioactive, emits radon, and reacts violently to air and water.
actinium	Ac	0.000	Radioactive
polonium	Po	0.000	Radioactive
radon	Rn	0.000	Radioactive and gaseous

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After eliminating these 20 elements from consideration, that leaves just four elements: gold, silver, platinum, and palladium. These four are commonly referred to in the investment community as “precious metals.”

Of the four precious metals, gold and silver have the longest history of monetary use. The reason for this is simple: platinum wasn't discovered until the 18th century, and palladium wasn't discovered until 1802. Plus, platinum and palladium are not prevalent throughout the world whereas gold and silver are found on every continent. So even though gold and silver are precious, they are both global metals, which is an important characteristic. Consequently, both gold and silver have been used as money for approximately 4,000 years of recorded history.

While silver, platinum, and palladium have some interesting monetary properties, for purposes of this analysis I am not going to provide additional detail on these metals. I will, however, provide some additional information about gold. In addition to not having negative properties like toxicity or radioactivity, gold has the following beneficial properties that make it attractive for monetary use:

- Most **malleable** of all metals. (Malleability is a material's ability to deform under compressive stress. This makes gold durable and easy to work with.)
- Most **ductile** of all metals. (Ductility is a material's ability to deform under tensile stress. This also makes gold durable and easy to work with.)
- Highly **inert**. (Gold is one of the eight “noble metals,” which means it is highly resistant to corrosion. This is important for stability and durability.)
- **Attractive**. (Gold has a shiny, distinctive look compared to many of the other elements. This can be very helpful when you are trying to impress a woman or convince her to marry you.)

Comparison Summary

Now that we have gone through the science behind precious metals, let's return to our discussion of the different potential types of currencies — fiat currencies vs. physical currencies. In light of everything we've discussed, here is a summary table comparing some of the different options:

Exhibit 4: Characteristics of Different Types of Currencies

	Divisible	Uniform	Valuable	Portable & Storable
	Perfectly Divisible	Perfectly Uniform	Reliable store of value due to scarcity	High value-to-weight makes it easy & inexpensive to move & store
Fiat Currencies				
US dollars	YES	YES	not long term	YES
Euros	YES	YES	not long term	YES
Yen	YES	YES	not long term	YES
Zimbabwe dollars	YES	YES	not anymore	YES
Any other fiat currency	YES	YES	not long term	YES
Commodities				
Land	YES	no	YES	no
Oil	YES	no	YES	no
Diamonds	no	no	YES	YES
Cattle	no	no	YES	no
Elements				
Lead	YES	YES	no	no
Copper	YES	YES	no	no
Carbon	YES	YES	no	no
Gold	YES	YES	YES	YES
Other precious metals	YES	YES	YES	YES
Other elements	YES	YES	no	no

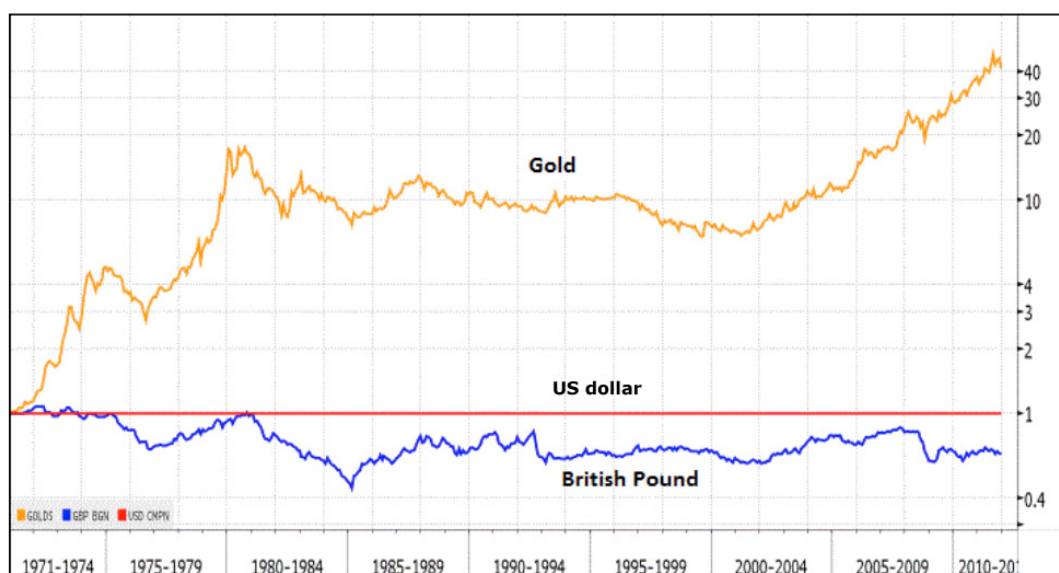
Source: SRC Capital Management research

Performance History: Fiat Currencies vs. Gold

Many investors might argue that fiat currencies are a reliable store of value. Over short periods of time, that is correct. Over longer periods of time, though, fiat currencies are not reliable stores of value. Let's examine data from the last 40 years. The year 1971 is a good starting point because that was the last year that the US dollar was still nominally backed by gold.

This first graph uses the US dollar as the constant or numeraire* from which to compare the performance of gold, the US dollar, and the British pound. To avoid distortions caused by a long time period, the chart uses a logarithmic scale, which I believe is a more conservative way to present the data.

**Exhibit 5: Gold vs. Two Major Fiat Currencies, 1971-2011
(with the US dollar as the constant)**



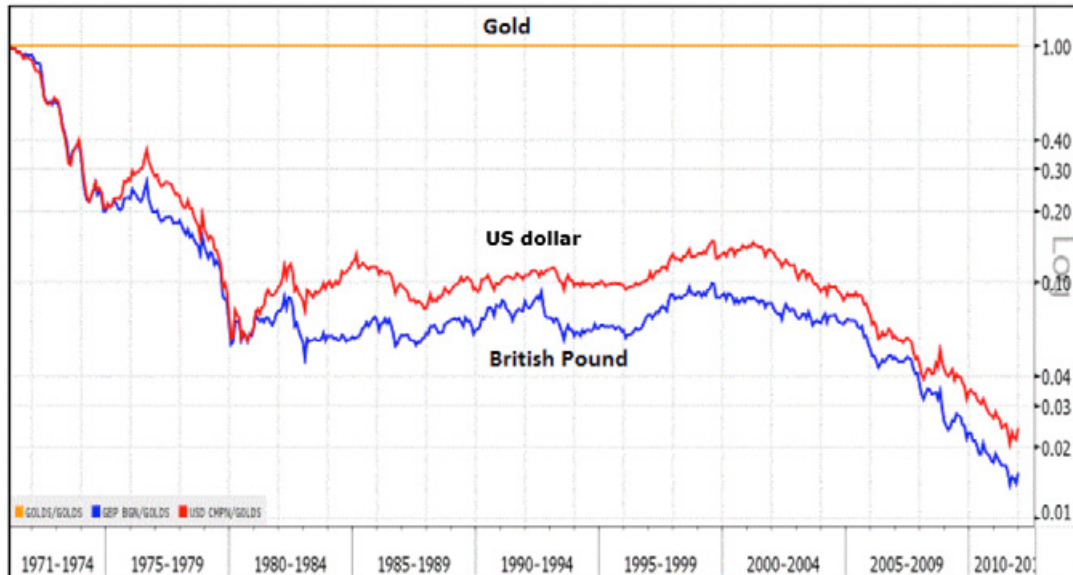
Source: Bloomberg

As you can see, gold is up approximately 4,100% (41-fold) compared to the US dollar during the last 40 years. That is a compound annualised growth rate of 9.5%. Most investors are surprised to learn that gold appreciated by such a large amount in the last four decades.

There is a different way to analyse the same information. In the next chart, we will use gold as the constant or numeraire, and measure the other two against gold. Again, to avoid distortions caused by the long time period, a logarithmic chart is used.

* The numeraire is simply the currency in which any transaction is denominated. For example, in the United States the assumed numeraire is the dollar, in Japan the yen, in Germany the euro.

**Exhibit 6: Gold vs. Two Major Fiat Currencies, 1971-2011
(with Gold as the constant)**



Source: Bloomberg

Looking at it this way, you can see that the two fiat currencies have depreciated significantly against gold. The US dollar lost 97% of its value, and British pound lost 98% of its value. Please remember that the US dollar was one of the more trusted currencies in the world during the last five decades — and many other currencies didn’t even survive the entire 40-year period.

The above graphs aren’t perfect. They don’t take into consideration interest or taxes. Some might argue that fiat currencies could have been earning interest all those years, so the loss is overstated. That is partly true. If fiat currencies are loaned out, they earn interest, of course. But the same goes for gold and silver — they could have also earned interest if they were loaned out (the “interest” rate on gold is typically referred to as the “lease” rate). Also, in each case, taxes would have to be paid each year on any interest earned. But please don’t miss the main point: *over long periods of time, even the good fiat currencies get diluted and lose value.* Even more importantly, a bad fiat currency can lose its value quickly.

So why did the US dollar depreciate 97% compared to gold during the last 40 years? One of the main reasons is the supply of gold only grew approximately 1-2% per year during that period, thus the entire monetary base of gold was only diluted at 1-2% per year. Meanwhile, the supply of US dollars grew approximately 6-10% per year. More specifically, the monetary base grew 10%, M1 grew at 6%, and M2 grew at 7%. Thus, the holders of dollars were diluted at a much faster rate than holders of gold. Over short periods of time, this dilution may appear inconsequential. Over longer periods, however, the difference can become significant — especially during periods when central banks are rapidly expanding the monetary supply.

Addressing Some of the Common Criticisms of Gold

Despite gold's significant out-performance vs. fiat currencies during the last 40 years, gold continues to have numerous critics. I believe it is worthwhile to listen to the arguments of those who question the value of precious metals. I also believe it is instructive to bring a fresh perspective to the debate.

The section below offers a different way to think about some of the common complaints.

A Different Perspective on Gold and the Dollar

Here are some of the common criticisms of gold:

Gold has little or no industrial use. It has no intrinsic value. Gold is just a piece of metal that sits there doing nothing. If gold does have value, it is difficult to value. It takes a lot of faith to invest in gold. Its stored value concept is simply a cultural convention. Somehow people just all seem to agree that gold has stored value. Unlike bread, air, or water, we could very easily spend the rest of our lives without gold. Therefore, gold could simply lose its value by everyone deciding that they no longer believe in its value.

Now, to be fair, the same criticisms can apply to the US dollar — or any other fiat currency for that matter:

The US dollar has little or no industrial use. It has no intrinsic value. The dollar is just a piece of paper that sits there doing nothing. If the dollar does have value, it is difficult to value. It takes a lot of faith to invest in the dollar. Its stored value concept is simply a cultural convention. Somehow people just all seem to agree that the dollar has stored value. Unlike bread, air, or water, we could very easily spend the rest of our lives without the dollar. Therefore, the dollar could simply lose its value by everyone deciding that they no longer believe in its value.

Questions & Answers

QUESTION: Besides jewellery, isn't gold useless?

ANSWER: No. Gold has some very important uses. First, it is used as money, and the last time I checked, money was a very useful item. Gold is also used in making jewellery, of course. Finally, gold does have some important industrial uses, which account for approximately 15% of annual gold demand. So gold has three main uses — monetary use (money and investing), consumer use (jewellery), and industrial use (various).

QUESTION: Gold doesn't pay interest. How do you address that issue?

ANSWER: That statement is both true and false. If you don't loan gold out, then it doesn't pay interest. But if you do loan gold out, then it does pay interest. The same is true for US dollars or any currency for that matter. If you loan out dollars, they pay interest. But if you don't loan out dollars, then they don't earn interest.

QUESTION: OK. But isn't the interest rate for gold lower than the interest rate for most fiat currencies?

ANSWER: Yes, that is true. The interest rate for gold is typically lower — and for good reason. Most borrowers would rather borrow money that loses its value over time. Also, the banking laws and legal tender laws in many countries make it difficult or impossible for most gold owners to earn interest. Finally, some holders of gold are concerned about counterparty risk and prefer to hold their gold instead of lending it out. Thus, they are willing to forego loss of interest for the safety of reducing counterparty risk.

QUESTION: Gold is so old-fashioned. Do you really expect everyone to store their own gold and carry around gold coins to buy stuff?

ANSWER: No. Gold can be held and transferred with all the benefits of modern technology. Gold is easily purchased and sold electronically.

QUESTION: Isn't it difficult to value gold?

ANSWER: Yes, it is. Valuing gold isn't easy — but it can be done. There are numerous ways to quantitatively value gold. As with any currency or asset, different people will use different methods and come up with various answers. But that is true of nearly any currency or asset. By the way, it is also difficult to value the US dollar or any other currency.

QUESTION: So how do you quantitatively value gold?

ANSWER: There are a number of different ways. In order to go through all the details, that would take another 50+ pages. I wish I had the time now, but I don't. In the meantime, here are a few of the different quantitative methods:

- QBAMCO's Shadow Gold Price methodology, which uses the same formula as Bretton Woods.
- James Turk's Gold Money Index, which uses the following formula:
$$\frac{\text{Central Bank Foreign Exchange Reserves}}{\text{Central Bank Gold Reserves}}$$
- The Federal Reserve Act of 1913 method, which used 40% backing of the currency.
- Various other percentages of US or global M0, M1, M2, or M3.
- As a percentage of US or global GDP.
- As a percentage of US or global net worth.
- As a percentage of US or global total credit market debt.
- Marginal cash cost of production methodology.
- Normalised total cost of production methodology.

Note: for some good details on some of these methodologies, you might want to read a 90-page report written by Erste Group Research entitled "Special Report Gold — July 2011." Here is a link to the report:
www.scribd.com/doc/59283769/Special-Report-GOLD-In-GOLD-We-TRUST-July-2011

Note: another interesting source is page 243 of a recently-published book by Jim Rickards entitled *Currency Wars: The Making of the Next Global Crisis*.

QUESTION: Using the above methodologies, what are the price targets for gold?

ANSWER: The price targets for gold's exchange rate vary from \$2,500 to \$12,000+ per ounce.

QUESTION: Many experts say gold is overvalued. What is your response?

ANSWER: The next time someone claims gold is overvalued, please ask them to quantify their claim. Many people give plenty of qualitative arguments about why gold might be overvalued, but they rarely provide any quantitative explanation. I would be sceptical of qualitative-only arguments.

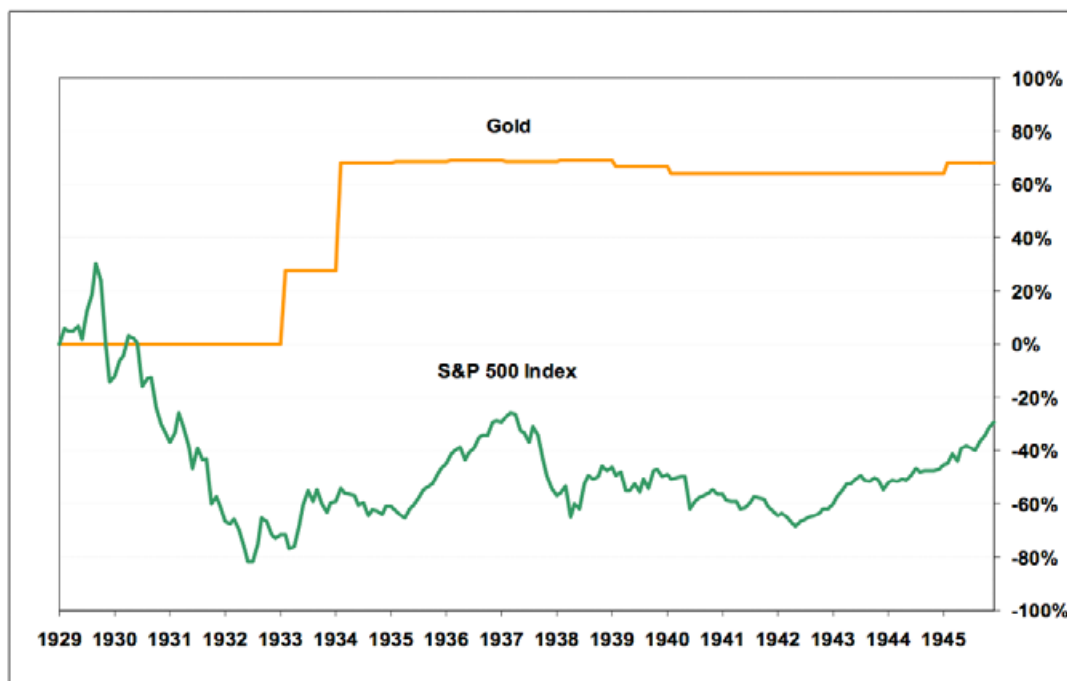
QUESTION: How high can the gold price go?

ANSWER: I prefer to start with a different question: “How low can the US dollar go?” I believe it is better to start with that question, because the debasement of the dollar and other fiat currencies is going to be one of the main drivers of the price of gold. Worldwide inventories of gold remain fairly constant, and an ounce of gold remains exactly constant. Meanwhile, the US dollar and other fiat currencies are being significantly diluted. If the dollar continues to lose a lot of its value, then the price of gold can go much higher.

QUESTION: Some people think there are large deflationary forces in the world. Doesn't gold perform poorly during deflationary periods?

ANSWER: No, not necessarily. I agree that there are large deflationary forces in the world, but during the two greatest deflationary periods in US history, gold performed quite nicely. During the Great Depression, gold actually rose 69% whereas most other assets dropped significantly in price. Additionally, during the 23-year deflationary period from 1873 to 1896, gold held its value while most other assets dropped in price. Below is a chart showing gold's performance during the Great Depression:

Exhibit 7: Gold vs. the S&P 500 Index from 1929-1945 (normalised)



Source: Bloomberg

QUESTION: Gold has had a terrific 11-year run. Have I missed it? Am I buying at the top?

ANSWER: I don't think so. Even after appreciating during the last 11 years, I believe gold is still undervalued and under-owned. It is significantly under-owned by mutual funds, hedge funds, pension funds, sovereign wealth funds, retail investors, and central banks. If gold comprised 5-10% of global portfolios, then I would be more worried. But gold only comprises approximately 1% of global portfolios. So there is plenty of additional buying that could send the price of gold higher.

QUESTION: Why isn't there more scientific discussion about gold?

ANSWER: Good question. While there hasn't been much recent scientific discussion of precious metals, there is actually a long history of scientific analysis of money and gold going all the way back to Aristotle, who wrote about gold and money in his great work on political philosophy entitled *Politics*. In fact, one of the greatest scientists of all time — Sir Isaac Newton — spent 31 years of his career analysing precious metals and money. In addition to Newton's numerous achievements in science, he became the Warden of the British Royal Mint in 1696. Then three years later in 1699, Newton became the Master of the Royal Mint, a position he held until his death in 1727.

QUESTION: How does fiat currency debasement happen, and why is gold immune to currency debasement?

ANSWER: In the old days, governments and politicians would try to debase the currency by mixing in less precious metals into the coins, or by making the coins smaller and trying to pass them off for the same value. With the invention of fiat paper currency, governments could just print more and thus devalue all of the currency in circulation. Today, they just create more electronically with the click of a mouse.

Meanwhile, unlike a fiat currency where the money supply can be increased by 5% or 10% with the click of a mouse, the supply of gold only increases by about 1% or 2% a year. In order to increase the supply of gold by 10% in one year, the world would have to build a huge number of new mines, which isn't likely to happen. Hence, the supply of gold has some significant constraints, which prevents oversupply. This allows it to be a reliable store of value.

QUESTION: What would cause you to sell gold?

ANSWER: I would sell gold when some combination of the following four things happens: First, if the US Federal Reserve were to raise the Fed Funds Rate to 10% similar to what Paul Volcker did in the early 1980s. (As you may recall, in that period the Fed Funds Rate averaged over 10% for nearly four years and even hit 20% on three occasions.) Second, if the Fed significantly reduced the size of its balance sheet. Third, if central bank balance sheets in Japan, Europe, and the United States stopped expanding so rapidly. And fourth, if gold were to become overvalued. As of this moment, however, none of the first three things are even close to happening. As for the fourth item, I believe that gold is undervalued, not overvalued.

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