1907
CAPITAL

First Principles of Central Banks and Asset Pricing, using Gold as a Window

Computing the Price of Gold using One Equation with One Variable

By: Adam Pieczonka, Hari Ravi, Andrew Barr, Samir Meghji

$$\textbf{\textit{Gold Price}}\ (\$) = e^{.6655 \ln(\textit{total fed assets}\ (\$)) - 12.1492}$$

Have you ever wondered about the plumbing of central banks? By "plumbing", we mean the sequence of transactions that underlie the monetary system. Yes – the circular mathematics that are derivative of these transactions are prevalent and cause much confusion. However, the physical transactions that underlie the resultant mathematics are much more important and valuable for any investor to understand. Once these physical transactions are understood and agreed upon, the mathematics – namely those underlying gold pricing – become obvious.

We will frame this topic with one central thought experiment. In 2020, the U.S. federal debt increased by ~22% from $23 trillion to $28 trillion. Over the same period, inflation held at just 1.4% while unemployment increased by 3%. However, the S&P 500 returned ~18% and the price of gold increased by ~31%. Why – with modest inflation and a decline in employment – did the stock market rise by ~18% and gold by ~31%?

Precedent A: A "price" is just a ratio of exchange of one asset for another

The most simplistic way to understand the U.S. monetary system is to begin with the most basic monetary unit: a dollar bill. A dollar bill – or more specifically a dollar "note" – is globally accepted as a store of value and unit of exchange – by governments, banks, corporations, and individuals.

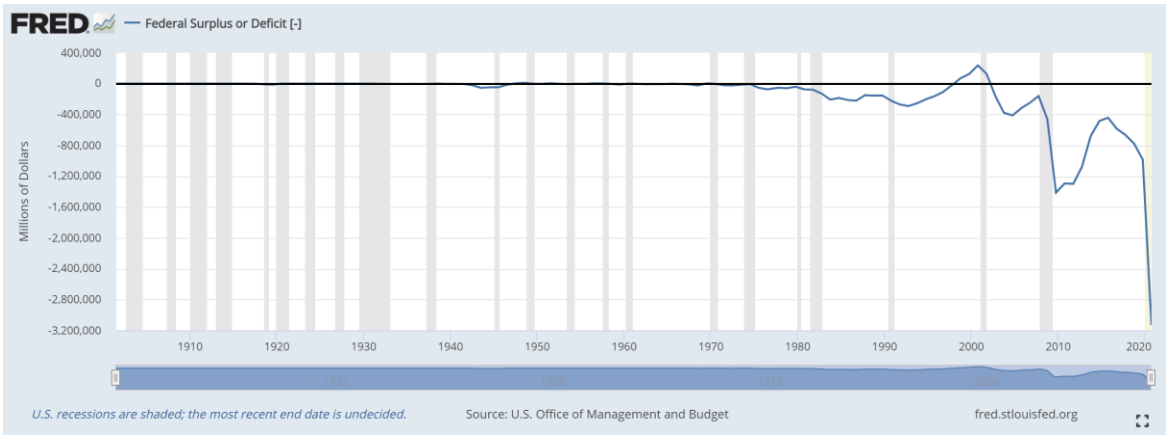
Prior to Bretton Woods breaking the gold standard in 1944 and Nixon breaking the fixed exchange ratio of the dollar to gold in 1971, the underlying "price" of the dollar was directly tied to gold. Historically, gold was recognized as a store of value that is finite in supply and relatively light in weight relative to its perceived value (and, thus, mobile). By pegging the price of a dollar to gold, the dollar's supply was transparently benchmarked against a commodity that was globally accepted as a means of exchange.

Under the gold standard, the dollar was a liability of the U.S. government, redeemable into gold. However, the dollar has since become a fiat currency, meaning the dollar is not pegged to a given commodity, but instead has value because the government has declared it has value. A 2003 one-dollar bill is pictured below. You can see that paper currency is a "note" (i.e., a liability) of the U.S. Federal Reserve, a private bank separate from but affiliated with the U.S. government. But, if Precedent A is correct, what ratio denotes the "price" or worth of this currency?

Precedent B: Money is debt, and debt is money

The value of a fiat currency is based on a circular web of liabilities. To understand this, one must understand how a government is funded and how liabilities are exchanged. Under a fiat system, the underlying "price" of a currency is the ratio of exchange of one liability to another.

So, how do these liabilities originate in the first place? It must first be mentioned that a government is a business like any other. The government has revenues (i.e., taxes) and costs (i.e., government salaries, defense, social security, outlays to foreign nations, among others) and the difference is represented as either a fiscal surplus (when revenues > costs) or a fiscal deficit (when revenues < costs). The U.S. government is regularly in a state of deficit and, as exhibited in the graph below, this deficit has been consistent and growing since the early 2000s. Moreover, with a Democrat-led government committed to combatting the macroeconomic implications of COVID-19 with greater stimulus, the U.S. government's fiscal deficit position is very unlikely to reverse course in the near-term.



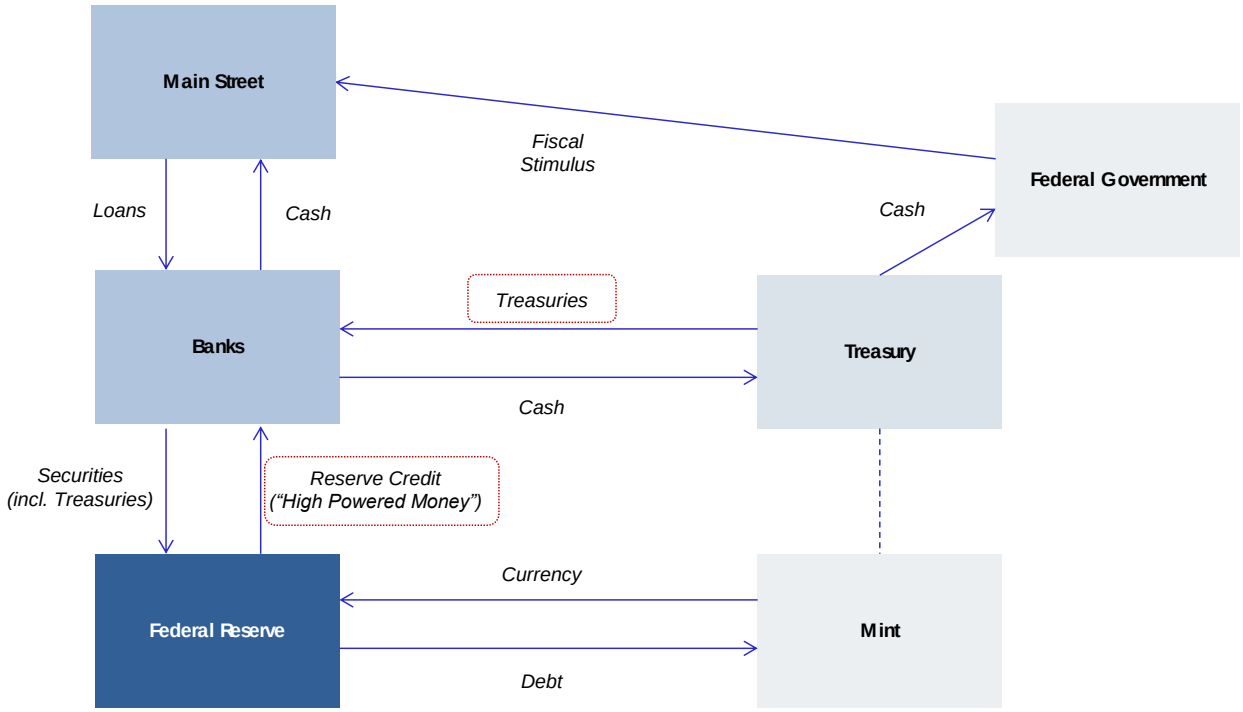
When a government has a fiscal deficit, raising debt (or liabilities) to fund a cash shortfall is common. The U.S. government sells treasuries to banks at auction and these banks then sell these acquired treasuries to entities such as foreign governments and corporations, individuals, and, importantly, the Federal Reserve.

The Federal Reserve, the "bank of banks", is a key participant in auctions for treasuries and other securities. Historically, the Federal Reserve's mandate was to mitigate inflation by influencing interest rates. Over time, that mandate expanded to a "dual mandate" (i.e., curbing inflation and assuring full employment), and now, arguably a "tri mandate" (i.e., curbing inflation, assuring full employment, and stabilizing capital markets).

How does the Federal Reserve fund the purchase of treasury securities? It borrows money – from the U.S. Treasury. Hence, why a one-dollar bill is a "Federal Reserve Note" …"legal tender for all debts, public and

private." While historically the Federal Reserve had the Mint print paper money to receive these funds, today much of this process is done electronically. When the Federal Reserve purchases treasuries from private banks, rather than printing currency and exchanging that currency for treasuries, the Federal Reserve simply electronically debits the reserves of private banks, thereby creating new electronic currency.

The resulting process is diagrammed below:



Source: 1907 Capital

Much like any other business, the Federal Reserve's assets equal its liabilities plus equity. In fact, the Federal Reserve's financial statements are available here. The Federal Reserve's balance sheet is comprised of assets (i.e., treasuries, private securities, gold, etc.) and liabilities (i.e., currency, deposits from private banks, etc.). If the Federal Reserve seeks to reduce interest rates by purchasing private bonds and money market instruments, the Federal Reserve's balance sheet grows. Further, if the Fed "monetizes" the Treasury's debt by purchasing Treasuries at auction (indirectly through banks, who acquire debt from the Treasury directly), the Federal Reserve's balance sheet grows. Each of these events creates additional currency (paper and electronic).

The whole process is circular, and the fiat monetary system is based on a U.S. dollar that represents a liability (i.e., Federal Reserve notes owed to the U.S. Treasury) based on a different liability (i.e., treasuries owed to the Federal Reserve, governments, corporations, and individuals). Above all, benchmarking the U.S. dollar against gold is simply a way of reasoning away from the circularity.

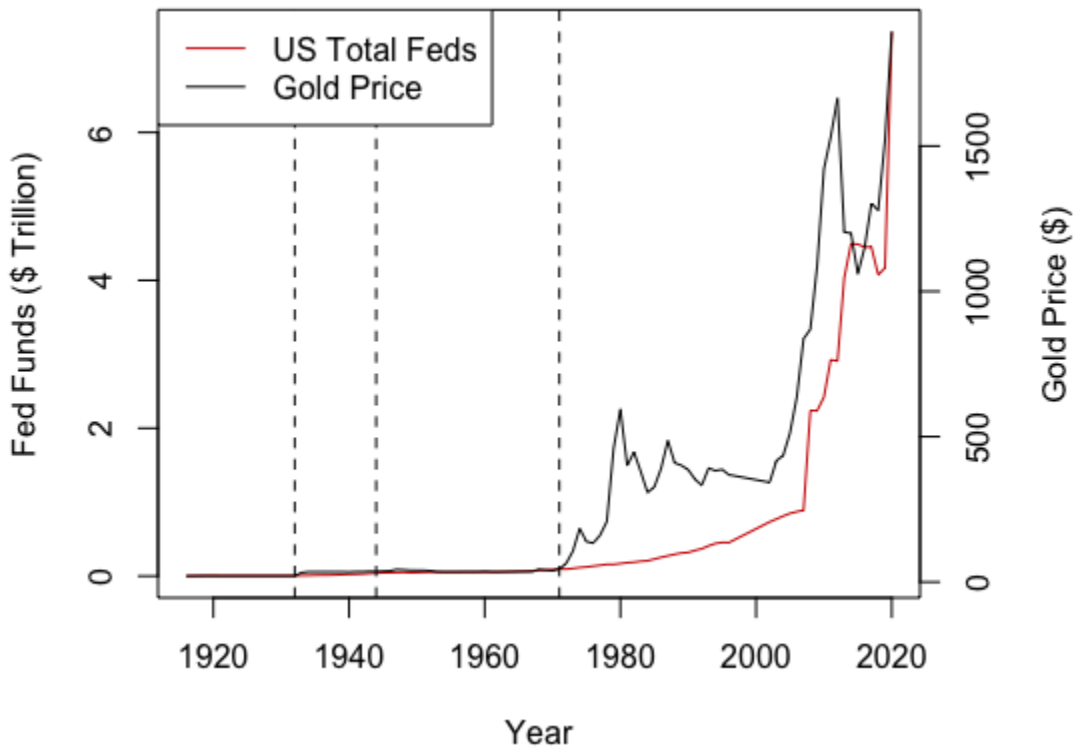
Precedent C: Gold's price is a ratio of global central banking currency to a finite commodity

To be clear, a universal "value" for gold does not exist. Rather, gold is simply exchangeable into other assets, including currencies. When quoting the price of gold in U.S. dollars, the ratio is simply the number of dollars to the amount of gold. The ratio (or "price" of gold) rises over time, not because gold is worth more, but rather because the number of dollars relative to the amount of gold rises. We have therefore established:

1) The U.S. dollar is a note payable, owed by the Federal Reserve
2) If there is a fiscal deficit, U.S. government's debt increases
3) If U.S. government debt increases, Federal Reserve's assets increase

4) If Federal Reserve assets increase, Federal Reserve liabilities also increase
5) If Federal Reserve liabilities (i.e., currency) increase, the ratio of Federal Reserve liabilities to the amount of gold increases

We have demonstrated in the graph below that fiscal deficits paired with asset purchases by the Federal Reserve results in a rising Federal Reserve balance sheet, and a rising Federal Reserve balance sheet impacts the "price" of gold. Said differently, the price of gold has been increasing not because gold is fundamentally worth more, but rather because the expansion of the Federal Reserve's balance sheet renders the value of the U.S. dollar relative to gold worth less.



Source: 1907 Capital

This is exactly what we observe in the graph above. Prior to the free float of gold in 1971, the ratio of gold and U.S. currency moved in lockstep. Afterward, while there would be short-term differentials in Federal Reserve assets to the price of gold (partially explained by market volatility, flights to / from safety, policy changes for central banks outside the U.S., etc.), the long-term value of gold can be predicted by dollar assets on the Federal Reserve's balance sheet. Further, since we spread long-term gold and Federal Reserve balance sheet data back to the early 1900s, we can use a logarithmic regression to test the predictive power of this relationship against the market price of gold today.

The resulting equation from a log-log regression is as follows[1]:

$$\textbf{\textit{Gold Price}}\ (\$) = e^{.6655\ln(\textit{total fed assets}\ (\$))-12.1492}$$

Therefore, if we assume today's value of the Federal Reserve's assets of $7.442 trillion, the imputed price of gold is $1950 versus a market price of $1842 (as of February 10th, 2021).

[1] See Model Out of Sample Performance in appendix to get a sense of how well this model generalizes to new data.

If we simplistically assume a further $1.900 trillion deficit over the next twelve months (e.g., coronavirus relief plan), and 60% of this deficit is monetized[2], the imputed price of gold is $2143.

Conclusion: There is no free lunch, unless if you can eat liabilities derived from liabilities

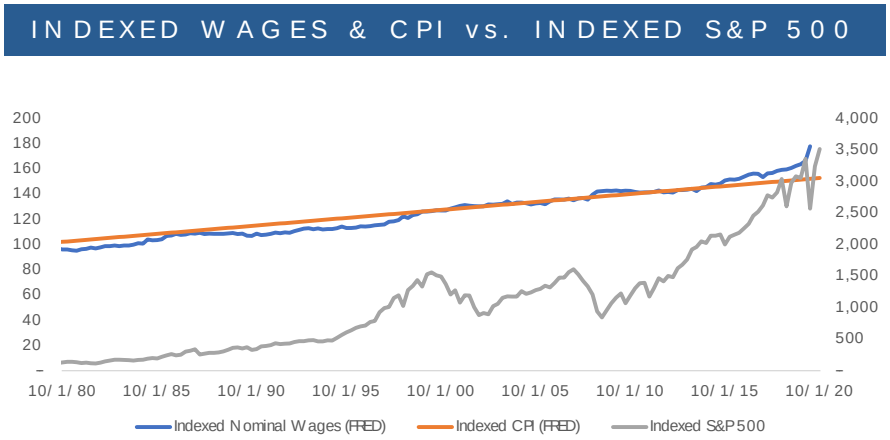
While Bretton Woods and Nixon's float changed the short-term trading patterns of gold, the long-term relationship holds. Why – because, as we have outlined, gold's "price" is a ratio, and this global ratio remains fixed to the amount of U.S. dollars today.

This takes us back to our initial thought experiment. In 2020, the U.S. federal debt increased by ~22% from $23 trillion to $28 trillion. Over the same period, inflation held at just 1.4% while unemployment increased by 3%. However, the S&P 500 returned ~18% and the price of gold increased by ~31%. Why – with modest inflation and a decline in employment – did the stock market rise by ~18% and gold by ~31%?

Precedents A, B and C still hold. In 2020, we saw record fiscal stimulus, which increased U.S. government debt by $5 trillion. Also, the Federal Reserve, after the longest bull run in U.S. history, expanded its mandate even further to include the purchase of corporate bonds and a record ~60% of new issue Treasuries were acquired by the Federal Reserve. Both fiscal stimulus and Federal Reserve intervention resulted in – you guessed it – a rising Federal Reserve balance sheet. If currency is just an obligation of the Federal Reserve and these obligations increased, isn't it therefore logical that asset "prices" moved in lockstep with the increase in U.S. government debt? Are the S&P 500 and gold worth more, or is the U.S. dollar just worth less?

Post-script: Implications

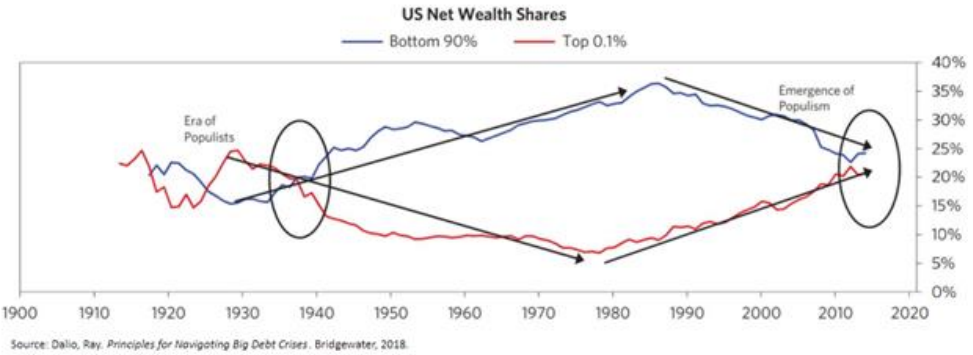
Over the last 40 years, the S&P 500 increased by a factor of 3,400x while wages increased 60% over the same period.



Source: FRED, FactSet

We have not seen material CPI "inflation,"; however, we have observed rampant asset inflation and wealth dislocation. These trends of wealth inequality will uniquely impact companies, industries, and countries as the economic, demographic, and geopolitical consequences manifest over time.

[2] https://www.pgpf.org/blog/2021/01/the-federal-reserve-holds-more-treasury-notes-and-bonds-than-ever-before, in this source the increase in the total fed assets was ~2/3 of the purchased notes

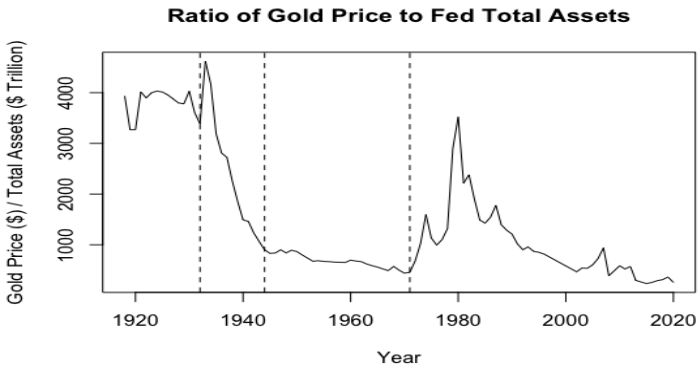


//Volatility is ahead

The 1907 Capital Team

Appendix

Below is a plot showing Gold Price / Fed Total Assets (with 1933 (gold standard broken), 1941 (Bretton Woods), and 1971 (Nixon Shock) highlighted)



Constructing the model:

Our first challenge was finding the data. We came across a database[3] with published federal reserve balance sheets starting from January 1, 1916. We manually transcribed ~80 years' worth of data of this format (with the additional 20 years coming from the FRED[4]). Similarly, we found historical gold prices[5], and constructed a database consisting of total federal assets and gold prices from 1916 to 2020.

A classic Federal Reserve balance sheet published 1/1/1916

Released for publication Saturday morning January 1, 1916. Not earlier.

STATEMENT OF COMBINED RESOURCES AND LIABILITIES OF THE FEDERAL RESERVE BANKS OF THE UNITED STATES AT CLOSE OF BUSINESS DECEMBER 30, 1915.

RESOURCES.	December 30, 1915	December 23, 1915	October 1, 1915	July 2, 1915 (a)	December 31, 1914.
Gold coin and certificates in vault	$266,546,000	276,197,000	227,274,000	231,368,000	228,641,000
Gold settlement fund	77,293,000	69,960,000	55,180,000	31,640,000	... ...
Gold redemption fund with U. S. Treasurer	1,124,000	1,224,000	1,202,000	1,080,000	428,000
Total gold reserve	344,963,000	347,381,000	283,656,000	264,288,000	229,069,000
Legal tender notes, silver, etc	13,525,000	9,673,000	16,493,000	24,841,000	26,578,000
Total reserve	358,488,000	357,054,000	300,149,000	289,129,000	255,647,000
Bills discounted and bought:					
Maturities: Within 10 days	6,467,000	6,133,000	5,765,000	13,322,000	4,632,000
From 11 to 30 days	14,278,000	13,524,000	12,267,000		
" 31 to 60 days	16,859,000	17,861,000	15,790,000	9,735,000	3,531,000
" 61 to 90 days	13,696,000	12,830,000	9,606,000	8,097,000	1,746,000
Over 90 days	4,081,000	4,073,000	1,452,000	5,033,000	
Total	55,381,000	54,421,000	44,880,000	36,187,000	9,909,000
Investments: U. S. bonds	15,797,000	15,060,000	9,329,000	7,652,000	205,000
Municipal warrants	13,220,000	14,094,000	27,381,000	12,390,000	734,000
Federal reserve notes - Net	21,910,000	21,008,000	15,378,000	7,601,000	5,418,000
Due from Federal reserve banks - Net	20,767,000	24,977,000	11,194,000	9,862,000	7,930,000
All other resources	6,547,000	4,194,000	3,326,000	3,660,000	5,931,000
TOTAL RESOURCES	$491,110,000	490,808,000	411,637,000	366,481,000	285,774,000
LIABILITIES.					
Capital paid in	54,915,000	54,901,000	54,728,000	54,128,000	18,051,000
Government deposits	15,000,000	15,000,000	15,000,000	... ...	... ...
Reserve deposits - Net	400,012,000	398,603,000	324,884,000	297,883,000	263,948,000
Federal reserve notes - Net	13,486,000	14,670,000	14,359,000	12,797,000	3,775,000
All other liabilities	7,697,000	7,634,000	2,666,000	1,673,000	... ...
TOTAL LIABILITIES	$491,110,000	490,808,000	411,637,000	366,481,000	285,774,000
Gold reserve against net liabilities (A)	84.6%	86.1%	82.7%	87.9%	88.2%
Cash reserve against net liabilities (A)	87.9%	88.5%	87.5%	96.1%	98.4%
Cash reserve against net deposit liabilities after setting aside 40% gold reserve against net amount of F. R. notes in circulation (A)	89.6%	90.4%	89.6%	98.6%	99.3%
(A) Less items in transit between F.R. banks - viz:	$20,767,000	24,977,000	11,194,000	9,862,000	7,930,000

(a) Amended Statement.

A more recent balance sheet, published 1/4/1990

[3] https://fraser.stlouisfed.org/title/h41-factors-affecting-reserve-balances-depository-institutions-condition-statement-federal-reserve-banks-83?browse=1990s#65839

[4] https://fred.stlouisfed.org/series/WALCL

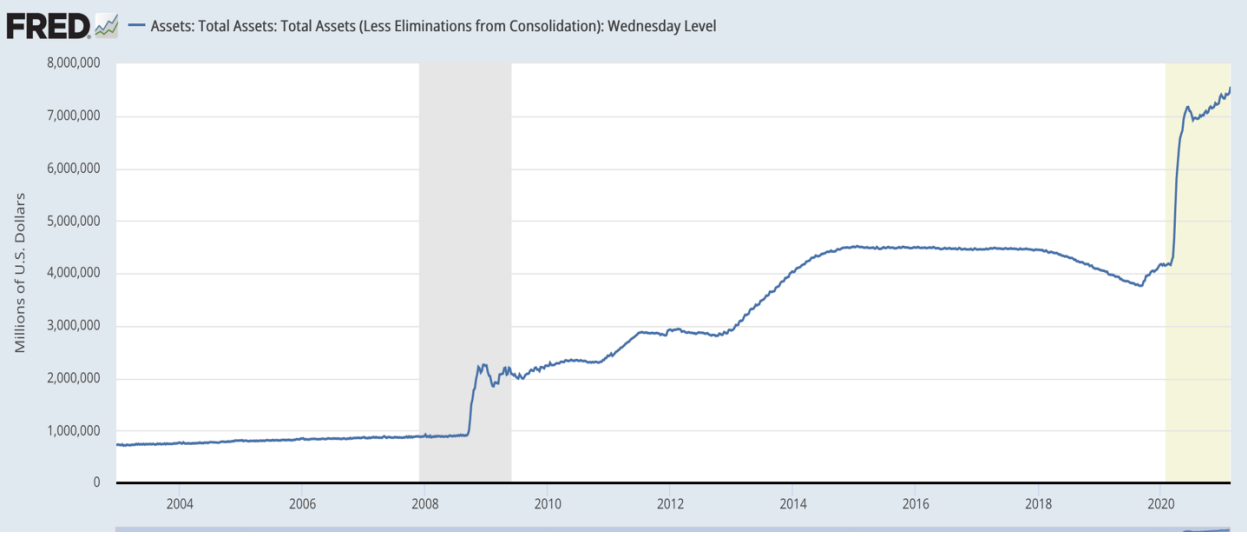
[5] i.e., https://onlygold.com/gold-prices/historical-gold-prices/

CONSOLIDATED STATEMENT OF CONDITION OF ALL FEDERAL RESERVE BANKS
Millions of dollars

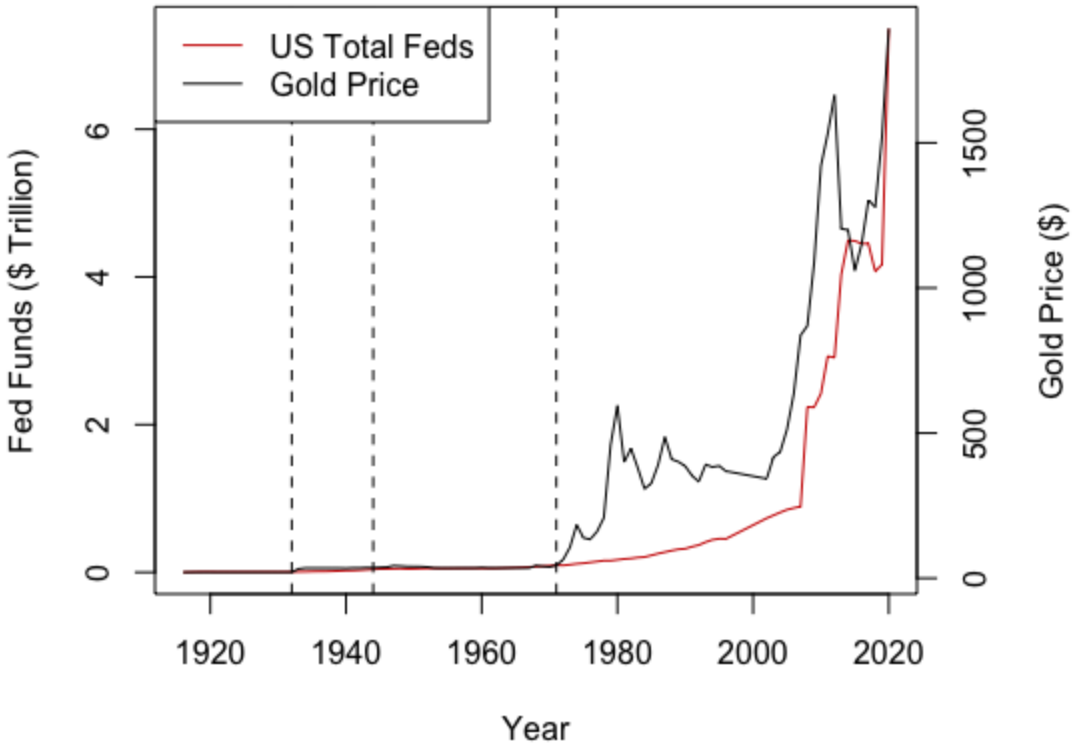
	*	Wednesday Jan 3, 1990	Change since Wednesday Dec 27, 1989	Change since Wednesday Jan 4, 1989
ASSETS				
Gold certificate account		11,059	0	- 1
Special drawing rights certificate account		8,518	0	+ 3,500
Coin		447	- 20	+ 65
Loans		166	- 1,993	- 1,828
Acceptances		0	0	0
Federal agency obligations				
Bought outright		6,525	0	- 441
Held under repurchase agreements[1]		785	- 716	- 2,779
U.S. government securities				
Bought outright--Bills		101,549	+ 1,549	- 10,596
Notes		91,381	0	+ 431
Bonds		30,814	0	+ 884
Total bought outright[2]		223,744	+ 1,549	- 9,281
Held under repurchase agreements[1]		5,123	- 6,633	- 1,974
Total U.S. government securities		228,867	- 5,084	- 11,255
Total loans and securities		236,343	- 7,793	- 16,303
Items in process of collection	(1,233)	10,830	+ 2,680	- 2,185
Bank premises		790	+ 1	+ 40
Other assets[3]		38,076	+ 939	+ 20,155
TOTAL ASSETS	(1,233)	306,063	- 4,193	+ 5,271
LIABILITIES				
Federal Reserve notes		241,878	+ 279	+ 12,266
Deposits				
Depository institutions		38,948	- 9,188	- 4,600
U.S. Treasury--general account		7,203	+ 2,174	- 1,611
Foreign--official accounts		282	+ 13	+ 93
Other		172	- 352	- 158
Total deposits		46,606	- 7,353	- 6,275
Deferred availability cash items	(1,233)	8,925	+ 2,288	- 1,514
Other liabilities and accrued dividends[4]		3,980	+ 782	+ 559
TOTAL LIABILITIES	(1,233)	301,389	- 4,003	+ 5,036
CAPITAL ACCOUNTS				
Capital paid in		2,243	- 4	+ 129
Surplus		2,243	+ 131	+ 130
Other capital accounts		188	- 317	- 24

* Figures in parentheses are the eliminations made in the consolidation process

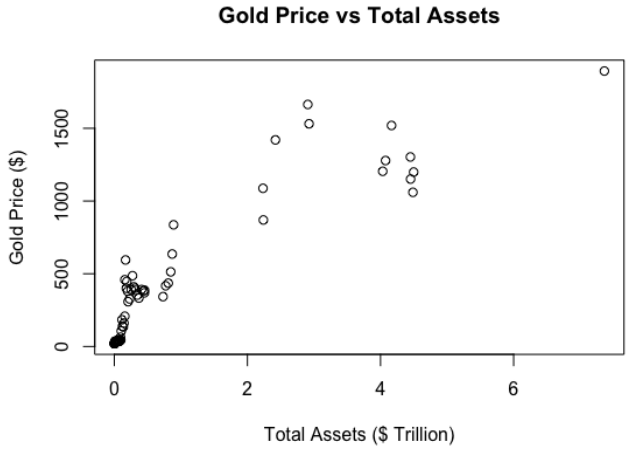
Total Federal Assets from 2002 to 2021



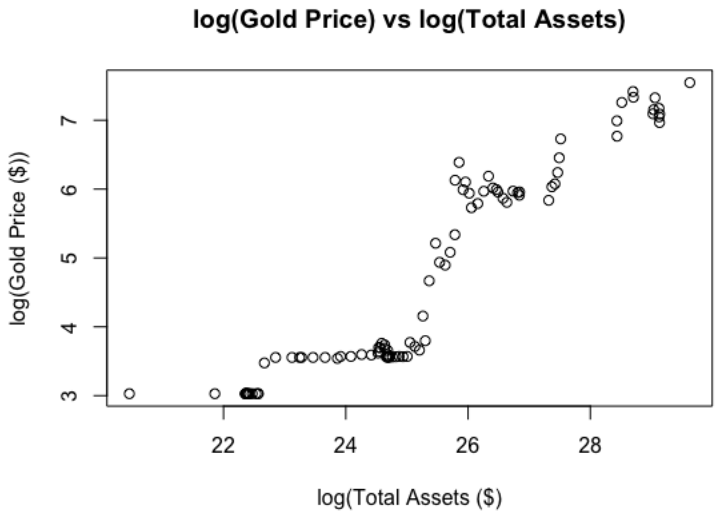
Next, based on the time series plot below we observed a strong correlation between gold price and total fed assets.



As a result, we attempted to model gold price as a function of total fed funds, so first we present a plot to display the composition of our data.



There is an evident relationship, and this is further observed when we reduce some of the variation in the data by performing a log-log transformation.



Note that there exist some gold prices that are the same for a wide span of total assets, and in other instances there are different gold prices corresponding to identical total assets – thus we cannot construct a perfect model. Still, there was a clear trend which appeared somewhat linear, we started by performing a simple regression, and the correlation was strong as seen in the output.

Regression Output: Note the high R^2 (~0.87), and statistical significance of log(Total Fed assets), and also provided is the log-log plot with the regression fit.

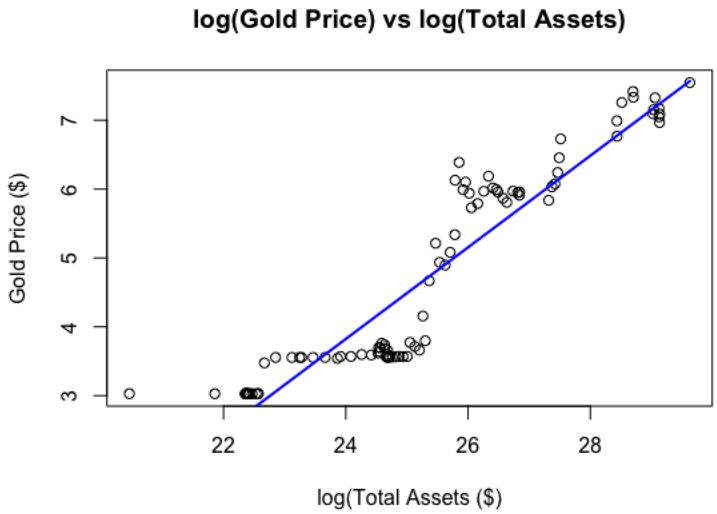
```
Residuals:
    Min      1Q  Median      3Q     Max
-0.9635 -0.5065  0.1170  0.3107  1.5620

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       -12.14924    0.66726  -18.21   <2e-16 ***
log(Total.Assets)   0.66551    0.02635   25.25   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.546 on 98 degrees of freedom
Multiple R-squared:  0.8668,    Adjusted R-squared:  0.8655
F-statistic: 637.8 on 1 and 98 DF,  p-value: < 2.2e-16
```

The regression equation:

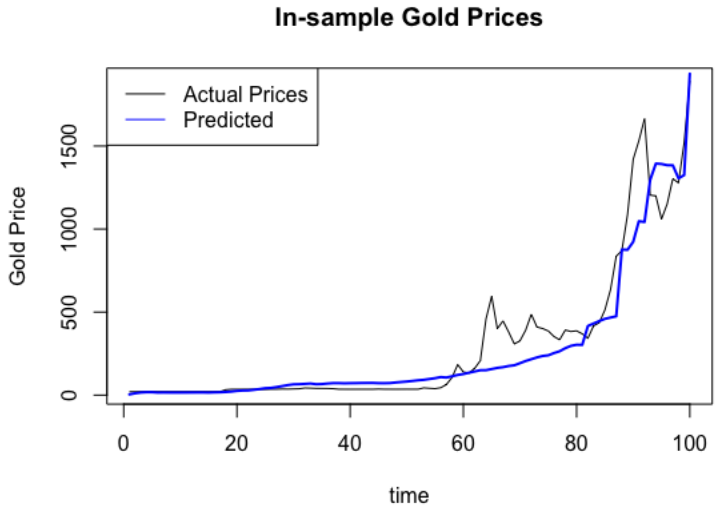
$$ln(Gold\ Price\ \$) = .66551 * ln(Total\ FedAssets) - 12.14924$$



Translating this regression to compute prices, by exponentiating both sides of the regression equation:

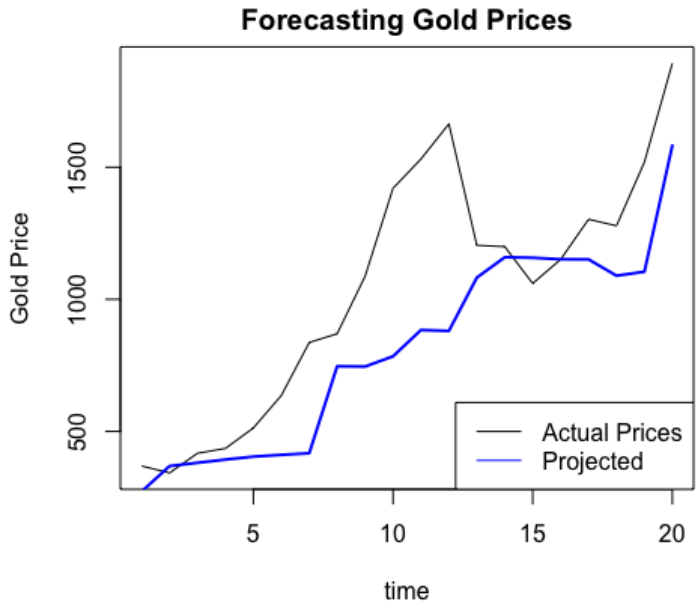
$$Gold\ Price\ (\$) = e^{.6655 \ln(total\ fed\ assets\ (\$)) - 12.1492}$$

We present the in-sample predicted gold prices below – again, even in-sample the regression is far from perfect, primarily due to the identical values problem previously described, but it provides a good trace. However, this is not meaningful – we are predicting gold prices using data we used to train our prediction model, how does this work on unseen data?



Model Out of Sample Performance:

We fit a model on the first ~80 years of training data and showed how well it predicted gold prices from 2000-2020. Our analysis captures the general trend. Also, we could further refine this model with additional data transcription, i.e., manually transcribing the balance sheets pictured earlier on a weekly basis as opposed to a yearly basis from 1916 onwards.


Forecasting Gold Prices
Gold Price
500
1000
1500
5
10
15
20
time
Actual Prices
Projected