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Park Edge Advisors LLC is a registered investment advisor

Below is some of the early research that laid the groundwork for our active risk management process at Park Edge Advisors. Put Growth First (PGF) is an economic policy and pro-growth advocacy group that I co-founded in 2013 following my role as Senior Economic Advisor to Herman Cain's presidential campaign (2011) and his successor organization Cain's Solutions (2012). My most active involvement with PGF was 2013-2016 briefing and advising members of congress on the benefits of stabilizing the dollar's *real* value as a means of restoring GDP growth strong enough to solve our fiscal problems and ending income stagnation for the bottom 90%. The effort culminated in the House passing the Centennial Monetary Commission to examine Fed policy and consider alternatives such as this. But a shallow victory it was as the Senate never called a vote and the bill effectively died.

The main conclusion of this paper is that dollar volatility should not be dismissed as "transitory" as the Fed too often does, but to the contrary should be taken quite seriously. A stable real dollar results in significantly better economic performance compared to a volatile one. As such, from an investment standpoint, changes in volatility are an important market signal. This led to building out an investment process that, among other variables, incorporates volatility in the dollar's real value as an important risk on/off signal. This forms the chassis for several of Park Edge's active-risk-managed investment strategies including Risk Managed Equities (RME), RME Focus, Moderate-Active Risk Management, and Moderate Long-Short Active Risk Management. For more, visit <https://ParkEdgeAdvisors.com/>

Dollar Stability vs. Dollar Volatility

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Put Growth First
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Statement of Problem:

The Fed often says the dollar is a "transitory factor¹." The American Heritage dictionary defines transitory as "Existing or lasting only a short time; short-lived or temporary." While it doesn't have a formal definition in an economics context, it is my interpretation that if the dollar is indeed transitory, the effects would come and go, they would even out over time. In this regard, a volatile

¹ Numerous statements by Federal Reserve officials made in speeches, press conferences, transcripts, and congressional hearings.

dollar may have some positive effects as it moves in one direction, and those effects may be offset as it moves in the opposite direction, resulting in overall economic performance that shouldn't be too different than if it were stable all along.

This project tests whether certain dependent variables representing economic performance, namely real GDP growth (GDP%) and real income growth for the bottom 90% (B90%), behave differently during periods in which the dollar is stable compared to other periods in which it is volatile. GDP% is a measure of overall prosperity and B90% is a gauge of the breadth of prosperity. Periods of dollar *stability* have been aggregated into a population (\$S) and periods of dollar *volatility* have been aggregated into a separate population (\$V) based on coefficient of variance (independent variable). If the dollar is a transitory factor, there should be no statistically significant difference in GDP% or B90% across the two populations. The null hypothesis is set accordingly.

Background Context:

There are two broad schools of thought on what drives the economy: consumption (i.e., demand side, exemplified by John Maynard Keynes) or production (i.e., supply side, exemplified by classical economists such as Jean-Baptiste Say or Fredrick von Hayek). I have approached this study from the standpoint that production is the main driver. In this context, business investment is the fuel. A stable dollar facilitates investment by sending clean price signals, leading to efficient allocation of capital investment. The price of anything is that item's value divided by one nominal dollar. If the denominator has a relatively steady *real* value, then an increase in price for a certain item signals relative scarcity and engages producers to invest to produce more (and consumers to consume less), thus restoring equilibrium. However, if the denominator declines, causing the price of the measured item to go up, it may similarly lead to more investment (and less consumption), but it is only because of the declining dollar, not because of any true relative scarcity. If the denominator later reverses course back to its original level, bringing the price of the measured item back down, it may render those investments whose basis was the faulty price signal as unviable, possibly leading to write-offs and lay-offs. In contrast to the first case, this one can be viewed as a misallocation of resources caused by a volatile unit of measure; a waste of precious economic fuel. Thus, the research hypothesis is that the \$V and \$S populations are not the same, that prosperity will be impacted by a volatile unit of measure. Additional tests have been conducted to measure the amount of impact, and test for its significance.

From the opposite school of thought, that consumption drives the economy, the dollar's value is viewed in comparison to a lagging index of sampled prices for finished goods, such as the Consumer Price Index (CPI) or the Implicit Price Deflator for Personal Consumption Expenditures (PCE). This view was illustrated in testimony before the House Financial Services Committee by the Fed's chairman at the time, Ben Bernanke who, in response to a question about the dollar, said, "My definition of the dollar is what it can buy. Consumers don't want to buy gold; they want to buy food, and gasoline, and clothes and all the other things that are in the consumer basket. It is the buying power of the dollar in terms of those goods and services that is what is important, and that's what I call price stability."²

On one level, there is no disagreement that the dollar should be stable. But on another level, there is disagreement on the question of "stable against what?" Stabilize it against commodities, which are inputs to all of GDP, or against output prices of consumer goods that make up only 2/3 of GDP. Stabilize it real time, or with the lag of a price index? Stabilize it in a way that best facilitates production, or in a way that facilitates consumption?

For this study, I have examined the difference in GDP% and B90% between two populations, one in which the dollar's commodity value shows persistent stability (\$S), and one in which it exhibits persistent volatility (\$V). If the dollar is transitory, the difference should not be significant, as indicated by the null hypothesis. The research hypothesis says there is a significant difference. Thus:

Null Hypothesis:

- 1) $H_0: \mu(\text{GDP\%}-\$S) = \mu(\text{GDP\%}-\$V)$,
- 2) $H_0: \mu(\text{B90\%}-\$S) = \mu(\text{B90\%}-\$V)$

Research Hypothesis

- $H_a: \mu(\text{GDP\%}-\$S) \neq \mu(\text{GDP\%}-\$V)$ and
- $H_a: \mu(\text{B90\%}-\$S) \neq \mu(\text{B90\%}-\$V)$

If the null hypothesis can't be rejected, then it offers evidence in support of the dollar being a transitory factor. I have tested at the $\alpha=.05$ significance level. If the t-value produced by the hypothesis is more extreme than the t-value that corresponds to $\alpha/2$ (two tailed test), the null hypothesis will be rejected. In this case, it may suggest the dollar is more than just transitory, that its stability is important. Whether the null is rejected or not, its t-value will be converted to a probability which may aid in the interpretation of the results.

² House Financial Services Committee hearing, Feb. 2011

The Commodity Value of the Dollar: A proxy for the dollar's real value:

It is perhaps most common to look to foreign exchange rates to assess the value of the dollar. These are useful because they are real-time, market-determined rates, unlike a price index, which is lagging, sampled data. An exchange rate is simply a ratio of one currency to another, a numerator and a denominator. However, in a world of freely floating fiat currencies, it is difficult to ascertain whether the ratio is changing because of the numerator or denominator. If the dollar, euro and yen all move in the same direction, exchange rates could be unchanged, and because these currencies dominate a trade-weighted basket, the dollar versus the basket might be little changed.

For this analysis, I need a fixed reference, something real in the physical world, something with intrinsic value, something constrained by the real resources required to produce it, unlike fiat money.

There is a long history of tying money to commodities, particularly gold, which has spanned centuries and covered the globe. Commodities give money intrinsic value. Unlike finished goods, commodities do not change in character. A pound of copper today is exactly the same pound of copper as any point in history. If it hasn't changed its character at all, perhaps the change in its price is due to a change in the yardstick that measures it, the dollar. When the dollar was defined as a specific weight of gold, it may have been easier to see the dollar's real value (relative to other commodities) as being the same as gold's real value. Just because a formal link no longer exists, it doesn't follow that one can no longer serve as a proxy for the other.

A price is a ratio, just like an exchange rate, where an item is divided by the yardstick measuring it. So if an item is priced in dollars, the dollar can be priced in terms of that item by inverting the same ratio. If the price of a commodity index such as the CRB Index in terms of dollars is, say, \$200 (i.e., 200/\$1), then the price of the dollar in terms of the CRB Index is \$1/200. Throughout this study, the dollar's commodity value can be interpreted as the inverse of the CRB Index price. Thus, a rising index implies a decline in the dollar's commodity value and a falling index implies an increase in the dollar's commodity value. The dollar's commodity value is synonymous with its real value.

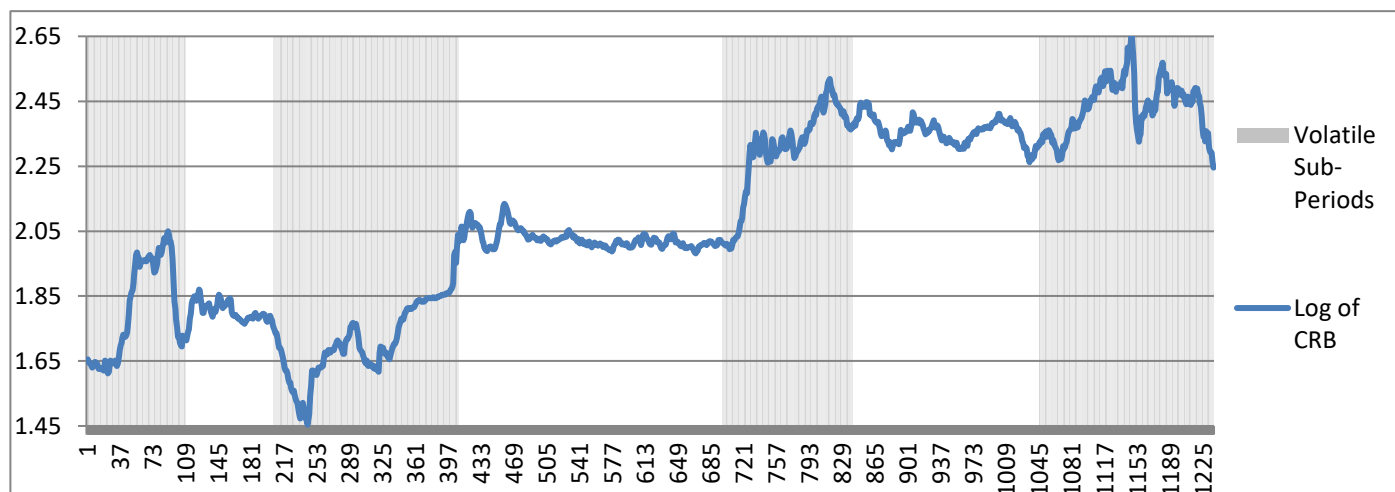
A commodity index is preferable to any single commodity in this context, so historical data will be based on a reconstructed CRB Index provided by Bianco Research³. Because the index is diversified and equally weighted, it neutralizes supply/demand characteristics and elasticities of any particular commodity. Investment decisions are made real-time and large, global commodities markets offer real-time prices. In a diversified global index, it is unlikely every commodity would be undergoing the same supply/demand conditions at once. But if the denominator changed, all commodities would undergo the same directional move in price at the same time.

Going back to foreign exchange rates, if the dollar appreciated against the yen, but was unchanged against commodities, the dollar's commodity value would be unchanged and the yen's commodity value would have depreciated. The neutral reference provided by commodities would offer insight.

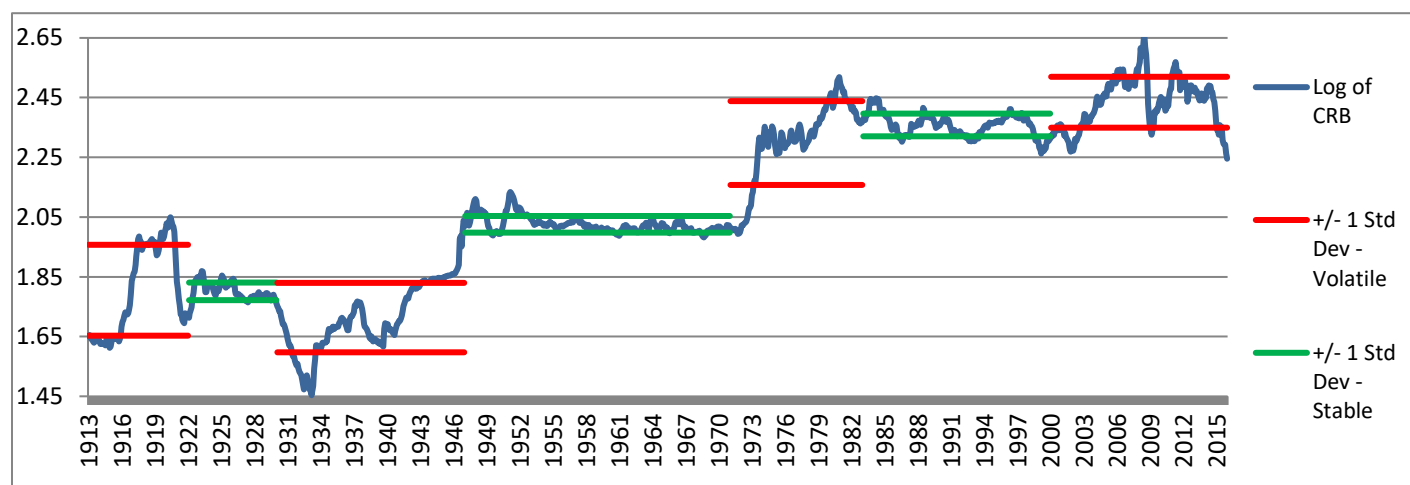
Methods:

A monthly time series of CRB Index prices from 1913 to 2015 was converted to a log scale. Monthly prices are more revealing of volatility than annual prices, which can conceal intra-year volatility. Because the index has ranged over this time from 28 to 462, log values have the effect of standardizing percentage moves in the index. The graph below was visually inspected and segmented into sub-periods in which commodity prices were relatively volatile (shaded in blue) or relatively stable (no shading). Thus, the dollar's commodity value is deemed volatile during the shaded periods and stable during the unshaded periods.

³ Formerly the Commodity Research Bureau Index, now known as the Thompson-Reuters/Jeffries CRB Index. See Appendix-A for a more detailed explanation of the data set.



For each sub-period, a range based on the mean for that period ± 1 standard deviation was superimposed against the log of CRB prices. The chart below indicates such ranges.



The process of grouping consecutive years representing a sub-period into either population is similar to *judgement sampling*, except here it was used to determine populations. As such, some degree of subjectivity is unavoidably introduced. For example, two people may agree that the 1950's and 1960's generally featured stable commodity prices (and a stable commodity value for the dollar), but they could reasonably differ on the exact year in which the sub-period began and ended. In fact, the exact cut offs for every sub-period are open to a degree of interpretation. Every cut off had to be made on an annual basis to correspond with the dependent variables of GDP, which is reported quarterly, and B90, which is reported annually. Thus, the common denominator

for the analysis is annual data, which means that even if a change in volatility commenced at, say, the mid-point of a year, the full year had to be designated in a given sub-period.

To incorporate objectivity into an otherwise subjective exercise, two additional steps were incorporated to validate the segmentation. First, significant monetary policy changes that occurred over the time series were reviewed. To the extent that policy changes were associated with a change in price behavior, segmentation was aided by considering them. The table below summarizes the events and any actions taken as a result.

Event	Year	Comment
Federal Reserve Established	1913	Begin analysis
Genoa Conference	1922	Established the dollar as a reserve currency. Associated with a subsequent change in price behavior. Used 1922 to mark the beginning of the next sub-period
Gold Reserve Act	1934	Dollar devalued in terms of gold. No meaningful change in price behavior, relative volatility continued. No action taken.
Bretton Woods	1946	Defined the dollar in terms of gold and established fixed exchange rates. Associated with a subsequent change in price behavior. Used its implementation in 1947 to mark the beginning of the next sub-period.
Closing of the Gold Window	1971	Gold convertibility suspended. Associated with a subsequent change in price behavior. Used 1971 to mark the beginning of the next sub-period.
Other changes in Fed operating procedures	1982	NBER research paper ⁴ concluded the Fed changed methods of intervention during 1982. Associated with a subsequent change in price behavior. Used 1983 to mark the beginning of the next sub-period

In the initial chart of CRB log values, which is broken down in 7 sub-periods, there are 6 transitions from one period to the next. Of these, 4 are accounted for by referencing the above policy actions. This leaves 2 transitions, the one after 1929, and the one after 1999, to be determined by judgement. While it may be clear to most observers that prices became quite volatile after 1929, the case of 1999 is not as clear cut. Reasonable observers could conclude that this period of relative stability ended within a year or two of the date I chose. In this case, I will rely on the law of large numbers to claim that whether this sub-period ends as indicated or a year or two on either side of it, the results shouldn't change that much. To confirm this, I looked for outliers in values for the dependent variables. If extreme values occurred around 1999 for GDP% and B90%, then it is

⁴ National Bureau of Economic Research. U.S. FOREIGN-EXCHANGE-MARKET INTERVENTION AND THE EARLY DOLLAR FLOAT: 1973 – 1981, Michael D. Bordo, Owen F. Humpage, Anna J. Schwartz, Working Paper 16647 <http://www.nber.org/papers/w16647>

possible that changing the sub-period cutoff could change results slightly. Based on z-scores for the years in question, I found no such outliers.

The nearby table summarizes the years that correspond to the volatile sub-periods that comprise the \$V population, and the years that comprise the \$S population.

Summary of Populations			
Volatile-\$V	n	Stable-\$S	n
1913-1921	9	1922-1929	8
1930-1946	17	1947-1970	24
1971-1982	12	1983-1999	17
2000-2015	16		
Total	54	Total	49

The second step to minimize subjectivity was to conduct statistical analysis to verify the populations are *different enough*. Descriptive statistics were calculated for the \$V and \$S populations. A hypothesis test was conducted to determine whether it is tenable that the populations aren't that different, that the difference can be explained by normal statistical variation.

To standardize the price data, the initial value of each sub-period was indexed to equal 100. From there, the percentage changes that occurred in the CRB Index throughout the period were applied to this common starting point. Thus, the mean used for the hypothesis test is the mean for the indexed values rather than the CRB actual prices. The null hypothesis and research hypothesis are as follows:

$H_0: \mu(\text{\$V-indexed sub-periods}) = \mu(\text{\$S-indexed sub-periods})$ and

$H_a: \mu(\text{\$V-indexed sub-periods}) \neq \mu(\text{\$S-indexed sub-periods})$

The results are summarized in the table below.

At the 5% significance level, the t-value is 4.72066, which is more extreme than the critical value of 2.002, leading to rejection of the null hypothesis. The theoretically superior segmentation would

CRB Monthly Prices - The beginning of each sub-period indexed to 100 to make prices comparable					
Volatile Sub Periods - \$V		Stable Sub Periods - \$S		t-value calculations	
				n	
				n-1	
Mean	138.949	Mean	102.219	s	
Standard Error	2.18856	Standard Error	0.47358	s^2	
Median	121.829	Median	98.9816	s^2/n	
Mode	120.887	Mode	100	(s^2/n)^2	
Standard Deviation	55.8834	Standard Deviation	11.5129	1/n-1	
Sample Variance	3122.95	Sample Variance	132.548	df numerator	
Kurtosis	-0.0471	Kurtosis	0.70479	df denominator	
Skewness	0.80726	Skewness	1.04585		
Range	269.46	Range	63.8643		
Minimum	49.2553	Minimum	78.2722	df=	
Maximum	318.716	Maximum	142.137	t (a/2=.025, df=57)	
Sum	90594.7	Sum	60411.7	t numerator	
Count	652	Count	591	t denominator	
Confidence Level(95.0%)	4.29749	Confidence Level(95.0%)	0.93011	t value	4.72066
Coefficient of Variance	0.40219	Coefficient of Variance	0.11263	p(T<=t)	1

result in a t-value that is maximized. Based on the probability associated with this t-value, it is a near certainty these populations are different, where the difference is well beyond normal variation. Said another way, the populations are different enough, even if a different grouping exists that would result in a more extreme t-value.

With the populations determined, the next step matched values for GDP% and Bottom 90% with their corresponding years within each sub-period to arrive at two populations for each dependent variable: GDP%-\$V and GDP%-\$S, and B90%-\$V and B90%-\$S⁵.

A review of the dependent variable data revealed outlier values, particularly associated with war years. WWI lasted from 1914 to 1918, and WWII from 1940-1945. Even if our direct involvement did not align with those years, it is possible GDP got a war-related boost from supplying our allies prior to our direct involvement. Hypothesis testing was done treating WWI GDP% and WWII GDP% as separate populations and comparing each to the non-war population for GDP%⁶. At the 5% significance level ($\alpha/2=.025$), there isn't sufficient evidence to reject WWI GDP%. At the

⁵ See Appendix-A: Data Sources, for more detailed information on the data sets.

⁶ The calculations and results are summarized in Appendix-B: Adjustment for War Years

same significance level, WWII GDP% could be rejected. However, the t-value of 2.75 was only slightly higher than the critical value of 2.57. Opting for more caution and a desire to minimize a chance of a Type I error, I increased the significance level to 1% ($\alpha/2=.005$) and narrowed the population to the years 1941, 1942, and 1943. This resulted in a t-value of 22.015 compared with a critical value of 4.604. Thus, the null hypothesis was rejected and those years removed from the analysis of the relation of dependent variables to the independent variable.

The same approach was applied to B90%. However, a problem surfaced unique to this data series. It begins in 1917, so the first year for determining a growth rate is 1918. Thus, the WWI “population” would consist of a single year. This is problematic for a hypothesis test.⁷ Without sufficient evidence to reject the null hypothesis, WWI B90% is included. Because of the data limitation of B90%, this sub-period went from n=9 to n=4, with one of the 4 remaining years being distorted by war.

The hypothesis test for B90% - WWII years of 1941-1943 - produced a t-value of 11.969 compared to a critical value of 2.571 at 5% significance and 5 degrees of freedom, resulting in a rejection of the null hypothesis and the exclusion of these years from the analysis. The null would still be rejected even at 1% significance.

The table to the right summarizes the populations for GDP% and B90% that will be assessed for their relationship to \$V and \$\$.

For each sub-period, descriptive statistics of interest are the coefficient of variance for the dollar’s commodity value (CRB Index) and the annual real percentage change in GDP and B90. The following tables summarize the results.

Summary of GDP Population			
Excluding WWII Years ('41,'42,'43)			
Volatile-\$V	n	Stable-\$\$	n
1913-1921	9	1922-1929	8
1930-1946*	14	1947-1970	24
1971-1982	12	1983-1999	17
2000-2015	16		
Total	51	Total	49
*excluding 1941-1943			

Summary of B90 Population			
Excluding WWII Years ('41,'42,'43)			
Volatile-\$V	n	Stable-\$\$	n
1917-1921	4	1922-1929	8
1930-1946*	14	1947-1970	24
1971-1982	12	1983-1999	17
2000-2014	15		
Total	45	Total	49
*excluding 1941-1943			

⁷ The set up for the calculation is included in the appendix anyway, except I used 1 degree of freedom to prevent error messages, even though this is not technically correct.

	sub-pd	Coefficient of Variance	GDP%	n
\$V	1913-1921	0.34798	1.89%	9
\$S	1922-1929	0.06874	4.87%	8
\$V	1930-1946 (ex-war)	0.29640	1.26%	14
\$S	1947-1970	0.06782	3.77%	24
\$V	1971-1982	0.28050	2.72%	12
\$S	1983-1999	0.08782	3.72%	17
\$V	2000-2015	0.19592	1.93%	16
	Sub-pd			100
			p(\$V)	0.51
			p(\$S)	0.49

	sub-pd	Coefficient of Variance	B90%	n
\$V	1917-1921	0.20998	-8.37%	4
\$S	1922-1929	0.06874	3.93%	8
\$V	1930-1946 (ex-war)	0.29640	-0.50%	14
\$S	1947-1970	0.06782	2.68%	24
\$V	1971-1982	0.28050	-0.43%	12
\$S	1983-1999	0.08782	0.76%	17
\$V	2000-2014	0.18694	-0.79%	15
				94
			p(\$V)	0.48
			p(\$S)	0.52

To test the relationships, the dependent variables GDP% and B90% were plotted against the corresponding coefficient of variance of the dollar's commodity value.

GDP%

A least squares regression line was fitted to the data by manual calculation. The relationship of GDP% to the coefficient of variance of the dollar's commodity value produced an equation of $y = 0.04664 - 0.09287x$.

The negative slope implies that as dollar volatility increases, GDP% is negatively impacted. For example, if the coefficient of variance of the dollar's commodity value increases from say .100 in one period to .300 in the next period, GDP can be expected to average 1.857% less growth than in the prior period.

x-bar	0.19217				
y-bar	2.88%				
					(xi-xbar)*
xi	xi-xbar	(xi-xbar)^2	yi	yi-ybar	(yi-ybar)
0.347984	0.15581	0.02428	0.018894	-0.99%	-0.00154
0.068741	-0.12343	0.01523	0.04868	1.99%	-0.00245
0.2964	0.10423	0.01086	0.012561	-1.62%	-0.00169
0.067823	-0.12435	0.01546	0.037691	0.89%	-0.00111
0.280504	0.08833	0.00780	0.027215	-0.16%	-0.00014
0.087816	-0.10435	0.01089	0.037241	0.84%	-0.00088
0.195925	0.00375	0.00001	0.019294	-0.95%	-3.6E-05
	Σ	0.08455		Σ	-0.00785
Slope:					
b1=	Sxy	-0.0078519	=	-0.09287	
	Sx^2	0.08455			
Intercept:					
b0=	ybar	-	b1* xbar		
=	2.88%	-	-0.09287	0.19217	
=	0.046644				
y= 0.046644 + -0.09287 (x)					

A hypothesis test determined whether this linear relationship is significant using the formula $t = b_1 - \beta_0 / S_{b1}$, where $S_{b1} = s / \sqrt{(\sum (x_i - \bar{x})^2)}$

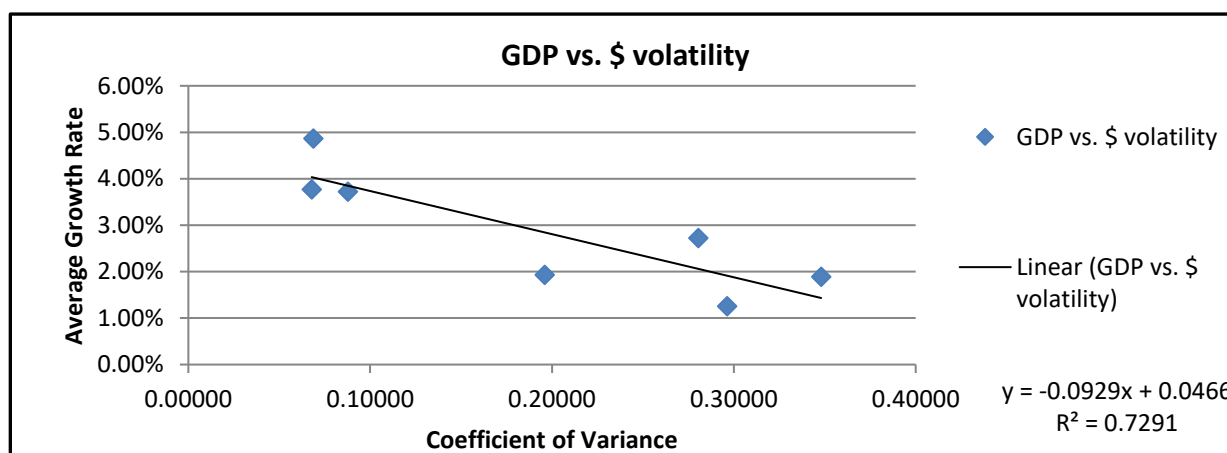
At a 5% significance level ($\alpha/2=.025$, $df=5$), the critical value is -2.571. The test statistic of -3.668 is more extreme than the critical value, providing evidence to reject the null hypothesis, and suggesting the negative linear relationship is meaningful.

The correlation between the variables, noted by R^2 , indicates the amount of variation in the response variable that can be explained by the movement in the explanatory variable. It is a measure of how well a linear function fits a stochastic relationship. With an R^2 of .729, it suggests that 72.9% of the movement in GDP% can be explained by volatility (coefficient of variance) in the dollar's commodity value.

A scatter plot of this relationship is below.

GDP: t-value for slope hypothesis					
b1	-0.09287	xbar	0.192170325		
b0	0.046644	ybar	0.028796564		
		$\hat{y}$			
	x	$b_1 \cdot x + b_0$	y		$xi - xbar^2$
	0.347984	0.014326	0.018894	0.00456829	2.09E-05
	0.068741	0.04026	0.04868	0.00842061	7.09E-05
	0.2964	0.019117	0.012561	-0.00655596	4.3E-05
	0.067823	0.040345	0.037691	-0.00265438	7.05E-06
	0.280504	0.020593	0.027215	0.00662253	4.39E-05
	0.087816	0.038488	0.037241	-0.0012475	1.56E-06
	0.195925	0.028448	0.019294	-0.00915359	8.38E-05
					0.08454555
				SSE=	0.000271
				n-2	5
				s^2	5.42E-05
				s=	0.007362
	t= $\frac{b_1 - B_1}{Sb_1}$	$\frac{b_1 - B_1}{Sb_1}$		-0.09287	-3.6679658
		$s / (\sum (xi - xbar^2)^{1/2})$		0.02532	

R^2		
	$(\hat{y} - \bar{y})^2$	$(y_i - \bar{y})^2$
	0.000209400	0.000098057
	0.000131402	0.000395361
	0.000093702	0.000263605
	0.000133365	0.000079103
	0.000067300	0.000002500
	0.000093926	0.000071302
	0.000000122	0.000090294
Σ	0.000729218	0.001000222
$R^2 =$	0.729055641	



The final step of the GDP% analysis was to address the original hypothesis for the overall populations:

$$H_0: \mu(\text{GDP\%-}\$S) = \mu(\text{GDP\%-\$V})$$

$$H_a: \mu(\text{GDP\%-}\$S) \neq \mu(\text{GDP\%-\$V})$$

Here, the analysis is on the statistics of the entire population of \$V vs. \$S rather than the sub-periods comprising them. The t-value of -2.3555 is more extreme than the critical value ($\alpha/2=.025$, $df=74$) of -1.993. Thus, the null hypothesis can be rejected at the 5% significance level in favor of the alternate hypothesis, which says there is a difference in GDP% between the \$V and \$S populations and it is significant. The p-value of the test statistic of .0106 nearly approaches the p-value if a 2% significance level were used ($.0106*2=.0212$).

GDP	\$V	\$S
Mean	0.019239018	0.039328701
Standard Deviation	0.054280096	0.027082415
n	51	49
n-1	50	48
s	0.054280096	0.027082415
s^2	0.002946329	0.000733457
s^2/n	0.00005777	0.00001497
(s^2/n)^2	3.33751E-09	2.24056E-10
1/n-1	0.02	0.020833333
df numerator	5.29106E-09	
df denominator	7.1418E-11	
	74.08583015	
df=	74	
t (a/2=.025, df=74)	-1.993	1.993
t numerator	-0.02008968	
t denominator	0.008528755	
t value	-2.35552345	
P(T<=	-2.35552345	0.0106

B90%

The relationship between B90% and dollar volatility produced an equation of $y = .03152 - .20678x$. This negative slope of $-.207$ implies that as the dollar's commodity value becomes more volatile, bottom 90% income is negatively impacted. If the coefficient of variance of the dollar's commodity value increased from say .100 in one period to .300 in the next period, bottom 90% income can be expected to average 4.14% less growth than the prior period.

A hypothesis test determined the significance of this linear relationship, using $t = b_1 - \beta_0 / S_{b1}$, where $S_{b1} = s / \sqrt{(\sum (x_i - \bar{x})^2)}$.

At a 5% significance level ($\alpha/2 = .025$, $df = 5$), the critical value is -2.571 . The test statistic of -1.3385 is not extreme enough to lie in the rejection region. The p-value that corresponds to a test statistic of -1.3385 is .1182, so the significance level would have to increase to 23.845% or more to reject this null hypothesis. Thus, there is insufficient

R²	
(yhat-ybar)²	(yi-ybar)²
0.000064386	0.006365036
0.000448609	0.001866807
0.000670532	0.000001246
0.000456691	0.000941150
0.000511108	0.000000155
0.000297083	0.000130881
0.000010630	0.000016276
Σ	0.002459040 0.009321550
R²=	0.263801586

evidence to reject the null hypothesis

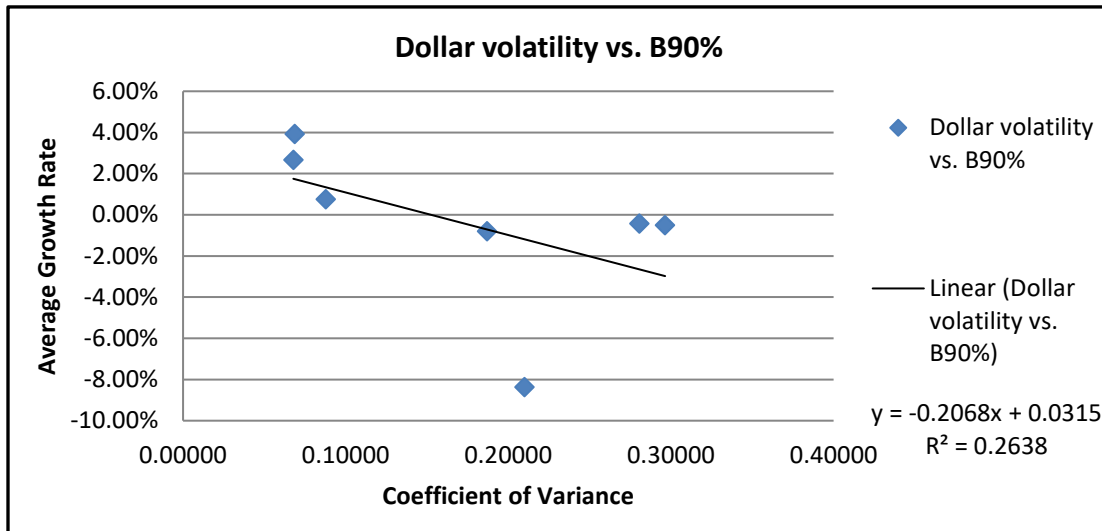
and infer that the linear relationship is meaningful.

The correlation of .2638 indicates the amount of variation in B90% that can be explained by movement in the dollar's commodity value is 26.38%.

x-bar	0.17117119				
y-bar	-0.00387289				
					(xi-xbar)*
xi	xi-xbar	(xi-xbar)²	yi	yi-ybar	(yi-ybar)
0.20998	0.03881	0.00151	-8.37%	-7.98%	-0.0031
0.06874	-0.10243	0.01049	3.93%	4.32%	-0.00443
0.29640	0.12523	0.01568	-0.50%	-0.11%	-0.00014
0.06782	-0.10335	0.01068	2.68%	3.07%	-0.00317
0.28050	0.10933	0.01195	-0.43%	-0.04%	-4.3E-05
0.08782	-0.08336	0.00695	0.76%	1.14%	-0.00095
0.18694	0.01577	0.00025	-0.79%	-0.40%	-6.4E-05
	Σ	0.05751		Σ	-0.01189
Slope:					
b₁=	S_{xy}	-0.0118921	=	-0.20678	
	S_x²	0.05751			
Intercept:					
b₀=	ybar	-	b₁* xbar		
=	-0.39%	-	-0.20678 0.17117		
=	0.03152172				
y= 0.03152172 + -0.20678 (x)					

B90: t-value for slope hypothesis					
b₁	-0.20678	xbar	0.171171189		
b₀	0.031522	ybar	-0.00387289		
		ŷ			
x	b₁*x+b₀	y	residual		xi-xbar²
0.20998	-0.01190	-8.3654%	-0.0717571	0.005149	0.00150583
0.06874	0.01731	3.9334%	0.02202617	0.000485	0.01049192
0.29640	-0.02977	-0.4989%	0.02477853	0.000614	0.01568219
0.06782	0.01750	2.6805%	0.00930784	8.66E-05	0.01068094
0.28050	-0.02648	-0.4266%	0.02221431	0.000493	0.01195364
0.08782	0.01336	0.7567%	-0.00579578	3.36E-05	0.00694808
0.18694	-0.00713	-0.7907%	-0.00077397	5.99E-07	0.00024862
					0.05751122
			SSE=	0.006863	
			n-2	5	
			s²	0.001373	
			s=	0.037047	
t=	b₁-B₁	b₁-B₁		-0.20678	-1.3385243
	S_{b1}	s/(Σ(xi-xbar²))^{1/2}		0.154483	

A scatter plot of this relationship is depicted below.



The final step of the B90% analysis was to test the original hypothesis for the overall populations:

$$H_0: \mu(\text{B90\%}-\$S) = \mu(\text{B90\%}-\$V)$$

$$H_a: \mu(\text{B90\%}-\$S) \neq \mu(\text{B90\%}-\$V)$$

The t-value of -3.326 is more extreme than the critical value ($\alpha/2=.025$, $df=74$) of -1.993. Thus, the null hypothesis can be rejected at the 5% significance level in favor of the alternate hypothesis, which says there is a significant relationship between stability in the dollar's commodity value and B90%. The p-value of the test statistic of .0007 indicates the null can be rejected at higher than 1% significance.

B90%	\$V	\$S
Mean	-0.01276149	0.02217637
Standard deviation	0.05980469	0.0388878
n	45	49
n-1	44	48
s	0.05980469	0.0388878
s^2	0.0035766	0.00151226
s^2/n	0.000079480	0.000030862
(s^2/n)^2	6.3171E-09	9.5249E-10
1/n-1	0.02272727	0.02083333
df numerator	1.2175E-08	
df denominator	1.6341E-10	
	74.5071188	
df=	74	
t (a/2=.025, df=74)	-1.993	1.993
t numerator	-0.03493786	
t denominator	0.0105044	
t value	-3.32602022	
p(T<=	-3.32602022	0.0007

Conclusions:

Based on statistical analysis, there is a negative relationship between sustained volatility in the dollar's commodity value and measures of economic performance. As tested, these relationships showed statistical significance for both GDP% and B90%.

Test	Result	Comment
GDP% regression analysis	Negative relationship	For every .2 increase in the coefficient of variance of the dollar's commodity value, average GDP growth is reduced by 1.86%
GDP% slope of regression line	Linear relationship is statistically significant.	Functional relationship well represents stochastic relationship.
GDP% different between \$V and \$S populations.	Difference is statistically significant.	Stability of the dollar's commodity value is important to economic growth. Argues against treating it as a "transitory factor."
B90% regression analysis	Negative relationship	For every .2 increase in the coefficient of variance of the dollar's commodity value, average B90 growth is reduced by 4.14%
B90% slope of regression line	Linear relationship not statistically significant.	Residual error(s) too large for a "tight fit." Likely distorted not by WWI, but by 1921 decline of 18.6% ($z=-3.66$)
B90% different between \$V and \$S populations	Difference is statistically significant.	Stability of the dollar's commodity value is important to income growth of the bottom 90%. Argues against treating it as a "transitory factor."

Discussion:

The analysis raised many questions that may be worthy of further investigation.

This study can be viewed as a single trial where the statistics allow an inference to be made about the population's true parameters, which are unknown. Several trials could be repeated, each having a slightly different composition of years comprising \$V and \$S. For example, I used 1947 as the first year of a new \$S sub-period and justified it on the basis of a new monetary regime being enacted. However, the dollar's commodity value didn't really stabilize until a few years later. The next trial could designate 1947 as the last year of the \$V sub-period, and 1948 as the beginning of the next \$S sub-period. The threshold for each such trial would be the hypothesis test that

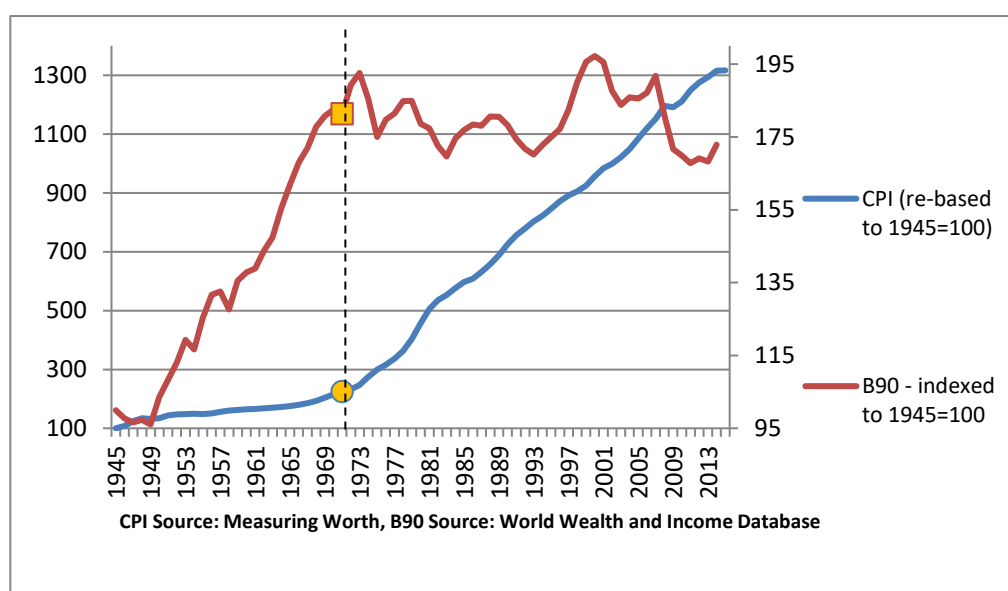
determines whether the populations are *different enough* (i.e., $H_0: \mu(\text{\$V-indexed sub-periods}) = \mu(\text{\$S-indexed sub-periods})$ and $H_a: \mu(\text{\$V-indexed sub-periods}) \neq \mu(\text{\$S-indexed sub-periods})$), where trials in which the null is also rejected would form a new population, and trials in which the null isn't rejected would be thrown out. This new population would consist of the statistics of each trial and it would have its own sampling distribution.

This would neutralize the bias inherent in the process of designating sub-groups as \$V or \$S. It will also allow a stronger inference to be made about the true population parameters. Several different analyses become possible. For example, the t-values of each trial for the hypothesis test to determine whether \$V and \$S are different could be plotted against t-values of the hypothesis test used to determine whether GDP%-\$V and GDP%-\$S are different. The slope of the regression line between coefficient of variance and GDP% could be averaged across trials and this too would have its own sampling distribution. The difference between GDP%-\$V and GDP%-\$S for each trial could be plotted against the difference in coefficient of variance for \$V and \$S for the respective trials. What would these relationships tell us? What are the linear relationships and are they a good fit? Is it significant?

Beyond neutralizing bias, this should increase confidence in the interpretation of the results. Although the single trial I conducted produced results that show a relatively strong relationship, several trials would improve the quality of the inference because they would move us closer to the true parameters of the population.

Another area for further study could be based on the previously mentioned alternative way of defining dollar stability as being stable against a lagging index of sampled prices of consumer goods. The results of that study could be compared to this one. Is there a relationship between a stable dollar and low CPI readings? If a stable real dollar means stable commodity prices, do stable input prices help anchor stable output prices? If low CPI readings have coexisted with slow GDP growth during volatile dollar periods (post 2000), that might invalidate the usefulness of aiming for low CPI readings and indicate the Fed should aim instead for dollar stability. Based on these results, one could examine the tools available to the Fed, and how they would use them, to directly stabilize the dollar's real value versus using them to indirectly impact an inflation index.

Additional questions were raised as a result of this analysis and they could merit further investigation. First is the question about the Federal Reserve's "dual mandate," which by statute says it has to balance both "full employment and price stability." Many economists claim that the Fed doesn't have the tools to directly influence any real variables such as employment and therefore view one mandate as often being in conflict with the other. Based on this analysis, it seems as if stabilizing the dollar's commodity value is not inconsistent with their current mandate. In fact, further analysis could test whether it could help in achieving it. As the test results indicate, a stable commodity value of the dollar has been shown to be associated with stronger income growth for the bottom 90%. As a means of bringing people back into the labor force to reach full employment, there probably aren't many variables more effective than rising incomes. As far as the price stability component, a cursory comparison of B90 to the CPI in this chart shows



that in the period leading up to the dotted line that represents 1971 (the cutoff for a sub-period defined as \$S), the dollar's stability was not just associated with rising incomes but also stable consumer prices. Further testing over a larger population would provide evidence of the significance of any relationship. A new study could look at stability of the dollar's commodity value against employment and a price index (i.e., the dual mandate).

Applications:

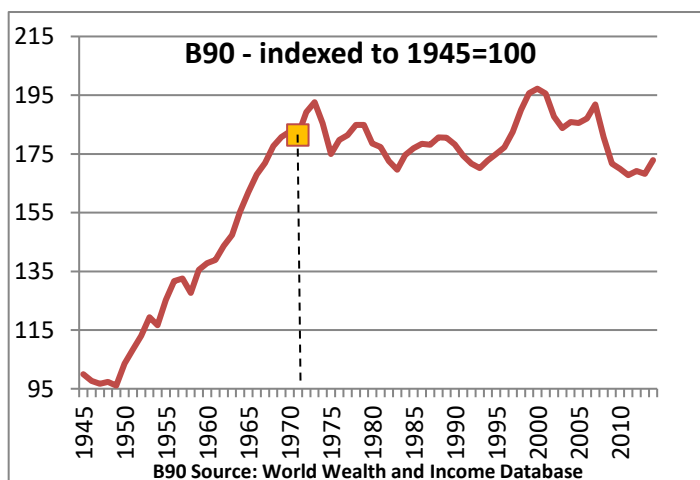
Based on the evidence that allows an inference to be made that there is a relatively strong relationship between stability in the dollar's commodity value and economic performance, I reviewed the time series to identify opportunities in which this information could be useful in offering insight. Granted, this was not an exhaustive review. Perhaps previous literature has already addressed the points I've selected below. Further, I have not attempted to "explain everything" as if a comprehensive model has been developed. Instead, the following is an exercise in applying the information embodied in the dollar's commodity value consistently over time and across different circumstances.

Going back to the original statement of the problem, if the dollar is transitory then, by extension, it probably doesn't contain much informational value. Since I conclude it is not transitory then, by extension, it should contain informational value. Finally, it is understood that this is a subjective exercise, one that may contain its own hindsight bias of knowledge of subsequent events. Going back in history and saying this is what the dollar's commodity value was telling us at that time is quite different than being in the moment at that very time and saying this is what it is telling us now. Nonetheless, I found the exercise to be useful.

Has Dollar Instability Contributed to Income Stagnation?

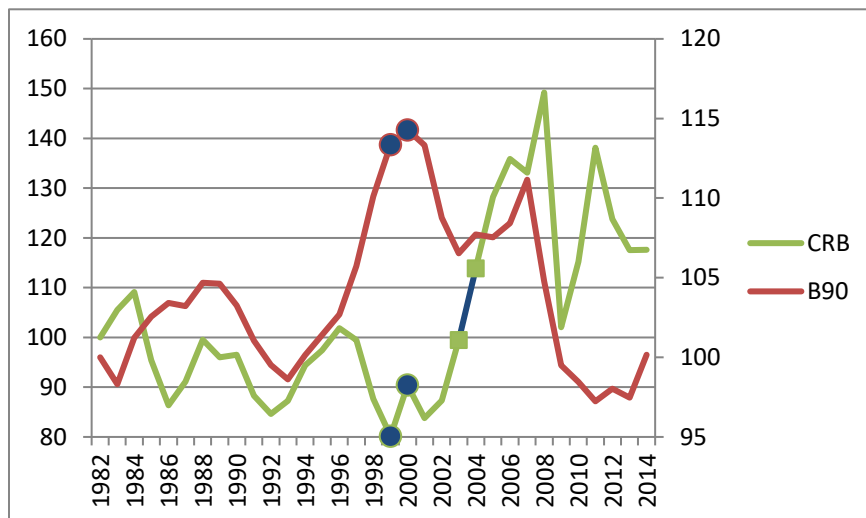
One observation that stands out from reviewing the B90 time series is the stagnation that has occurred since 1971. This is clearly illustrated in this chart. Can the dollar's commodity value tell us anything about the stagnation?

According to this study, B90 real income increased an average 2.68% during the



1947-1970 \$\$ period, declined an average of -.43% during the 1971-1982 \$V period, increased an average of .76% during the 1983-1999 \$\$ period, then declined an average of -.79% during the 2000-2014 \$V period. A closer, but also very cursory, look at more recent history may shed some

light. The following chart (which uses the same data sources) shows both B90 and the CRB Index from 1982 to 2015. The blue highlighted data points mark a cycle of 6 consecutive rate increases by the Fed. At this point, the bottom 90% was the most prosperous ever. At the same time, the dollar's commodity value had been *strengthening* (i.e., the

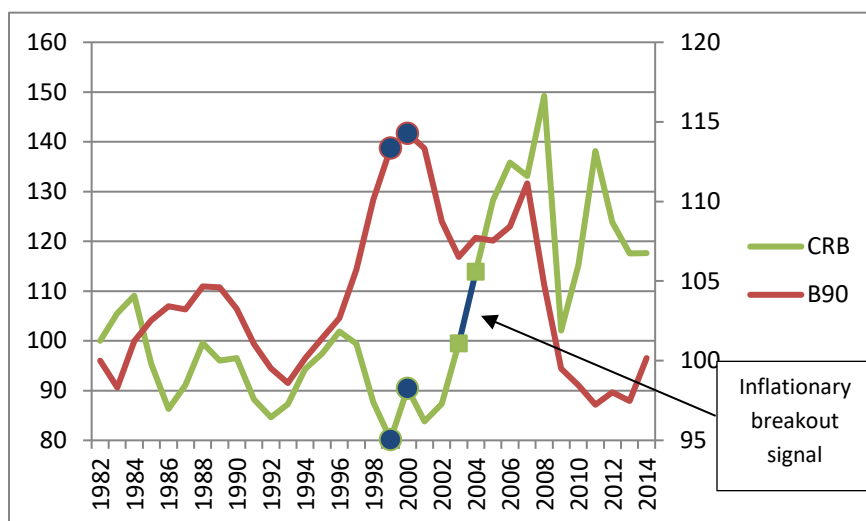


commodity index was in a down trend from 1982). In fact, it stood at the highest level since the early 1970's. Markets were signaling a scarcity of dollars, and an objective of stabilizing the dollar's commodity value would have said to increase their supply, not raise interest rates. It would be interesting to further investigate their justification for raising rates in the presence of such dollar scarcity. Perhaps this period marks the beginning of the primacy of the Phillips Curve and NAIRU (non-accelerating inflation rate of unemployment) as policy tools. Both posit that inflation is caused by labor markets that are "too tight." At the time, bottom 90% income reaching its highest levels ever may have been construed by Phillips Curve and NAIRU models as a sign of pending inflation, despite non-confirmation from the dollar's commodity value. A review of the Fed's meeting transcripts of that era should indicate their justification for tightening policy.

This divergence between what the dollar's commodity value was saying then and what the Fed did has at least a parallel to the Fed's most recent rate hike in Dec. 2015. The dollar's commodity value was even stronger last December than it was in 1999, signaling a scarcity of dollars. Yet the Fed hiked interest rates anyway presumably because the unemployment rate breached its NAIRU threshold. Further research over a larger sample size would be necessary to see if there is a relationship between bottom 90% income growth and Fed tightening cycles. Theories like the Phillips Curve suggest there is a relationship and that the Fed should counteract "tight labor markets." If so, it would be fair to wonder how we can end this present era of income stagnation if the very thing that ends it (income growth) is the same thing that might be associated with Fed tightening.

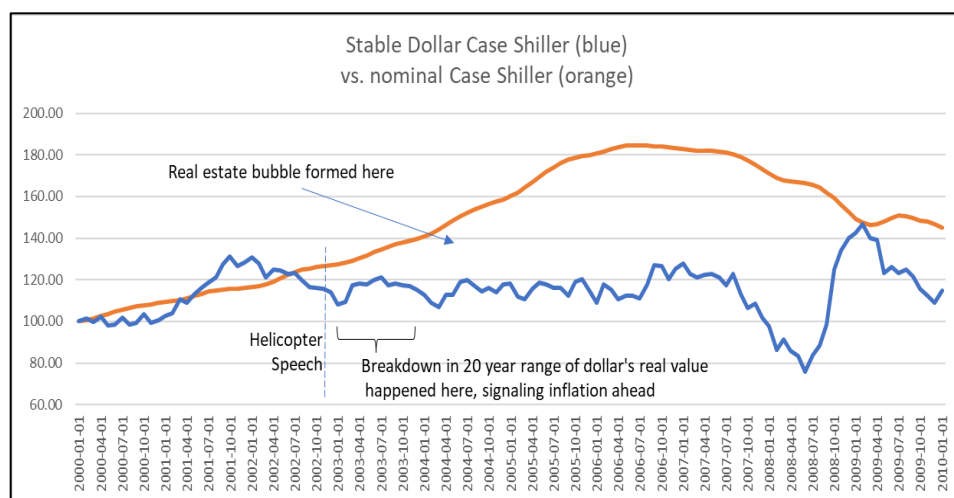
Did Dollar Instability Plant Seeds of the 2008 Real Estate Crisis?

In the same chart, the point at which the CRB series turns from a green line to a blue line (2003-2004) indicates a “breakout” point for commodities relative to the prior twenty years. This fall in the dollar’s commodity value beyond an established range could



have been a signal to authorities to reduce the monetary base enough to arrest this decline. This period was preceded by Ben Bernanke’s now-infamous Nov 2002 “Helicopter Speech”⁸ whereby he foreshadowed a central bank indiscriminately pumping liquidity into the system, figuratively dropping it from helicopters, to stave off deflation. As the economy rebounded 2003-2004, the Fed held the funds rate at a then record low 1%, still concerned about deflation when the dollar signal was saying inflation ahead. Had they paid attention to this, it is reasonable to consider whether real assets such as oil and real estate might have had the boom and bust that followed. While the Fed eventually proceeded with gradual interest rate increases, they proved insufficient to restore the dollar’s commodity value.

The consequences of failing to see this dollar signal could have planted the seeds for what became the real estate bubble – and crash. Adjusted for the dollar’s real value, the Case Shiller National Home



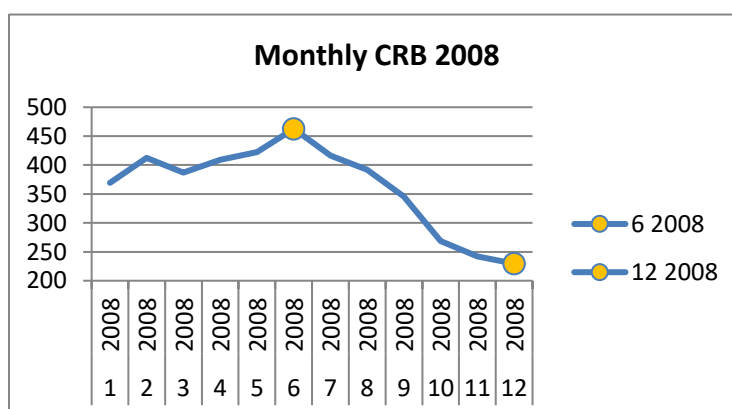
⁸ <https://www.federalreserve.gov/BOARDDOCS/Speeches/2002/20021121/default.htm>

Price Index would have remained relatively flat (blue), yet the nominal index price soared 73% (orange line), the epitome of false price signals transmitted by a volatile unit of measure, in this case one that is shrinking, making real assets measured in it appearing to rise. It is fair to ask whether the estate crisis would have occurred had the dollar remained stable and the bubble not formed. There were plenty of other factors at play leading to the crisis for sure. According to American Enterprise Institute scholar Peter Wallison, in his book *Hidden in Plain Sight*, government policy produced a combustible mix that culminated in the crisis. In a nutshell⁹, the government essentially forced banks, through the Community Reinvestment Act, to make subprime loans, then changed Fannie Mae's mandate allowing it to acquire said loans. Fannie's quotas quickly rose and by 2008, 31 million of the nation's 55 million mortgages were subprime, and 76% of those were on the books of the government. What could go wrong? But without the falling-dollar induced bubble in the first place, would the rest have happened?

Did the Dollar's Real Value Signal Deflation Ahead of the 2008 Crisis?

Finally, it looks like the dollar's commodity value might have provided a useful signal ahead of the 2008 financial crisis. This chart shows the commodity index peaked at 462 in June and declined 51% to 229 by December 2008. This implies a near doubling of the dollar's commodity value ($1/229$ divided by $1/462$ or $462/229$).

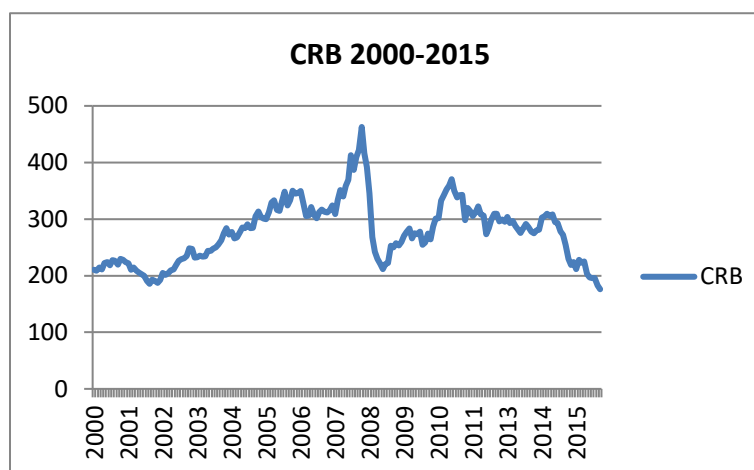
From June until September (the most severe month of the crisis), the dollar had already soared 34%. Markets were signaling by such sharp movements that dollars were becoming increasingly scarce, for whatever reasons. Quantitative easing (QE-I) did not commence until December 2008.



⁹ See Wallison presentation to Institute of World Politics <https://www.youtube.com/watch?v=YsemuVU5kwY> or this AEI post 1/13/15 <https://www.aei.org/economics/hidden-plain-sight-qa-peter-wallison-2008-financial-crisis-might-happen/>

In a larger context, for several years preceding the crisis, the dollar's steadily declining commodity value (rising CRB) was signaling a surplus of dollars. In other words, the denominator was declining, sending artificial price signals. This may have also contributed to the preceding boom

energy sector investment. We are still dealing with the fallout of the real estate crisis. Now that the dollar's commodity value has come full circle, bringing oil prices back down, we may be just beginning to see some fallout of crashing oil prices. Investments that took place at \$100+ oil prices

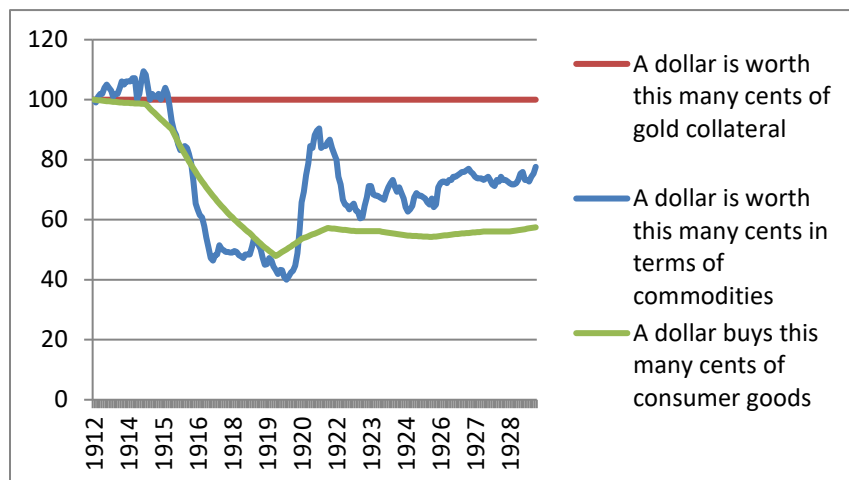


are considerably less viable now that prices are back down to the \$40's. Perhaps this was a misallocation of resources caused by faulty price signals of a volatile unit of measure.

Researchers may spend years dissecting the underlying factors that may have caused or contributed to the 2008 financial crisis in the same way that the Great Depression is still being studied today. The dollar's commodity value may provide a fruitful way to engage on the subject.

Did Dollar Instability Plant the Seeds of the Great Depression?

Another noticeable disparity took place in the years following 1913. With an influx of gold from the warring European countries, the Fed increased the domestic money supply. The dollar's commodity value began a sharp decline, suggesting, with hindsight,

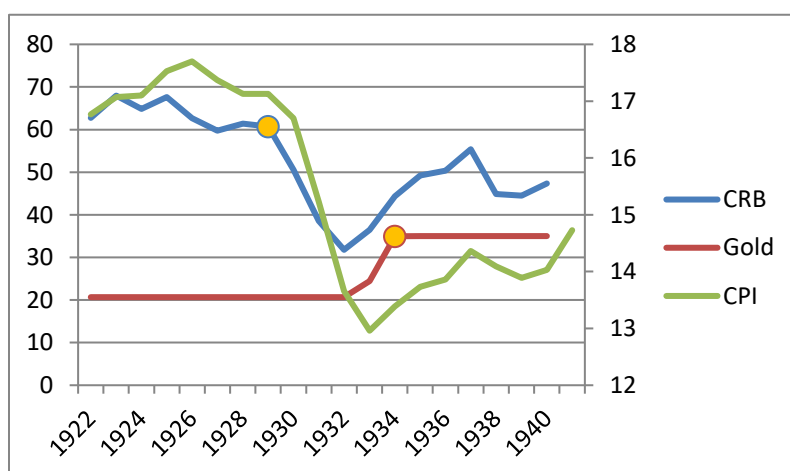


they might have been better off parking the gold in a vault rather than issuing domestic currency against it. Further, by not suspending gold convertibility as the U.S. did during the Civil War and the War of 1812, an imbalance was created between the dollar's commodity value and its collateral value. The chart above shows what a dollar bought in terms of commodities and consumer goods. Notice the gaps compared to the dollar's gold collateral backing. While both consumer prices and commodity prices stabilized during the 1920's, the dollar was "overvalued" in gold terms. Thus a dollar could buy an average of 70 cents worth of commodities or 55 cents worth of consumer goods, but could be cashed in for 100 cents of gold.

Did the Dollar's Real Value Signal Deflation Ahead of the Great Depression?

This imbalance persisted throughout the 1920's. The results of this project show the sub-period from 1922-1929 to be the second best overall in terms of dollar stability and the clear winner in terms of both GDP% and B90%, which registered growth of 4.87% and 3.93%, respectively. It appears this imbalance did not impact prosperity, at least during this time frame. To exchange a dollar for its collateral value amounts to figuratively melting coins for their metal content; it takes a dollar out of circulation at a time when a growing economy prized it as a circulating medium. To extend the analogy, would one melt down a quarter (assuming it was legal) in order to have 40 cents of metal? What would one do with the metal? In a high growth economy there may be little motivation to do so. But such an imbalance creates pressure that can be relieved one of two ways, devalue the dollar in terms of gold, or the price level would have to come down (so that the dollar could again buy 100 cents of consumer goods). As we know from history, the price level did indeed fall in the Great Depression. The following chart shows how the dollar's commodity value offered an early signal that this gap was about to close. Commodity prices started a steep decline a year ahead of the decline in the price

level, and a full 5 years ahead of the official decision to revalue the dollar's gold parity. Perhaps faced with dim economic prospects as the Depression unfolded, it seems plausible that people might have rushed to exchange dollars for the more valuable gold, contracting



the money supply. If so, the dollar's sharply rising commodity value (i.e., falling CRB) might have been a signal to increase the money supply rather than allowing it to contract. There are numerous possibilities for further investigation of the Great Depression, and perhaps this "angle" of looking further into the imbalances that pre-staged it could be one of them.

Does Dollar Stability Best Represent Fed Accountability, Transparency, and Independence?

This brings me to a final, overarching question. Is it possible for a monopoly issuer of a reserve currency, the demand for which is determined globally, to set policy primarily based on domestic circumstances? The dollar's commodity value is set in global markets. When it is stable, the evidence presented herein indicates the domestic economy performs better. Economist Robert

Triffin developed the Triffin Paradox¹⁰ which points out the conflict between short-term domestic interests and long-term international interests for any reserve currency. Moreover, in international monetary economics there exists an *Impossible Trinity*¹¹ that says a monetary authority can't simultaneously pursue three objectives of open capital flows, a stable exchange rate and independent monetary policy. It may achieve any two, but not all three. As it stands today, the Fed pursues independence and capital flows and eschews fixed exchange rates. However, what does *independence* really mean? Independence from what? Independence to pursue policy independent of the dollar's commodity value may not be a good thing, as evidence suggests. However, independence from political factors so authorities may pursue dollar stability might indeed be a good thing. A monetary policy regime that sought to stabilize the dollar's commodity value might balance short-term domestic interests with long-term international interests to satisfy the Triffin Paradox. After all, the dollar's commodity value is set globally and if signals are responded to in a way that stabilizes its value, it helps our domestic economy. Further, based on one definition of independence, perhaps the impossible trinity could be solved, or at least mitigated. First, by stabilizing the dollar's commodity value, foreign exchange rates might become more stable. Second, a dollar more stable in real terms (vs. commodities) and against other currencies should not hinder capital flows. Third, by pursuing a stable commodity value for the dollar, Fed independence might increase if one assumes the independence sought was from conflicting political considerations and pressures. Clearly, this area is full of opportunities for further exploration.

Putting Statistics in Context:

Stepping back from the statistical analysis, where significance is precisely quantified by t-values, and considering the implications of what the difference in growth means for ordinary Americans, would it be less desirable to pursue policy associated with stronger growth even if the difference wasn't statistically significant? The \$S population had GDP growth averaging 3.93% while the \$V population averaged 1.92%, which was shown to be statistically significant. If the last 15 years averaged 3.9% instead of 1.9%, GDP would have ended 2015 at \$22.392 trillion instead of \$16.325 trillion, a difference of \$6 trillion of output we never had. Who knows what kind of innovations or

¹⁰ https://en.wikipedia.org/wiki/Triffin_dilemma 5/6/16

¹¹ https://en.wikipedia.org/wiki/Impossible_trinity 5/6/16

medical breakthroughs we missed out on? GDP of \$22 trillion may well render our deficit, debt, entitlement solvency, and other problems moot.

Working backward from the calculations in the main GDP% hypothesis, the difference in growth (i.e., the numerator of the t-score calculation) necessary to produce a test statistic equal to the critical value is 1.6997 (assuming no change in the denominator). In other words, if GDP%-\$V remained 1.92% but GDP%-\$S was only 3.60% instead of 3.93%, this difference of 1.68% would produce a t-value falling within the acceptance region and statistically the null couldn't be rejected at 5% significance. However, 3.6% growth is still quite good. To ordinary people, this is still robust, albeit not statistically significant. To illustrate, had the growth rate for the last 15 years been this "lesser" rate of 3.6%, GDP would have ended 2015 at \$21.349 trillion. Many would consider this a big difference. This points out that as more and more decisions are driven by statistical analysis, care and judgement have to be exercised. In some cases, a policy action may not carry with it statistical evidence of significance, yet it may still be desirable and worth pursuing. Likewise, equal care and judgement should be employed if it looks as if statistical evidence is the primary basis for pursuing a particular action.

This was fun, for me at least. Hope you enjoyed reading. Congratulations for making it this far.

Appendix-A: Data Sources:

CRB: The CRB Index (CRB) was created in 1957 by the Commodity Research Bureau and is perhaps the most widely followed and recognized commodity index. Prior to 2005, it was an equally weighted index of 17 major commodities¹². It has undergone ten revisions in its history. The first nine were to replace various components that lost prominence, such as lard, with more prominent commodities. The 10th revision in 2005 was significant in that it changed from being equally weighted. As such, crude oil now represents 23% of the index versus 5.866% in the equally weighted 9th version of the index. Meanwhile, the 9th version of the index continues to operate, but is called the Continuous Commodity Index (CCI). For purposes of serving as a proxy for the dollar's real value, an equally weighted index is preferable, so the data consists of CRB from 1957 to 2005 and CCI after the revision in 2005. **Bianco Research LLC** of Chicago¹³ has reconstructed the equally weighted index forward from 2005, and going back farther in time, in fact to 1749. To do so, they obtained data from the Wholesale Price Index (now called the Producer Price Index) as calculated by the Bureau of Labor Statistics, Statistical Tables of Commodity Prices from "Wholesale Commodity Prices in the United States, 1700 to 1861" by Arthur Harrison Cole (Harvard University Press, 1938), the 'Warren And Pearson Index of Commodity Prices in New York', by George F. Warren and Frank A. Pearson (Wiley, 1933), the Jeavons Index compiled in 1865, and the Sauerback-Statist Index of Commodities in England. The data sources were made available to Bianco through The Foundation For The Study Of Cycles.

GDP: Data for GDP was obtained from **MeasuringWorth.com**. The website was founded in 2006 by economics professors Lawrence Officer and Samuel H. Williamson, both of the University of Illinois at Chicago, although the database is not directly connected to any institution. It has a board of advisors consisting of seventeen other economics professors. Their GDP data comes from the Department of Commerce, Bureau of Economic Analysis. Official government GDP statistics were not collected nor even well-defined before the 1933. A congressional act in 1933 mandated such, and the National Bureau of Economic Research (NBER) was commissioned for the initial study. Results were published in 1934, and included data going back to 1929. MeasuringWorth has published their methodology for recreation of the data series prior to 1929¹⁴, and it generally follows NBER's approach. A drawback with MeasuringWorth data prior to 1929, which is not unique to them, is that the farther back the data is recreated (theirs goes back to 1790) the more it must rely on census data for certain information, which means values for individual years between each census must be interpolated. Thus, the closer to 1790, the more the reliance on the census/interpolation, and the closer to 1929, the more the data may approximate the NBER approach. In this project, I will use GDP data for 1913-2015, so the 1913-1928 figures will rely on the MeasuringWorth recreation of the data, and 1929-2015 will be the NBER/BEA official statistics. The figures will be based on real GDP using the GDP Deflator, indexed to 2009=100.

¹² Gold, silver, platinum, crude oil, heating oil, natural gas, wheat, corn, soybeans, copper, cotton, live cattle, lean hogs, coffee, sugar, cocoa, orange juice.

¹³ <https://www.biancoresearch.com/visitor-home/>

¹⁴ <https://www.measuringworth.com/uscompare/sourcegdp.php>

B90: Income for the bottom 90% (B90) was obtained from the World Top Incomes Database (which since my last visit there has been renamed the **World Wealth and Income Database**¹⁵). This was created by economists Thomas Piketty, Emmanuel Saez, Facundo Alvaredo, Anthony B. Atkinson, and Gabriel Zucman. The database covers 33 countries and includes historical values for variables on income, wealth, saving, prices and population. For the U.S., there are a total of 344 statistics for different measures of these variables. The statistic I'm interested in is the time series for income for the bottom 90% which I'll use as a proxy for the breadth of prosperity. This is denoted in their database as "Bottom 90% Average Income." This time series was derived by segmenting total income into deciles, where each decile marked a threshold. Tax returns were the primary data source. The bottom 8 deciles were averaged to arrive at an average income for the bottom 90%. In the early years of the tax code when only the highest earners had to file a return, figures for the bottom 90% are total income less income of the top 10%. They used statistical analysis to determine the decile thresholds. This estimation is prevalent from 1917 to the early 1940s. The figures are adjusted for inflation using 2014 real dollars based on the consumer price index. The figures are reported for "tax units" rather than individuals (which assumes a spouse doesn't file a separate return). I was unable to locate an explanation of why the bottom 90% income series begins in 1917, yet the top 10% income series starts in 1913. Lastly, the most recent year for income data is 2014. As such, my hypothesis test for GDP will use 1913-2015 data, while my hypothesis test for B90 will use the 1917-2014 data.

The income figures are pre-tax and exclude capital gains. They also exclude transfer payments and non-cash compensation such as employer provided health insurance. In some ways, this data may understate the actual well-being or purchasing power of the bottom 90%. For example, if people receive more tax credits and more transfer payments, the purchasing power of the recipients will be more than the data reflects. However, because of these exclusions, I believe this data makes it a more relevant measure of the breadth of prosperity for the economy. In other words, if incomes excluding these items are rising, I view it as a sign the economy is healthier than one in which incomes are stagnant and where government transfers provide the only means of improvement.

I am aware of several criticisms of Piketty's data that commenced with the publishing of it in his bestselling book, "Capital in the 21st Century." Leaving aside objections to his thesis or conclusions, the Financial Times, as one example, notes several mistakes it found¹⁶. Their criticisms pertain to foreign country data and seem to center on the early part of the 20th century when there was less complete data. Moreover, many of the criticisms are directed at computations of shares of wealth. Seeing such criticism creates a "where there's smoke, there's fire" atmosphere, and raises questions whether such mistakes could be lurking in the U.S. income data, but just have not been detected yet. On the other hand, his 500+ page book was heavily scrutinized. If there were problems with the U.S. income data, it would probably have been widely reported by now. After a fairly extensive search for reports of problems with the U.S. income data series, I haven't found any. For purposes of this project, I will assume that U.S. income data going back to 1917 is reasonably reliable and is independent of the data sets that have been identified as having problems.

¹⁵ Facundo Alvaredo, Anthony B. Atkinson, Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, The World Wealth and Income Database, <http://www.wid.world>, 04/10/2016

¹⁶ <http://www.ft.com/intl/cms/s/0/c9ce1a54-e281-11e3-89fd-00144feabdc0.html#axzz45RH8NSLO>

Appendix B: Treatment of War Related Years:

GDP	WWI	WWII	Non War	GDP	41-'43	Non War
mean	3.10%	11.58%	2.82%	mean	17.88%	3.21%
n	5	6	92	n	3	77
n-1	4	5	91	n-1	2	76
s	0.086293512	0.077291866	0.0412936	s	0.00936565	0.0341938
s^2	0.00744657	0.005974033	0.0017052	s^2	8.77154E-05	0.0011692
s^2/n	0.0014893	0.0009957	0.0000185	s^2/n	0.0000292	0.0000152
(s^2/n)^2	2.21806E-06	9.91363E-07	3.435E-10	(s^2/n)^2	8.54888E-10	2.306E-10
1/n-1	0.25	0.2	0.010989	1/n-1	0.5	0.0131579
df numerator	2.27361E-06	1.02861E-06		df numerator	1.97341E-09	
df denominator	5.54518E-07	1.98276E-07		df denominator	4.30478E-10	
	4.100150543	5.187782625			4.584229435	
df=	4	5		df=	4	
t (a/2=.025, df=75)	-2.776	2.571		t (a/2=.005, df=4)	4.604	
t numerator	0.28%	8.76%		t numerator	14.67%	
t denominator	0.038831023	0.031846607		t denominator	0.006665063	
t value	0.070981619	2.749954881		t value	22.01459246	
Reject/do not reject	Don't Reject	Reject		Reject/do not reject	Reject	

B90	WWI	41-'43	Non War
mean	-4.75%	23.93%	0.60%
n	1	3	90
n-1	0	2	89
s	0	0.032337628	0.0532092
s^2	0	0.001045722	0.0028312
s^2/n	0.000000	0.000348574	0.00003146
(s^2/n)^2	0	1.21504E-07	9.896E-10
1/n-1	0	0.5	0.011236
df numerator	9.89607E-10	1.44424E-07	
df denominator	1.11192E-11	6.07631E-08	
		2.376845202	
df=	Assume 1	5	
t (a/2=.025, df=1)	-12.706	2.571	
t numerator	-5.35%	23.33%	
t denominator	0.005608745	0.019494412	
t value	-9.537089074	11.96864105	
	Don't Reject	Reject	

Appendix C: Source Data & Calculations:

See Excel spreadsheet labeled “Final Paper – Data and Calculations - Lowrie”