Granger-causality of real oil prices after the Great Recession

Szilard Benk* Max Gillman†

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Abstract

Oil prices (WTI) surged to a sustained high level from 2009 through 2014. The magnitude of this real price "shock" compares to that of the height of the second 1970's "oil shock". Then the US inflation rate was at its highest level since 1946; post-2008 it has been subdued. This at first glance seems to rule out monetary causes of the recent oil shock, making it hard to explain. Yet, this paper shows strong Granger causality of nominal and real oil prices by adjusted measures of the US monetary base, M1 and Divisia M1. Without the adjustment, no causality results. The adjustment is to subtract out the short-lived Central Bank Liquidity Swaps of 2008-2009 from the base, M1 and M1 Divisia. These Swaps constituted Fed temporarily borrowing reserves from other Central Banks when their excess reserves turned negative in 2008, during the investment bank panic. With this adjustment, strong causality results hold for monetary aggregates for the entire post 1947 sample and for various sub-periods, including post-2008. In addition, results show that inflation as measured by the CPIE index also Granger causes the real and nominal oil price. These monetary findings extend those of Gillman and Nakov (2009) and Alquist et al. (2013) in which, contrary to Hamilton (1983), inflation and monetary series are found to Granger cause oil prices. This contributes new robust evidence on nominal factors causing oil prices, including during the recent post-Great Recession oil shock period. These results can be important for oil price forecasting. And the paper extends them to gold prices, the oil to gold price ratio, and the US dollar exchange rate index. This demonstrates the importance of monetary factors for benchmark international commodity markets.

Keywords: Oil Price Shocks, Granger Causality, Monetary Base, M1 Divisia, Swaps, Inflation.

JEL Code: Q43, E510, E520

*Head of Research, Hungarian National Bank, Szabadság tér 9, 1054 Budapest; benk.szilard@gmail.com

†University of Missouri - St. Louis, Department of Economics, University of Missouri - St. Louis, 1 Uninversity Boulevard, St. Louis, MO 63121; gillmanm@umsl.edu

1 Introduction

Oil shocks have been said to be caused by episodes of unrest (Baumeister and Kilian, 2016), monopoly power (Mankiw, 2014), and by money supply growth (Alquist et al., 2013). The latter hypothesis is intriguing first because the unrest and monopoly power theses do not resonate well for the recent 2010-2014 oil price rise. Second, the money hypothesis is based on findings, of Granger causality of oil prices by US money supply growth, which stand in contrast to Hamilton's famous (1983) results that no macroeconomic series Granger causes oil prices. The recent post 2010 oil "shock" seems to defy the same monetary explanation of Alquist et. al in that it can be shown that neither the US monetary base or M1 growth rates Granger cause oil prices when this post 2010 period is included. This seems to open up the range of explanations for the past oil shock with no consensus in sight.

The original Hamilton (1983) finding supports the idea that the 1970's oil shocks were purely "exogenous". That would mean that they could have arisen from OPEC one-time monopoly power or any number of ad hoc reasons. However the data Hamilton used was from 1948 to 1972. During this period the US dollar was the anchor of the Bretton Woods gold standard by which gold was fixed to the US dollar at $35 an ounce. Under that regime, data shows a non-volatile, little changing, nominal oil price over time ($2.57 WTI Spot price, in January 1948, rising to $3.56 in July 1973). This reflects the long term fixed price oil contracts that the gold standard facilitated.[1] As opposed to their behavior in the 1950's and 1960's, data also shows that after the 1980's development of spot oil price markets, oil prices moved closely with inflation rate changes.[2] In fact, the rising inflation of the 1960's and near constant oil prices were part of a 15 year decline in the real price of oil until the 1973 "oil shock" (See Alquist et al., 2013, Figure 2: The Real Price of Oil). Of course 1971 to 1973 is when President Nixon ended the Bretton Woods agreement; exchange rates began floating more freely; and the US dollar price of gold shot up by a similar percent as did the US dollar price of oil. Thus, using a data period that ends well after 1979, understandably leads to Gillman and Nakov's (2009) and Alquist et al's. (2013) results that both the US inflation rate and the US money supply growth rate Granger cause US dollar denominated oil prices.

The problem for which this paper contributes a solution is why US inflation and US

[1] "In the old concession system which pervailed in the OPEC region until the early 1970's....spot transactions were few and far between. These sparse transactions were not well reported...Contract prices were not published. They were embedded in clauses of long-term trade agreements between major o i l companies or between major oil companies and third parties. ...There was no real option but to use posted prices....a posted price, which can only be changed through bargaining between [oil] tax farmers and [oil] tax payers, may well remain frozen for fairly long periods" (Mabro, 1984).

[2] "Beginning in 1981, the North Sea or Brent market began to develop. But the development of the spot crude market was also fostered by other factors. ..The development of a spot market in which forward transactions are made invites the establishment of a futures market. This took place in 1982/83 in New York, Chicago and London ...SPOT PRICE of a transaction is the price at which a given cargo of crude oil changes hands."(Mabro, 1984, pp.58-59).

money supply do not similarly effect oil prices when including the recent 2010-2014 oil shock data. The complication with the recent second big oil shock period, which compares in magnitude to the 1970's, is that a banking panic occurred in 2008-2009. This led to changes in the monetary base that were not related to the typical sequence of Federal Reserve Bank (Fed) financing of deficits by buying Treasury debt, thereby "printing money", and so causing subsequent money-caused inflation. Rather in 2008-2009, the liquidity crisis among the investment banks not insured by the FDIC led to the Fed borrowing reserves from other international central banks in order to shore up reserves in the peak crisis time. In particular, from August 2008 to December 2008, the Fed's excess reserves shot up from near zero to $600 Billion through the Central Bank Liquidity Swaps ("Swaps"; on Federal Reserve Economic Data base name as SWPT). These Swaps were quickly "unwound", which means paid back, by April 2009. But excess reserves at that time then continued to grow as the Fed bought more Treasury debt while paying interest on excess reserves (IOER: paid for the first time ever starting in October 2008). The initial 2008 shot upwards in excess reserves as a result of the Swaps caused the US monetary base to rise even as at the same time international asset markets broadly declined. The 2008 decline included US stock markets, gold prices, and oil prices. Our paper shows that the opposite movement of oil prices going down, while the Swap-augmented monetary base went up, breaks up Granger causality of the monetary base, and M1, to oil prices.

Formally the Swaps are counted as a part of the US monetary base. But since the Swaps were a temporary measure for the bank liquidity crisis, rather than part of inflation-pressure inducing reserve increases, we calculated the monetary aggregates with these Swaps subtracted out. As Bordo et al. (2014) show in their history of the Swaps, subtracting these out has little effect on the monetary aggregates except during 2008-2009. Using what we call MB-SWP for the monetary base minus the Swaps, as well as M1 minus the Swaps (M1-SWP) and M1-Divisia minus the Swaps, we find robust Granger causality of these monthly adjusted aggregates, being the monetary base, M1 and M1-Divisia, to oil prices both real and nominal. That is the paper's main finding. The Granger causality of the Swap adjusted aggregates holds at below a 1% level of significance in terms of p-values; reverse causality is rejected.

Granger causality also results from M1-SWP to the CPI price index more strongly than for M1 to the CPI. And the inflation to oil price Granger causality is tested as well. The CPIE (minus energy prices) does Granger cause real and nominal oil prices. Such Granger causality results are less robust for the CPI such as during the 2009-2017 subperiod, when the CPIE Granger causes oil prices but the CPI does not. Given the close comovement of oil and gold prices, the paper presents additional causality results for both nominal and real gold prices. Extensions also include tests of monetary factors causing the oil/gold price ratio and the US exchange rate in terms of a trade-weighted US dollar index.

Section 2 describes the literature and some empirical trends. Section 3 provides the data, Section 4 presents the Econometric Methodology, and Section 5 the results. Section 6 offers some conclusions.

2 Literature and Empirical Facts

Subtracting out the Swaps is similar in spirit perhaps to how Lucas and Nicolini (2015) use an adjusted M1 to find a stable money demand function. They expand the definition of M1, which they call M1MMDA, by taking money market deposit accounts from M2 and adding them to M1. More broadly, the alternate monetary theory of oil shocks was presented descriptively by Barsky and Kilian (2004) for the 1970's. Using data up to 2006, Gillman and Nakov (2009) provide evidence of Granger causality of nominal oil prices by inflation, but not conversely. Their accompanying perfect foresight model shows how nominal oil prices need to jump in response to jumps in the inflation rate simply to keep the real return to oil (and gold) investment constant. From this view, the 1970's oil shocks were "catching-up" for fifteen years of declining real oil prices; they show how oil price movements follow inflation closely starting after the early 1980's. Alquist et al. (2013) show robustness of these causality finds from inflation to oil prices, using data from 1975 to 2009, and add monetary aggregate causality as well. In particular, they show Granger causality of M1 to oil prices.[3]

Explanation of the 2009-2015 shock has been less clear from the monetary perspective in that this oil shock did not coincide with an inflation surge. Baumeister and Kilian (2016) instead presents an episodal analysis of each major post WWII US oil shock episode and suggest that the 2009-2015 oil shock is driven by a relative increase in global demand. He suggests that evidence for this shock is not supported by financial factors related to the Great Recession.

Consider four key nominal data series of interest here. Figure 1 graphs from January 1, 1947 to May 1, 2017, at monthly intervals in US dollars and in natural logs, the WTI spot oil price (Blue), the Consumer Price Index (CPI, Red), the Monetary Base (M0, Green), and the "Gold Fixing Price" (Purple). The CPI series and the Gold series are shifted down

[3] Alquist, Kilian and Vigfussion (2011, pp.11-12): "There are several reasons to expect the dollar-denominated nominal price of oil to respond to changes in nominal U.S. macroeconomic aggregates. One channel of transmission is purely monetary and operates through U.S. inflation. ... Indeed, the Granger-causality tests in Table 1a indicate highly significant lagged feedback from U.S. headline CPI inflation to the percent change in the nominal WTI price of oil for the full sample, consistent with the findings in Gillman and Nakov (2009)....an alternative approach of testing the hypothesis of Gillman and Nakov (2009) is to focus on Granger causality from monetary aggregates to the nominal price of oil. Given the general instability in the link from changes in monetary aggregates to inflation, one would not necessarily expect changes in monetary aggregates to have much predictive power for the price of oil, except perhaps in the 1970s (see Barsky and Kilian 2002). Table 1a nevertheless shows that there is considerable lagged feedback from narrow measures of money such as M1 for the refiners' acquisition cost and the WTI price of oil based on the 1975.2-2009.12 evaluation period."

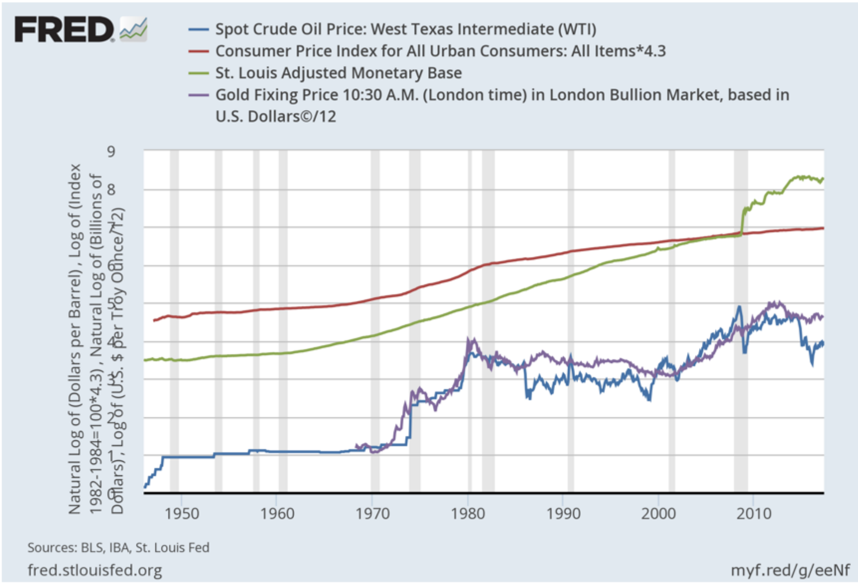

Figure 1: Oil, CPI, Monetary Base, and Gold post-WWII Data Series.

for comparison to the other two series. Certainly the oil and normalized gold prices appear to move rather closely together. And broadly, one can see how both of these commodity series have some broad comovement with the CPI and with the monetary base. Further, the post 2008 jump in the monetary base seems to comove somewhat closely with the oil price; both turn downwards at nearly the same time in 2014. The WTI oil price fell from 106 in June 2014 down to 47 in January 2015. Almost simultaneous, in August 2014, "Excess Reserves" of the Fed (data series EXCSRESNS) reached its all-time peak and has dropped ever since.

For January 1, 1947 to May 1, 2017, Figure 2 shows in addition to the dollar, nominal, WTI price (Blue), the real WTI price (Green). The real price is derived by dividing the WTI by the CPI for all Urban consumers (1982=100), and normalized by dividing by 100. Also drawn are endpoint to endpoint trend lines in Red and Purple. The Red line endpoints trend is from \$1.62 to \$52.50. Calculating $\frac{52.5-1.62}{1.62} = 31.4$, gives a 3,141% increase. As the time length for this period is 70.25 years, this gives a high average annual nominal oil price increase of $\frac{3141\%}{70.25} = 45\%$. In contrast, the average annual real oil price increase is from 7.54 to 19.88, a $\frac{19.88-7.54}{7.54} = 1.64$, or a 164% increase. On an annual basis, this is a $\frac{164\%}{70.25} = 2.3\%$ increase. The latter real oil price average annual increase resembles a rather reasonable

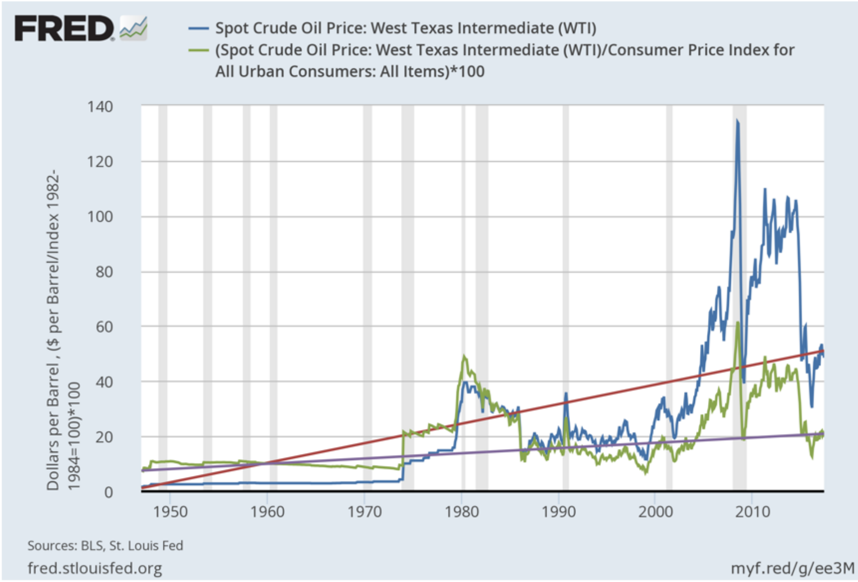

Figure 2: Nominal and Real WTI Oil Prices, with trend lines.

return similar to some trend estimates of the average real interest rate in the US over this period.

Figure 3 provides growth rates for the CPI and the monetary base. It graphs the natural log of each data series so that the slopes of the series indicates the growth rate. Over the same 70.25 years, Figure 2 shows the CPI index and its Red trend line, as compared to the upper graph of the monetary base and its trend lines, as presented in three sections of the trend. These three sections are in Blue for the first years, Purple up until the Great Recession, and then an Orange steeper slope trend line for after 2008. The CPI index rises from 21.48 to 243.846 in the lower graph, for a $\frac{243.846-21.48}{21.48} = 10.35$ -fold increase, or by 1035%; at an annual rate this is $\frac{1035\%}{70.25} = 14.73\%$. The monetary base rose by much more, especially after 2008.

In Figure 3, from January 1, 1947 to January 1, 1960, the slope of the arc (not shown) of the CPI line indicates an annual rate of $\frac{3.38-3.076}{13} = 0.0234$; so inflation is a 2.3% annual rate for this period. For the arc line segment for the CPI from 1-1-1960 to 1-1-1982 (not shown), the annual increase is $\frac{4.547-3.38}{12} = 0.097$; the inflation rate arc rises to 9.7% average per year. This shows the acceleration of inflation during the Vietnam war; however the actual average rate of increase is less than this since the data forms a convex curve below

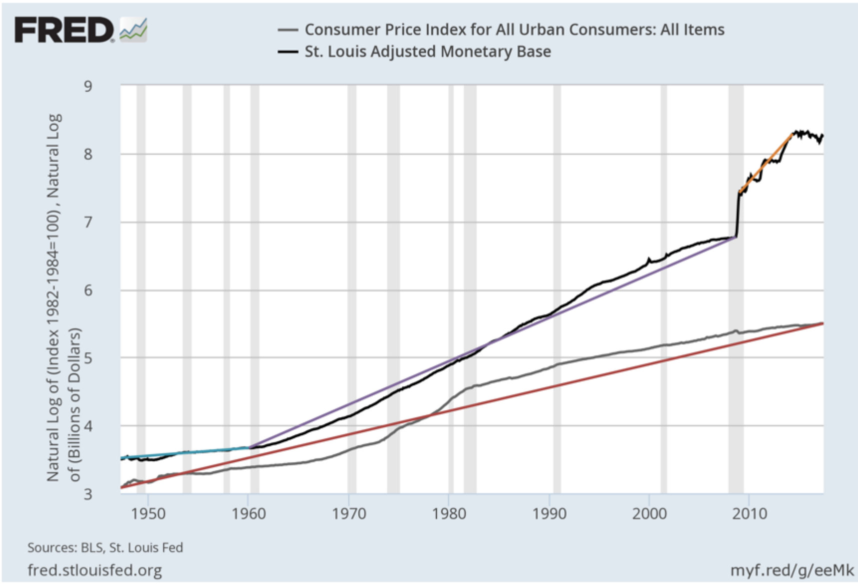

Figure 3: Natural Log of CPI and Monetary Base, 1947-2017.

the arc. Then from January 1, 1982 to August 1, 2008, the arc (not shown) slope indicates a $\frac{5.387-4.547}{26.583} = 0.0554$, or a 5.54% average annual inflation rate. From 10-1-2008 to 5-1-2017, the arc (not shown) slope decreases to $\frac{5.50-5.387}{8.75} = 0.013$, or a 1.3% average annual inflation rate. These form four markedly different regimes. The first three are broadly shadowed by the monetary base; the fourth and last one is not.

Consider now a fifth data series: real GDP. Figure 4 shows the natural logs of all four of the series in Figure 1 along with the natural log of real constant dollar GDP, shifted so the top three figures intersect start from the same point. The acceleration of the monetary base, relative to both the inflation rate and the real GDP growth rate, is clear in the Figure for the period after the 1971 (to 1973) breakdown of Bretton Woods and the worldwide adoption of fiat money. This world stock of US dollars may well be reflected in the post 1971 oil and gold prices beginning their higher growth rate levels. And the US inflation may stay below what the monetary base growth and real GDP growth would suggest because the fiat US dollar became demanded internationally as both reserve and circulation currency. Absorbing this US monetary base expansion by buying up dollars would enable other countries to keep their exchange rates stable with respect to the US. If so then there should also be a relation between US nominal factors and exchange rates, a thesis extension that is explored below in the Granger causality tests.

Given the seeming graphical comovement of oil and gold prices, would it not be reasonable to consider an oil shock as one defined relative to the price of gold?. Figure 5 shows that this series, starting with the FRED data for gold in 1968, at first glance looks like random noise. It may be that a nominal story can be told for some movements in the series, or the opposite type of thesis, that of relative price changes from supply or demand shifts, may apply. While the 1970's may indicate a nominal story, after 1998 and up to 2008 is there an unusual rise that may be a relative price feature. For example the latter could be a relative price (demand caused) increase due to such well-known candidates as China entering international capital markets more fully after its 1997 acquisition of Hong Kong. As an extension, this oil/gold price is also tested for nominal causality.

Finally, Figure 6 shows the monetary base, along with the monetary base minus the Central Bank Liquidity Swaps. It also includes the Excess Reserves minus the Swaps. Subtracting the Swaps from Excess Reserves shows that these reserves turned negative in April 2008, with a negative peak in October 2008. This offers explanation of why the Fed borrow reserves from other central banks through the Swaps, during their liquidity crisis.

Here the Swaps themselves are shown in Figure 7 for the Great Recession period.

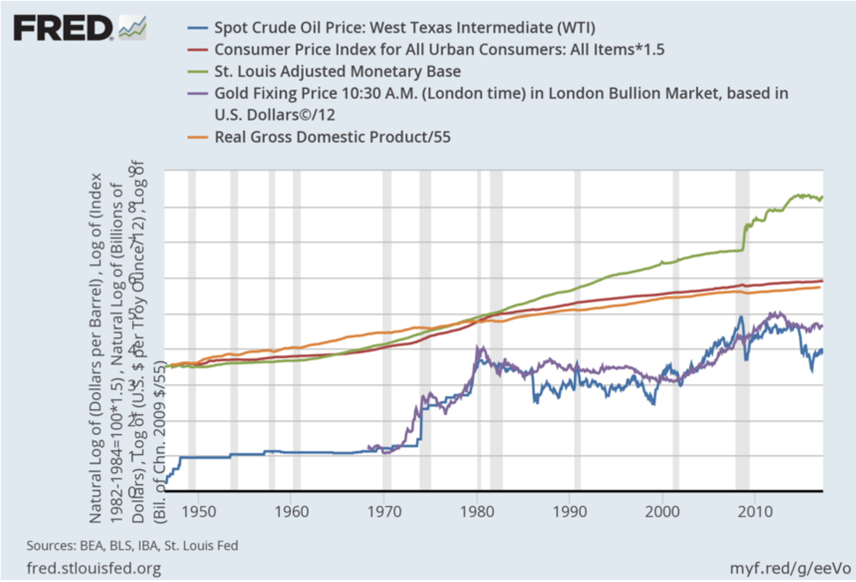

Figure 4: Natural Log of Real GDP lags the Natural Log of the Monetary Base.

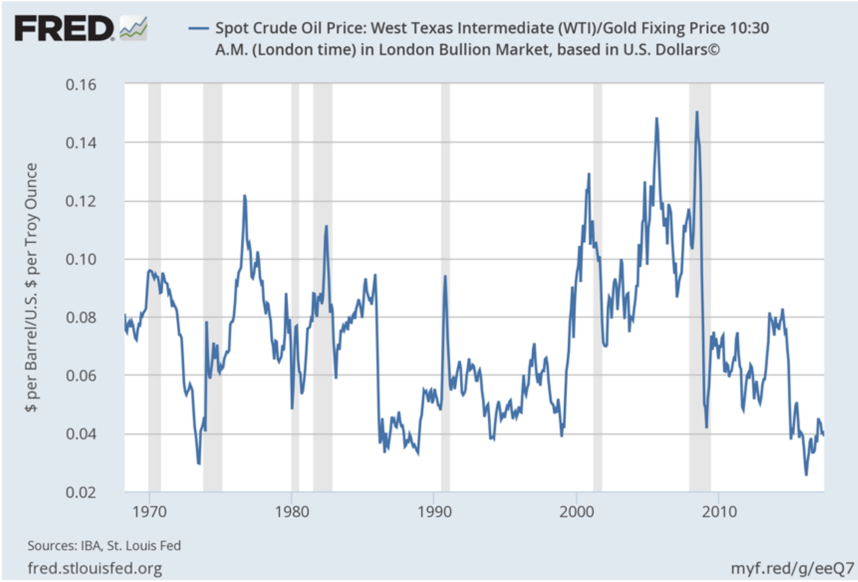

Figure 5: Oil to Gold Price Ratio

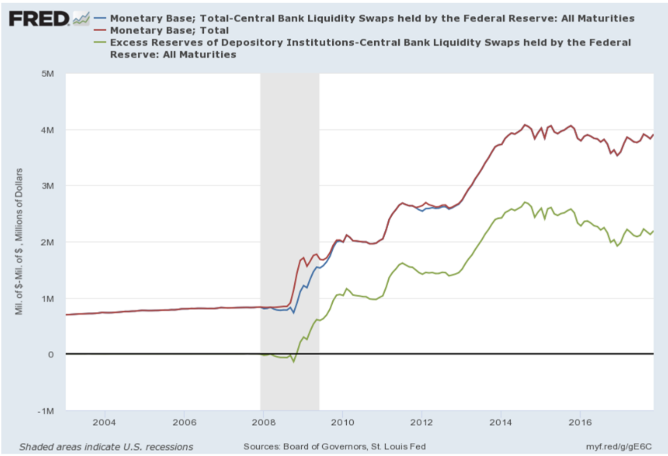

Figure 6: Monetary Base; Monetary Base minus Swaps; Excess Reserves minus Swaps turned Negative in 2008.

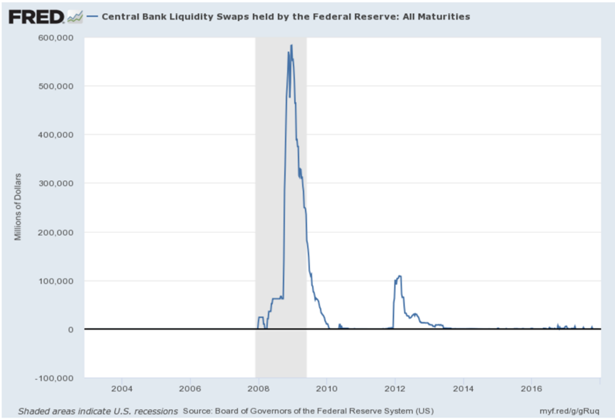

Figure 7: Central Bank Liquidity Swaps; Peak at $580 Billion in December 2008

3 Data

The data used in this paper is downloaded from the FRED database (Federal Economic Data base of the Federal Reserve Bank of St. Louis), unless otherwise indicated. For each variable it covers the full data sample where data was available, as indicated below (FRED code in parenthesis):

MB: Money Base (AMBSL, 1946m1 - 2017m4)

SWP: Central Bank Liquidity Swaps (SWPT, 2003m1 - 2017m5)

DEMDEP: Demand deposits (DEMDEPSL, 1959m1 – 2017m4)

M1: M1 Money Stock (M1SL, 1959m1 – 2017m4)

M2: M2 Money Stock (M2SL, 1959m1 – 2017m4)

CPIE: CPI less Energy (CPILEGSL, 1957m1 – 2017m4)

CPI: CPI for all urban consumers (CPIAUCSL, 1947m1 – 2017m4)

WTI: Spot Crude Oil Price WTI (WTISPLC, 1946m1 – 2017m4)

GOLD: Gold fixing price in London Bullion Market (GOLDPMGBD228NLBM, 1968m4 – 2017m5)

M1 Divisia: Monetary services Index M1 (MSIM1P, 1967m1 – 2013m12)

M2 Divisia: Monetary services Index M2 (MSIM2, 1967m1 – 2013m12)

EXCH: Trade Weighted U.S. Dollar Index: Broad (TWEXB, 1973m1 – 2017m4)

4 Testing Methodology

Our testing methodology is similar to Hamilton (1983), which was applied also by Gillman and Nakov (2009) and Alquist, Kilian and Vigfusson (2013). Hamilton tests for the endogeneity of oil prices by following the suggestion of Granger (1969). This method constitutes estimating a VAR model of the following form:

$Y_t = c_0 + c_1 Y_{t-1} + ... + c_p Y_{t-p} + d_1 X_{t-1} + ... + d_p X_{t-p} + v_t$

Then X is said to Granger-cause Y if Y can be better predicted using the histories of both X and Y than it can by using the history of Y alone. This reduces to testing the null hypothesis $H_0 : d_1 = d_2 = ... = d_p = 0$, against H_A: 'Not H_0'. Rejection of the null is is equivalent to saying that X does Granger-cause Y.

The test comes with limitations, since it requires that X and Y to be stationary. The test cannot be applied if X and Y are of a different order of integration. Should X and Y be integrated of the same order, we differentiate X and Y by the necessary amount of times so that they became stationary. If of a different order of integration, in such particular cases we follow instead the Toda and Yamamoto (1995) procedure to test for Granger causality. Giles (2011) offers a very useful set of instructions on how to apply the Toda and Yamamoto (1995) procedure in practice, which we follow closely. To determine the order of integration of each series, we apply the Augmented Dickey-Fuller (ADF) test for unit roots.

5 Econometrics

We run the unit root tests and Granger causality tests both on the full sample, and on various subsamples. The breakpoints and subsamples have been chosen because of various considerations. The post-1973 and post-1975 tests are a replication of Alquist, Kilian and Vigfusson (2013). The 2008 breakpoint separates the pre- and post-crisis periods.

5.1 Data Properties

We test all series for unit roots on various subsamples. Table 1 shows the p-values of the ADF unit root test for the first differences. All series proved to be integrated of order 1 (I(1)), except for the CPIE that proved to be I(2). Then we apply the standard Granger (1969) causality test to all the I(1) pairs of series. In addition, we employ the Toda and Yamamoto (1995) procedure to test for causality by the CPIE that we found to be I(2).

	full sample	1973-2017	1975-2017	1991-2017	Data Start-2008m9	2008m10-2017
MB	0	0	0	0	0	0
MB-SWP	0	0	0	0	0	0
MB+DEMDEP	0	0	0	0	0	0
MB-SWP+DEMDEP	0	0	0	0	0	0
M1	0	0	0	0	0	0
M1-SWP	0	0	0	0	0	0
M2	0	0	0	0	0	0
M2-SWP	0	0	0	0	0	0
CPIE	**0.2185**	**0.3369**	0.0278	0.0023	**0.2332**	0
CPI	0	0	0	0	0.0001	0
WTI	0	0	0	0	0	0
GOLD	0	0	0	0	0	0
realOil	0	0	0	0	0	0
realGold	0	0	0	0	0	0
M1 Divisia	0	0	0	0	0	0
M2 Divisia	0	0	0	0	0	0
EXCH	0	0	0	0	0	0

Note: for p>0.05 the stationarity hypothesis is rejected

Table 1: p values for ADF test on the first difference of the series

Note that "Data Start-2008m9" indicates the subperiod starting with when the particular data series begins, which varies from 1946 (monetary base) to 1967 (gold), and ending in 2008m9. This is also abbreviated as Start-2008m9 in the rest of the tables after Table 1. Starting dates for the data series are given in each of the causality result tables below.

5.2 Results

The Table 2 results show Granger causality of dollar oil prices by the monetary base minus swaps (MB-SWP) for the full sample, starting in 1946, with a p-value significance at less than two-tenths of one percent. Similar results hold for the 1975-2017 subperiod. The post 2008 subperiod shows a p-value near 5%, while the 1991-2017 value is 2.4% and the 1973-2017 value is 6%. These all show considerable robust of the monetary causality finding.

However should only the monetary base (MB) be used in these tests, the table shows a rejection of Granger causality of nominal oil prices in all subperiods. The same results hold for tests of M1. In contrast, for M1 minus Swaps (M1-SWP), the Granger causality results are even stronger than using MB minus Swaps. The M1-SWP results show a p-value below 1% for all post-WWII subperiods. Furthermore, tests with M1 Divisia minus Swaps also indicates Granger causality with p-values at less than 3% for all post WWII subperiods.

There are other results of note here. M2 and M2-SWP, along with M2 Divisia and M2 Divisia minus Swaps, show no Granger causality, these aggregates being broader and perhaps less reflective of inflation expectations. Seeking further robustness for the Swap

causality to $WTI		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1946	0.1425	0.5046	0.4216	0.5773	0.8911	0.7593
MB-SWP	1946	**0.0017**	**0.0607**	**0.0068**	**0.024**	0.9852	**0.0483**
MB+DEMDEP	1959	**0.0755**	0.2289	0.1348	0.1243	0.8518	0.325
MB-SWP+DEMDEP	1959	**0.0159**	**0.0846**	**0.0102**	**0.0253**	0.9035	**0.0231**
M1	1959	0.4826	0.6716	0.4199	0.2152	0.8273	0.3679
M1-SWP	1959	**0.0003**	**0.0053**	**0.0005**	**0.0011**	0.8111	**0.0011**
M2	1946	0.7509	0.8688	0.797	0.3413	0.8273	0.5959
M2-SWP	1946	0.8698	0.9141	0.8126	0.5564	0.8297	0.1404
CPIE	1957	**0.0014**	**0.0001**	0.7814	0.5171	**0.0003**	**0.0173**
CPI	1947	**0.0931**	**0.0154**	0.1439	**0.0488**	**0.032**	0.6129
M1Divisia	1967	0.6818	0.7172	0.372	0.3499	0.8846	0.7799
M1Divisia-SWP	1967	**0.0124**	**0.0271**	**0.0041**	**0.0045**	0.9134	**0.0017**
M2Divisia	1967	0.6253	0.6649	0.3832	0.1915	0.8801	0.5889
M2Divisia-SWP	1967	0.855	0.8743	0.7058	0.718	0.8893	0.322

Note: p values in bold (<0.10) indicate the presence of causality

Table 2: Causality to nominal oil price (WTI)

results, we constructed an aggregate by adding the monetary base to demand deposits (MB+DEMDEP), which is the same as M1 plus reserves. We also constructed this aggregate with Swaps subtracted (MB-SWP+DEMDEP). For the latter, results are similar to those with MB-SWP. For the monetary base plus demand deposits, one exception to the Swap results is that this aggregate does Granger cause the dollar and real oil price for the full post-WWII sample, with a p-value of 7.6%. This is the only monetary aggregate without Swaps showing such causality.

Table 3 shows the results for testing the real oil price, as defined as the US dollar WTI price divided by the CPI price index. The results for the monetary aggregates are very similar. The inflation causality of oil prices is also tested in the two tables.

Both tables show strong Granger causality of the CPI minus Energy prices (CPIE) for most of the subperiods. It is notable that for the regular CPI (for all urban consumers), there are similar results except for the 1991-2017 and 2008-2017 subperiods. The CPIE Granger causes oil prices in 2008-2017, but not in 1991-2017; the CPI Granger causes oil prices in 1991-2017, but not in 2008-2017. Certainly taking out energy prices from the price index would seem to be more likely to result in Granger causality in the post 2008 period, as is indeed found.

The comovement of oil and gold prices seen in the Figures above suggest causality testing of these as well, to see whether the monetary phenomenon effecting oil prices is isolated to oil. Tables 4 and 5 show the results. M1 minus Swaps, M1 Divisia minus Swaps, M2 minus Swaps and M2 Divisia minus Swaps all show Granger causality of both nominal and real gold prices for some of the post-WWII subperiods. M2-SWP shows such causality for the

causality to real Oil		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1947	0.1305	0.4985	0.4065	0.5728	0.7909	0.7486
MB-SWP	1947	**0.0019**	**0.0602**	**0.0066**	**0.0241**	0.9545	**0.0538**
MB+DEMDEP	1959	**0.075**	0.2299	0.1288	0.1227	0.852	0.299
MB-SWP+DEMDEP	1959	**0.0151**	**0.0816**	**0.0095**	**0.0246**	0.9064	**0.0244**
M1	1959	0.4581	0.6533	0.4001	0.1983	0.8001	0.3475
M1-SWP	1959	**0.0004**	**0.0067**	**0.0006**	**0.0011**	0.793	**0.0013**
M2	1947	0.7671	0.8821	0.8119	0.3224	0.8405	0.5765
M2-SWP	1947	0.8882	0.9326	0.8412	0.5326	0.8432	0.1393
CPIE	1957	**0.0021**	**0.0001**	0.8309	0.4942	**0.0003**	**0.0169**
CPI	1947	0.1605	**0.0187**	0.1521	**0.0462**	**0.0572**	0.5931
M1Divisia	1967	0.664	0.7003	0.3634	0.3257	0.8704	0.7573
M1Divisia-SWP	1967	**0.0151**	**0.0323**	**0.0048**	**0.0046**	0.9024	**0.0016**
M2Divisia	1967	0.6046	0.6439	0.3758	0.165	0.8704	0.5612
M2Divisia-SWP	1967	0.8466	0.8679	0.7038	0.6873	0.8803	0.3214

Note: p values in bold (<0.10) indicate the presence of causality

Table 3: Causality to real oil price (WTI/CPI)

entire post 1950 "full sample" period, as well as for 1991-2017 and 2008-2017. M1-SWP also shows causality for the latter two subperiods, of 1991-2017 and 2008-2017. M1 Divisia minus Swaps shows causality only for 1991-2017. Also of interest, the CPI Granger causes gold prices in all subperiods except for 2008-2017. This suggests that the norm of inflation Granger-causing gold prices fell apart post 2008 when the expected inflation did not actually materialize.

Given the nominal influence on both oil and gold prices, it arises as a possible way to define an oil shock in terms of its price relative to gold prices. Table 6 tests Granger causality of the oil/gold price ratio. It may be surprising to find that the results are quite similar to the tests on oil prices alone in the first two tables. For M1 minus Swaps (M1-SWP) and M1 Divisia minus Swaps, the results are basically the same, with robust causality across all post-WWII subperiods. For the Monetary Base minus Swaps (MB-SWP), and for MB-SWP+DEMDEP, a difference is a lack of causality in the 1973-2017 and 2008-2017 subperiods.[4]

There are scattered other differences in the oil/gold price table as compared to the oil price tables. M1 shows causality for 1991-2017, unlike previous oil price results, and M2 minus Swaps shows causality for the 2008-2017 subperiod. In terms of inflation, the CPIE causality results are similar to the first two tables, with causality found in most subperiods. For the CPI, there is causality only for the Start (1950)-2008 subperiod. These results allow for a new "oil price shock" definition that in some sense shows broader monetary causality

[4] One difference in the data is the later starting date for the gold price of 1950, as compared to 1946 in the first two oil price Tables, but this would seem negligible since the US was on the Bretton Woods gold standard from 1946-1950.

causality to GOLD		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1950	0.8764	0.9723	0.9213	0.7626	0.7871	0.7878
MB-SWP	1950	0.6631	0.895	0.8815	0.486	0.4564	0.7802
MB+DEMDEP	1959	0.8798	0.9501	0.8886	0.6053	0.811	0.6083
MB-SWP+DEMDEP	1959	0.5147	0.7108	0.724	0.3426	0.7685	0.5197
M1	1959	0.7509	0.8441	0.878	0.5101	0.8141	0.1387
M1-SWP	1959	0.3909	0.5935	0.5222	**0.0619**	0.8361	**0.0886**
M2	1950	0.3451	0.4633	0.6182	0.6526	0.2214	0.58
M2-SWP	1950	**0.0489**	0.1143	0.1719	**0.0362**	0.2521	**0.0263**
CPI	1950	**0.0254**	**0.047**	**0.0082**	**0.0102**	**0.0142**	0.6118
M1Divisia	1967	0.5263	0.5086	0.6597	0.8013	0.4483	0.9496
M1Divisia-SWP	1967	0.3506	0.411	0.3505	**0.0346**	0.5093	0.3074
M2Divisia	1967	0.2818	0.3018	0.4588	0.9093	0.1473	0.8601
M2Divisia-SWP	1967	**0.0913**	0.113	0.2029	0.2032	0.1692	0.2994

Table 4: Causality to nominal gold price

causality to real gold		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1950	0.8887	0.9705	0.9045	0.7706	0.8020	0.834
MB-SWP	1950	0.7126	0.906	0.8844	0.4962	0.4959	0.82
MB+DEMDEP	1959	0.8374	0.9239	0.8286	0.6155	0.7484	0.6548
MB-SWP+DEMDEP	1959	0.4822	0.6748	0.6781	0.3253	0.7122	0.5551
M1	1959	0.7128	0.8077	0.8456	0.4755	0.7948	0.108
M1-SWP	1959	0.4588	0.6514	0.5491	**0.0889**	0.8300	0.1145
M2	1950	0.3291	0.4372	0.5991	0.6677	0.2165	0.5908
M2-SWP	1950	**0.0619**	0.1291	0.1819	**0.0578**	0.2481	**0.0339**
CPI	1957	**0.0234**	**0.0506**	**0.0089**	**0.0155**	**0.0146**	0.6753
M1Divisia	1967	0.4462	0.4292	0.5826	0.7558	0.3841	0.9539
M1Divisia-SWP	1967	0.4001	0.4585	0.3652	**0.048**	0.4441	0.3705
M2Divisia	1967	0.2206	0.2414	0.3916	0.9125	0.1181	0.8967
M2Divisia-SWP	1967	**0.0902**	0.1111	0.1993	0.2562	0.1372	0.3816

Note: p values in bold (<0.10) indicate the presence of causality

Table 5: Causality to real gold price

Oil/Gold price ratio		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1950	0.149	0.4696	0.3808	0.5503	0.5377	0.7825
MB-SWP	1950	**0.02**	0.1707	**0.0342**	**0.0923**	0.6695	0.2309
MB+DEMDEP	1959	**0.0481**	0.1601	**0.0879**	0.1321	0.4415	0.2015
MB-SWP+DEMDEP	1959	**0.0366**	0.1383	**0.023**	**0.0524**	0.5073	**0.0693**
M1	1959	0.1507	0.3089	0.1367	**0.0713**	0.6941	0.2947
M1-SWP	1959	**0.0004**	**0.0057**	**0.0005**	**0.0016**	0.7207	**0.0031**
M2	1950	0.6722	0.796	0.813	0.2315	0.8291	0.4188
M2-SWP	1950	0.4433	0.5443	0.3823	0.3026	0.8184	**0.0427**
CPIE	1957	**0.0321**	**0.0014**	0.5804	0.8658	**0.0063**	**0.0516**
CPI	1950	0.1048	0.1072	0.3225	0.0903	**0.0152**	0.6126
M1Divisia	1967	0.5318	0.6001	0.3863	0.2475	0.6241	0.7606
M1Divisia-SWP	1967	**0.0087**	**0.0175**	**0.0019**	**0.0014**	0.6538	**0.0018**
M2Divisia	1967	0.5808	0.6847	0.6058	0.121	0.8882	0.3128
M2Divisia-SWP	1967	0.6857	0.7416	0.5621	0.4088	0.8861	**0.0704**

Note: p values in bold (<0.10) indicate the presence of causality

Table 6: Causality to Oil/Gold price ratio

		full sample	1973-2017	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB to CPI	1947	**0.0029**	**0.0013**	**0.001**	**0.0013**	**0.0237**	**0.0929**
MB-SWP to CPI	1947	**0.0011**	**0.0073**	**0.0026**	**0.0076**	**0.0044**	**0.0245**

Note: p values in bold (<0.10) indicate the presence of causality

Table 7: Causality of Base Money to Inflation

in the 2008-2017 subperiod because of the added M2-SWP causality, as compared to the first two tables.

Two last monetary tests are monetary causality of inflation and the US dollar exchange rate index. Table 7 shows that both the monetary base and the base minus the Swaps Granger cause the CPI inflation rate. Lower p-values are found on average for the case with Swaps subtracted, such as in the 2008-2017 and Start-2008 subperiods.

Table 8 examines the Causality of the US dollar trade-weighted exchange rate index by nominal factors. The monetary base (MB), and the base minus Swaps (MB-SWP), significantly cause the exchange rate index only in the 2008-2017 subperiod. For three different subperiods, M1 minus Swaps, M2 Divisia and M2 Divisia minus Swaps all Granger cause the index; these subperiods are the "full sample", 1975-2017 and 1991-2017. M1 Divisia minus Swaps has similar results except for no causality in 1991-2017. The CPI causality is robust for all the subperiods.

to Exch rate		full sample	1975-2017	1991-2017	Start-2008m9	2008m10-2017
MB	1973	0.1862	0.2221	0.1557	0.8803	**0.0285**
MB-SWP	1973	0.4269	0.4725	0.496	0.6024	**0.0752**
MB+DEMDEP	1973	0.3385	0.3642	0.3496	0.9056	0.1049
MB-SWP+DEMDEP	1973	0.3987	0.4205	0.6351	0.7276	0.1432
M1	1973	0.2451	0.1882	0.2745	0.8167	0.7234
M1-SWP	1973	**0.0233**	**0.0408**	**0.0786**	0.5833	0.2508
M2	1973	0.2447	0.156	0.123	0.5582	0.9102
M2-SWP	1973	0.163	0.1298	0.1178	0.4786	0.5678
CPI	1973	**0.0488**	**0.0571**	**0.0227**	**0.0825**	**0.0000**
M1Divisia	1967	0.2039	0.1336	**0.0314**	0.9214	0.2844
M1Divisia-SWP	1967	**0.049**	**0.0803**	0.1338	0.7689	0.7387
M2Divisia	1967	**0.0962**	**0.059**	**0.0289**	0.3907	0.5327
M2Divisia-SWP	1967	**0.0522**	**0.0444**	**0.0602**	0.3122	0.8328

Note: p values in bold (<0.10) indicate the presence of causality

Table 8: Causality to the Exchange rate

6 Discussion

The results show strong evidence of money and inflation Granger causing oil prices. Also money strongly Granger causes inflation, as has been found before (Haug and Dewald, 2012). And money and inflation causes international gold prices, the oil to gold price ratio, and the US dollar exchange rate index. This is a robust set of monetary facts that reinforce the nominal factors causing oil prices. The additional facts make clear that oil is not special in this way. As oil is an international commodity denominated in US dollars, such results may be not surprising.

Granger causality results for gold prices, nominal and real, by the M2 minus Swaps (M2-SWP) aggregate, with much less robust results for narrower aggregates. In contrast, it is the narrower aggregates, of the monetary base minus Swaps (MB-SWP), M1 minus swaps (M1-SWP) and M1 Divisia minus Swaps that Granger cause oil prices. Gold is a bit different from oil in usage in that oil needs to be used much more urgently for day to day production of output. Gold is more of an investment hedge, with it safe to say, that involves production use that is less urgent. The inference here could be that the gold price builds in longer term expectations of inflation while the oil price also builds into its price expectations of inflation, but seemingly on a shorter term basis.

This could mean that an oil shock in terms of the results for the oil to gold price ratio of Table 6 reflect in part the short term expectations of inflation relative to long term expectations of inflation. The Granger causality results of the oil/gold price are similar to the oil price results. However a notable difference is that in the 2008-2017 period, the oil/gold price ratio is Granger caused also by M2 minus Swaps, while the oil prices of Tables 2 and 3 are not so effected. So post Great Recession, there is some unusual behavior in that the broader aggregate provides what might be valuable information on expectations of inflation. If so, this may have resulted because the interest on excess reserves kept the reserves from being lent out and expanding the M1 aggregate in the typical money multiplier fashion; this could then have resulted in giving M2 additional weight even for shorter term inflation expectations. This oil/gold price ratio provides an intriguing way to consider oil shocks. However inference on short term versus long term inflation expectations is speculative here; it could be tested more precisely using other measures of inflation expectations, a topic left for future research.

The results overall then cast doubt at least on alternative hypotheses of monopoly power and local war or political instability factors in causing oil prices. The results still allow for war and instability factors as applied to the US to factor into oil prices, in that the US has financed wars and bank panics through the Fed buying Treasury debt (now holding a fifth of all public federal debt). The recent rise in excess reserves, with interest paid on these reserves, is also a symptom of this that has enabled the "money printing" to be "sterilized" and not enter circulation, albeit this may have repressed the real interest rate across international capital markets (into prolonged negative territory).

As Phil Gram and Thomas R. Saving write:[5]

> "Today, banks hold $12 of excess reserves for every dollar they are required to hold, and the Fed balance sheet contains 20% of all publicly held federal debt and 34% of the value of all outstanding government-guaranteed mortgage-backed securities....While the initial injection of liquidity into the economy in 2008 clearly helped stabilize the financial market and was a classic central-bank response to a financial crisis, the monetary easing program of the Obama era was unprecedented... To maintain price stability in an environment of rising interest rates, the Fed would not only have to soak up existing excess reserves; it would also have to reduce bank reserves to prevent the increase in velocity from inflating demand and igniting inflation."

It seems safe to assert that markets expected inflation to result after 2009 because the Fed had bought so much Treasury debt. Then the logic follows that this expected inflation was built into oil price expectations, causing the 2009-2014 oil "shock". When the excess reserves finally stopped rising in April 2014, expectations of future inflation finally collapsed, and so did oil prices.

For a broader perspective on oil prices, consider them as a part of capital used in production. For this, take the Lucas (1988) production function, which combines human and physical capital stocks to produce a flow of output.[6] One can view a barrel of oil (or better,

[5] "A Booming Economy Will Challenge the Fed", by Phil Gram and Thomas R. Saving, Wall Street Journal, Dec. 13, 2017.

[6] Lucas (1988) uses human capital investment to endogenize Solow growth by making the technological

perhaps, the *stock* of the oil fields) as part of the physical capital that is used in production of aggregate output. From this view, under a generally competitive world oil market, the best way to predict nominal and real oil prices is to expect that the capital stock of oil will yield its normal real return. This return is that which is equalized across various forms of capital, with risk-adjustments to the returns. For real oil prices since 1947, the average 2% return to oil shown in Figure 2 in terms of the average annual increase in real oil prices, seems reasonable. To get this normal real return, for a nominally priced asset, nominal factors would need to be taken into consideration.

7 Conclusion

The jump in the monetary base and excess reserves after 2008 might be a topic that Friedman (1994) would write about in a revised *Money Mischief,* if he could. He might describe how money causes inflation, how oil and gold prices can reflect this expectation, and how if the expectations of inflation for some reason are not met, then these international commodity prices might fall precipitously. He might continue along the lines that the post-2008 payment to banks of some $100 billion not to lend out the base reserves ("interest on excess reserves"), tampered the reserves from leaving the Fed so that they did not cause new loan and demand deposit creation, and subsequent inflation. Such a scenario arguably induced "stagnation" in terms of repressed investment and output growth rates, without inflation. The results of this paper are not inconsistent with the idea that the Fed's new 2008 policy of paying interest on reserves induced an unpredicted oil shock along the way because of expectations of inflation that were not realized. No one knew what distortions interest on excess reserves would cause, since there never had been such interest paid until 2008. Friedman might have guessed.

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