International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2019, 9(4), 172-180.

Oil Prices and Money Neutrality

Samih Antoine Azar[1]*, Philip Karam[2]

[1]Faculty of Business Administration and Economics, Haigazian University, Mexique Street, Kantari, Beirut, Lebanon, [2]Advisory Team, Bank Julius Baer, Geneva, Switzerland. *Email: samih.azar@haigazian.edu.lb

Received: 21 May 2019 **Accepted:** 11 July 2019 **DOI:** https://doi.org/10.32479/ijefi.8276

ABSTRACT

The purpose of this paper is to estimate a parsimonious model of money demand. The model relates international crude oil prices to the US money stock with the addition of a valuation adjustment. The main econometric estimation procedure is the autoregressive distributed lag approach. The model is checked for robustness by changing the econometric procedure to the Johansen estimator, by changing the functional form of the conditional variance, and by applying alternative cointegration tests. Oil prices and the US money stock move in tandem in the long run. The association is unit proportional which implies money neutrality. The major conclusion is that oil prices have an anchor, which is the US money stock, and no event whether intended or unintended is capable to destabilize the model. Hence monetary authorities are passive observers, and cannot manipulate economic variables to control *real* oil prices in the long run.

Keywords: Crude Oil Prices, US Money Stock, Cointegration, Long Run, Money Neutrality, Robustness
JEL Classifications: E41, E44, E51, E52, C5

1. INTRODUCTION

Oil prices are a major indicator of worldly performance, and are widely and quickly publicized, and are scrutinized and monitored by very diverse economic agents. It is by now clear that oil prices and oil derivatives are extremely volatile (Azar, 2019), and their markets are deemed highly speculative. What is surprising is that oil prices, like for example the west Texas intermediate (WTI), provide a zero monthly return, making oil an exceptionally bad investment, unlike gold which has a noticeable positive price appreciation and return. However, oil is characterized by a convenience yield, which makes oil attractive to hold physically and its possession insures that markets are not subject to perturbation. This might explain the magnitude of US oil reserves. A parallel concern is whether oil prices are anchored to other financial variables. The presumption is that oil is not anchored to any asset or macroeconomic variable. This notion is dispelled in this paper. One of the main conclusions of this paper is that oil prices fluctuate relative to US money, after having removed valuation effects. This monetary link by oil unto US money is consistently proportionate, meaning that in the long run money is neutral on oil prices. This result is obtained by applying different econometric techniques to check the general robustness of the effect. One feature about the different approaches of the underlying model is that it is parsimonious. It is astonishing that such a simple model was not discovered previously.

The paper is organized as follows. In the next section, section 2, a sketch of the theoretical approach is provided, along with the pertinent literature survey. Section 3 identifies the source of the data and presents the empirical results with the basic autoregressive distributed lag approach (ARDL) method. Section 4 dwells on the robustness of the relationships by carrying out alternative econometric specifications. Section 5 rehearses some policy implications. And section 6 summarizes and concludes.

2. THE THEORETICAL BACKGROUND

The paper is based on the quantity theory of money demand. According to this theory there is an economic identity, which incorporates four variables: The money stock (M), the real economy-wide output (Y), the price level (P), and the velocity of circulation of money (V):

$$MV \equiv PY$$

There is evidence that velocity and aggregate output move in tandem with unit proportionately. Hence they drop out of the relation. What is left is M=P. Since we are estimating a long run behavior, this equation implies money neutrality whereby the US money stock and prices are co-integrated. It is necessary to account for valuation effects when the price level is the price of crude oil. The relation between the price level and oil prices follows the contribution of Dornbusch (1976), and Frankel (1986). The price level is composed by a weighted average of commodity prices that overshoot in the short run, and consumer prices that are sticky. In the long run commodity prices return to equilibrium, and consumer prices stickiness is over (Browne and Cronin, 2010). This theoretical approach is simple but it is quite relevant. The implications are that money is neutral in the long run, and that there exists an unstable relation between overshooting oil prices and money supply in the short run, while a stable long run relation, which is unit proportional, is revealed. On the sides, it is expected that the valuation effect is unit elastic also.

This is no place to reiterate the vast literature on money demand. The early research is well summarized in Mishkin (2016). A rather recent paper (Azar, 2014) rehearses some of the literature up to 2011. Most studies that will be cited thereafter contain a list of research on the topic that can be referred to. We shall dwell on the current trend on the subject. The current trend is not divorced totally from the distant trend. The issues at stake are surprisingly similar.

One, is money demand sensitive to interest rates? The following authors exclude an interest rate variable in their estimates of money demand: Browne and Cronin (2010); Azar (2012a, 2012b, 2012c). Authors who have found an interest effect are: Stock and Watson (1993) and Ball (2001). Choi and Jung (2009) include also the interest rate but they find that the money demand function is unstable for the whole period under study, but stable in two subsamples. Benati et al. (2017) carry out a test for an effect of interest rates on the velocity of circulation of money. They find evidence of a stable long run money demand function with international data.

Two, if the interest rate is a valid variable then does a liquidity trap exist? If the interest rate is taken as is there is indication of no trap, and there is "satiety." If the interest rate is taken in logs, there is evidence for a trap. The recent developments in financial markets showed that there is a zero-bound constraint on the interest rate in monetary policy, making money demand unusable as a policy instrument at low interest rates. See Azar (2014) for evidence on the preferred specification which supports a liquidity trap.

Three, is there a stable definition of money aggregates that incorporate all financial innovations? Some observers reckon that the money supply M1 must be revamped once again (Lucas and Nicolini 2015), after it suffered from what was dubbed the missing money phenomenon (Goldfeld et al., 1976). Narayan (2008) finds better stability with the usage of the M2 stock of money. However he finds also that the function breaks down during the last years of his sample, i.e., before 2014. Davis et al. (2013), using quarterly data find a break outside which the relation is unstable, and within which a stable relation exists. Foresti and Napolitano (2013) surmise that by including a wealth variable the money demand function becomes stable. In this regard a quote from Benati et al. (2017) is appropriate: "Yet, over recent decades many economists have come to the view that monetary aggregates convey no useful information and have turned to macroeconomic models in which measures of money do not appear at all. One driver of this change was the alleged instability of the relationships between these series."

Four, do coefficient constraints exist like a unitary and proportionate sensitivity of money to the scale variable and to the price level? Five, is there a non-linear effect in the demand function? Six, and finally, does estimating the demand function without any imposed constraints on the coefficients solve the problems of instability and non-linearity (Azar, 2014)?.

3. THE EMPIRICAL RESULTS

3.1. Source of Data

Three variables are considered: the dollar index, the money stock, and the spot crude oil price. All three series are retrieved from the web site of the Federal Reserve Bank of Saint Louis. The dollar index is the Trade Weighted US Dollar Index: Broad, goods, under reference TWEXBMTH. An increase in this index denotes an appreciation of the US dollar. The money stock is the MZM money stock under reference MZMSL. The crude oil price is the spot crude oil price of the WTI, under reference WTISPLC. The monthly data span the common sample of the variables, from January 1973 to October 2018, i.e., 551 observations.

3.2. Unit Root Tests

At first, unit root tests are carried out. Three procedures are selected: the Augmented Dickey-Fuller test, the KPSS test, and the Phillips-Perron test. The reader is reminded that the KPSS test has the null hypothesis of stationarity whereas the other two tests have the null hypothesis of non-stationarity. The three tests are in concordance with the same results: the three variables under scrutiny are non-stationary in log-levels, and stationary in the first difference of the logs. There is one exception: the log of the price of the WTI crude oil which rejects the null hypothesis of non-stationarity at the 5% marginal significance level. However, given the other two tests, it was decided to consider the log of the oil price as non-stationary. Details are included in Table 1.

Since it is agreed that all three variables are non-stationary in logs-levels, it makes little sense to provide for them descriptive statistics. Hence Table 2 computes descriptive statistics on the stationary variables, which are in the first difference of the logs.

Table 1: Unit root tests, with a constant but without a trend

Variable	ADF	KPSS	PP
LOG (OIL)	−2.893565 (1)*	1.986687 (0)**	−2.796351 (0)
LOG (MONEY)	−0.825442 (0)	2.984975 (0)**	−0.826442 (0)
LOG (DOLLAR)	−1.715458 (1)	2.575567 (0)**	−1.450284 (0)
ΔLOG (OIL)	−18.26967 (0)**	0.157823 (0)	−18.17656 (0)**
ΔLOG (MONEY)	−10.94090 (1)**	0.099364 (0)	−10.45732 (0)**
ΔLOG (DOLLAR)	−15.75879 (0)**	0.320834 (0)	−15.81029 (0)**

Lag length in parentheses (); ** 1% marginal significance level; * 5% marginal significance level; Sample size=550; Sample period 1973M01 till 2018M10. The lag length is selected by the Schwarz information criterion

A feature of these log returns is that they approximate percentage changes when they are multiplied by 100. Moreover these log returns are monthly estimates.

The mean, median, maximum, and minimum observations need to be multiplied by 1200 to get annual percentage changes. The standard deviations, which are in the same units as the above four statistics, need to be multiplied by $100\sqrt{12}$ to become annual percentage changes. All three variables fail to follow a normal distribution, as evidenced by the Jarque-Bera normality test, which is based on both the skewness and the kurtosis. All the three means and the three medians are positive, except the median of the log return of the oil price, which is zero. The maxima and the minima are astounding when converted to annual percentage changes. The highest standard deviation is for the price of oil, around 30% in annual terms, which is substantial given that a portfolio of common stocks has only a volatility of 20% (Brealey et al., 2017). This is remarkable because this lack of precision for the estimate of the mean of the log returns of this variable ends up in failing to reject the null hypothesis that the mean log return is statistically different from zero. This same hypothesis is rejected for the log returns of the money supply and that for the log returns of the dollar index, at very low marginal significance levels. Average growth of the money supply is 7.2% annually, and that for the dollar is 2.9%, while their annual standard deviations are 2.6% and 4.5%. It is also remarkable that the money stock has a higher growth rate but a lower standard deviation than the dollar index.

Table 2: Monthly descriptive statistics

Statistic	ΔLOG (OIL)	ΔLOG (Money)	ΔLOG (dollar)
Mean	0.005041	0.006008	0.002416
Median	0.000000	0.005239	0.002495
Maximum	0.852587	0.093596	0.064681
Minimum	−0.396009	−0.022470	−0.041750
Standard deviation	0.085660	0.007530	0.012927
Skewness	1.398846	3.754412	0.180786
Kurtosis	21.96099	41.31041	4.019287
Null hypothesis: Mean=0	0.1681	0.0000	0.0000
Jarque-Bera	8418.354	34926.60	26.80517
Probability of the Jarque-Bera test	0.000000	0.000000	0.000002
Observations	550	550	550

The actual P value of the null hypothesis of zero on the mean is provided

Table 3: Cointegration regression with the log of oil prices as a dependent variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG (Dollar)	−1.409824	0.608805	−2.315723	0.0209
LOG (MONEY)	0.977964	0.275804	3.545862	0.0004
Constant	1.776312	1.193005	1.488939	0.1371

3.3. ARDL Cointegration

The next step is to estimate the cointegration regression, and test statistically whether our three variables are cointegrated. The ARDL procedure is selected for that purpose. ARDL has two advantages: It allows for non-dynamic variables and does not constrain all lags to be of the same length. The first property is not crucial for this paper because all variables are dynamic. The second property is more relevant and saves degrees of freedom. Nonetheless, the ARDL procedure includes all interim lags for each specific dependent variable. Moreover, the vector error-correction model (VECM) does not adjust for conditional variance. It is known that oil prices possess high degrees of conditional heteroscedasticity. The ARCH (6) LM test for heteroscedasticity, applied on the first difference of the log of the oil price, produces an F-statistic of 28.25093, which has a p-value of 0.0000. But, the ARCH(3) LM test produces an F-value of 0.065954, that carries a p-value of 0.9779. The first test rejects homoscedasticity while the second test fails to reject homoscedasticity. This disparity in ARCH test results comes from the fact that the fifth lag in the ARCH(6) test is highly statistically significant. Since we are using monthly observations the ARCH(6) test may be more appropriate than the ARCH(3) test, because the former accounts for a bigger scope of seasonality. This issue is essential for a proper specification of the econometric model, which, if adopted, may render better statistical inferences when hypothesis tests are conducted. For all these reasons the functional form of the short run VECM is retrieved from the ARDL computer output, but is subjected to, and estimated with, the presence of a conditional variance equation. However, the cointegrating regressions have always the same functional form: the log of oil prices regressed on the log of the money stock and on the log of the US dollar index. The ARDL procedure gives the results in Table 3.

The two coefficients, besides the intercept, have the correct sign, the expected magnitudes, and the desired statistical significance. Since the variables are in logs, these coefficients are also elasticities. Oil prices move in the same direction, in tandem and proportionately, with the money supply. A one percent increase in the US money stock is transmitted to the oil market with a one percent increase in nominal oil prices. The oil moves in the opposite direction to the dollar index. A one percent increase in the dollar, or a one percent appreciation of the dollar, decreases by one percent nominal oil prices. This is as expected from a valuation effect. Details are in Tables 3 and 4. Finally, Table 5 reports the F-bounds test which determines whether there is cointegration or not. The value of the test statistic is 4.469416 and it lies between the 1% and 2.5% marginal significance levels. Hence we can quite easily reject the hypothesis of no levels relationship, i.e., reject the null of no-cointegration.

Table 3: ARDL cointegration equation. The dependent variable is the natural log of the spot price of the WTI crude oil. The number of monthly observations is 550. The sample spans the period from January 1973 till October 2018. The model selection method is by the Schwarz criterion. The number of models evaluated is 294. The source of the data is from the web site of the Federal Reserve Bank of Saint Louis. DOLLAR is the broad trade-weighted US dollar. MONEY is the US MZM money stock. LOG is the natural logarithm. The p-values are two-sided.

3.4. ARDL VECM

Having established cointegration between the log of the oil price and the logs of the money stock and of the dollar index, we can further the analysis by estimating the corresponding VECM. The ARDL procedure, which has the log return of the oil price as a dependent variable, specifies the VECM as being composed of one lag of the dependent variable along with the current log return of the dollar index. The third variable is the lagged cointegration residual. The latter is defined to consist of three variables: the first lag of the logged oil price, along with the first lags of the money stock and the dollar index. Although there is a loss of two degrees of freedom because the lagged cointegration residual is used by estimating freely the two cointegration regression coefficients in place of retrieving it from the cointegration regression as one variable, this specification provides enough additional information on the cointegration regression since the cointegration equation is estimated jointly with the VECM. And since the sample is relatively large, amounting to 550 observations, the loss of two degrees of freedom is well compensated by the additional information provided by an unconstrained cointegration residual. Having specified the VECM we are ready to append to it a conditional variance equation in order to account for the inherent conditional heteroscedasticity.

Table 6: The dependent variable is Δ(LOG(OIL)). Δstands for the first-difference operator. OIL is the spot price of the WTI crude oil. Convergence achieved after 36 iterations. The estimation method is ML ARCH - normal distribution (BFGS/Marquardt steps). The Q-statistic is the Ljung-Box portmanteau test on the standardized residuals. The Q^2-statistic is the Ljung-box portmanteau test on the standardized residuals. The actual P-values of these portmanteaux are reported. The standardized residuals are the regression residuals divided by the conditional standard deviations obtained from the variance equation.

$$\Delta LOG(OIL)=\alpha_0+\alpha_1\ \Delta LOG(OIL[-1])+\alpha_2\ \Delta LOG(DOLLAR)+\alpha_3\ LOG(OIL[-1])+\alpha_4 LOG(MONEY[-1])+\alpha_5 LOG(DOLLAR[-1])+\in\ \sigma^2=\beta_0+\beta_1\ (\in[-1])^2$$

The resulting model is reported in Table 6. This model comprises three parts: the short run part, the long run part and the variance part. What is remarkable in the first short run part is that it does not include any variable related to the money stock. Hence the

Table 4: Hypothesis testing on the results of Table 1

Hypothesis	Coefficient	Std. Error	t-Statistic	Prob.
Slope on LOG (MONEY) is+1	−0.02204	0.275804	−0.079897	0.8564
Slope on LOG (DOLLAR) is-1	−0.40982	0.608805	−0.673161	0.5012

Table 5: F-bounds test on the regression in Table 1

F-bounds test		Null hypothesis: No levels relationship		
Test statistic	**Value**	**Significance %**	**I (0)**	**I (1)**
			Asymptotic: n=1000	
F-statistic	4.469416	10	2.63	3.35
k	2	5	3.1	3.87
		2.5	3.55	4.38
		1	4.13	5
Actual sample size	550		Finite sample: n=80	
		10	2.713	3.453
		5	3.235	4.053
		1	4.358	5.393

US money supply is not associated with the price of oil in the short run, probably because the relation is volatile and unstable. Another remarkable feature is that oil prices are sticky, granted that the regression includes the first lag of the dependent variable. The half-life of mean reversion is fast and short at a 0.3839 fraction of a year, or about 4.61 months. A third remarkable feature is that the short run impact of the valuation effect is statistically no different from -1, making the relation proportional. The p-value for the null hypothesis that the coefficient is no different from -1 is a mere 0.1920 (Table 7). If one takes into consideration the stickiness of the price of oil, by dividing the impact coefficient by one minus the coefficient on the lagged dependent variable, $(\alpha_2/(1-\alpha_1)$, the P-value for the same null hypothesis is higher at 0.5602 (Table 7), giving a high likelihood that this null is not going to be rejected.

The long run part is the estimate of the cointegration vector. The long run coefficients are computed by dividing the coefficient on the lagged variable over the coefficient on the lag of the dependent variable. This long run coefficient $(-\alpha_4/\alpha_3)$ on the money stock variable is statistically significantly different from zero (P-value=0.0000). However, it is statistically no different from +1 (P-value=0.1602). The long run coefficient on the dollar index variable $(-\alpha_5/\alpha_3)$ is statistically significantly different from zero (P-value=0.0000). Also, it is statistically significantly different from −1 (P-value=0.0030). The speed of adjustment to the long run $(-1/\alpha_3)$ takes 17.89 months, or around 1 year and a half which, besides being statistically significantly different from zero (P-value=0.0000), is a relatively very fast adjustment. All these tests on the long run part are posted in Table 7.

The last part is the conditional variance equation which is specified as an ARCH(1) model without the inclusion of a GARCH variable. This ARCH component produces a coefficient which is statistically highly significant (P-value=0.0000).

Table 6: Error-correction regression with the log relative of oil prices as a dependent variable

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CONSTANT α_0	0.123687	0.026285	4.705609	0.0000
Δ(LOG (OIL[−1]) α_1	0.164352	0.044973	3.654430	0.0003
Δ(LOG[DOLLAR]) α_2	−0.702579	0.227689	−3.085690	0.0020
LOG (OIL[−1]) α_3	−0.055896	0.004998	−11.18356	0.0000
LOG (MONEY[−1]) α_4	0.066034	0.009008	7.331033	0.0000
LOG (DOLLAR[−1]) α_5	−0.104549	0.015540	−6.727734	0.0000
Variance equation				
CONSTANT β_0	0.003328	0.000305	10.92658	0.0000
RESID(−1)^2 β_1	0.687688	0.105434	6.522453	0.0000
R-squared	0.065541	Mean dependent variable		0.005041
Adjusted R-squared	0.056953	Standard deviation dependent variable		0.085660
S.E. of regression	0.083185	Akaike criterion		−2.279839
Sum squared resid	3.764326	Schwarz criterion		−2.217149
Log likelihood	634.9557	Hannan-Quinn criterion		−2.255341
Durbin-Watson stat.	1.764621			
Q-statistic for lag k:		Q^2-statistic for lag k:		
K=3	0.058	K=3		0.934
K=6	0.204	K=6		0.995
K=12	0.069	K=12		1.000

Table 7: Hypothesis testing on the results of Table 6

Hypothesis	Coefficient	Std. Error	t-Statistic	Prob.
Slope on ΔLOG (DOLLAR) is−1 α_2=−1	0.297421	0.227689	1.306258	0.1920
Slope on ΔLOG (DOLLAR) over (1–ΔLOG[OIL(–1)]) is−1 ($\alpha_2/(1-\alpha_1)$=−1	0.159241	0.273138	0.583005	0.5602
Long run slope on LOG (MONEY[–1]) is 0–α_4/α_3=0	1.181387	0.128993	9.158549	0.0000
Long run slope on LOG (MONEY[–1]) is+1–α_4/α_3=1	0.181387	0.128993	1.406179	0.1602
Lon run slope on LOG (DOLLAR [–1]) is 0–α_5/α_3=–0	–1.870427	0.292204	–6.401105	0.0000
Long run slope on LOG (DOLLAR [–1]) is –1–α_5/α_3=–1	–0.870427	0.292204	–2.978836	0.0030
Speed of adjustment to the long run in months –1/α_3=0	17.89047	1.599712	11.18356	0.0000

The R-square for the whole model is not great at 0.065541. The Durbin-Watson statistic is adequate and fails to reject no serial correlation in the non-standardized residuals. In what concerns the standardized residuals and the standardized squared residuals, and using the Ljung-Box Q-statistics, they both refrain from rejecting remaining serial correlation and remaining conditional heteroscedasticity respectively. The standardized residual is equal to the regression residual divided by the square root of the corresponding conditional variance.

4. ROBUSTNESS TESTS

Three robustness tests will be carried out in order to ascertain that the results are consistent across econometric procedures. The first test is to subject the data to a Johansen econometric procedure (Johansen, 1991, 1995; and Johansen and Juselius, 1990). The purpose is to check for cointegration and carry out hypothesis testing on the cointegration coefficients. The second test is to change the conditional variance specification, and check whether there are any substantial changes to be reported. The third is to estimate the cointegration regression with alternative econometric procedures, like the fully modified least squares (FMOLS), the dynamic least squares (DOLS), and the canonical cointegrating regression (CCR), and carry out hypothesis testing similar to the above.

4.1. Johansen Procedure

Tables 8-10 pertain to this procedure. In Table 8 two test statistics are computed: The trace test, and the maximum eigenvalue test. The null hypothesis of the existence of no single cointegration at all is rejected with the Trace test at a P=0.0169, while the maximum eigenvalue test rejects the same hypothesis has a P=0.0244.

Table 9 presents the estimates of the two cointegration coefficients. In the long run the log of the dollar index has an elasticity of −1.840925 with respect to the log of the oil price. This coefficient is highly significant statistically with a P=0.0000 (Table 9). However, this same coefficient is statistically no different from −1 with a P=0.162515, evidenced by subjecting the regression to a restriction and calculating the Chi-square statistic for that restriction (Table 10). In the long run the log of the money stock has an elasticity of 1.328251 with respect to the log of the oil price. This coefficient is highly significant statistically with a P=0.0000 (Table 9). However, this same coefficient is statistically no different from +1 with a P=0.093646, evidenced by subjecting the regression to a restriction and calculating the Chi-square statistic for that restriction (Table 10). Finally, the joint hypothesis that both constraints are validated by the data, fails to be rejected with a P=0.238127 (Table 10). The conclusion is strong that the money stock is neutral in the long run and that the valuation effect has, as expected, a negative unitary impact also in the long run.

4.2. An IGARCH Functional form of the Conditional Variance

The second robustness test is by changing the conditional variance from an ARCH(1) specification to an IGARCH specification. The results are shown in Table 11.

In Table 12 hypothesis testing is conducted similar to the testing in Table 7. All coefficients are found to be statistically significantly different from zero. Moreover all coefficients have the expected correct signs. However the short run, the intermediate run, and the long run coefficients on the dollar index variable are statistically significantly different from -1. To be exact, these coefficients are higher than −1. The fact that the valuation effect of the dollar index is so low (in negative terms) is still disturbing. This finding may denote overshooting in both the short and the long runs, or a spurious relation that depends on the chosen functional form. The long run impact of the money stock, which is the crucial effect, is higher than +1. However, the null hypothesis of a slope of +1 on this variable is rejected at a marginal significance level of only 0.0385. This means that, with a low Type I error assumed, this null hypothesis is not rejected. Hence, in this case, money can still be considered as neutral, and the neutrality hypothesis is salvaged. There is evidence that this IGARCH formulation is supplanted by the ARCH(1) formulation above. If one compares the three information criteria, Akaike, Schwarz, and Hannan-Quinn, between Tables 6 and 11, all three are lower for the ARCH(1) formulation and, so, the econometric diagnostics favor this last ARCH(1) specification.

Table 8: Johansen unrestricted cointegration rank tests for Table 8

Hypothesized number of cointegration equations	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.
None	0.041544	33.70316	29.79707	0.0169
At most 1	0.012832	10.40801	15.49471	0.2507
At most 2	0.006024	3.317409	3.841466	0.0685
Hypothesized number of cointegration equations	**Eigenvalue**	**Maximum eigenvalue Statistic**	**0.05 Critical value**	**Prob.**
None	0.041544	23.29514	21.13162	0.0244
At most 1	0.012832	7.090605	14.26460	0.4785
At most 2	0.006024	3.317409	3.841466	0.0685

Table 9: Johansen cointegration regression. The dependent variable is the log of the price of crude oil. The constant is 0.631514

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG (DOLLAR)	−1.840925	0.46081	−3.99494	0.0000
LOG (MONEY)	1.328251	0.20971	6.33383	0.0000

Table 10: Hypothesis testing on the Johansen cointegration regression in Table 8

Hypothesis	Chi-square	Degrees of freedom	Prob.
Slope on LOG (MONEY) is+1	1.950668	1	0.162515
Slope on LOG (DOLLAR) is−1	2.810547	1	0.093646
Both the above Two hypotheses	2.869898	2	0.238127

4.3. Alternative Cointegration Regressions

In this section three alternative cointegration regressions are run: FMOLS, DOLS, and CCR. Econometric specifics for these three approaches are available from the authors. One assumption is pervasive: The Schwarz method is used to select the length of the lags. The results on these alternative cointegration regressions are tabulated in Table 13, and hypothesis testing results are shown in Table 14. The estimates of the long run coefficients are correct as expected, they have the same purported signs, and they are all statistically significantly different from zero (Table 13). The long run coefficients on the money stock variable are all three insignificantly different from +1, supporting strongly money neutrality (Table 14). The long run dollar valuation effects are all three statistically insignificantly different from −1, supporting full indexation of the price of oil with respect to the dollar exchange rate (Table 14). Finally the joint null hypothesis that all coefficients are unitary in absolute values fails to be rejected. The evidence from these three cointegration alternatives is very strong, and fails to reject money neutrality and full indexation.

Three different robustness tests produce consistent and strong results. The hypothesis of no-cointegration is strongly rejected between the money stock, the dollar index, and the price of the WTI crude oil. Long run money neutrality is a common and strong conclusion from the tests. Long run and short run valuation effects are also strongly endorsed by the data. One finding deserves attention: the money stock has no impact on oil prices in the short run in the two VECM models. Oil prices may be too volatile in the short run to warrant a stable relation.

5. WHAT ARE THE POLICY IMPLICATIONS?

We have found a stable long run relation between the US money stock and oil prices, after allowance is made for valuation effects, i.e., after controlling for the evident correlation of oil prices with the US dollar. It would be preposterous to conclude any causality pattern between oil prices and money. The only conclusion from

Table 11: Error-correction model of the short run cointegration regression, which includes a conditional variance equation. The dependent variable is ΔLOG (OIL). Convergence achieved after 47 iterations. The functional form is the same as in Table 6. However, the conditional variance equation is different. This equation is integrated-GARCH

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CONSTANT α_0	0.166505	0.013927	11.95592	0.0000
ΔLOG (OIL[−1]) α_1	0.246906	0.030826	8.009612	0.0000
ΔLOG (DOLLAR) α_2	−0.340230	0.130732	−2.602501	0.0093
LOG (OIL[−1]) α_3	−0.049302	0.002169	−22.72911	0.0000
LOG (MONEY[−1]) α_4	0.058122	0.003572	16.26961	0.0000
LOG (DOLLAR[−1]) α_5	−0.106340	0.007675	−13.85455	0.0000
		Variance equation		
RESID(−1)^2	0.208206	0.016475	12.63794	0.0000
GARCH(−1)	0.791794	0.016475	48.06118	0.0000
R-squared	0.067984	Mean dependent var		0.005041
Adjusted R-squared	0.059418	S.D. dependent var		0.085660
S.E. of regression	0.083076	Akaike info. criterion		−2.246290
Sum squared resid	3.754486	Schwarz criterion		−2.191437
Log likelihood	624.7298	Hannan-Quinn criter		−2.224854
Durbin-Watson stat.	1.930830			

Table 12: Hypothesis testing on the results of Table 11

Hypothesis	Coefficient	Std. Error	t-Statistic	Prob.
Slope on ΔLOG (DOLLAR) is−1 α_2=−1	0.65977	0.130732	5.04674	0.000
Slope on ΔLOG (DOLLAR) over (1−ΔLOG[OIL(−1)]) is−1 (α_2/(1−α_1)=−1	0.45178	0.16800	3.2632	0.0012
Long run slope on LOG (MONEY[−1]) is 0–α_4/α_3=0	1.17890	0.08622	19.6730	0.0000
Long run slope on LOG (MONEY[−1]) is+1–α_4/α_3=1	0.17890	0.08622	2.0749	0.0385
Lon run slope on LOG (DOLLAR [−1]) is 0–α_5/α_3=–0	–2.15692	0.21057	–10.2432	0.0000
Long run slope on LOG (DOLLAR [−1]) is –1–α_5/α_3= –1	–1.15692	0.21057	–5.49423	0.0000
Speed of adjustment to the long run in months –1/α_5=0	9.4038	0.67875	13.8546	0.0000

the research here is that the US money stock and the price of oil move together. If oil prices are representative of commodity prices in general then the short run overshooting of the oil prices dissipates in the long run. Because of this overshooting no stable relation was dispelled between oil prices and the US money stock in the short run. In the long run commodity prices, including oil prices, act as an indicator of long run inflation. The fact that US money has a unit proportionate impact on oil prices is further evidence of a long run unitary link, or of money neutrality. A quite surprising finding is that adjustment to the long run takes only around 18 months (Table 7). This contrasts with the adjustment to the long run of consumer price inflation upon oil prices which takes between 10 and 14 years (Browne and Cronin, 2010; Azar, 2013). It is difficult to state any policy implications. Since the sample includes disparate US monetary regimes, and many international economic occurrences and crises, the natural conclusion is that whatever the monetary policy adopted, whatever the incumbent administration of the government and whatever the varied and different constituency of the board of the federal reserve, money neutrality in the long run holds quite well, despite more than 45 years of time stance and turmoil. Furthermore, long run evolutions of oil prices can only be interpreted to be as a sign of long run inflation, otherwise the relation has no sense. Hence, no one, whatever her position and inclination, is able to untie the anchor that exists between oil prices and the US money stock. With another perspective, long run money neutrality gives a sign of relief to economists who believe in the efficiency of the price mechanism, in the absence of money illusion, and in supporting the rational and intuitive contention, which has the status of a famous dictum, that "inflation is always and everywhere a monetary phenomenon."

6. CONCLUSION

Based on a simple and parsimonious equation for money demand that is derived from the quantity theory of money, the paper has unveiled a stable long run relation between oil prices and the US money stock. The elasticity is unitary: A 1% increase in US money is associated with a 1% increase in oil prices. Although the sample mixes together periods of severe fluctuations and periods of exuberance, although political and economic developments were diverse, the model remains robust.

It is surprising that the relation has not been discovered earlier. It is found that he monetary authorities cannot manipulate real

Table 13: Cointegration regressions

Dependent Variable: LOG (OIL)				
Sample (adjusted): 1973M01 2018M10				
Included observations: 550 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Method: Fully modified least squares				
LOG (MONEY)	1.142055	0.220860	5.170953	0.0000
LOG (DOLLAR)	−1.356317	0.487648	−2.781345	0.0056
C	−0.144200	0.883492	−0.163216	0.8704
R-squared	0.609998	Mean dependent var		3.381374
Adjusted R-squared	0.608572	S.D. dependent var		0.711830
S.E. of regression	0.445351	Sum squared resid		108.4905
Long-run variance	4.523114			
Method: Dynamic least squares				
LOG (MONEY)	1.063750	0.098263	10.82553	0.0000
LOG (DOLLAR)	−1.254324	0.216174	−5.802380	0.0000
C	0.181793	0.389432	0.466817	0.6408
R-squared	0.685053	Mean dependent var	3.381374	
Adjusted R-squared	0.682741	S.D. dependent var	0.711830	
S.E. of regression	0.400944	Sum squared resid	87.61194	
Long-run variance	0.873060			
Method: Canonical cointegrating regression				
LOG (MONEY)	1.135037	0.220440	5.148960	0.0000
LOG (DOLLAR)	−1.350456	0.486274	−2.777152	0.0057
C	−0.111911	0.878575	−0.127377	0.8987
R-squared	0.611539	Mean dependent var	3.381374	
Adjusted R-squared	0.610119	S.D. dependent var	0.711830	
S.E. of regression	0.444470	Sum squared resid	108.0618	
Long-run variance	4.523114			

Table 14: Hypothesis testing on the results in Table 13. The dependent variable is LOG (OIL). The first test is on whether the slope on LOG (DOLLAR) equals−1; the second hypothesis is on whether the slope on LOG (MONEY) is+1; the third hypothesis is whether the above two hypotheses hold jointly

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Method: Fully modified least squares				
LOG (DOLLAR)	−0.356317	0.487648	−0.730685	0.4652
LOG (MONEY)	0.142055	0.220860	0.643190	0.5204
Both absolute slopes=1	−0.356317	0.487648	P-value of F (2,547)=0.7646	
	0.142055	0.220860		
Method: Dynamic least squares				
LOG (DOLLAR)	−0.254324	0.216174	−1.176478	0.2400
LOG (MONEY)	0.063750	0.098263	0.648769	0.5168
Both absolute slopes=1	−0.254324	0.216174	P-value of F (2,545)=0.2903	
	0.063750	0.098263		
Method: Canonical cointegrating regression				
LOG (DOLLAR)	−0.350456	0.486274	−0.720697	0.4714
LOG (MONEY)	0.135037	0.220440	0.612579	0.5404
Both absolute slopes=1	−0.350456	0.486274	P-value of F (2,547)=0.7668	
	0.135037	0.220440		

oil prices because an increase in money supply is associated with an increase in nominal oil prices. If money is increased the result is higher oil prices, keeping real prices steady. However, no short run impact was discerned, leading us to conclude that the overshooting hypothesis of oil prices is well supported. If the relational elasticity is unitary then one might conclude that oil prices are perfect hedges against inflation or money supply changes for the long run.

REFERENCES

Azar, S.A. (2012a), Commodity prices and the US money supply in the long run. International Journal of Trade and Global Markets, 5(3-4), 316-335.

Azar, S.A. (2012b), Commodity price indexes and the US money supply in the long run: Further tests. Journal of Financial Markets Research, 4, 35-43.

Azar, S.A. (2012c), Commodity futures and the US money supply. The Empirical Economics Letters, 11(10), 1039-1046.

Azar, S.A. (2013), Oil prices, US inflation, US money supply and the US dollar. OPEC Energy Review, 37(4), 387-415.

Azar, S.A. (2014), The demand for money in the United States, 1959.1-2013.11. International Journal of Finance and Accounting Studies, 2(1), 21-28.

Azar, S.A. (2019), The standalone and the portfolio risk of the Rogers energy commodity index. Theoretical Economics Letters, 9, 675-690.

Ball, L. (2001), Another look at long-run money demand. Journal of Monetary Economics, 47(1), 31-44.

Benati, L., Lucas, R.E. Jr., Nicolini, J.P., Weber, W. (2017), International Evidence on Long-Run Money Demand. Minneapolis Fed Research, Working Paper, No. 737.

Brealey, R., Myers, S., Allen, F. (2017), Principles of Corporate Finance. 12th ed. New York: McGraw-Hill.

Browne, F., Cronin, D. (2010), Commodity prices, money and inflation. Journal of Economics and Business, 62(4), 331-345.

Choi, K., Jung, C. (2009), Structural changes and the US money demand function. Applied Economics, 41(10), 1251-1257.

Davis, B., Karemera, D., Whitesides, L. (2013), The intertemporal stability of the US money demand function: New evidence from switching regressions. Applied Economics Letters, 20(6), 581-586.

Dornbusch, R. (1976), Expectations and exchange rate dynamics. Journal of Political Economy, 84(6), 1161-1176.

Foresti, P., Napolitano, O. (2013), Modelling long-run money demand: A panel data analysis on nine developed economies. Applied Financial Economics, 23(22), 1707-1719.

Frankel, J.A. (1986), Expectations and commodity price dynamics: The overshooting model. American Journal of Agricultural Economics, 68(2), 344-348.

Goldfeld, S.M., Fand, D.I., Brainard, W.C. (1976), The case of the missing money. Brookings Papers on Economic Activity, 3, 683-739.

Johansen, S. (1991), Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica, 1991, 1551-1580.

Johansen, S. (1995), Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford: Oxford University Press.

Johansen, S., Juselius, K. (1990), Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bulletin of Economics and Statistics, 52(2), 169-210.

Lucas, R.E. Jr., Nicolini, J.P. (2015), On the stability of money demand. Journal of Monetary Economics, 73, 48-65.

Mishkin, F. (2016), The Economics of Money, Banking, and Financial Markets. 11th ed. United Kingdom: Pearson.

Narayan, P.K. (2008), Revisiting the US money demand function: An application of the Lagrange multiplier structural break unit root test and the bounds test for a long-run relationship. Applied Economics, 40(7), 897-904.

Stock, J.H., Watson, M.W. (1993), A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica, 1993, 783-820.