

The Fed's Exit Strategy – The Effect of Asset Selloffs on Overnight Interest Rates

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1. The Problem

The 2008 financial crisis and its aftermath have proven to be a great challenge for the Federal Reserve. Typically, the FOMC changes the federal funds rate target to achieve its dual mandate of maximum sustainable economic growth and price stability. From September 2007 to December 2008, the FOMC incrementally lowered the federal funds rate target from 5.25 percent to 0.25 percent where it has remained as turmoil engulfed credit markets.

Nominal interest rates cannot go below zero and the Fed needed to continue to support a weakened economy. As conditions worsened, the Fed turned to nontraditional/unconventional policies to bolster financial market conditions. Such policies include large-scale asset purchases of, for example, mortgage-backed securities and Treasury securities. This action is commonly called “quantitative easing” (QE).

QE affects the economy through changes in interest rates on long-term Treasury securities and other financial instruments (e.g., corporate bonds). To have an appreciable impact on interest rates, QE requires large-scale asset purchases. When the Fed makes such purchases of, for example, Treasury securities, “the result is an increased demand for those securities, which in turn raises their prices. Treasury prices and yields (interest rates) are inversely related: As prices increase, interest rates fall,” (Ricketts, 2011). As interest rates fall, the cost to businesses for financing capital investments, such as new equipment, decreases. Over time, new business investments should stimulate economic activity, create new jobs, and reduce the unemployment rate.

The policies were enacted on the largest scale ever to be seen in the Fed's history. The Fed began buying up enormous amounts of illiquid assets, adding 1.5 times

to its balance sheets. The growth rate of reserves grew to highs of above 1000% and M2 growth rates peaked at around 20% annual rates, (Meltzer 2009). Today the Fed is buying \$60 billion worth of bonds and mortgage backed securities a month. It pays for all of these asset purchases by issuing reserves to banks and printing money.

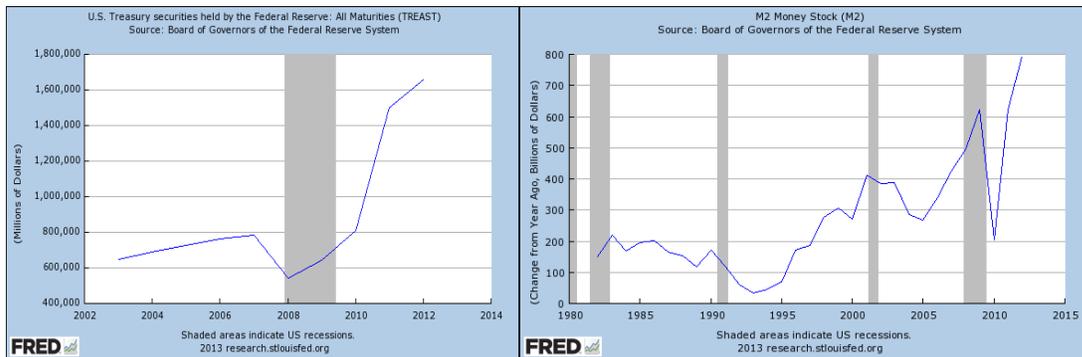


Figure 1: US Treasury Securities held by Fed

Figure 2: M2 Money Stock

Figure 1 shows the historically high, annual amount of treasury securities held by the Fed in millions of dollars. Figure 2 shows the annual change in the M2 money stock from one year ago in billions of dollars. You will see the post-recession monetary policy has drastically increased the money supply through the use of open market purchases.

In this scenario, it would be normal to predict inflation. Standard economic theory teaches that an increase in money supply devalues the net worth of each dollar and causes inflation. So why in the graph below of CPI Index (standard measure of inflation) do we not see such a case? The graph shows the change in CPI, the latest trend being a downward dip in inflation, instead of the expected rise in trend.

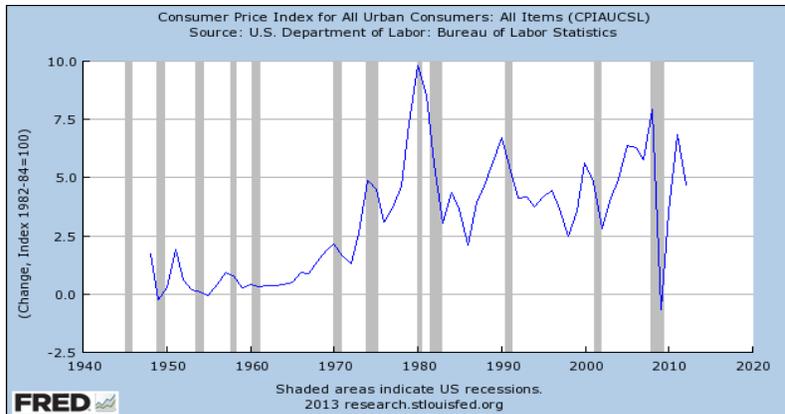


Figure 3: Consumer Price Index

What exactly is happening with all these reserves the Fed have issued them? Where is the inflation?

The simple answer is – nothing. Instead of lending them out, banks are holding large amounts of excess reserves due to the amount of fear and uncertainty that exists in regard to the Fed’s future policy actions. Banks have failed to pass the monetary stimulus to customers, both corporate and individual users. They have instead built up excess cash reserves in order to limit vulnerability to any future potential shocks should the economy worsen. With this transition broken, the follow through into increased inflation expectations has failed to materialize. However the day will come where confidence is restored and banks will then lend out and consumers will spend. This scenario will put huge pressure on the Fed to mop up the large reserve balances in an effort to curb inflation. The big question is whether the Fed will actually be able to do so. The Fed will need to reduce the volume of money supply in the economy. This could be done by either increasing the rate of interest paid on Bank reserves at the Fed or by looking to reduce the volume of excess reserves in circulation by selling off some of the assets on the Fed’s balance sheet.

2. The Debate:

In an effort to control the risk of rising inflation the Fed is in the process of taking steps to begin the process of normalizing its monetary policies – “restoring interest rates to more normal levels and the Fed’s balance sheet to its pre-crisis size and composition,” (FOMC 2011). In his June 19, 2013, press conference, Federal Reserve Chairman Ben Bernanke discussed the process of “normalizing policy for the long run,” (Bernanke, 2013). This process was initially outlined in a set of principles published in the June 2011 FOMC minutes.

There is a lot of controversy surrounding the Fed’s ability to normalize their monetary stance without denting the current recovery effort and sending the economy back into recession. One of the main reasons behind the debate is the uncertainty caused by the fact that the Fed has never before implemented a policy on such a large magnitude. They therefore face a number of challenges when aiming to unwind the policies they have put in place.

Firstly, according to the 2011 FOMC minutes during its normalizing policy the Fed will limit the scope of asset sales and look to hold on to mortgage related assets until they mature organically. Doing so limits the risk exposure to volatile housing markets however it also lengthens the time it will take them to normalize their balance sheet.

Secondly, the process of interest rate normalization – “that is, returning the intended federal funds rate to target to its long run level” – may occur much sooner if the economy proceeds as the FOMC expects, (FOMC, 2011). When this happens all of the excess reserves the banks are currently holding on to will be loaned out as confidence returns to the economy. The Fed will need to keep those reserves locked up so to speak

and stop banks' lending them out. The main tool that is being used to do this currently is paying interest on reserves held at the Fed. The issue is that this rate paid on reserves must be higher than the market rate in order to stop banks' lending them out and causing higher expected inflation.

Finally, the Fed may unintentionally create some uncertainty in the market if it does not signal its intentions clearly. Since small changes in bank reserves can potentially generate much larger changes in money growth, the Fed may find it necessary to adjust the interest rate on reserves frequently in response to evolving economic conditions.

3. My Model vs. What's been done before:

The purpose of my paper is to model the interplay between the Federal Reserves balance sheet as they sell off assets and overnight interest rates, while allowing for interdependencies among these rates at the same time. By using the model created by Marquez et al. (2013) as a framework I can assess the removal of the monetary policy accommodation currently in place based on the exit principles specified in the June 2011 minutes of the Federal Reserve Open Market Committee. I am going to introduce two dummy variables to the model. The first variable, "M" is used to control for the introduction of interest on excess reserves being used as a policy tool and the second "FF" is used to account for the fluctuation we saw in the data in the time period from late 2007 to beginning 2009 during the recent financial crisis. In order to assess the removal of policy I am going to extend the time period used in the study to the beginning of 2014 in order to give me a more current look at the effect of reducing the Fed's balance sheet and therefore excess reserves, in current markets.

There has been a lot of previous work done on the “liquidity trap” – the response of short term interest rates to a change in the amount of reserve balances – as studied by Hamilton (1996), Hamilton (1997), Carpenter and Demiralp (2006), Carpenter and Demiralp (2008), Judson and Klee (2010), Bech and Klee (2012), and Kopchak (2011).

In all of the work except Bech and Klee (2012) the effect of monetary policy changes is quantified without allowing for interdependencies among short-term interest rates. The model created by Marquez et al. (2013) however, allows linkages among banks various short-term funding channels with associated implications for overnight rates. In this framework it shows the “simultaneous effect of a change in the federal funds rate on the repo rate and Eurodollar rate and how it then feeds back into the federal funds rate” (Marquez et al. 2013).

The model used in Marquez’s study uses the “maximum likelihood method for parameter estimation in order to account for the simultaneous determination of reserves and the federal funds rate” (Marquez et al. 2013). Previous work uses limited information estimation to avoid simultaneity biases. This is not suited to my approach because it treats reserves as endogenous for parameter estimation but exogenous for policy analysis. In my study I am going to use three-stage least squares regression in order to estimate the parameters in the system of simultaneous equations. This model also treats interest rate paid on reserves as an endogenous variable in predicting the effect of Fed asset sell offs. No previous literature or modeling efforts have this, mainly due to the fact that paying interest on reserves is a policy tool that has never been used by the Fed until now.

Finally, all prior literature is mostly concerned with interest rate responses to changes in reserve balances. Instead, this framework allows me to examine the relation

between the levels of overnight interest rates and reserve balances, which in turn allows an estimation of the amount of reserve balances consistent with a certain level for the federal funds rate.

4. Challenges with the Model/Data:

An empirical assessment of the FOMC's exit principles is particularly challenging because they provide no information on the associated magnitudes or implementation dates of policy actions. It is also challenging because in order to effectively estimate the parameters you have to avoid certain sampling problems. Using a sample from the pre-crisis period is problematic because this data will not reflect the role of the interest rate paid on excess reserves. This is a problem because this variable is treated as endogenous in the model and the exit principles rely on this policy tool. Alternatively one could use a sample from the post-crisis period, however the variability in interest rates is virtually absent and so the rates will not be statistically reliable for assessing the exit principles. Another alternative is to estimate two sets of parameters, one pre-crisis and one post-crisis. This approach assumes that, at some point, the economy switches automatically from one set of values to the other. The pre-crisis estimates are done without the introduction of interest payments on excess reserves and so are not applicable to the exit period. The study done in Marquez et al. (2013) used data from January 9, 2003 and March 30, 2012 whereas my study is going to extend this data from January 2001 to January 2014. One potential hurdle is that I cannot get access to the daily data because it is not released to the public. I can only access the monthly observations of the overnight interest rates from the St Louis Fed, FRED data website. Including the more current data enables me to observe the results that include the beginnings of the Fed's exit strategy to

assess whether it has had any effect or not and predict what kind of effects we can expect to see. More recent data will also help to eliminate any possible distortions caused by the “lag factor” in policy implementation.

5. **Model Framework:**

A. Supply of reserves balances

Prior to the financial crisis, temporary open market operations in the form of repurchase agreements (RP) were the main tool used in order to manipulate reserve balances and attain federal funds rate targets. At this time reserve balances constituted only a tiny fraction of a depository institutions balance sheet, shown in the data for required and excess reserves published by the Federal Reserve in their statistical release, H.3.

As the financial crisis hit, credit markets began to dry up deeming it necessary for the Fed to intervene by implementing various liquidity facilities to support the functioning of funding markets. In terms of assets these repurchase agreements (RP) were replaced with outright acquisitions of substantial amounts of US treasury securities, Agency debt securities and Agency mortgage-backed securities (MBS). These purchases increased deposits of DI's (depository institutions), which became the largest liability with most of these deposits making up excess reserves. By the end of April 2012, the net change in the size of the balance sheet was \$2,013 billion as it increased from \$877 billion to \$2,900 billion.

The model aims to estimate the effect of the selloff of these securities and so for modeling purposes it treats all outright securities as a single asset. Therefore in the model, US treasury securities, Agency debt securities and Agency mortgage-backed

securities can be seen as perfect substitutes that combine together into a single aggregate, S.

- S:** - Securities on the Fed's balance sheet.
- RP:** - Repurchase Agreements
- OA:** - All other assets such as foreign exchange swaps, loans extended through the discount window or other liquidity facilities.
- R^e:** - Excess Reserves held at DI's
- R^r:** - Required Reserves
- C:** - Currency in Circulation
- OL:** - Other Liabilities

For liabilities reservable deposits are split in both excess reserves R^e and R^r . We use C to represent the currency in circulation and OL to represent all other liabilities such as reverse repurchase agreements and term deposits. Following Marquez et al. (2013), the simplified balance sheet identity is:

$$1) \quad S + RP + OA = (R^e + R^r) + C + OL$$

I assume that S and OA are determined by monetary policy and are therefore, exogenous. However repurchase agreements are treated as an endogenous variable because the Fed accommodates any changes in the required reserves. Similarly C and OL are exogenous variables whereas R^e and R^r endogenized in the model.

R^r is modeled as a fraction of reservable deposits D held at DI's.

$$2) \quad R^r = \lambda \times D, \quad \lambda > 0,$$

Where λ is the average required reserve ratio that I acquired from the Federal Reserve's webpage.

$$3) \quad D = f^D(i^{\text{fed}}, Y),$$

Where i^{fed} is the federal funds rate and Y is personal income acquired from the bureau of economic analysis. Theory suggests that an “increase in i^{fed} raise short-term interest rates faster than interest rates on checkable deposits. This means that the opportunity cost of holding reservable deposits increases, and D decreases,” (Marquez et al. 2013).

As I mentioned, I assume that the Fed accommodates changes in required reserves such that a change in required reserves is matched with a one for one change in repurchase agreements.

$$4) \quad RP = R^r + AF,$$

Where AF stands for autonomous factors (e.g., the US Treasury’s General Account) that, in addition to changes in R^r , determine the size of the temporary open market operations (RP) by the Fed.

Using the above equations and substituting, the supply of reserves can be expressed, as in Marquez et al. (2013), with the following equation:

$$5) \quad “R^e = S + RP + OA - (C+OL) - (\lambda \times f^D(i^{\text{fed}}, Y)).$$

B. Demand for reserve balances

Following Marquez et al. (2013), the inverse demand curve for excess reserve balances can be expressed as:

$$6) \quad i^{\text{fed}} = f^{\text{fed}}(i^{\text{repo}}, i^{\text{eurdol}}, R^e, i^{\text{disc}}, i^{\text{er}}),$$

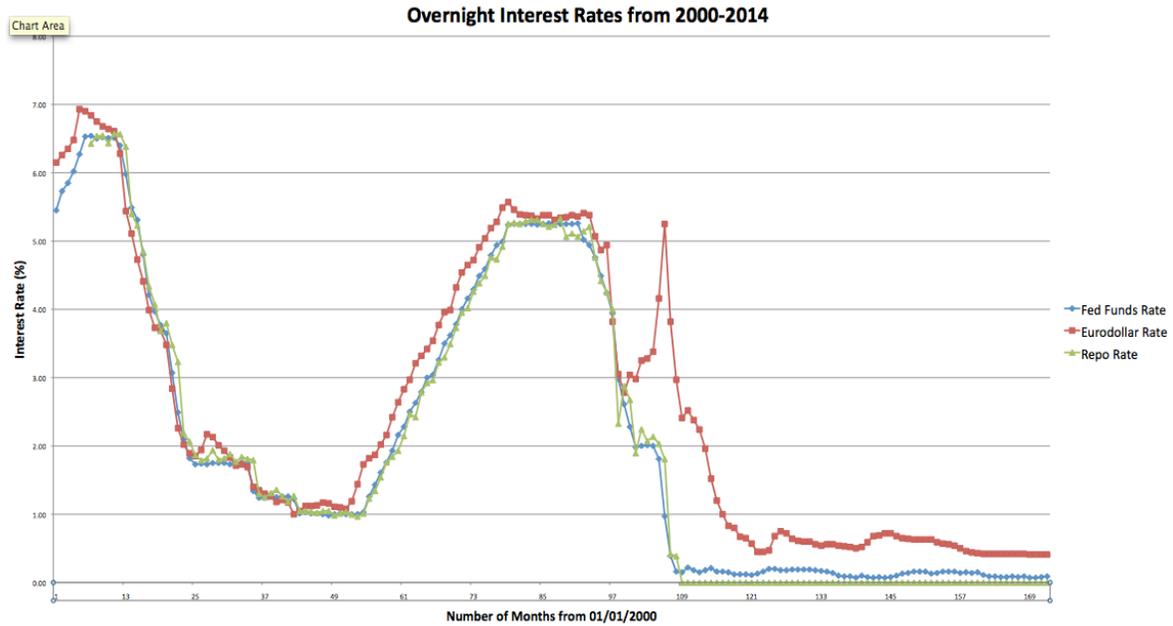
Where i^{repo} is the overnight Treasury general collateral (GC) repo rate, i^{eurdol} is the Eurodollar rate, i^{disc} is the discount rate, and i^{er} is the interest rate on excess reserves. A

reduction in the fed funds rate lowers DI's opportunity cost of holding excess reserves and hence creates an incentive to demand additional reserves above required reserves. This therefore results in an expected inverse relationship between R^e and i^{fed} , all else unchanged.

However, in reality there are various other funding rates that affect the demand for excess reserves. If other funding rates increase, the demand for funding in the federal funds market will increase which in turn, will raise the federal funds rate for a given supply of excess reserve balances.

As shown in Figure 1 below, the fed funds, Eurodollar and repo rates generally co-move in similar fashions around each other. The US unsecured money market consists of two segments, Eurodollar deposits and fed funds purchases and sales. Pre-financial crisis the two segments were highly integrated. However during the crisis period you can see large disintegration between the fed funds and Eurodollar deposit rate. Possible reasons for the heterogeneity in intraday fed funds rates include different transaction timings. As unanticipated news comes in, the market fed funds rate changes every second throughout the day. Different fed funds rate are realized at different times. As well as this, heterogeneous market participants may face different risk premiums as these different fed funds rates are realized even if they make transactions at the same time.

Figure 4: Overnight interest rates from 2000-2014



However, for the most part all three rates are interdependent of each other. This is because of the fact that DI's borrow in all three markets. Given these interdependencies we endogenize both i^{repo} and i^{eurdol} as,

$$7) \quad i^{\text{repo}} = f^{\text{repo}}(i^{\text{fed}}, i^{\text{eurdol}}), \text{ (Marquez et al.2013)}$$

$$8) \quad i^{\text{eurdol}} = f^{\text{eurdol}}(i^{\text{fed}}, i^{\text{repo}}) \text{ (Marquez et al.2013).}$$

Equations 6-8 are taken from the framework for the model used by Marquez et al. 2013 and provide a way to include in the model, the interdependencies that exist among funding markets. It also includes the policy tool of paying interest on excess reserves and accounts for the effect this has. Both of these are key reasons that make the Marquez et al. 2013 model unique and help to extend the current literature on the liquidity effect. By using this model and modernizing the data I hope to add further to the literature by providing a better look at the effect of asset sell offs on the fed funds in the present markets.

C. Transmission channels

Changes in S affect the fed funds rate through two channels.

- 1) A reduction in S reduces reserve balances as DI's deposits at the Fed are debited when the DI's purchase the securities. These sales reduce the excess reserves, which increases the federal funds rate.
- 2) The increase in fed funds rate raises the cost of borrowing in all other funding markets which then feeds back into the fed funds rate.

Even though the increases in i^{fed} raise the opportunity cost of holding reservable deposits and thus reduce D as well as reserve requirements, there is no feedback channel to i^{fed} via changes in excess reserves. As required reserves decrease, the Fed conducts temporary open market operations in the form of repurchase agreements to accommodate the decrease in R^r , leaving excess reserves unchanged. Given this, there is a negative relationship between the fed funds rate and S.

D. Model

The econometric model follows Marquez et al. (2013):

- 9)
$$\ln i^{\text{fed}}_t = \alpha_0 + \alpha_1 \ln i^{\text{repo}}_t + \alpha_2 \ln i^{\text{eurdol}}_t + \alpha_3 \ln i^{\text{disc}}_t + \alpha_4 R^e_t + \alpha_5 i^{\text{er}}_t + \alpha_6 \ln i^{\text{fed}}_{t-1} + \alpha_7 M + \alpha_8 FF + u^{\text{fed}}_t$$
- 10)
$$\ln i^{\text{repo}}_t = \beta_0 + \beta_1 \ln i^{\text{fed}}_t + \beta_2 \ln i^{\text{eurdol}}_t + \beta_3 \ln i^{\text{repo}}_{t-1} + \beta_4 F + u^{\text{repo}}_t$$
- 11)
$$\ln i^{\text{eurdol}}_t = \delta_0 + \delta_1 \ln i^{\text{fed}}_t + \delta_2 \ln i^{\text{repo}}_t + \delta_3 \ln i^{\text{eurdol}}_{t-1} + \delta_4 F + u^{\text{eurdol}}_t$$
- 12)
$$R^e_t = S_t + RP_t - (R^r_t + C_t - OA_t + OL_t)$$
- 13)
$$RP_t = R^r_t + AF_t$$

- 14)
$$R_t^r = \lambda_0 + \lambda_1 D_t + \lambda_2 R_{t-1}^r + \lambda_3 F u_t^r$$
- 15)
$$D_t = \pi_0 + \pi_1 Y_t + \pi_2 \ln i_t^{\text{fed}} + \pi_3 D_{t-1} + \pi_4 F + u_t^D$$
- 16)
$$u_t = (u_t^{\text{fed}}, u_t^{\text{repo}}, u_t^{\text{eurdol}}, u_t^r, u_t^D)' \sim N(0, \Omega).$$

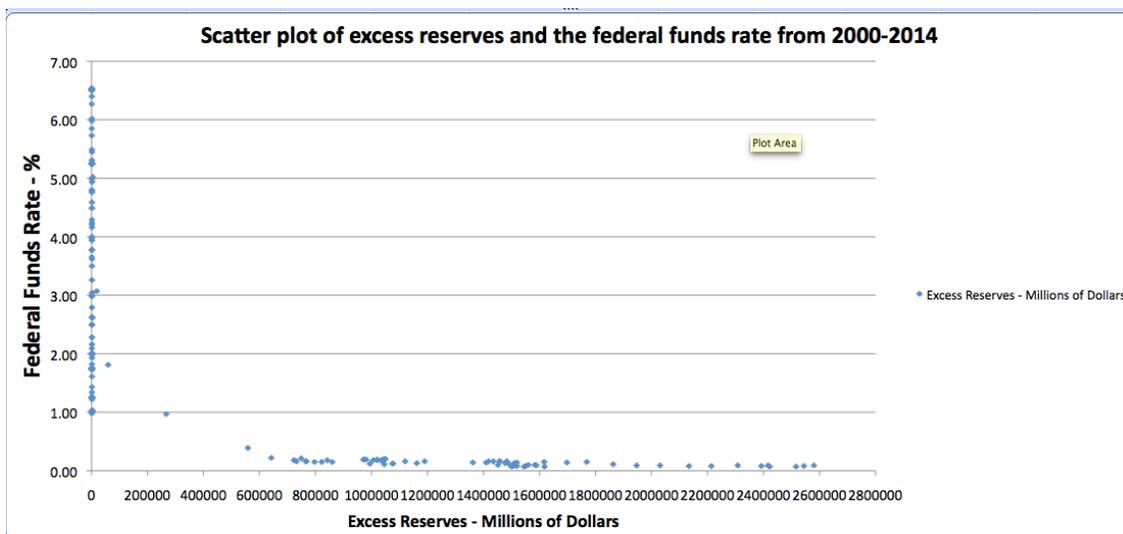
For my study I have added two dummy variables to the original model that can be seen as M and FF. M is a dummy variable to account for the introduction of paying interest on excess reserves as a policy tool in 2008. FF is a dummy variable that I added to the model to account for observations between late 2007-2009. I added this variable after looking at the plots of the actual vs. fitted values that resulted from running the initial model without the FF variable. I observed larger distortions from the trend line for dates between 2007-2009, which I attributed to the volatility of rates in response to the financial crisis. Therefore, the dummy variable FF aims to separate these effects and control for this time period in order to be able to report more accurate parameter estimates.

It is important to control for M because prior to 2008 paying interest rate on excess reserves was not a policy tool used by the Fed. Before October 08 the rate was zero and it exhibited wide swings upon introduction in October 08 before stabilizing at 25 basis points. In order to control for its novelty the dummy variable carries a value of 1 from October 2008 to January 2009 and zero otherwise.

The model has three interesting properties. First it allows for the possibility of delayed responses to changes in market conditions with the inclusion of the lagged variables at t-1. Second, the model captures the nonlinear relationship between short term

interest rates and reserve balances over our sample when we take the logarithms. This is also discussed in Bech and Klee (2012) and supported in the scatter plot below of the relationship between the Fed funds rate and reserve balances (Figure 2). The model uses logarithm of interest rates to accommodate the presence of non-linearity's.

Figure 5:



By looking at the equation used to estimate the effect of a change in S on the fed funds rate, I can expect to observe an inverse relationship (Marquez et al. 2013).

Therefore the sign regarding the change, di^{fed}/dS should be negative.

A decline in S reduces excess reserves directly, which then raises the Fed funds rate. The decline in S is otherwise known as open market sales. This reduces the supply of reserves from the Fed to banks. With fewer reserves banks are not as willing to make as many loans. When banks are willing to lend less the interest rate rises (fed funds rate) and is reflected in channel 1. This increase in the federal funds rate is

transmitted to all other interest rates, which then feeds back as an additional impulse to the federal funds rate represented in channel 2. Bearing this in mind I expect to see an inverse relationship between securities holdings and the fed funds rate keeping all else constant. To determine just how sensitive the fed funds rate is to a change in S I use this model to conduct an empirical analysis.

6. Estimation Results/Empirical Analysis

The data I am using for my study is based off of the nominal monthly rates reported on the Federal Reserve public website in their statistical releases as well as the St Louis Fed, FRED data website. The repo rate was taken from the Federal Reserve Bank of New York's website and was also a nominal monthly rate. Data on reservable deposits and DI's excess reserves are measured in Millions of Dollars and are obtained from FRED. This is also along with data on both required reserves and personal income which are measured in Billions of Dollars.

Previous studies such as Marquez et al.2013 used daily observations for each interest rate however such information is not made available to the public by the Fed. This may allow for a better estimate of the effect of a change in S as there considerably more data points with the daily data.

I used STATA to perform a three stage least squares regression in order to estimate the parameters in the system of simultaneous equations, (equations 9-15). Figure 3 below is the output table produced from my estimation. This is different from previous studies that used Matlab to conduct maximum likelihood estimates for the coefficients.

FIGURE 6: Stata 3OLS Output

Equations 1-5

	Lnfedfunds #1	Lnrepo #2	Lnneurodollar #3	Required Reserves #4	Reservable Deposits #5		
Constant	-0.189 [-0.081]	0.175 *** [0.074]	-0.106 *** [0.042]	10.071 *** [1.08]	-14.002 [10.893]		
FF	0.137 *** [0.052]	-0.112 ** [0.063]	0.130 *** [0.035]	-2.551 *** [0.559]	8.058 [5.452]		
Lnfedfunds		0.056 *** [0.025]	0.017 [0.014]		-5.604 *** [1.412]		
Lnneurodollar	0.728 [0.045]	-0.043 [0.046]					
Lnrepo	0.184 *** [0.081]		-0.044 *** [0.022]				
Excess reserves	0.214 *** [.0463]						
Interest paid on excess reserves	0.868 *** [0.322]						
M	-0.008 [0.166]						
Reservable Deposits				0.066 *** [0.006]			
Required Reserevs							
Personal Income					0.002 *** [0.001]		
Ln discount rate	0.086 *** [0.0315]						

*** = significant 95% level

** = significant at 90% level

Numbers below in '[...]' = Standard Errors

NOTE: variables at t1 not shown

Endogenous variables = Lnfedfunds, Lnrepo, Lnneurodollar, required reserves, reservable deposits.**Exogenous variables** = Ln discount, excess reserves, interest paid on excess reserves, Ln fedfundst1, M, FF, Ln repot1, Lnneurodollart1, required reservest1, personal income, reservabledeposits1

In terms of the estimates for the coefficients the results confirm the inverse and statistically significant relationship between excess reserves and the fed funds rate. In the first equation, the coefficient on excess reserves is -0.214. This shows that for every 1 billion dollar increase in excess reserves, the fed funds rate will decrease by .214%. This number makes sense considering current excess reserves held by DI's are around \$2.8 trillion. It also statistically significant, this enables us to conclude that there is a significant negative linear relationship between excess reserves and the fed funds rate.

Going hand in hand with this is the relationship you can see between reservable deposits and the fed funds rate in equation 5. As you would expect to see, when the fed funds rate increases, the amount of reservable deposits decreases. More specifically, a 1% increase in the fed funds rate causes a \$5.604 billion decrease in reservable deposits. This is because an increase in fed funds rates occurs when the Fed engages in open market sales to try and decrease the money supply. During this process the amount of excess reserves held at banks decreases and so causes the interest rate to rise. This relationship is also statistically significant as the $p\text{-value} = 0.000 < 0.05$.

Not only this, but the model shows the interdependencies among overnight interest rates however not to the same extent as observed in Marquez's study. When looking at the effect of the repo rate in equations 1 and 3, we can see that the elasticity of the repo rate with respect to both the fed funds rate and Eurodollar rate is .18 and -.04. This is different from the observations in Marquez's 2013 study where they found the repo rate to have positive effects on both rates. They also found similar results for the Eurodollar rate, that it had positive and significant impacts on both the fed funds and repo rates in their study. Here we can see in equations 1 and 2 that the Eurodollar rate is

insignificant in both regression equations. Therefore we cannot draw any conclusions about whether or not it has a positive effect and cannot say how big of an impact it has on the other two rates either. The last part of the comparison to Marquez's study looks at the effect of the fed funds rate in equations 2 and 3. In Marquez's study they observed a positive significant elasticity between the fed funds and repo rate but an insignificant elasticity between the fed funds and Eurodollar rates like I did. Therefore, I can say that that a 1% increase in the fed funds rate will cause a .56% increase in the repo rate.

Even given the fact that I followed the model very closely, it could be such that the two dummy variables that I added caused the results between interest rate interdependencies to be different for my model than in Marquez's study. With this in mind it could prove to be an area that requires further research as to whether or not controlling for certain time periods as I did affects the impact that the interest rates have on each other. Having said that it could simply be that the monthly observations I used didn't capture the true relationship between the three rates. The fact that it was monthly data smooths out a lot of the daily fluctuations that, if accounted for, might portray a different relationship that yields results that are closer to those found in Marquez's study. However it is worth noticing the trend we can see in Figure 4 back on page 13. Looking at the historical data we can see that right up until the time period used in my dummy variable, the three interest rates have generally moved together. However once the end of 2007/beginning of 2008 hit, the Eurodollar rate split away and spiked, rapidly increasing while the others were in periods of downward trends. This is why controlling for this time period is necessary and would explain why the Eurodollar rate is insignificant in my regression.

Figure 7: Correlation Matrix

```
. corr lnfedfunds lnrepo lneurodollar
(obs=172)
```

	lnfedf~s	lnrepo	lneuro~r
lnfedfunds	1.0000		
lnrepo	0.8064	1.0000	
lneurodollar	0.9182	0.7750	1.0000

The above correlation matrix also shows the interdependencies between the overnight rates in my study. As you can see each have strong positive linear relationships.

In the output above we can see that the dummy variable I introduced, “FF” is significant in all equations other than #5. The way we can interpret this variable can be seen below:

Equation #1: When controlling for the time period Dec 07- Jan 09 the federal funds rate is on average 114.72% higher.

Equation #2: When controlling for the time period Dec 07- Jan 09 the repo rate is on average, 89.4% higher.

Equation #3: When controlling for the time period Dec 07- Jan 09 the eurodollar rate is on average, 113.87% higher

Equation#4: When controlling for the time period Dec 07- Jan 09 the required reserves on average, is \$2.55 billion lower.

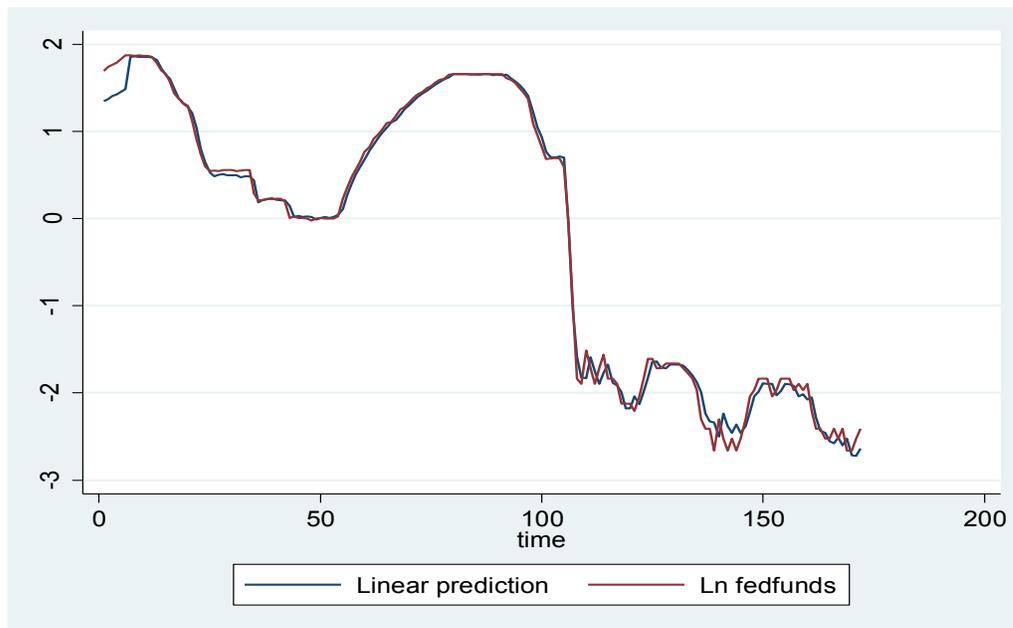
These numbers make sense when you look at the plots in Figure 8 below. You can see around month 100, how the fed funds rate was gradually building up higher before

declining rapidly at the time of the financial crisis. You can see similar trends in both other interest rates as well.

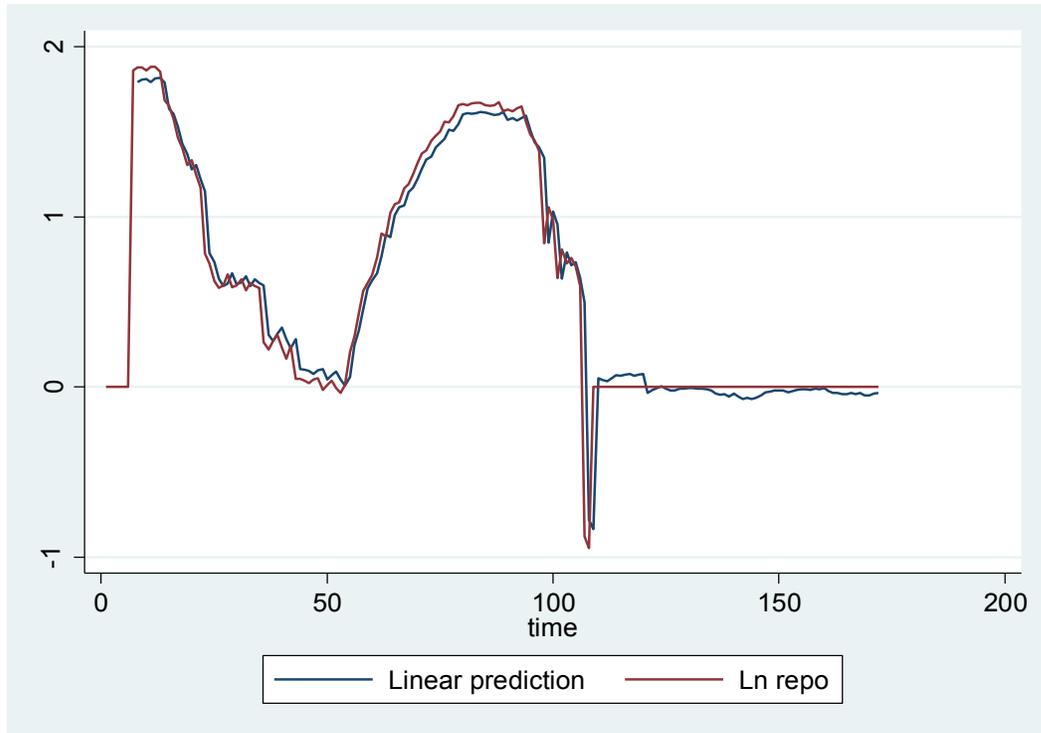
The model also has good fit as can be seen in Figure 8 below. The actual vs fitted value plots show the predictive accuracy of each variable in the model. Each plot shows slightly larger variation around the trend line around the time of the financial crisis in 2008.

Figure 8: Actual vs Predicted Plots

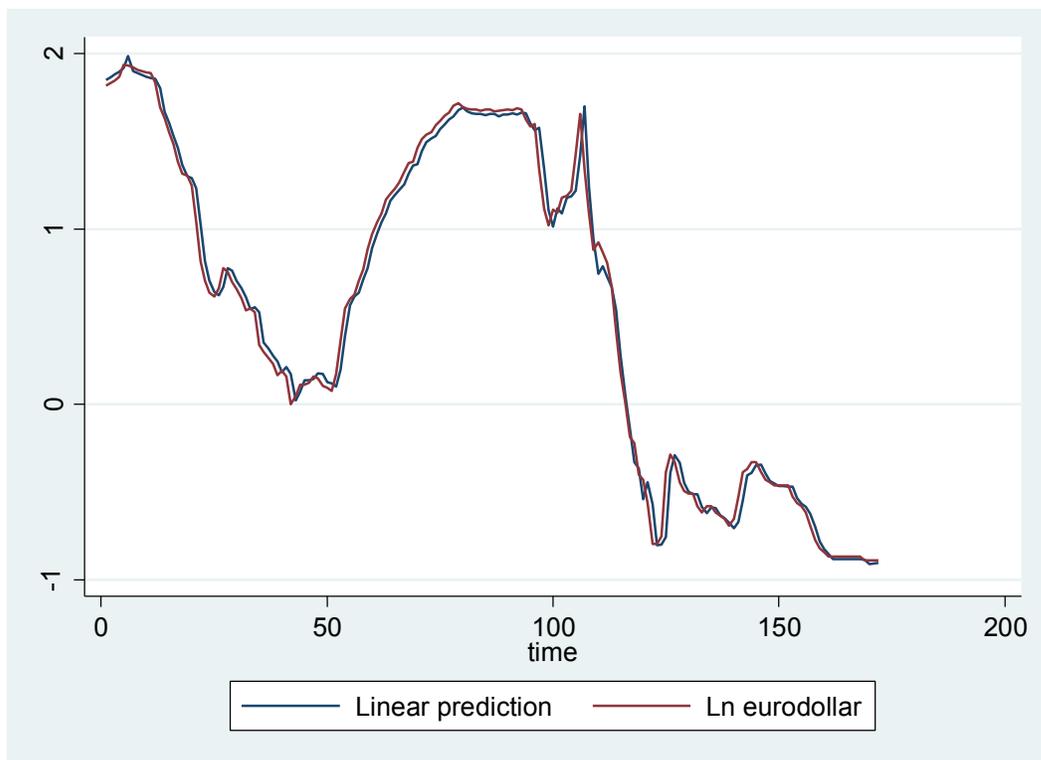
Federal Funds Rate



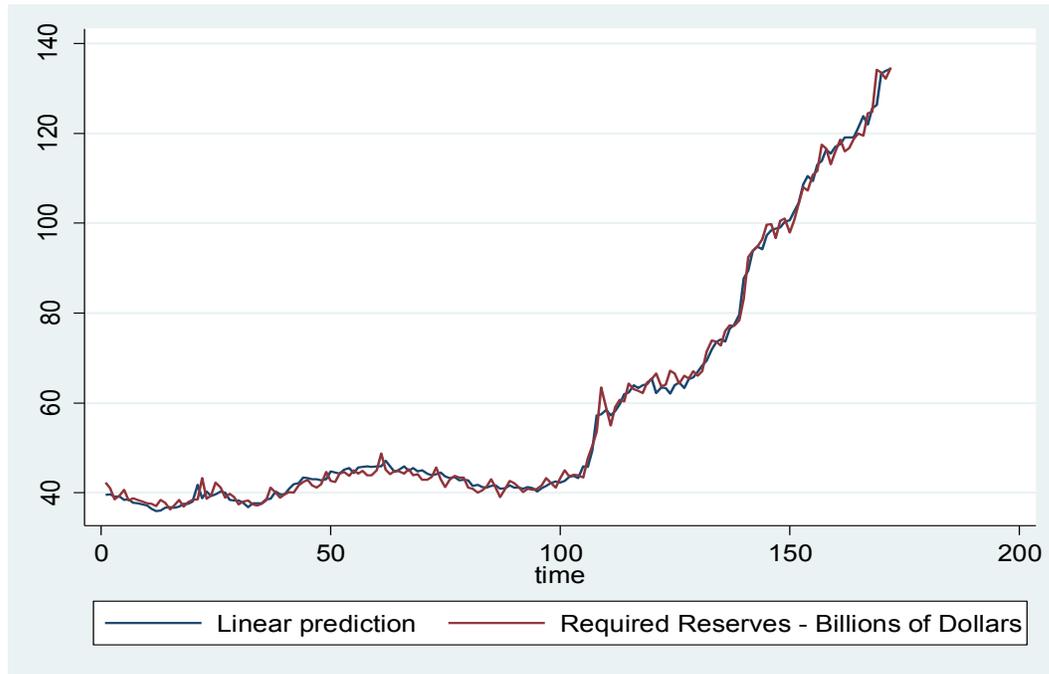
Repo Rate



Eurodollar Rate



Required Reserves



Reservable Deposits

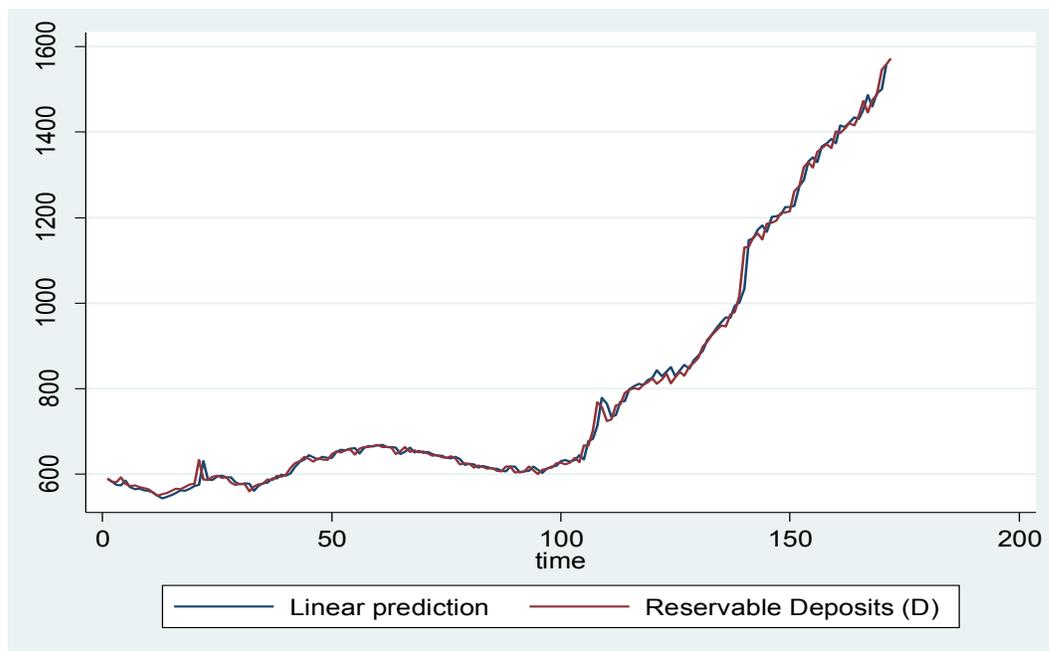


Figure 9: Autocorrelation

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. lmareg3
=====
* System Autocorrelation Tests (3sls)
=====
*** Single Equation Autocorrelation Tests:
Ho: No Autocorrelation in eq. #: Pij=0

Eq. lnfedfunds: Harvey LM Test = 37.2517 Rho = 0.2271P-Value > Chi2(1) 0.0000
Eq. lnrepo: Harvey LM Test = 1.5832 Rho = 0.0097 P-Value > Chi2(1) 0.2083
Eq. lnneurodollar: Harvey LM Test = 28.2415 Rho = 0.1722P-Value > Chi2(1) 0.0000
Eq. reservabledepositsd: Harvey LM Test = 4.2732 Rho = 0.0261P-Value > Chi2(1) 0.0387
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Eq. lnfedfunds: Durbin-Watson DW Test = 0.9498
Eq. lnrepo: Durbin-Watson DW Test = 1.8074
Eq. lnneurodollar: Durbin-Watson DW Test = 1.1702
Eq. reservabledepositsd: Durbin-Watson DW Test = 2.2573
```

Above are the results for the testing of autocorrelation in my model. When interpreting the Durbin Watson statistic a value less than 1 indicates that the errors are positively correlated. An increase in one period follows and increases in the previous period. A value of 2 indicates no autocorrelation, and a value of 3 or more indicate the errors are negatively correlated. An increase in one period follows a decrease in the previous period. With this in mind I am only concerned with autocorrelation in the first equation for the fed funds rate. Positive autocorrelation does have certain implications for the estimated standard errors. The estimators will still be unbiased and consistent but it does affect their efficiency. The estimates of standard errors will be smaller than the true standard errors. This will lead to the conclusion that the parameter estimates will be more precise than they really are.

Drawing on the results from my model we can see that the response of i^{fed} to a change in S is,

$$17) \quad di^{\text{fed}} = -i^{\text{fed}} \times .00000214 \times dS$$

The empirical analysis confirms our theory that a decrease in S raises the federal funds rate. The response however does depend on the value of i^{fed} , due to the non linearity of the model.

The long run responses of i^{fed} to policy rates are,

$$18) \quad di^{\text{fed}} = i^{\text{fed}}/i^{\text{disc}} \times .0857 \times di^{\text{disc}}, \text{ and}$$

$$19) \quad di^{\text{fed}} = i^{\text{fed}} \times -8.679 \times di^{\text{er}}$$

Translating these elasticities into an effect on the level of i^{fed} needs information on the initial values for all three interest rates. For example using June 2012 values, we get,

$$20) \quad di^{\text{fed}} = .10/.75 \times .0857 \times di^{\text{disc}} = .01142 \times di^{\text{disc}}_t$$

This therefore means that the federal funds rate reacts to policy rate changes less than one for one at the June 2012 levels of rates.

7. Conclusion

This paper contributes to our understanding on the effect that the selloff of assets from the Fed's balance sheet has on overnight interest rates. This is important because as the Fed enters into a phase of trying to return their balance sheet and interest rates to sustainable norms they are going to have to sell off assets. It is important that when doing this that there is no follow on effect on interest rates that would endanger sending the economy back into recession. Without government intervention interest rates would rise sharply reflecting the true market equilibrium as markets began to clear. Such a spike in interest rates have the ability to impact credit markets, reducing lending and funds available in the market for loanable funds. With this, there is a likely chance the US economy could fall back into recession as spending and consumption falls. Therefore a controlled withdrawal from current monetary policy is desirable and in order to do this it

is necessary to have an accurate estimate for impact of asset sell offs have on overnight rates.

My study is effective in showing the inverse relationship between the amount of excess reserves held at banks and the federal funds rate. It also shows how the fed funds rate is interdependent on the repo and Eurodollar rates and so any change to the fed funds will also have a similar effect on these two rates as well. However a lack of access to daily data means that perhaps there are not enough observations to really capture the true relationship between these three rates and excess reserves. In order to get even more accurate results, reproducing the study with daily data is necessary. This is crucial considering the policy implications that may or may not take place as a result of this study. The results can directly affect the size of open market operations conducted by the Fed and in a time of such volatility and uncertainty, precision is vital in order to ensure a controlled exit. Too much either way could cause drastic consequences, whether it is a spike in rates or spiraling inflation.

When looking at the effect that open market sales have on the fed funds rate, there has not been a large amount of literature prior to this day. Unlike the model used by Marquez, and the one I have used, previous studies that have been done have failed to recognize how various rates depend upon each other. Without this the results will not be relevant as the assumption is that only the level of open market operations affects the fed funds rate. This assumption does not hold and so cannot be applied to a real economy where in reality the federal funds rate is affected by other variables as well.

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