Modeling U.S. Monetary Policy During the Global Financial Crisis and Lessons for Covid-19

Ramaprasad Bhar  
*The University of New South Wales*

A. (Tassos) G. Malliaris  
*Loyola University Chicago*, tmallia@luc.edu

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Abstract:
The paper formulates the modeling of unconventional monetary policy and critically evaluates its effectiveness to address the Global Financial Crisis. We begin with certain principles guiding general scientific modeling and focus on Milton Friedman’s 1968 Presidential Address that delineates the strengths and limitations of monetary policy to pursue certain goals. The modeling of monetary policy with its novelty of quantitative easing to target unusually high unemployment is evaluated by a Markov switching econometric model using monthly data for the period 2002-2015. We conclude by relating the lessons learned from unconventional monetary policy during the Global Financial Crisis to the recent bold initiatives of the Fed to mitigate the economic and financial impact of the Covid-19 pandemic on U.S. households and businesses.

Key words: Modeling Unconventional Monetary Policy, Quantitative Easing, 10-Year Treasury, Unemployment, Labor Market, the Covid-19 Pandemic and the Fed.

JEL Classification: C10; C45; C58; E52; E58.

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1. INTRODUCTION

The Federal Reserve Act of 1913 established the U. S. Central Bank called the Federal Reserve System and charged it to design a national currency and conduct a monetary policy to promote financial stability. In 1977, Congress amended The Federal Reserve Act, stating explicitly the monetary policy objectives of the Federal Reserve as:

"The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices and moderate long-term interest rates."

Among the three goals of maximum employment, stable prices and moderate long-term interest rates, the first two have received precedence and thus most consideration over the years. For example, during the late 1970s and early 1980s when the Fed was fighting inflation and long-term interest rates had approached very high levels, around 20%, such elevated interest rates did not cause the Fed to deviate from its inflation targeting.

The pursuit of maximum employment and price stability as the Fed’s primary goals has evolved into the Fed’s “dual mandate”. This dual goal involves some possible trade-offs between inflation and unemployment, often called the Phillips curve and the appraisal of their associated risks. For example, the fight against inflation during the 1970s and early 1980s had as a consequence the increase in unemployment. More recently, after the Global Financial Crisis of 2007-09, the Fed pursued maximum employment, understanding the risks of possible inflation.

In this paper we accomplish four goals: first, present the methodological elements of M. Friedman’s approach to modeling monetary policy; second, focus on modeling the unconventional monetary policy from the beginning of the Global Financial Crisis of 2007-09 to the end of 2015; third, empirically test the effectiveness of unconventional monetary policy, and fourthly, we relate the lessons learned from unconventional monetary policy to the recent bold initiatives of the Fed to mitigate the economic and financial impact of the Covid-19 pandemic on U.S. households and businesses.
Prior to the bankruptcy of Lehman Brothers on September 15, 2008, monetary policy modeling followed its dual mandate without facing a major financial instability. Actually, since the establishment of the Fed in 1913, the U.S. economy experienced only two periods of significant financial instability that challenged conventional monetary policy: the Great Depression of the 1930s and the Great Recession of 2007-09. In December 2008, monetary policy modeling took the form of unconventional monetary policy when fed funds essentially reached the zero lower bound. During this period, the modeling of monetary policy changed profoundly. In section 2 below, we examine the basic principles of modeling the unconventional monetary policy that was proposed in late 2008. This section also offers a representative sequential sample of earlier models of monetary policies to facilitate comparisons. This analysis leads to the formulation of unconventional monetary policies followed during the 2008-2015 period articulated in section 3. Then in section 4, we present a brief narrative of quantitative easing. Section 5 formulates a set of hypotheses relating to the effectiveness of unconventional monetary policy. Next, in section 6 we perform the econometric testing and give an economic analysis of the results obtained. The lessons learned from the unconventional monetary policy are listed and applied to the Fed’s recent response to Covid-19, in section 7. In the last section, we highlight the originality of our contribution and the conclusions reached.

2. MILTON FRIEDMAN’S APPROACH TO MODELING

The epistemological prominence of models in science has increased significantly during the past several decades and both philosophers and historians of science have studied these valuable tools. Frigg and Hartmann (2018) present a critical literature overview on models and modelling in science and list a large group such as: computational models, developmental models, explanatory models, testing models, theoretical models, heuristic models, mathematical models, and formal models, among several others. This large variety makes it difficult to propose a uniform definition. Milton Friedman (1953) participated in debates about the role of models in economic methodology and is known to have argued that models should not be judged by the realism of their assumptions but only by the success of their predictions.

For our discussion, a model is a conceptual representation of some aspect of reality we wish to understand; or a model may highlight important connections among sets of data representing certain variables. According to Friedman we may not have an exact set of
assumptions about the behavior of economic agents but if the model generates a testable prediction and offers a policy recommendation then such a model is useful. So a model is like a tool. If it works it is useful. This pragmatic methodology of modeling suggested by Friedman (1953) is carefully explored methodologically in Isaac (2013).

How have economists modeled monetary policy? Keynes observed that during the Depression of the 1930s interest rates were very low and investments were unresponsive. He offered a model for monetary policy known as the liquidity trap and argued that monetary policy under such circumstances is ineffective and cannot help an economy overcome the depression. Monetarists who followed Keynesians in early 1960s argued that monetary policy had a major impact on an economy and played an important role on business cycles, exactly in opposition to the Keynesian model.

Milton Friedman (1968) proposed a model by discussing what monetary policy cannot do, what it can do and how to do it. He argued logically that monetary policy cannot peg interest rates for more than very limited periods and likewise it cannot peg the rate of unemployment. However, monetary policy can prevent money itself from being a major source of economic disturbance; offer a stable background of expectations and offseting major disturbances in the economic system arising from other sources. How should monetary policy be conducted? Friedman advises that the most appealing guides for monetary policy are exchange rates, the price level as defined by some index, and the quantity of some monetary aggregate. Friedman (1968, p.15) asserts “I believe that a monetary total is the best currently available immediate guide or criterion for monetary policy-and I believe that it matters much less which particular total is chosen than that one be chosen.”

Fifty years later, Mankiw and Reis (2018) skilfully evaluate the brilliant contribution of Friedman on modeling the role of monetary policy by affirming the intellectual prescience of some of his proposals but also by replacing others that were less enduring. Friedman’s view that in the long run the central bank cannot peg unemployment nor real interest rates has persisted. Instead of targeting Friedman’s suggested variable of the growth rate on some monetary aggregate, central banks for the last two decades embraced price stability and in particular, often advocate a precise 2% inflation target. Also, the emphasis has shifted from using monetary variables as tools to using the very short term interest rate. Mankiw and Reis (2018) give a
detailed exposition of the role of the natural rate of interest, introduced by Knut Wicksel, and explain how central banks currently interpret inflation targets in a flexible framework that adjusts to the business cycle. Put differently, the short run flexible decision-making by central banks to achieve their mandates by setting short term interest rates subject to new data may not have appealed to Friedman who preferred a much longer run strategy. It was in the longrun that “major sources of economic disturbances” occurred as in wars, periods of financial exhuberance or panics and Friedman’s insightful advice suggested “offseting” such developments. Such “offseting” is central to the modeling of “unconventional monetary policy” presented next.

3. MODELING UNCONVENTIONAL MONETARY POLICY

We now know that the financial crisis began as a subprime mortgage lending problem in the summer of 2007 and evolved to become one of the worst financial disasters since the Great Depression. It quickly impacted the real economy. According to the National Bureau of Economic Research, the economic recession started shortly after the subprime mortgage problems in December 2007 and lasted until June 2009. During this period, more than 15 million workers were permanently displaced from their jobs, the unemployment rate increased from about 4.8% to about 10%, and real GDP dropped by about 4% from its previous cyclical peak during the 4th quarter of 2007 to the trough of the 2nd quarter of 2009. Also, the S&P 500 declined from its peak of 1561 on October 12, 2007 to 676 on March 9, 2009, a drop of 57% and fed funds rate. Thus, the urgency of fashioning a suitable monetary policy to offset the crisis and deliver an economic recovery rose dramatically.

The bankruptcy of Lehman Brothers on September 15, 2008 was particularly difficult for the Fed because the achievement of stable employment growth and low inflation during the long period from the mid-1980s to 2008 had given it much credibility for stabilizing the U.S. economy. It had also validated that using the fed funds as a tool to achieve its dual mandate was most appropriate. These significant accomplishments of monetary policy were called the “great moderation”. So when unemployment reached a high of 10% during the Great Recession, the Fed’s objective function had to prioritize targeting unemployment over inflation. Initially, while the economy was in recession, the risks of inflation were very low but from mid-2009 to the end of 2015, when the Fed increased the fed funds rate from the range of 0% to 0.25% to the range of 0.25% to 0.50%, the assessment of pursuing easy policies to achieve maximum employment
against the potential risks of reigniting inflation were continuously monitored and assessed. The importance of job creation as the primary goal of unconventional monetary policy is expounded in Baghestani (2008), Evans (2010), Raskin (2011), and Kuttner (2018).

During September 2008, fed funds were between 1.75% to 2%. Three months later, during December 2008, fed funds were between 0% to 0.25%. This great tool of normal monetary policy over several decades had become of no further use. In late 2008, the Fed decided to use an unconventional method to stimulate the U.S. economy constrained by the zero lower bound of fed funds. These tools included the so called Large-Scale of Asset Purchases (LSAP) or Quantitative Easing (QE). The tool of QE consists of the Federal Reserve purchasing longer-term U.S. Treasury securities and agency mortgage-backed securities (MBS) with the aim of driving down longer-term interest rates, thereby stimulating economic activity. In other words, if the short-term fed funds rate has reached the zero level and cannot go any lower, the next option for the Fed to accomplish its dual mandate was to target the longer-term interest rate.

Independent of the debate whether the Fed can influence longer-term interest rates, Bernanke (2012, 2015) argues that QE works via the portfolio balance channel. The simple logic of this channel indicates that different classes of financial assets are not perfect substitutes in portfolios formed by investors and if the Fed can purchase large quantities of a certain asset and influence its price and therefore its yield, such changes may, through arbitrage transactions, spread to other asset classes. If the final result of QE is the increase of long-term bond prices and the decline of yields across many asset classes, the overall economic result is an increase in wealth that leads to more consumption and investment. With increases in consumption and investment, the economy grows and generates jobs to achieve the Fed’s goal of maximum employment. Not all economists accept this line of reasoning. Thornton (2014) does not find any empirical evidence in support of the portfolio balance channel and Taylor (2014) argues against monetary policy using unconventional tools. However, Gertler and Karadi (2015) offer evidence on the nature of the monetary policy transmission mechanism. A detailed exposition of U.S. monetary policy during the past 100 years is presented in Hetzel and Richardson (2016).

Next, we formulate the modeling of unconventional monetary policy as consisting of 5 conceptual modules:
First, the objectives of unconventional monetary policy were financial stability in the short-run and reduction of unemployment back to pre-crisis level of about 4%, during a much longer period. The Bernanke Fed relied heavily in Friedman’s admonition (1967, p.14) “monetary policy can contribute to offsetting major disturbances in the economic system arising from other sources”.

Second, the tools of unconventional monetary policy were quantitative easing and an emphasis on detailed forward guidance. Bernanke (2020) reaffirms the relevance of the same tools, adding that their effectiveness has been well-documented. During the past decade.

Third, there was an elevated methodological emphasis on assessing economic and financial risks driven by frequent forecasting of macroeconomic variables, measuring banking risks via stress testing, introduction of various regulations including the Dodd–Frank Wall Street Reform and Consumer Protection Act of July 21, 2010, stronger collaboration among major global central banks and enduring commitment to the goal of restoring full employment that ultimately required 3 rounds of quantitative easing over 5 years.

Fourth, unconventional monetary policy was supported by an articulation of the transmission of quantitative easing to the real economy, by what Bernanke called the portfolio balance channel. Recently, Wang (2016), Igan, Kabundi, De Simone and Tamirisa (2017), Gertler and Karadi (2015), and Gertler and Gilchrist (2018) have described the numerous developments that have articulated the transmission of changes from financial variables to the real economy. These and related studies empirically and theoretically articulate the transmission mechanism from interest rates and financial conditions to the macroeconomy by placing the emphasis on the balance sheets of firms, banks, shadow banks, consumers and the Fed. This approach articulates the wealth effect in addition to the portfolio effect. In other words, as the Fed increased its balance sheet by increasing liquidity to the financial sector, it also improved the net worth of banks, businesses and consumers who thus spent more than otherwise. Forward guidance supplemented the tools used by the Fed to provide communication to the public about the likely future course of monetary policy.

Fifth, the regime of unconventional monetary policy was repeatedly contrasted with a return to normal monetary policy and a reversal of quantitative easing that meant to emphasize an expectation of returning back to normal economic conditions with a normal monetary policy.
The earliest exposition of unconventional monetary policy modeling is given in Bernanke (2009).

4. QUANTITATIVE EASING IN THE U.S.

Pieces of the unconventional monetary policy modeling evolved gradually. Bernanke (2012) and Kuttner (2018) discuss the progression of QE in detail. It was not known at the beginning how many rounds of QE were necessary for the restoration of financial stability in the financial sector and economic recovery in the real economy. Today, with the benefit of historical experience we know that the Fed executed 3 main rounds of QE.

QE1 was announced by the FOMC on November 25, 2008. The plans were for the Fed to purchase $600 billion of Mortgage Backed Securities (MBS) and Agency Debt. The strategy was officially implemented on December 15, 2008. It was extended on March 18, 2009 when the FOMC announced the purchase of an additional $750 billion of MBS and $300 billion of Treasuries. The plan was concluded by December 2009, about a year later.

QE2 was announced by Chairman Bernanke in his Jackson Hole speech on August 27, 2010 and officially implemented in early November 2010. QE2 consisted of $600 billion of Treasury Bonds purchases. On September 21, 2011, the FOMC announced plans for purchasing $400 billion of longer-dated Treasuries by selling shorter-dated ones. This was known as Operation Twist. This Program was extended by an additional $267 billion on June 20, 2012.

QE3 was announced by the FOMC on September 2012. It did not specify the total amount but indicated monthly purchases of $40 billion of MBS. This amount was increased by another $45 billion of purchases of Treasuries on December 12, 2012. This monthly amount of Large Scale Asset Purchases of $85 billion consisting of both MBS and Treasuries continued for all of 2013 and was tapered gradually over 10 months prior to its termination on October 29, 2014.

5. HYPOTHESES FORMULATED

During the long period of about seven years, 2008-2015, with fed funds rate remaining essentially at zero, monetary policy followed QE and increased its balance sheet from about 1 trillion to 4.5 trillion to stimulate the economy that found itself to be in a liquidity trap. The use of QE was motivated by the pursuit of its goal of maximum employment. It was modeled in
Friedman’s belief that it is the role of monetary policy to offset major economic disturbances and the prediction of lowering unemployment was viewed as verification of its appropriateness.

Forward guidance about keeping the fed funds rate at the zero lower bound and pursuing lower longer term interest rates was carefully articulated in numerous Fed communications to reduce financial uncertainty while at the same time it was made clear that inflationary expectations were clearly and carefully monitored to enhance the Fed’s hard won credibility as an inflation fighter. Numerous speeches by Fed officials document in detail these strategic efforts to employ unconventional monetary policy tools. Bernanke (2015) emphasizes the firmness of commitment to pursue unconventional monetary policy over a relatively long period of about 7 years and the large increase of the Fed’s in assets from about 1 trillion in 2008 to about 4.5 trillion in 2015.

Jointly using monthly QE data and also longer term interest rates (say for 10-year Treasury Notes), how have these 2 series impacted the U.S. labor market? We formulate basic hypotheses to connect empirically monthly QE and longer term interest rates to various data describing labor markets to investigate empirically the effectiveness of unconventional monetary policy that targeted maximum employment in the aftermath of the financial crisis? We claim that the unconventional tools of monetary policy targeted primarily the unemployment rate. We also view the Bernanke Fed’s targeting of employment as confirmation of the validity of its policies. It was the Fed’s affirmation of its new policies that QE and lower longer term T-Notes rates would yield the forecasted lowering of unemployment. We use all six measures of Unemployment, U1, U2, U3, U4, U5, and U6 to perform an exhaustive analysis of this dimension of labor markets. U3 is the most representative measure that is used most commonly.

These hypotheses display the very practical and realistic goal of unconventional monetary policy that targeted the reduction in unemployment. What do we mean by such a statement? By unconventional monetary policy we mean the use of QE as a tool whose goal was to reduce the steepness of the yield curve, increase financial wealth, eventually increase aggregate demand and thus bring down unemployment. In the spirit of Friedman’s scientific methodology numerous assumptions are made about these developments and what matters most is not the exact nature of these assumptions but the prediction that unemployment will decline. An early analysis of QE is found in Gagnon et al. (2011) and more recently in Engen et al. (2015). The comprehensive paper of Gagnon et al. (2011) argues that in contrast to the pre-crisis
period when the Fed did too little too late, the post crisis record establishes a new convention of doing a lot but still too late.

During the past three decades a huge literature has grown to offer an understanding of the determinants of unemployment and the effectiveness of monetary and fiscal policies to reduce it. Ball (1999) gives a comprehensive evaluation of the ideas prevailed prior to the financial crisis and Mankiw and Weinzierl (2011) explore optimal stabilization policies with an emphasis on the appropriateness of monetary policy. In particular, Mankiw and Weinzierl propose four lines of defense for a big shock to the aggregate demand, such as the shock from the collapse of the housing bubble in 2007 and the Lehman Brothers bankruptcy that destabilized the financial system: first, lower the fed funds rate, if necessary to zero; second, reduce longer-term interest rates; third, increase private spending by reducing taxes; finally, if all else fails resort to government spending.

Additional theoretical support for the hypotheses we are formulating can be provided by Chiarella and Guilmi (2011). Actually these authors develop a dynamic macroeconomic model in the spirit of Hyman Minsky’s (1977) financial instability hypothesis that argues how the dynamics of financial distress are transmitted to the real economy causing both output to decline and unemployment to increase. This model explains well the Global Financial Crisis which is included in our sample but does not address issues of QE. However, it is clear that this model argues that repairing the financial sector contributes to macroeconomic growth of output and consequently to declines in unemployment.

All data related to employment are monthly, while Total Fed Assets are weekly and the 10 Year Treasury Note is daily. Both the Fed Assets and the T-Note are converted into monthly equivalent. The period studied is from the beginning of 2003 to the end of 2015. The hypotheses outlined indicate our motivation is to explore which measures of unemployment are influenced by the monetary policy proxy variables. In that sense we would have to focus on each of these dependent variables individually and not in some collective way. Also, at the same time, we recognize that the period under investigation had episodes of volatility surges. Considering these, we model each of the dependent unemployment variables under the influence of the monetary proxy variables subject to unobserved changing variable driving uncertainty in the economy. Our hypotheses are tested via the regime switching regressions in (1), assuming there
are two regimes only and the regimes switch according to a Markov chain with time invariant transition probabilities.

The independent variable is monetary policy. We employ two proxies for monetary policy during the period studied: first we use Total Fed Assets and second we use the 10-Year Treasury Note which under normal conditions is determined solely by market conditions but during the financial crisis was targeted by the Fed via its QE strategies. We hypothesize:

$$\Delta(U_{i,t}) = \alpha_{0,S_t} + \alpha_{1,S_t} (\Delta FA_{i-1}) + \beta_{1,S_t} (\Delta TY_{i-1}) + \beta_{2,S_t} \Delta(U_{i,t-1}) + \beta_{3,S_t} \Delta(U_{i,t-2}) + \epsilon_{i,S_t}$$ (1)

$$\epsilon_{i,S_t} \sim N(0, \sigma^2_{i,S_t})$$ (2)

Following Hamilton (1994), the matrix of transition probabilities is defined as:

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}, \text{ with } \sum_{s=1}^{2} p_{sj} = 1, \text{ and } p_{sj} \geq 0 \text{ for } s, j = 1, 2.$$ (3)

The expected duration of the high volatility regime is given by $E(S=1) = 1/(1 - P_{11})$ and that for the low volatility regime is given by $E(S=2) = 1/(1 - P_{22})$.

6. EMPIRICAL METHODOLOGY
Since we are interested in establishing the efficacy of the modelling approach over this rather long sample period, we initially focus on the diagnostic tests of the model. Although, the residual analysis from the regression equation (1) without switching shows no significant serial correlations, the CUSUM-square test shows instability in variance and/or parameters. This is further corroborated by the Chow Break Point test. These results are not included in the paper.

Although the GARCH variance captures the time varying nature of conditional variance, it cannot address it, if there is structural discontinuity in the level of variance. In order to explore more effectively the influence of the independent variables on the various measures of unemployment as well as parameter and variance discontinuity over the long sample, we investigate the non-linear modelling approach via a two state Markov chain shown in equation (3).

The subscript is used to denote dependence of these parameters on the prevailing Markov state. The law guiding the evolution of this unobserved state variable is a time homogenous transition probability matrix. The residual term is also dependent on the Markov state occurring and the variance of this residual variable is also state dependent. In fact, the realization of the
residual variance is one way of classifying the states to which we may be able to attach economic significance.

In contrast to linear models that assume stationary distributions, regime-switching models are based on a mixture of parametric distributions whose probabilities depend on unobserved state variable. In our model, the economy alternates between two unobserved states of high volatility and low volatility according to a Markov chain process.

Since we have identified that the parameters are not constant through time, and some sort of structural break occurs in the series, we have certain modelling choices. One alternative is to estimate the model over different sub-samples if the timing of the break is known. Another alternative is to make the structural break endogenous to the model since in many cases the timing of the shift may not be known. By making the shift(s) endogenous to the model, we can also make inferences about the process that drives these shifts. Models that shift between various densities allow us to incorporate structural breaks in the estimation procedure.

A source of uncertainty, idiosyncratic to regime switching models is the ex-post determination of regimes. In switching models, it is assumed that the occurrence of a regime is observed by the market but not by the econometrician who must infer it from the model. Until recently, the quality of regime classification was determined by focusing on the smoothed ex-post regime transition probabilities. An innovation in this area is the Regime Classification Measure (RCM) proposed by Ang and Bekaert (2002). This is essentially a sample estimate of the variance of the probability series. It is based on the idea that perfect classification of regimes would infer a value of 0 or 1 for the probability series and would be a Bernoulli random variable. The Regime Classification Measure (RCM) is defined as: what is the probability of being in a certain regime at time $t$? Good regime classification is associated with low RCM statistic values. A value of 0 means perfect regime classification and a value of 100 implies that no information about the regimes is revealed. Weak regime inference implies that the model cannot successfully distinguish between regimes from the behavior of the data and may indicate misspecification.

The RCM measures are given below the Figures. This shows that for most of the models the approach is able to confidently distinguish which regimes are occurring at each point in time. The switching regime model appears to capture the effect of asset purchase and long-term Treasury notes on different measures of unemployment data quite well.
The results are presented in Tables 1-6. The hypotheses claim that monetary policy targeted unemployment during the period of September 15, 2008 (the declaration of Lehman Brothers’ bankruptcy) to the end of 2015. The BLS divides unemployment into six categories (known as U1 through U6), defined as follows:

• U1 = Percentage of labor force unemployed 15 weeks or longer.
• U2 = Percentage of labor force who lost jobs or completed temporary work.
• U3 = Percentage of labor force who are without jobs and have looked for work in the last four weeks (note that this is the officially-reported unemployment rate).
• U4 = U3 plus the percent of the labor force that count as "discouraged workers," i.e. people who would like to work but have stopped looking because they are convinced that they can't find jobs.
• U5 = U4 plus the percent of the labor force that count as "marginally attached" or "loosely attached" workers, i.e. people who would theoretically like to work but haven't looked for work within the past four weeks.
• U6 = U5 plus the percent of the labor force that count as "underemployed," i.e. part-time workers who would like to work more but can't find full-time jobs. Graph 1 illustrates these six proxies for the unemployment rate.
Technically speaking, the statistics for U4 through U6 are calculated by adding discouraged workers and marginally attached workers into the labor force as appropriate. (Underemployed workers are always counted in the labor force.) In addition, the BLS defines discouraged workers as a subset of marginally attached workers but is careful not to double count them in the statistics. Of course, these 6 measures of unemployment are highly correlated and behave very similarly; also the percentage of unemployed is the lowest for U1 and increases monotonically for the ordered sequence of levels of unemployment. Also, U3 is the officially reported statistic for unemployment and the one targeted by the Federal Reserve. Tables 1 to 6 summarize the econometric results. The main empirical findings of the 6 Tables are the following:

**Good place for the six graphs, pages 19-24**

First, all 6 Tables show that all measures of unemployment changes are driven by changes in independent variables that are significant in both the low and the high volatility Markov regimes. We work with first differences because of the non-stationarity of our variables.

Second, the 2 monetary policy instruments used by the Fed after the Lehman Brothers bankruptcy were QE and its impact on reducing longer-term interest rates on government bonds.
The effectiveness of the 3 rounds of QE on longer-term interest rates has been exhaustively studied and summarized in Williams (2011, 2013) and more recently in Bhar, Malliaris and Malliaris (2015). U1 is driven by the long-run 10-Year T-Note rate in the low volatility regime and by its own 2-period lag in the high volatility regime. U2 is driven by the lagged T-Note rate in the low volatility regime and by Fed Assets in the high volatility regime. Autoregressive terms play also significantly for U2.

Third, our results are very interesting for U3 in Table 3. Since this is the official measure of unemployment, it is encouraging to observe that U3 is driven by Fed Assets in both the low (level of significance 1%) and high volatility (level of significance 5%) regimes. Also, it is important to indicate that the average duration of the high volatility regime for U3 is about 5.95 months that is higher than the low volatility regime that lasts only 1.91 months.

U4 is driven by Fed Assets (significance level 10%), the T-Note rate and autoregressive factors in the low volatility regime. U5 on the other hand is influenced by Fed Assets in the low volatility regime and by the T-Note rate in the high volatility regime.

Finally, U6 is significantly influenced by both Fed Assets and the T-Note rate in the low volatility regime and by autoregressive factors in the high volatility regime.

The over-all conclusion of these 6 Tables is that monetary policy in its unconventional approach with QE and the 10 Year T-Note Rate appears statistically significant in 9 out of 12 regimes—recall we analyze six unemployment measures each in a low and high volatility regime. If we focus on U3 as the official statistic that does not include chronically discouraged workers for whom monetary policy has very limited effectiveness, then our results are much stronger. Recall, as was said earlier that Fed Assets enter as statistically significant for both the low and high volatility regimes of U3 (at the 1% and the 5% level respectively).

7. LESSONS LEARNED DURING 2007 TO 2019 AND THEIR APPLICATION DURING COVID-19

This paper articulates that Friedman’s modeling of monetary policy emphasizes its role as offsetting major disturbances in the economic system arising from sources such as a financial crisis. This conviction is in opposition to the Keynesian model that pronounces the ineffectiveness of monetary policy during a liquidity trap. Friedman also argues that models
should not be judged by the realism of their assumptions but only by the success of their predictions. The Bernanke Fed, soon after fed funds were decreased close to zero in late 2008, chose new tools to target unemployment that had reached about 10%. No one knew during the months that followed the Lehman Brothers bankruptcy, the magnitude, duration and impact of these policies.

What was known at the beginning was the hard economic facts of high unemployment, very low inflation, frozen financial markets and both national and international financial instability. When fiscal policy faced both budgetary and political constraints, a consensus was rapidly built by FOMC members to target unemployment as directed by the Fed’s dual mandate. This consensus was not formed on solid analytical grounds of a macroeconomic model describing the channels connecting monetary policy to increased employment but rather on a careful calculus of risk management, that is, by assessing the benefits from lowering unemployment versus the risks of creating inflation, with a conviction in the effectiveness of monetary policy.

What central bankers learned during the 2007-2015 period is that the effectiveness of QE was due to four factors: first, the rapid and careful formulation of unconventional monetary policy to replace traditional fed funds management when these had reached zero; there was no lamenting that monetary policy had arrived to its dead end. Second, the commitment of central bankers to unconventional QE that was extended over 7 years with 3 major rounds rather than being abandoned after its first or second round. Third, the boldness of policy makers to pursue large QE rather than moving very cautiously, say by only doubling the size of the Fed’s balance sheet instead of actually growing it by 350%, and, fourth, the achievement of its goal to reduce unemployment substantially. Of course there was some good fortune, meaning that the monthly, data-driven, communications and evaluations of QE never were confronted with unpleasant issues of financial instability, rapid inflation or re-occurring recessions. The return of unemployment from a very high level of 10% down to normal levels of around 4% is pragmatic evidence that unconventional monetary policy has worked. The fifth lesson relates to the only goal that was not achieved; this was the rapid return to normal conditions that evolved very slowly during the 2016 to 2019 period. These lessons proved most invaluable in the early stages of Covid-19.
Jerome Powell took office as chairman of the Board of Governors of the Federal Reserve System in February 2018, with fed funds at 1.5%. There were 4 increases in fed funds during 2018 and by December, these rates had reached 2.5%. The economy during 2018 did very well with real GDP growth at 2.9% and unemployment at 3.9% and the expectation was for continued growth in 2019. By mid-2019, economic growth had slowed down and GDP for the year grew only at 2.1, with unemployment reaching a record low of 3.5. The Powell Fed cut fed funds 3 times and by December 31, 2019, fed funds were back to 1.75%.

Also, on December 31, 2019, the World Health Organization (WHO) was informed of a pneumonia outbreak of unknown cause in Wuhan, China. Cases increased in China and then began to spread internationally in January and February. WHO declared Covid-19 a global pandemic on March 11. In the U.S., the first case was reported on January 21, and by mid-March, all 50 states, the District of Columbia, New York City, and four U.S. territories had reported cases of Covid-19. The rapid spread and high degree of transmissibility of Covid-19 induced health experts to advise public officials to impose social distancing, restrictions on work and movement, and lockdowns across the country. Activities requiring face to face transactions, large congregations, schools, universities, churches and other places of worship, theaters, hotels, airlines, restaurants, shopping malls, banks and numerous other activities were immediately affected, revenues plunged and the U.S. stock market crashed for a high of 3380 in mid-February to 2237 on March 23, that is a 34% decline in 5 weeks. Stock market implied volatility, the VIX index, rose to 82% by mid-March from an average of about 15%, signaling high uncertainty about the future. Standard relationships in financial markets, such as those between stock prices and Treasury yields broke down, forced selling by leveraged financial firms increased dramatically and heightened illiquidity in the Treasury market emerged.

The Fed responded by decreasing the fed funds rate to 1.25% on March 3 and few days later to 0.25% on March 15. Having brought fed funds essentially down to zero, the Fed both rapidly and broadly took numerous initiatives to stabilize the financial system and the U.S. economy. These initiatives are described in detail in Fleming, Sarkar, and Van Tassel, (2020) who also compare whether the Covid-19 initiatives are similar to the ones taken during the Global Financial Crisis or new, specially designed for Covid-19.

To make some preliminary comparisons between the two crises—the Global Financial Crisis and Covid-19—the Fed’s balance sheet increased from about $1 trillion in late 2008 to
$4.5 trillion in late 2014 and remained at that level during 2015-2-17. The Fed proceeded with Quantitative Tightening during both 2018 and 2019 and reduced its balance sheet to $3.6 trillion. After the significant initiatives of the Fed in mid-March to provide liquidity by purchasing of U.S. Treasury securities, Agency Debt and Mortgage Backed Securities, its balance sheet expanded to $7 trillion in late May 2020. Furthermore, this extraordinary increase of about $3.4 trillion materialized in the very short period of two months. It is difficult to imagine the speed and size of these operations in the absence of the Fed’s modeling of monetary policy during the Global Financial Crisis.

8. SUMMARY
This paper discusses certain principles guiding general scientific modeling and focuses on Milton Friedman’s 1968 Presidential Address that delineates the strengths and limitations of monetary policy to pursue certain goals. The modeling of unconventional monetary policy with its novelty of quantitative easing during the Global Financial Crisis is discussed in detail and its components are clearly identified. The pursuit of full employment is evaluated by a Markov switching econometric model using monthly data for the period 2002-2015. Using a two-state Markov switching paradigm to capture the pre- and post-crisis periods, we find evidence that QE and the Fed’s extensive efforts over 7 years to reduce longer-term interest rates have indeed proven to be of some statistical significance. Thus, our work documents that the observed decline in unemployment during 2009 to 2015 is statistically associated with the Fed’s unconventional monetary policy modeling. We conclude by relating the lessons learned from unconventional monetary policy during the Global Financial Crisis to the recent bold initiatives of the Fed to mitigate the economic and financial impact of the Covid-19 pandemic on U.S. households and businesses.
\[ \Delta(\mathbf{U}_{1,t}) = \alpha_{S_t} + \alpha_{S_t} (\Delta \mathbf{Y}_{t-1}) + \beta_{S_t} \Delta(\mathbf{U}_{1,t-1}) + \beta_{S_t} \Delta(\mathbf{U}_{1,t-2}) + \epsilon_{S_t} \]

\[ \epsilon_{S_t} \sim N(0, \sigma_{S_t}^2) \]

### Table 1:
Dynamic of \( \mathbf{U}_1 \): Two State Markov Switching Paradigm

|                  | \( S_t = 1 \)       | \( S_t = 2 \)       |
|------------------|----------------------|----------------------|
| \( \Delta \mathbf{A}_t \) \( \cdot \) 0.001 | -0.0002              | 0.0005               |
|                  | (-1.43)              | (0.95)               |
| \( \Delta \mathbf{Y}_{t-1} \) \( \cdot \) 100 | -0.0011*             | 0.0028               |
|                  | (-2.59)              | (1.26)               |
| \( \Delta \mathbf{U}_{1,t-1} \)               | 0.1121               | 0.7975               |
|                  | (1.33)               | (0.78)               |
| \( \Delta \mathbf{U}_{1,t-2} \)               | 0.0783               | 0.7561*              |
|                  | (1.09)               | (2.09)               |
| \( \log(\text{Volatility}) \)                 | -7.1888              | -6.5870              |
|                  | (-63.55)             | (-41.19)             |

Transition probability matrix \( \mathbf{p}_{ij} : j \rightarrow i \)

|                  | \( j = 1 \)       | \( j = 2 \)       |
|------------------|-------------------|-------------------|
| \( i = 1 \)      | 0.815*            | 0.185             |
|                  | (1.99)            |                   |
| \( i = 2 \)      | 0.591*            | 0.409             |
|                  | (0.49)            |                   |

Average duration in a particular state (Months)

|                  | \( S_t = 1 \)       | \( S_t = 2 \)       |
|------------------|----------------------|----------------------|
|                  | 5.45                 | 1.69                 |

The numbers in parentheses are \( z \)-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 2.00, Hannan-Quinn criterion: -10.69

### Table 1a:
Smooth Probability (Low Volatility State)

[Graph showing probability over time]

Regime Classification Measure: 47.5
\[
\Delta(U_{2,t}) = \alpha_{0,S_t} + \alpha_{1,S_t} (\Delta FA_{t-1}) + \beta_{1,S_t} (\Delta TY_{t-1}) + \beta_{2,S_t} \Delta(U_{2,t-1}) + \beta_{3,S_t} \Delta(U_{2,t-2}) + \varepsilon_{2,S_t} \\
\varepsilon_{2,S_t} \sim N(0, \sigma^2_{2,S_t})
\]

Table 2
Dynamic of \(U_2\): Two State Markov Switching Paradigm

|                      | \(S_t = 1\)          | \(S_t = 2\)          |
|----------------------|-----------------------|-----------------------|
| Intercept            |                       |                       |
| \(\Delta FA(t-1) \times 0.001\) | 0.0001                | -0.0010               |
|                      | (0.89)                | (-2.71)               |
| \(\Delta TY(t-1) \times 100\) | -0.0016               | -0.0002               |
|                      | (-3.88)               | (-0.22)               |
| \(\Delta U_1(t-1)\)  | 0.5794                | -0.1957               |
|                      | (5.90)                | (-2.21)               |
| \(\Delta U_1(t-2)\)  | 0.3146                | -0.0998               |
|                      | (2.86)                | (-0.70)               |
| Log(Volatility)      | -7.6054               | -6.7177               |
|                      | (-28.10)              | (-102.61)             |

Transition probability matrix \(p_{i,j}\) : \(j \rightarrow i\)

| \(i = 1\) | \(j = 1\) | \(j = 2\) |
|------------|------------|------------|
| \(i = 1\) | 0.6599     | 0.3401     |
|            | (0.96)     | (--3.01)   |
| \(i = 2\) | 0.1187     | 0.8813     |
|            | (3.01)     | (--3.01)   |

Average duration in a particular state (Months)

|                     | \(S_t = 1\) | \(S_t = 2\) |
|---------------------|-------------|-------------|
|                     | 2.94        | 8.43        |

The numbers in parentheses are z-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 1.73, Hannan-Quinn criterion: -10.60

Table 2a
Smooth Probability (Low Volatility State)

Regime Classification Measure: 45.1
\[ \Delta( U_{3,t} ) = \alpha_{0,S_t} + \alpha_{1,S_t} (\Delta FA_{t-1} ) + \beta_{1,S_t} (\Delta TY_{t-1} ) + \beta_{2,S_t} \Delta( U_{3,t-1} ) + \beta_{3,S_t} \Delta( U_{3,t-2} ) + \varepsilon_{3,S_t} \]

\[ \varepsilon_{3,S_t} \sim N(0, \sigma^2_{S_t}) \]

| Table 3 |
| Dynamic of \( U_3 \): Two State Markov Switching Paradigm |

|            | \( S_t = 1 \) | \( S_t = 2 \) |
|------------|----------------|----------------|
| Intercept  | -0.0044**      | 0.0004**       |
| \( \Delta FA(t-1)*0.0001 \) | (-4.62) | (2.12) |
| \( \Delta TY(t-1)*100 \) | -0.0011 | -0.0012 |
| \( \Delta U(t-1) \) | -0.6175* | 0.1795 |
| \( \Delta U(t-2) \) | (-2.50) | (1.81) |
| Log(Volatility) | -6.6532 | -6.6825 |

Transition probability matrix \( p_{i,j} : j \rightarrow i \)

|            | \( i=1 \) | \( i=2 \) |
|------------|-----------|-----------|
| \( j=1 \) | 0.4766    | 0.1681    |
| \( j=2 \) | 0.5234    | 0.8319    |

Average duration in a particular state (Months)

|            | \( i=1 \) | \( i=2 \) |
|------------|-----------|-----------|
|            | 1.91      | 5.95      |

The numbers in parentheses are z-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 1.57, Hannan-Quinn criterion: -10.01

| Table 3a |
| Smooth Probability (Low Volatility State) |

![Probability Low Volatility State](image)

Regime Classification Measure: 54.2

21
\[
\Delta(U_{4,t}) = \alpha_{0,S_t} + \alpha_{1,S_t} (\Delta FA_{t-1}) + \beta_{1,S_t} (\Delta TY_{t-1}) + \beta_{2,S_t} \Delta(U_{4,t-1}) + \beta_{3,S_t} \Delta(U_{4,t-2}) + \varepsilon_{4,S_t}
\]

\[\varepsilon_{4,S_t} \sim N(0, \sigma^2_{4,S_t})\]

### Table 4
Dynamic of \(U_4\): Two State Markov Switching Paradigm

|                | \(S_t = 1\) | \(S_t = 2\) |
|----------------|-------------|-------------|
| Intercept      |             |             |
| \(\Delta FA(t-1) \times 0.0001\) | 0.0003***   | 0.0006      |
| \(\Delta TY(t-1) \times 100\)     | (1.73)      | (1.04)      |
| \(\Delta U_1(t-1)\)                | (13.11)     | (-1.39)     |
| \(\Delta U_1(t-2)\)                | 0.5651      | 0.2181      |
| \(\Delta U_1(t-2)\)                | (19.46)     | (2.13)      |
| \(\Delta U_1(t-2)\)                | -0.2064     | -0.2580*    |
| \(\Delta U_1(t-2)\)                | (-9.97)     | (-2.00)     |
| Log(Volatility)                     | -8.3644     | -5.5907*    |
| Transition probability matrix \(p_{ij}: j \rightarrow i\) | | |
| \(i = 1\) | \(j = 1\) | \(j = 2\) |
| 0.8854 | 0.1146 | |
| (4.77) | (1.49) | |
| \(i = 2\) | \(j = 1\) | \(j = 2\) |
| 0.7878 | 0.2122 | |
| (1.49) | (1.4) | |

Average duration in a particular state (Months)

- 8.73
- 1.27

The numbers in parentheses are z-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 2.19, Hannan-Quinn criterion: -8.13

### Table 4a
Smooth Probability (Low Volatility State)

![Smooth Probability Chart](image_url)

Regime Classification Measure: 19.0
\[
\Delta(U_{5,t}) = \alpha_{0,S_t} + \alpha_{1,S_t} (\Delta FA_{t-1}) + \beta_{i,S_t} (\Delta TY_{t-1}) + \beta_{2,S_t} \Delta(U_{5,t-1}) + \beta_{3,S_t} \Delta(U_{5,t-2}) + \varepsilon_{5,S_t}
\]

\(\varepsilon_{5,S_t} \sim N(0, \sigma^2_{5,S_t})\)

### Table 5
**Dynamic of \(U_5\): Two State Markov Switching Paradigm**

|                | \(S_t = 1\) | \(S_t = 2\) |
|----------------|-------------|-------------|
| Intercept      |             | -0.0001     |
| \(\Delta FA(t-1)*0.0001\) | 0.0005      | -0.0001     |
|                | (4.60)      | (-0.30)     |
| \(\Delta TY(t-1)*100\) | -0.0002     | -0.0019***  |
|                | (-0.25)     | (-1.95)     |
| \(\Delta U_1(t-1)\)  | 0.3144      | -0.0255     |
|                | (3.08)      | (-0.22)     |
| \(\Delta U_1(t-2)\)  | -0.0728     | 0.5777**    |
|                | (-0.80)     | (-1.99)     |
| Log(Volatility) | -7.1998     | -6.2807     |
|                | (-29.80)    | (-73.66)    |

**Transition probability matrix**

\[\begin{array}{c|cc}
 i = 1 & j = 1 & j = 2 \\
\hline
 1 = 1 & 0.6991*** & 0.3009 \\
 & (1.67) & \\
 1 = 2 & 0.5496 & 0.4504 \\
 & (0.25) & \\
\end{array}\]

**Average duration in a particular state (Months)**

\[\begin{array}{cc}
 3.32 & 1.82 \\
\end{array}\]

The numbers in parentheses are z-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 2.05, Hannan-Quinn criterion: -9.75

### Table 5a
**Smooth Probability (Low Volatility State)**

![Probability Low Volatility State](image)

Regime Classification Measure: 63.1
\[ \Delta(U_{6,t}) = \alpha_{0,6} + \alpha_{1,6} \Delta FA_{t-1} + \beta_{1,6} \Delta TY_{t-1} + \beta_{2,6} \Delta U_{6,t-1} + \beta_{3,6} \Delta U_{6,t-2} + \varepsilon_{6,S} \]

\[ \varepsilon_{6,S} : N(0, \sigma^2_{6,6}) \]

Table 6
Dynamic of \( U_6 \): Two State Markov Switching Paradigm

|                      | \( S_1 = 1 \) | \( S_1 = 2 \) |
|----------------------|---------------|---------------|
| Intercept            |               |               |
| \( \Delta FA(t-1) \times 0.0001 \) | 0.0015 | -0.0010 |
| \( \Delta TY(t-1) \times 100 \) | (45.29) | (-1.06) |
| \( \Delta U_1(t-1) \) | 0.4322 | 0.2263 |
| \( \Delta U_1(t-2) \) | (-25.85) | (-3.95) |
| Log(Volatility)     | -8.8587 | -5.3141 |
| Transition probability matrix | p_{i,j} : j \rightarrow i |
|                       | j=1          | j=2          |
| i=1                  | 0.9912       | 0.0088       |
| (4.37)               | (-1.13)      |
| i=2                  | 0.2162       | 0.7838       |
| (-1.13)              | (4.37)       |
| Average duration in a particular state (Months) | \( T \) |
|                      | i=1          | i=2          |
|                      | 113.80       | 4.05         |

The numbers in parentheses are z-statistics computed from the information matrix. Single * indicates significance at 1% level and double * indicates significance at 5% level and triple * indicates significance at 10% level. Model Diagnostics: Durbin-Watson Stat: 2.22, Hannan-Quinn criterion: -7.70

Table 6a
Smooth Probability (Low Volatility State)

Regime Classification Measure: 0.80
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