THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ECONOMICS

UNCONVENTIONAL MONETARY POLICY AND BEYOND

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SPRING 2013

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree in Economics
with honors in Economics

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ABSTRACT

Stagnant economic growth since the Great Recession has led to an important questioning of the Federal Reserve's ability to significantly impact real gross domestic product through monetary policy. To provide insight as to why the Federal Reserve's influence has waned recently, this thesis explores the effectiveness of monetary policy over the last forty years. Utilizing a myriad of analytical methods, I show that monetary policy has become weaker over time, and now has little, if any, influence on real output. By presenting important economic concepts relating to monetary policy from relevant literature, and by conducting a quantitative analysis using ordinary least squares regressions, Granger causality, vector autoregressions, and impulse response functions, this thesis demonstrates the Federal Reserve's lack of influence over the business cycle, and the increasing neutrality of monetary policy.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

It is with immense gratitude that I acknowledge the endless support and help of my thesis supervisor, Dr. Russell Chuderewicz. Without his knowledge, motivation, and insight, this paper would not have been possible. I also wish to thank Dr. David Shapiro for his advice and guidance. I am indebted to my family, including my parents, Geralyn Neely and Jerry Neely for their constant and steadfast encouragement. Finally, I would like to thank all of my classmates and friends. Particularly, I want to recognize and thank Rachel Engard for all of her patience and dedication. I truly could not have written this thesis without her.

Chapter 1

Introduction

During the last half century in the United States, the Federal Reserve has conducted counter-cyclical monetary policy primarily designed to smooth out the business cycle. In recent years, events including the 2008 financial crisis and the Great Recession have led to many questions about the forecasting ability of economists, as well as the power of monetary policy. Citizens have been constantly bombarded by news outlets about economic developments in the past few years, or the lack thereof, and Americans have been looking for an explanation for these poor developments. Experiencing persistent stagnant economic growth and lingering high unemployment rates since 2008, one question in particular stands out as particularly poignant: is monetary policy conducted by the Federal Reserve losing its effectiveness? It is vital to answer this question since we place such a high value on the influence that monetary policy is presumed to have in smoothing out the business cycle.

To attempt to answer this question, this paper explores the effectiveness of monetary policy conducted by the Federal Reserve in influencing real gross domestic product, from 1970 to 2012. Specifically, I am going to investigate the evolution of monetary policies including, but not limited to, the traditional channels of monetary policy as well as the unconventional channels that the Federal Reserve has been using to conduct policy since they hit the "zero lower bound" in December of 2008 (the "zero lower bound" is defined as the event in which the target for federal funds rate includes zero percent). I place specific focus on the events of the last twenty years, including the recent financial crisis, by examining the effects of conventional policies as well as unconventional monetary policies like Quantitative Easing 1, Quantitative Easing 2, and Operation Twist. By examining these results and comparing them to previous Federal Reserve policies, I hope to provide an accurate look at the effectiveness of monetary policy over the last four decades.

With our government debt at an extremely high level, fiscal policy cannot be relied on as it once was as the equal counterpart to monetary policy. Because of this, steering the economy is becoming increasingly difficult, making monetary policy more important than ever in terms of influencing the economy. With such an importance placed on monetary policy, it is vital to look at its effectiveness.

The structure of the paper is as follows: I begin with a literature review, follow that with a presentation of data and methods, next I present my findings in the results section, and finally, I provide a discussion of the results.

To provide a background of economic theory, I begin this analysis by presenting a brief history of two popular schools of economic thought: Classical and Keynesian economics. In terms of economic theory, increased Federal Reserve transparency, the dissolution of menu costs, perfect information with technology, and increased globalization have all contributed to the relevance of the classical model. Using pertinent literature to discuss the traditional view of how monetary policy is supposed to work, I will explain the logic of the transmission mechanism. After covering the beliefs of these two schools of thought, I present some relevant research conducted by Ben Bernanke and Mark Gertler in their paper, “Inside the Black Box: The Credit Channel of Monetary Policy Transmission” (1995).

To begin the data and methods section, I outline the major analytical methods used in this paper, including: ordinary least squares regressions, Granger causality, vector autoregressions, and impulse response functions. In order to demonstrate the validity of these methods, I examine two bivariate relationships: the well-known relationship between consumption and disposable income and an impractical relationship between the percent change in the M1 money supply and the average monthly temperature in New Jersey. In doing this, I can clearly show the soundness of my methodology.

For the results section, I collected a variety of data from the Federal Reserve Economic Database. Using that data, this thesis features constructions of a series of macroeconomic models, in order to create a solid representation of our economy. This paper utilizes methods similar to those used in Bernanke and Gertler's paper. Doing so enables the successful replication and updating of their results. In addition to updating Bernanke and Gertler's results (utilizing vector autoregressions), this paper provides additional and more detailed analysis by including ordinary least squares regressions, impulse response functions, accumulated responses, Granger causality tests, and redundant variable tests. By using these methods, this paper is able to examine the effect monetary policy has had on real GDP over a forty year period. In doing this, I also test the hypothesis that over the past few decades, the Federal Reserve's policy has become increasingly less powerful, and possibly neutral, in impacting real gross domestic product.

Lastly, after the results are presented, I offer a discussion as to the importance of this research, and to offer a more in-depth explanation and interpretation of the results. Here, I present theories to help explain the results, including personal comments, and a summarization of the "conundrum," as detailed by Alan Greenspan.

By examining the relevant economic concepts and literature, and by analyzing the data that I have collected from the Federal Reserve Economic Database, this thesis offers a thorough and insightful look at the effects of both conventional and unconventional monetary policy over the past forty years. By analyzing the data and providing a relevant discussion of the results, I hope to present an astute test of the effectiveness of Federal Reserve policies, and to offer additional pertinent research on this increasingly important topic.

Chapter 2

Literature Review

To preface the data, methods, and results in this paper, I will provide a review of relevant and pertinent literature. In this review, I will begin by providing a brief history of Classical and Keynesian economics. Next, I will present the basic economic models featured in Classical and Keynesian beliefs. In the context of these models and the associated literature, I will discuss the traditional view of how monetary policy is supposed to work (i.e., the transmission mechanism). After this, I will sum up the history of Federal Reserve policy from World War II up until we reached the zero lower bound (ZLB) in December 2008. Finally, this section will also cover the inception of unconventional monetary policy (UMP) as a tool of the Federal Reserve. By presenting these relevant models and literature, I hope to lend credibility and support to my analysis and results.

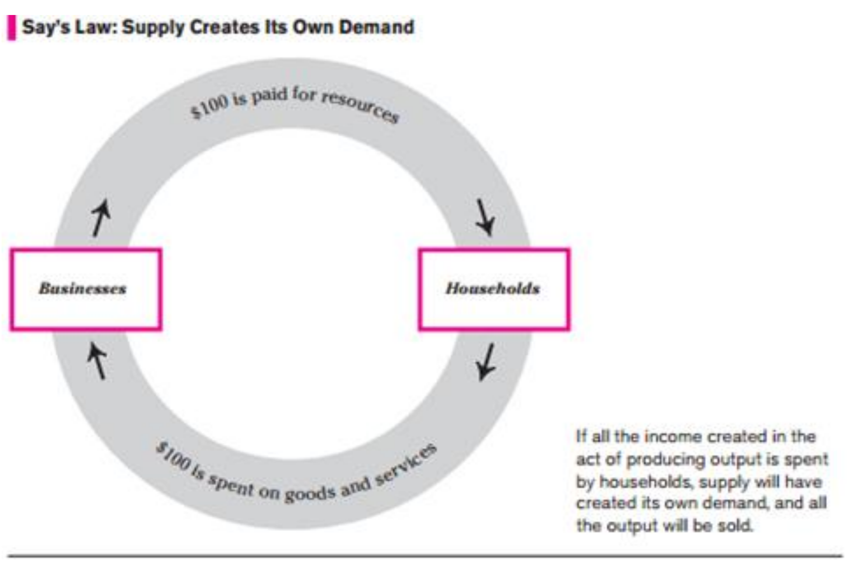
Classical Economics

The Federal Reserve Bank of San Francisco describes the Classical view of economics as one that began in 1776 with the publication of Adam Smith's *The Wealth of Nations* (FRBSF, 2011). In the book, Smith points out labor, land, and capital as the most significant factors of production that contribute to the wealth of a nation. Smith thought that the best economy would incorporate a self-regulating market system that would automatically suit the public's economic needs. This self-regulating aspect of the market system is referred to as an "invisible hand." Smith thought that the invisible hand would lead all self-interested individuals to produce the largest benefit for the nation overall. This laissez-faire approach was almost unanimously held by economists until the Great Depression, and because of this, discretionary fiscal and monetary policy were practically non-existent.

After Smith, David Ricardo and Thomas Robert Malthus made significant contributions to the Classical school of economic theory. Ricardo switched the focus from factors of production to the distribution of income that occurred between workers, landowners, and capitalists. He argued that with a fixed land supply, the growth of a nation's capital and population forced rents up and held wages and profits down. Malthus on the other hand, explained low living standards using the theory of diminishing marginal returns. He also had doubts about the market economy's ability to automatically produce full employment due to too much saving (FRBSF, 2011). The theories of Ricardo and Malthus helped advance the Classical school of thought from Smith's early work.

Along with the above-mentioned economists, J.B. Say provided significant contributions to Classical economics. For many years, Classical economists used a principle known as Say's Law to make forecasts about full employment. Say's Law states that, "Supply creates its own demand," which means that in producing output, businesses will create enough income to ensure that all the output would be sold (Rohlf, 2002, p. 2). See Figure 2.1 below for greater detail.

Figure 2.1:

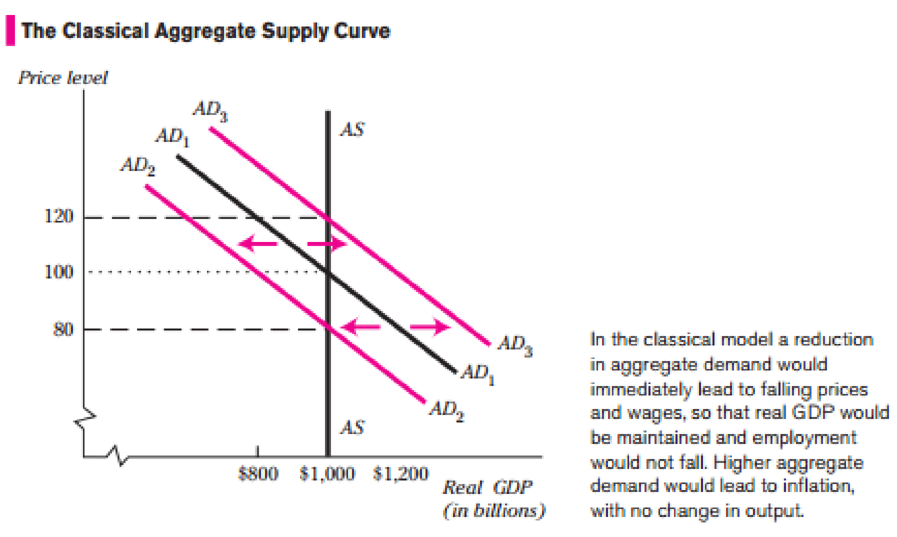


Source: Rohlf (2002)

As shown in Figure 2.1, when businesses create output, they also create income. In turn, this income flows to households in the form of wages, interest, rent, and profits. If the households then spend all received income, all goods produced will be sold. From this, we can see that supply has created its own demand, demonstrating the functionality of Say's Law (Rohlf, 2002, p. 2). Since Classical economists believed Say's Law, they thought that the existence of a fully employed economy was a natural result.

Say's Law and the flexibility of interest rates led Classical economists to believe that spending alone by households and firms would be able maintain full employment. This of course implies that any savings would be used by firms in the form of investment (which would remove money from circulation in Figure 2.1 above). As a solution to this problem, Classical economists assumed that there were perfectly flexible wages and prices along with aggregate demand (AD) and aggregate supply (AS) to guarantee full employment; this implies that all markets clear (Rohlf, 2002, p. 4). This end result therefore implies that the AS curve would be vertical, as in Figure 2.2 below.

Figure 2.2:



Source: Rohlf (2002)

Overall, we can see that the Classical economists thought that changes in AD would only affect the price level and not real GDP, which is consistent with their beliefs about the existence of flexible prices, and with output being determined by the supply side of the economy.

Keynesian Economics

Classical economic theory was the dominant school of thought from 1776 up until the 1930s. The Great Depression worldwide served as the catalyst for the Keynesian Revolution. When it appeared that the laissez-faire approach of the classical economists was ineffective in creating full employment, people were open to new ideas. Keynesian economics was introduced by John Maynard Keynes in the 1930s, and is widely considered one of the most influential economic schools of thought. Not convinced by the conclusions of Classical economics, Keynes conducted research into monetary theory, including discretionary counter-cyclical monetary and fiscal policy. In 1936, he published *The General Theory of Employment, Interest, and Money* (Greenlaw, 2011).

One of the main conclusions Keynes offers in *The General Theory* is that employment is based on aggregate demand (i.e., spending), and not on the price of labor as his Classical counterparts would argue. Unlike Classical economists who believed that the economy was always fully employed, or working towards being fully employed, Keynes argued that equilibria below full employment exist, as long as aggregate supply is equal to aggregate demand. Steve Greenlaw of the University of Mary Washington states the following about Keynes's theory, "Keynes argues that investment need not equal savings, since investment is a function of the expected rate of return as well as the interest rate. An increase in saving may lower the interest rate and provide an incentive for investment to rise, but if the expected rate of return is low investment will not rise in proportion to saving. Consequently, the level of aggregate demand will fall, and the insufficient demand will cause an equilibrium with less than full employment" (Greenlaw, 2011).

With his theory regarding the Marginal Propensity to Consume (MPC), consumption depends greatly on the amount of income an individual possesses. As income increases, so does consumption. Keynes also argues that increases in investment will lead to increases in income. To explain this, Keynes introduces one of the most influential and controversial economic theories, the expenditure multiplier. The following, Equation 2.1, was used in his analysis and looked at the relationship between real GDP (Y), consumption (*C*), investment (*I*), government purchases (*G*), and net exports (*X*).

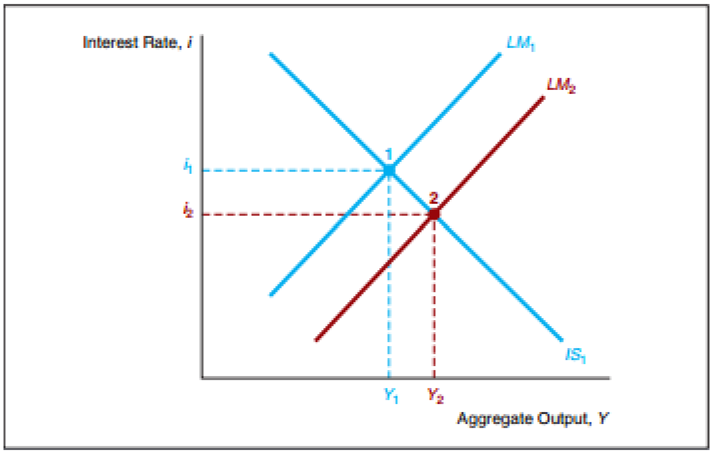
Equation 2.1:

$$Y = C + I + G + X$$

He assumed that in the short run, firms did not change their prices (sticky prices), and they sold the amount equal to the amount demanded. Therefore, the price level is fixed in the short run, and GDP is determined by aggregate demand (Parkin, 2004, p. 193). Michael Parkin states the following about the multiplier in chapter 13 of *Macroeconomics* 7th edition, "An initial increase in autonomous expenditure, such as investment, increases real GDP directly, but that is not the end of the story. The initial increase in real GDP generates an increase in induced expenditure, which further increases real GDP and thus creates further increases in (induced) expenditure. Induced expenditure occurs because the increase in real GDP created by the increase in autonomous expenditure raises disposable income" (Parkin, 2004, p. 193). The belief in Keynes' multiplier is an important piece of Keynesian economics, and is one of the main reasons monetary policy is conducted today.

The Keynesian world view and modern monetary policy are detailed by the Hicksian ISLM model. Introduced by Sir John Hicks in 1937, based off of Keynes' work in *The General Theory of Employment, Interest, and Money*, the ISLM model explains how, given a fixed price level (sticky prices), interest rates and total output produced in an economy are established (Mishkin, 2009, p. 519). By examining the relationship between aggregate demand and aggregate output, the ISLM model has become an influential economic forecasting tool, and can help gauge the effects for both fiscal and monetary policy on aggregate economic activity. A simple demonstration of how a monetary policy shock is represented in the ISLM model is seen in Figure 2.3 below.

Figure 2.3, ISLM Model:



Source: Mishkin (2009)

In this case, we are examining the effect of an increase in the money supply. Increasing the money supply shifts the LM curve down and to the right from LM_1 to LM_2. This in turn lowers the interest rate from i_1 to i_2, and increases aggregate output from Y_1 to Y_2. Increasing the money supply creates an excess supply of money and shifts the LM curve down and to the right. This results in a decline in the interest rate. This decline then leads to a rise in investment spending, consumption, and net exports, which raises aggregate demand and aggregate output. When the economy reaches point 2 on the graph, the excess supply of money is eliminated, and the economy is in equilibrium (Mishkin, 2009, p. 549). In the ISLM model, the Federal Reserve's expansionary monetary policy is successful in improving the overall economy.

The Hicksian ISLM model provides a real world application of Keynesian economics. Motivated by the economic woes of the Great Depression, the Keynesian school of economic thought became increasingly prevalent throughout the 1900s, and remains one of the most popular theories today.

Transmission Mechanisms

Subsequent to the Keynesian revolution, the federal government and the Federal Reserve began conducting discretionary counter-cyclical fiscal and monetary policy in an attempt to smooth the business cycle. Today, the Federal Reserve takes advantage of a variety of transmission mechanisms, including interest rate channels to affect aggregate demand, to influence real economic activity.

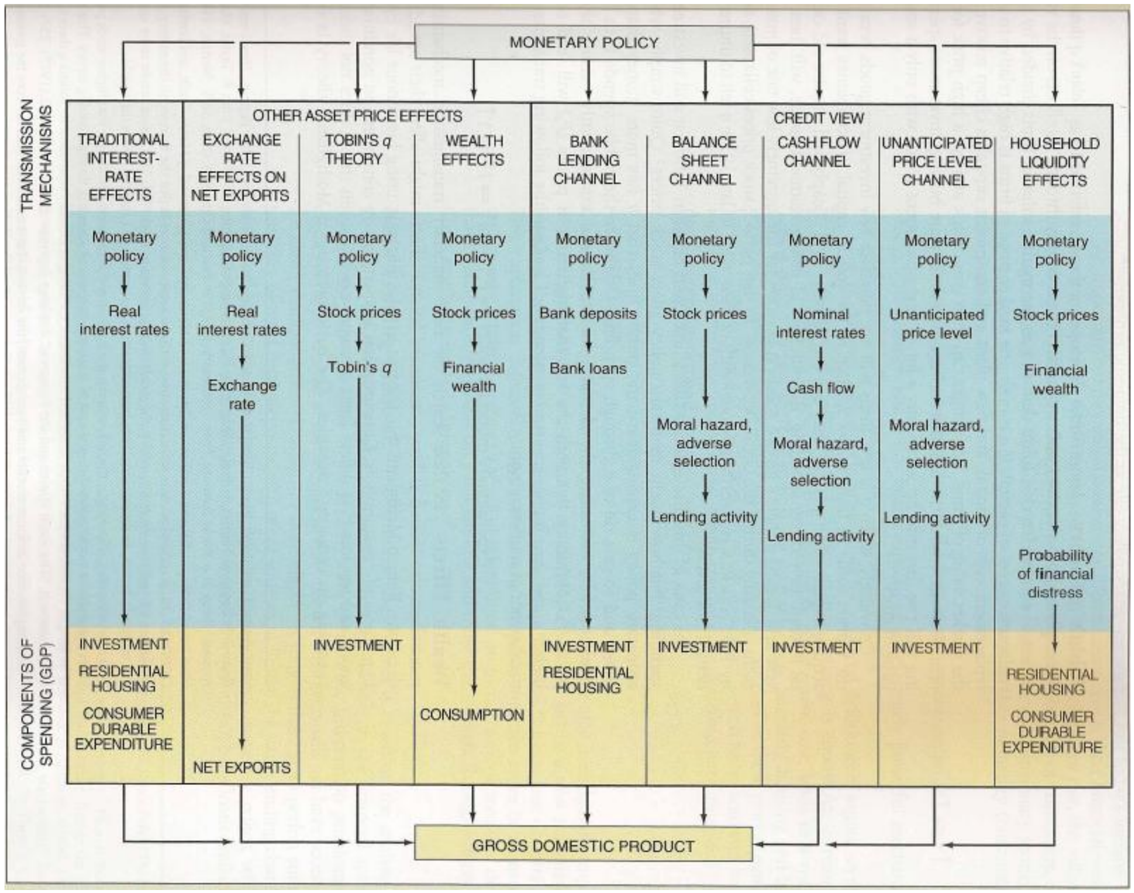
In an attempt to create macroeconomic and financial stability, the Federal Reserve uses the transmission mechanisms to conduct monetary policy. According to Federic Mishkin (2009), the traditional view of how monetary policy is supposed to work is given by the following:

$$\text{Expansionary monetary policy} \rightarrow i_r \downarrow \rightarrow I \uparrow \rightarrow Y \uparrow$$

In this case of expansionary monetary policy, the Federal Reserve uses its most common transmission mechanism, the interest rate channel. By lowering nominal interest rates, the real interest rate falls. This leads to a decrease in the cost of capital, an increase in investment, and an increase in output. This interest rate channel is an example of how counter-cyclical monetary policy is utilized today.

Figure 2.4 below shows a diagram of the traditional view of the functionality of monetary policy. It demonstrates how monetary policy is used through transmission mechanisms to influence GDP.

Figure 2.4, Transmission Mechanisms:



Mishkin (2009)

It is through these channels that monetary policy is supposed to work. The traditional transmission mechanisms have been used to conduct conventional monetary policy from after World War II up until the present. The use of the most popular transmission mechanism, the interest rate channel, arguably began in 1951 with the Fed-Treasury Accord. This agreement allowed for the Federal Reserve to become independent, let them set interest rates as necessary, and freed them from artificially keeping interest rates lower than they ought in order to cheaply finance World War II (Bernanke, 2012, lecture 2). Simply put, this allowed the Federal Reserve to set nominal interest rates at optimal levels, in order to better achieve economic stability (since they were no longer receiving political pressures from the Treasury). Achieving economic stability has been a major concern for the Federal Reserve; because of this, many monetary policies have been conducted to help achieve this goal. For a majority of the 1950s and 1960s the Federal Reserve used a “lean against the wind” policy in an attempt to keep inflation low and economic growth stable. Easy monetary policy in the 1960s and 1970s led to a period known as the Great Inflation. This development led to drastic changes in monetary policy in the late 1970s and throughout 1980s, led by Chairman Paul Volcker. Volcker sought to break the back of inflation by engaging in contractionary monetary policy by setting high interest rates to combat inflation (i.e., leaning against the wind). Under the Volcker chairmanship, and up through 2006 under the Greenspan chairmanship, a time known as the Great Moderation, the Federal Reserve continued to follow this disciplined monetary policy (Bernanke, 2012, lecture 2).

Up until we reached the zero lower bound in 2008, the Federal Reserve conducted conventional monetary policy. The zero lower bound occurs when the federal funds rate reaches a level of zero. Conventional monetary policy is conducted through open market operations, bank reserves, and the federal funds rate. Once the federal funds rate hit zero, the Federal Reserve had to make the transition to unconventional monetary policy. After hitting the zero lower bound, the Federal Reserve could no longer use short-term interest rates (like the federal funds rate) in an attempt to influence long-term interest rates (like the 10-year treasury rate). Instead, they had to target long-term interest rates directly. For the past four years, major unconventional policies including Quantitative Easing 1, Quantitative Easing 2, Operation Twist, and Quantitative Easing 3 have been conducted. With the federal funds rate at zero, the Federal Reserve has been conducting these unconventional policies by buying specified amounts of financial assets and United States treasuries in order to inject a specific amount of money into the economy. Hitting the zero bound forced the Federal Reserve to pursue alternative ways of using the channels of monetary policy; the alternatives were unconventional monetary policy. Said unconventional monetary policies were the first of their kind. Continuing to operate in uncharted waters, so to speak, the Federal Reverse has relied heavily on these unconventional policies recently as influencers of the economy.

Research conducted up until the early 2000s generally seems to show that traditional channels (conventional monetary policies) were effective in influencing GDP. In their 1995 paper "Inside the Black Box: The Credit Channel of Monetary Policy Transmission", current Federal Reserve Chairman Ben Bernanke and Mark Gertler use vector autoregressions (VARs) to evaluate the effectiveness of monetary policy. Bernanke and Gertler set the stage for their analysis by emphasizing the four basic facts about the economy in response to monetary policy.

Fact 1: Unanticipated tightening in monetary policy usually has transitory effects on interest rates. Monetary tightening is followed by sustained declines in price levels and real GDP.

Fact 2: Final demand falls relatively quickly after a change in policy, and production follows final demand downward, but with a lag. Inventory stocks rise in the short run, but ultimately fall. This inventory disinvestment accounts for a sizable fraction of the decline in GDP.

Fact 3: The quickest and largest declines in final demand happen in residential investment. Spending on durable and non-durable consumer goods is close behind.

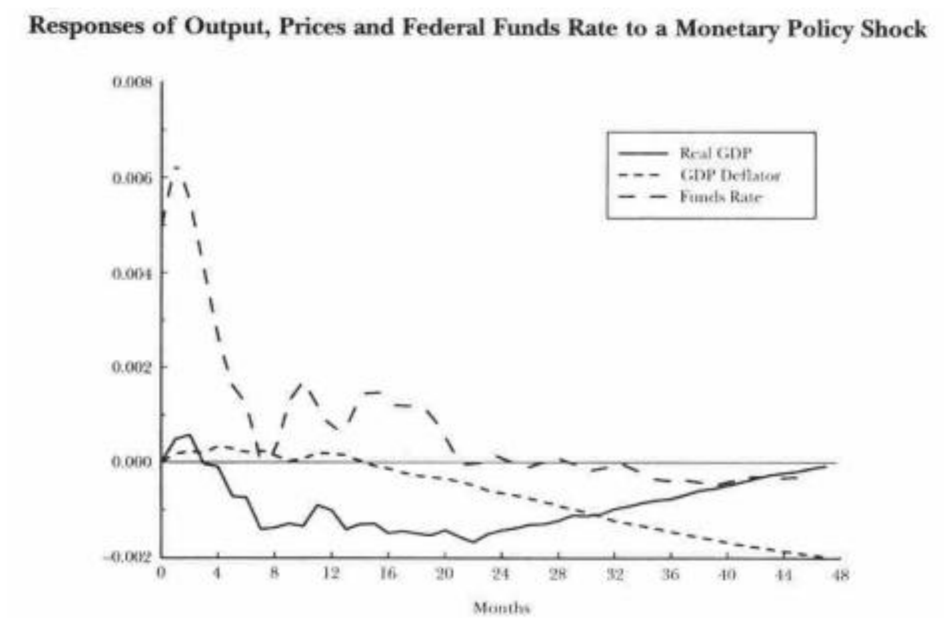
Fact 4: In response to monetary tightening, fixed business investment eventually declines (lagged behind housing, consumer durables, production and interest rates).

Bernanke and Gertler use VARs to show the dynamic responses of various economic aggregates to a shock (an unanticipated tightening in this case) of monetary policy[1]. Figure 2.5 shows a VAR system that includes the log of real GDP, the log of the GDP deflator, the log of an index of commodity prices (included exogenously in the model), and the federal funds rate. Real GDP and the GDP deflator are used as broad measures of economic activity, the commodity price index is included to control for oil price shocks and other supply-side shocks. The

[1]The use of the VARs in economic analysis was pioneer by Sims (1980). For a comprehensive discussion, see Watson (1994).

estimated dynamic responses of the log of real GDP, the log of the GDP deflator, and the federal funds rate to a positive, one-standard deviation shock to the federal funds rate is shown in Figure 2.5 below.

Figure 2.5:



Source: Bernanke, Gertler (1995)

From the figure presented above, Bernanke and Gertler show that GDP declines about four months after a monetary policy tightening, and bottoms out at approximately two years after the tightening. The price level begins to drop well after the decline in GDP begins. Lastly, they show that the federal funds rate begins to fall after three or four months (after rising sharply in the beginning).

The results presented in this figure are consistent with Fact 1 above, and are consistent with Keynesian beliefs; these results are right in line with the Hicksian ISLM model as well. By raising the federal funds rate, the Federal Reserve was able to shift the LM curve up and to the left, which then led to a decrease in aggregate output, or GDP. In this time period[2], the Federal

[2]Similar results are found in an updated data set from 1959 to 2001. For full results, see Bernanke et al. (2003).

Reserve was able to successfully use the interest rate transmission mechanism to influence the economy (real GDP).

After the recent financial crisis, and the conversion from conventional to unconventional monetary policy, the economy is in a different state than it was in the 1990s. This paper will explore whether this same success is possible in today's unconventional economic environment.

Chapter 3

Methodology

To begin, I will explain the methodology I used for my analysis. These methods include ordinary least squares regressions, Granger causality tests, vector autoregressions, and impulse response functions. To demonstrate the validity of these methods, in each section, I will focus on two bivariate relationships: the well-known relationship between consumption and disposable income and an impractical relationship between the percent change in the M1 money supply and the average monthly temperature in New Jersey. The descriptions and results will give us a good feel for how these methodologies work as well as how to interpret the empirical results.

Ordinary Least Squares Regressions

The first statistical method I will use to evaluate my data set is ordinary least squares regression (OLS) analysis. The purpose of OLS is to analyze the relationships among variables in a linear regression model (cmapskm.ihmc.us). By creating a line of best fit, OLS is able to measure the relationship(s) between variables, and is done primarily by finding a line of best fit, defined as a line that minimizes the sum of the squared error terms. The simplest case is a bivariate model, as we use here, where one investigates a very simple hypothesis: if some variable of interest is driven by another variable of interest. For simplicity's sake, let's say these variables are x and y. Letting i serve as the index of observations for the data set (x,y), the standard simple linear regression model is Equation 3.1.

Equation 3.1:

$$y_i = \beta_0 + \beta_1 x_i + \mu_i$$

Where:

β_0 = a constant

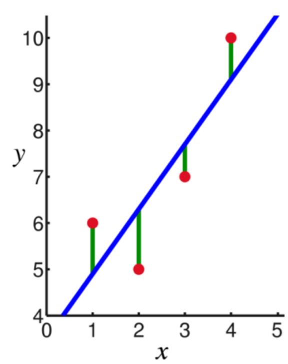
β_1 = the sensitivity parameter measuring how sensitive y_i is to changes in $x_{i,}$, the slope of the regression line.

μ_i = the error term

In this two-variable model, β_0 represents the *y*-intercept, and β_1 represents the slope (Sykes, 1992). By using regression analysis, I can test the impact of one of the variables in my data set, the independent variable x_i, on another, the dependent variable y_i. Incorporating simple and multiple regressions will give me a great starting point for analysis, and assist in accurately interpreting the empirical results.

A line of best fit, as calculated by the OLS method might look like the following:

Figure 3.1, Line of Best Fit:

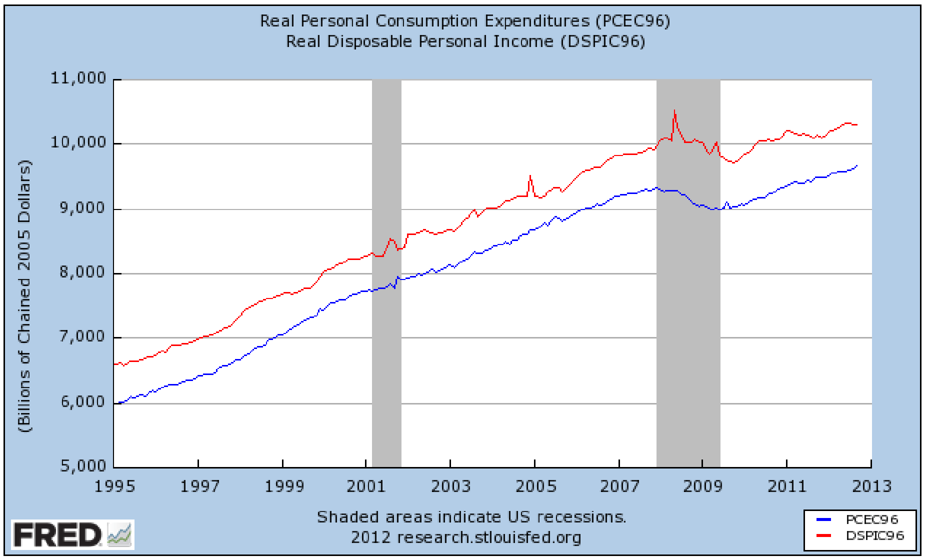


Source: Anh (2009)

As shown in the figure above, the blue line is the line of best fit which satisfies the criterion of minimizing the sum of squared errors. The y-intercept would be β_0, and the slope of the best fit line would be β_1.

To demonstrate the OLS method, let's investigate the relationship between disposable income and consumption. Our priors are that we would think that an increase in disposable income would lead to an increase in consumption. Observe Figure 3.2 below.

Figure 3.2, Consumption and Disposable Income:



Source: Federal Reserve Economic Database (2012)

From the figure above, it is clear that there is a positive relationship between these two variables. To test the sensitivity of levels in disposable income on consumption, I employ the OLS method.

The equation for this model is:

Equation 3.2:

$$C = \beta_0 + \beta_1 Y_D + \mu_i$$

Where:

C = Real Personal Consumption Expenditures

Y_D = Real Disposable Personal Income

OLS yields the following statistics in Table 3.1 below.

Table 3.1, Consumption OLS Results:

Dependent Variable: CONS
Method: Least Squares
Date: 12/02/12 Time: 14:38
Sample: 1970Q1 2009Q4
Included observations: 160

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-394.5989	34.86229	-11.31879	0.0000
PDI(-1)	0.951858	0.005241	181.6015	0.0000

R-squared	0.995232	Mean dependent var	5588.631
Adjusted R-squared	0.995202	S.D. dependent var	2081.025
S.E. of regression	144.1513	Akaike info criterion	12.79203
Sum squared resid	3283177.	Schwarz criterion	12.83046
Log likelihood	-1021.362	Hannan-Quinn criter.	12.80763
F-statistic	32979.11	Durbin-Watson stat	0.334426
Prob(F-statistic)	0.000000		

Table 3.1 above gives us many important statistics for use in explaining the relationships between the two variables[3]. First, the coefficient of 0.951858 for disposable income (PDI(-1)) tells us that if disposable income increases by 1, consumption (*C*) would increase by .951858.

This observation confirms our prior assumption, but how confident are we of this point estimate? To test this, we have to look at the 95% confidence interval. To do this, the coefficient for disposable income is added and subtracted by two times the standard error of the coefficient.

The formula for this particular case would be:

$$0.951858 \pm 2(0.005241)$$

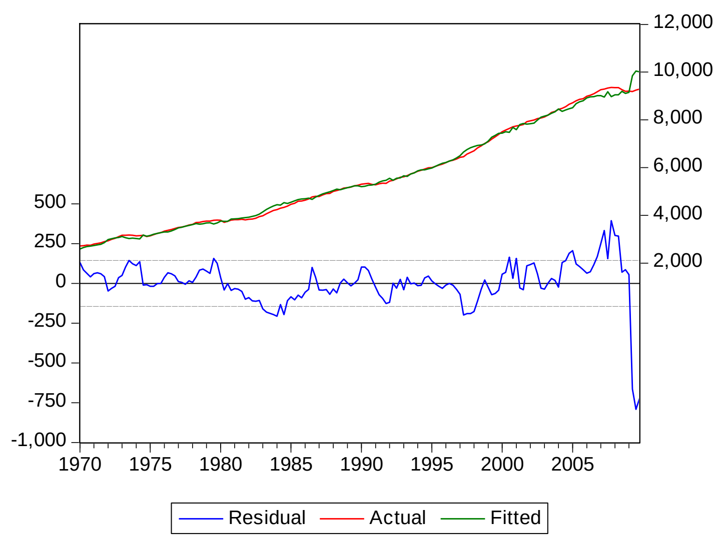
If zero is contained inside this interval, the null hypothesis that changes in disposable income does not have any effect on consumption cannot be rejected. In this particular case though, zero is far from the 95% confidence interval, so the null hypothesis is rejected, and changes in disposable income influence consumption. In particular, we can be 95% confident that the actual coefficient lies between 0.941376 and 0.96234.

[3]This model serves as a very simple analysis, and is used, as well as the models that follow, for expositional purposes only to demonstrate the basic features of OLS. In particular, we found that C and PDI are both non-stationary, so that inferences as to the significance of the coefficient on PDI are unreliable. Upon further testing, we found that PDI and C are co-integrated implying the coefficient on PDI (.951858) is super consistent.

Another equivalent method to support the confidence of the statistics is to examine the t-statistic or t-stat. If the absolute value of the t-stat is less than two, the null hypothesis stated above cannot be rejected. In this case, the t-stat, 181.6015, is very significant and leads to the rejection of the null hypothesis.

One more important statistic to note is the R-squared statistic. The R-squared gives some insight into how good the model fits the data. The value of the R-squared stat always lies between zero and one, with 1 being a perfect fit, and zero being no fit at all. Naturally, a value closer to one suggests that the model fits the data well. So in general, the higher the R-squared, the better the model fits the data. In the table above the R-squared is equal to 0.995232. From this number, we can argue that the model predicting consumption with disposable income fits the data extremely well (as seen in the figure below). Note how hard it is in Figure 3.3 to distinguish between the actual value of consumption (the red line) and the value of consumption fitted from our bivariate OLS regression.

Figure 3.3, Consumption OLS Regression:



In order to further demonstrate the functionality of these methods, I tested the relationship between two seemingly unrelated variables: the percent change in the M1 money supply (PCM1) and the average monthly temperature of New Jersey (NJTEMP). The prior is that there should be no relationship between these two variables, but to ensure the validity of my tests, I used the statistical techniques I defined above to verify the relationship, or lack thereof, between PCM1 and NJTEMP.

I began my analysis by utilizing the OLS method. The equation for this model is:

Equation 3.3:

$$NJTEMP = \beta_0 + \beta_1 PCM1 + \mu_i$$

The results of the OLS method are listed in Table 3.2 below.

Table 3.2, NJTEMP OLS Results:

Dependent Variable: NJTEMP
Method: Least Squares
Date: 10/31/12 Time: 14:47
Sample (adjusted): 1960M02 2012M09
Included observations: 632 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	52.71817	0.974380	54.10430	0.0000
PCM1(-1)	0.033448	0.136547	0.244953	0.8066

R-squared	0.000095	Mean dependent var	52.90142
Adjusted R-squared	-0.001492	S.D. dependent var	15.68255
S.E. of regression	15.69424	Akaike info criterion	8.347625
Sum squared resid	155174.9	Schwarz criterion	8.361704
Log likelihood	-2635.849	Hannan-Quinn criter.	8.353093
F-statistic	0.060002	Durbin-Watson stat	0.315258
Prob(F-statistic)	0.806572		

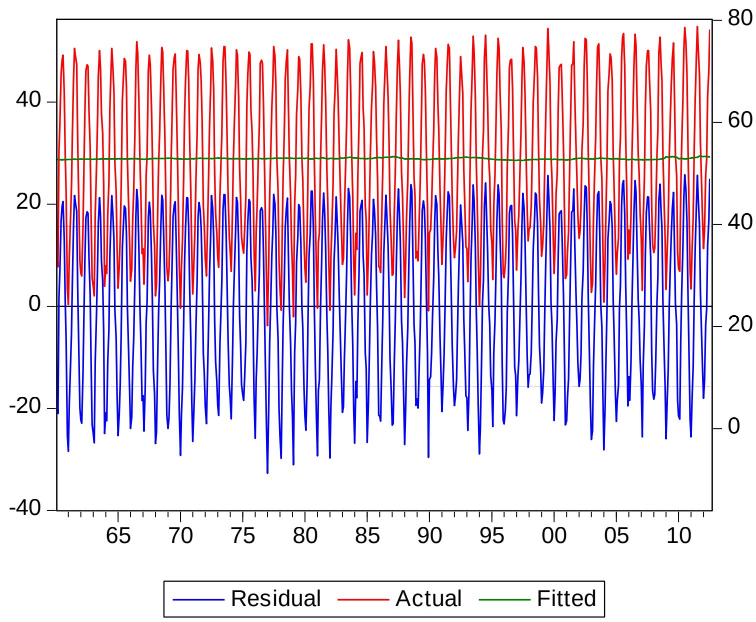
First, the coefficient for PCM1(-1) is 0.033448. This suggests that increases in PCM1 have a positive effect on NJTEMP. But, is this result statistically significant? To explore, we use the standard error and t-stats. Using the coefficient and its standard error, we can examine the 95% confidence interval.

$$0.033448 \pm 2(0.136547)$$

In this case, zero is clearly contained within the 95% confidence interval. Therefore, the null hypothesis that changes in PCM1 do not have any effect on NJTEMP cannot be rejected. It can thus be inferred that these two variables do not share a statistically significant relationship.

To further examine this inference using OLS, we can observe the t-stat and the R-squared. 0.244953, the t-stat in this analysis, is much less in absolute value than the critical number 2. This of course confirms that the null hypothesis of a zero coefficient cannot be rejected. The R-squared (0.000095) is extremely low signifying consistency with the above results. This number is very close to zero, which means that PCM1 has almost no power in helping to predict NJTEMP. This poor fitting model was expected and can be seen in Figure 3.4 below where the predicted (fitted) value is the relatively constant green line.

Figure 3.4, PCM1 and NJTEMP OLS Regression:



Granger Causality

Another methodology that I use is called Granger causality. This is a methodology that utilizes OLS and is typically used to determine timing and information content amongst two variables. Granger causality is not and cannot be used to assess whether or not one variable causes another. The null hypothesis for all Granger causality tests is that *x* does not Granger cause *y*, or that *y* does not Granger cause *x*. For example, using the consumption and disposable income example above, we could use Granger causality to test whether changes in Y_D precede changes in *C* or the other way around. In the *C* and Y_D example, the null hypothesis would be either, Y_D does not Granger cause *C*, or *C* does not Granger cause Y_D. The general form of the bivariate regressions that are ran for the Granger causality tests are shown below in Equations 3.4 and 3.5:

Equations 3.4 and 3.5:

$$3.4: x_t = \alpha_0 + \alpha_1 x_{t-1} + \ldots + \alpha_l x_{t-1} + \beta_1 y_{t-1} + \ldots + \beta_l y_{-1} + \mu_t$$

$$3.5: y_t = \Omega_0 + \Omega_1 y_{t-1} + \ldots + \Omega_l y_{t-1} + £_1 x_{t-1} + \ldots + £_l x_{-1} + \varepsilon_t$$

The way this analysis is approached is what makes it stand out. Examining the relationship between two variables, *x* and *y*, the Granger method tests if *y* Granger causes *x* by looking at how much of the current *x* can be explained by previous values of *x* (i.e., lagged values of *x*, x_{t-1}). It then checks to see if the addition of lagged *y* values contains additional information over and above the information already included in the lagged values of *x*. If *y* is found to help predict *x*, then we reject the null hypothesis that *y* does not Granger cause *x*. Put simply, *y* is Granger causal for *x* if *y* helps predict *x* sometime in the future (Sorensen, 2005).

An important component of the Granger Causality test is the F-statistic. The F-statistic is the value resulting from standard Analysis of Variance (ANOVA) and regression analysis. This value is used to determine if the variances between the means of two variables are significantly different (Hennekens, 1987). It is by examining the F-statistic that we can interpret the results of the Granger causality test. Put differently, the F-test compares the residual sum of squares without the *x* variables, to the residual some of squares with the *x* variables. The null hypothesis is that there is no explanatory power jointly added by the *x* variables.

EViews, the statistical program that I will use to analyze the data, estimates the bivariate regressions presented in Equations 3.4 and 3.5. In the case of the consumption and disposable income example above, *C* would be used in place of x_t, and Y_D would be used in place of y_t. These are run for all possible pairs of *x* and *y* series in the group (EViews User Guide, 425). The results of the Granger causality test for consumption and disposable income are below in Table 3.3.

Table 3.3, CONS and PDI Granger Causality Results:

Pairwise Granger Causality Tests
Date: 12/02/12 Time: 14:17
Sample: 1970Q1 2009Q4
Lags: 12

Null Hypothesis:	Obs	F-Statistic	Prob.
CONS does not Granger Cause PDI	160	0.92147	0.5276
PDI does not Granger Cause CONS		5.22012	4.E-07

Clearly, in this case, the null hypothesis that consumption (CONS) does not Granger cause personal disposable income (PDI) is not rejected due to the values of the F-statistic and the probability. In addition, the results indicate that we reject the null hypothesis that disposable income does not Granger cause consumption. These results are expected since our prior was that higher disposable income today will result in higher consumption in the future but not the other way around (consistent with the results above).

To further validate this method, I conducted Granger causality tests on the impractical relationship between PCM1 and NJTEMP. The test's results are as follows in Table 3.4.

Table 3.4, NJTEMP and PCM1 Granger Causality Results:

Pairwise Granger Causality Tests
Date: 10/24/12 Time: 19:47
Sample: 1948M01 2013M08
Lags: 6

Null Hypothesis:	Obs	F-Statistic	Prob.
NJTEMP does not Granger Cause PCM1	627	0.49620	0.8114
PCM1 does not Granger Cause NJTEMP		0.56803	0.7559

Our priors are that neither variable Granger causes the other. The results confirm our priors in that the F-statistics and probabilities are consistent with failing to reject that neither variable Granger causes the other. Knowing that neither variable Granger causes the other adds even more validity to the analysis.

By using the Granger causality approach, I can establish a relationship and test the significance between two variables. This in turn can create the foundation of my next analysis method: the vector autoregression model.

Vector Autoregression Model

Another method that I use to analyze my data set is vector autoregression analysis, or more commonly, VAR. VAR models are very common in economic analysis since they tend to be very successful and easily model analyses of multivariate time series. In particular, "The VAR model has proven to be especially useful for describing dynamic behavior of economic and financial time series and for forecasting. It often provides superior forecasts to those from univariate time series models and elaborate theory-based simultaneous equations models" (Zivot and Wang, 2003). It is because of these specific qualities that the VAR method is heavily used in my analysis.

The VAR is often used as a forecasting system of interrelated time series. It is also used to analyze the effect of random changes (shocks) on the variables in the system. By using the

VAR method, I can avoid structural modeling, since every endogenous variable in the equation is treated as a function of the lagged values of every endogenous variable in the system. (EViews User Guide, 347). A representative mathematical representation of a VAR is below in equation 3.6:

Equation 3.6:

$$X_t = c_0 + C_1 X_{t-1} + ... + C_p X_{t-p} + D_{yt} + U_t$$

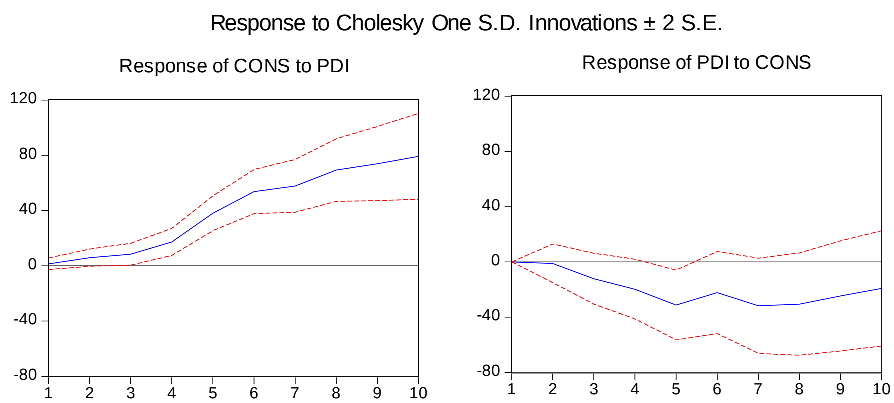
In the equation above, X_t is a *k* vector of endogenous variables, and y_t is a *d* vector of exogenous variables. $C_1, \ldots, C_p$ and *D* are matrices of coefficients to be estimated, and U_t is the error term (i.e., U_t is uncorrelated with the both the variables on the right-hand side of the equation, and with the lagged variables. But, it may be contemporaneously correlated).

Impulse Response Function

Included in VAR analysis are impulse response functions. Impulse response functions map the impact of a shock to a single endogenous variable on itself and all the other variables in the VAR. A shock to the *n*-th variable of an equation influences said *n*-th variable as well as possibly every other endogenous variable through the lag structure in the VAR. The purpose of the impulse response function is to measure the effect of this shock on both the current and future values of the endogenous variables (EViews User Guide, 355).

Running a VAR with consumption and disposable income yields the following impulse response functions, as seen in Figure 3.5. In all subsequent impulse response functions, the vertical axis represents the amount significantly above or below the impulse’s baseline value, and the horizontal axis represents periods.

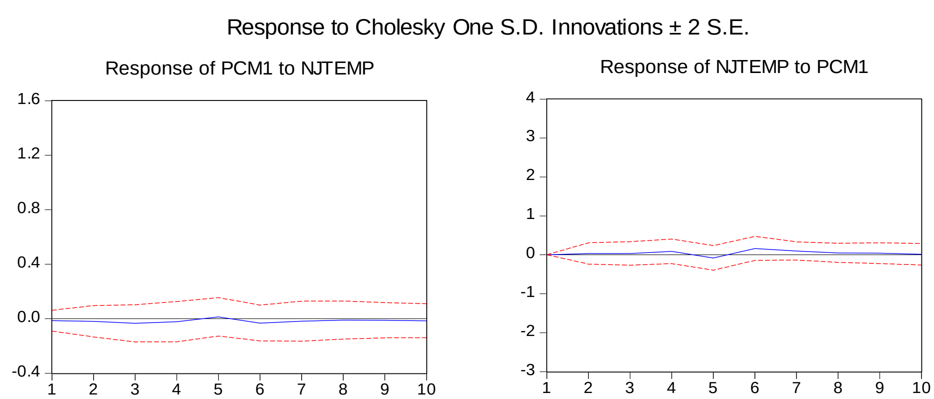
Figure 3.5:



The left hand side graphic depicts the response of consumption (CONS) to a one standard deviation (positive) shock to personal disposable income (PDI). As we can observe in the graphic, a positive shock on disposable income leads to an increase in consumption, but not the other way around. This result confirms my prior.

In addition, I ran a VAR with the variables PCM1 and NJTEMP. The prior of course is that a shock to either variable should not cause a significant response in the other since the two variables are most likely unrelated. The impulse response functions are shown in Figure 3.6.

Figure 3.6:



In viewing the impulse response functions, it is clear that zero is completely contained within the 95% confidence interval (the red dotted lines in graphic). The results are consistent with and confirm the initial hypothesis that there is not any relationship between these two variables.

Examining the above relationships using the OLS method, Granger causality, VARs, and impulse response functions has confirmed the initial assumption that PCM1 does not have any effect on NJTEMP and vice versa. By analyzing the relationship between consumption and disposable income and the relationship (or lack thereof) between PCM1 and NJTEMP, I have demonstrated the validity of my analytical/statistical techniques. Given the intuitive, valid, and legitimate results, I will employ these same techniques to examine the effectiveness of monetary policy.

Chapter 4

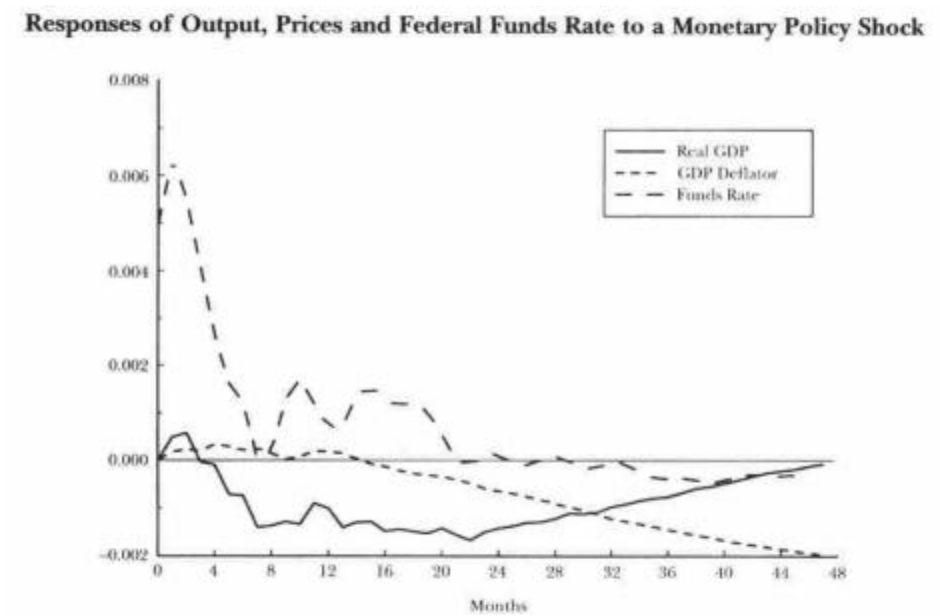
Empirical Results

To begin my analysis of the effectiveness of monetary policy, I employ the same techniques that I outlined above in the methods section, i.e., OLS, Granger causality, VARs, and impulse response functions. By using these methods to examine monetary policy over two time periods (1970q1 to 1993q4 and 1994q1 to 2012q2), I can compare and contrast the effectiveness of monetary policy over time. Though the time periods might seem peculiar, I selected these particular periods because the first period was analyzed in Ben Bernanke and Mark Gertler's paper, "Inside the Black Box: The Credit Channel of Monetary Policy Transmission" (1995). The second allows for an examination of a recent history of economic activity over a similar time frame.

Bernanke and Gertler Results: Replicated and Updated

I began by reproducing the results of Ben Bernanke and Mark Gertler's paper, "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." Incorporating a similar data set (the log of real GDP, the log of the GDP deflator, the log of an index of commodity prices, and the federal funds rate) as in Bernanke and Gertler's paper, I estimate a VAR system and depict the estimated dynamic responses of the log of real GDP (LRGDP), the log of the GDP deflator (LGDPDEF), and the federal funds rate (FF) to a positive, one-standard-deviation shock to the federal funds rate. I utilize quarterly data, given that GDP data is quarterly. My results, as well as Bernanke and Gertler's, are displayed below. Bernanke and Gertler's results are shown in Figure 4.1.

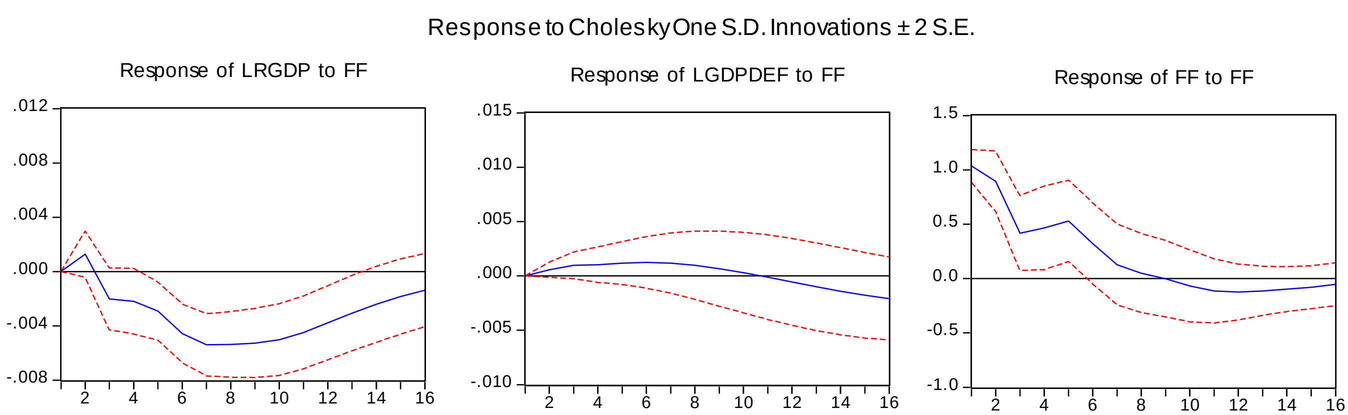
Figure 4.1:



Source: Bernanke and Gertler (1995)

Figure 4.2: Replication of Bernanke and Gertler's results in separate graphs, 1970q1 to 1993q4.

Figure 4.2, Replication of Bernanke and Gertler Results:



When comparing the replicated results to Bernanke and Gertler's original results, we can see almost identical outcomes. Looking at the left hand panel of Figure 4.2 above, we can observe that LRGDP (within the red-dotted line representing the 95% confidence interval) responds as we would expect to an increase in the federal funds rate; in particular, following a six month lag (two quarters), LRGDP begins to fall, and after two years, it begins to level out and eventually returns to its original level. My results are virtually identical to Bernanke and Gertler's results, and with the traditional expectations of monetary policy, including the effectiveness lag in policy, which states that policy has real effects in the short-run (non-neutral) but is neutral in the long-run. These results show that from the period of 1970 to 1993, monetary policy was effective, in the sense that it had a measurable impact on real GDP.

Since the publication of Bernanke and Gertler's paper, the methods of analyzing time series data have become more sophisticated. In particular, when conducting time series analysis, one must test the variables used in the analysis for stationarity. "A stationary time series is one whose statistical properties such as mean, variance, autocorrelation, etc. are all constant over time" ("Stationarity and Differencing," 2005). All of the variables used in Bernanke and Gertler's analysis are non-stationary, a typical result when using macroeconomic time series variables. These non-stationary variables are a significant concern when it comes to time series analysis in economics. The unit root test tests the stationarity of variables (see appendix A for more detailed information). To address the problem, it is common to first difference the non-stationary variables, and then re-test for unit roots. First differencing resulted in stationary time series, and therefore, in subsequent analyses, the difference of each variable is taken.

Ordinary Least Squares Regressions

I began my analysis by employing the OLS method to look at the effect that changes in the difference of the federal funds rate (monetary policy) had on the growth of real gross domestic product over time. The following regression was employed (Equation 4.1).

Equation 4.1:

$$DLRGDP = \alpha_0 + \sum_{i=1}^{4} \beta_i DLRGDP_{t-i} + \sum_{i=1}^{4} \gamma_i DFF_{t-i} + \sum_{i=1}^{4} \theta i DLGDPDEF_{t-i} +$$

$$\sum_{i=1}^{4} \tau i DLOIL_{t-i} + \mu_i$$

Where: *DLRGDP* = the Difference of the Log of Real GDP

DFF = the Difference of the Federal Funds Rate

DLGDPDEF = the Difference of the Log of the GDP Deflator

DLOIL = the Difference of the Log of Oil Prices

In this model, the difference of the log of real GDP and the difference of the log of the GDP deflator are used as broad measures of economic activity. The difference of the log of oil prices is included to control for various supply-side shocks.

OLS yields the following statistics, which are displayed in Table 4.1:

Table 4.1, DLRGDP OLS Results, First Sample:

Dependent Variable: DLRGDP
Method: Least Squares
Date: 01/23/13 Time: 15:52
Sample: 1970Q1 1993Q4
Included observations: 96

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001327	0.003695	0.359117	0.7205
DLRGDP(-1)	0.188681	0.109739	1.719372	0.0895
DLRGDP(-2)	0.124811	0.116959	1.067138	0.2892
DLRGDP(-3)	0.136028	0.115604	1.176670	0.2429
DLRGDP(-4)	0.131074	0.114344	1.146312	0.2551
DFF(-1)	0.000440	0.000859	0.512444	0.6098
DFF(-2)	-0.004053	0.000841	-4.818581	0.0000
DFF(-3)	-2.98E-07	0.000946	-0.000315	0.9997
DFF(-4)	-0.002043	0.000877	-2.330010	0.0224
DLOIL(-1)	-0.004407	0.006624	-0.665316	0.5078
DLOIL(-2)	-0.005539	0.006794	-0.815332	0.4173
DLOIL(-3)	0.002068	0.006832	0.302661	0.7629
DLOIL(-4)	-0.006373	0.006963	-0.915265	0.3628
DLGDPDEF(-1)	0.221985	0.301377	0.736571	0.4636
DLGDPDEF(-2)	0.162008	0.323648	0.500567	0.6181
DLGDPDEF(-3)	-0.358349	0.324668	-1.103740	0.2731
DLGDPDEF(-4)	0.122979	0.290932	0.422706	0.6737

R-squared	0.360938	Mean dependent var	0.007363
Adjusted R-squared	0.231508	S.D. dependent var	0.009754
S.E. of regression	0.008551	Akaike info criterion	-6.526329
Sum squared resid	0.005776	Schwarz criterion	-6.072226
Log likelihood	330.2638	Hannan-Quinn criter.	-6.342773
F-statistic	2.788671	Durbin-Watson stat	2.070415
Prob(F-statistic)	0.001355		

In the first sample period, we can observe some interesting statistics from the table above. When examining the 4 lagged coefficients of DFF, we can see that there are two with significant t-statistics, DFF(-2) and DFF(-4). Both of these t-stats are negative, indicating that real GDP growth and the difference of the federal funds rate share a negative relationship, consistent with economic theory.

To examine whether or not DFF belongs in the model, I ran a redundant variable test with the null hypothesis being that the four coefficients on DFF jointly equal zero. The redundant variable test compares the residual sum of squares without the DFF variables, to the residual sum of squares with the DFF variables. Put differently, the null hypothesis is that there is no explanatory power jointly added by the DFF variables (i.e., that DFF variables are redundant). A redundant variable test was run on DFF(-1), DFF(-2), DFF(-3), and DFF(-4), from 1970q1 to 1993q2. The OLS results for this test are displayed below in Table 4.2.

Table 4.2, DFF Redundant Variable Test, First Sample:

Redundant Variables: DFF(-1) DFF(-2) DFF(-3) DFF(-4)

F-statistic	6.114091	Prob. F(4,79)	0.0002
Log likelihood ratio	25.89140	Prob. Chi-Square(4)	0.0000

Here, by observing the low probability of 0.0002, we reject at extremely high levels, the null hypothesis that all coefficients (on DFF) are equal to zero. This suggests that DFF contains useful information in terms of explaining the variation in real GDP growth, over and above the information that is included in all the other lagged independent variables.

For comparison, I ran the exact same OLS regressions in the time period from 1994q1 to 2012q2. These results can be seen in Table 4.3 below.

Table 4.3, DLRGDP OLS Results, Second Sample:

Dependent Variable: DLRGDP
Method: Least Squares
Date: 01/23/13 Time: 15:59
Sample (adjusted): 1994Q1 2012Q2
Included observations: 74 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005683	0.003036	1.871827	0.0664
DLRGDP(-1)	0.321642	0.146306	2.198418	0.0320
DLRGDP(-2)	0.235950	0.148241	1.591663	0.1170
DLRGDP(-3)	-0.094955	0.144853	-0.655531	0.5148
DLRGDP(-4)	0.122201	0.137851	0.886473	0.3791
DFF(-1)	-0.000838	0.002516	-0.332947	0.7404
DFF(-2)	0.002771	0.002863	0.967942	0.3372
DFF(-3)	0.002694	0.002892	0.931832	0.3554
DFF(-4)	-0.001560	0.002597	-0.600838	0.5503
DLOIL(-1)	-0.003787	0.006211	-0.609746	0.5445
DLOIL(-2)	-0.005589	0.006632	-0.842720	0.4029
DLOIL(-3)	-0.013587	0.006538	-2.078122	0.0422
DLOIL(-4)	-0.002079	0.006393	-0.325199	0.7462
DLGDPDEF(-1)	0.258179	0.431111	0.598868	0.5516
DLGDPDEF(-2)	-0.094742	0.445247	-0.212786	0.8323
DLGDPDEF(-3)	-0.305822	0.419925	-0.728277	0.4694
DLGDPDEF(-4)	-0.352782	0.413820	-0.852501	0.3975

R-squared	0.425989	Mean dependent var	0.006101
Adjusted R-squared	0.264863	S.D. dependent var	0.006636
S.E. of regression	0.005690	Akaike info criterion	-7.301844
Sum squared resid	0.001845	Schwarz criterion	-6.772532
Log likelihood	287.1682	Hannan-Quinn criter.	-7.090695
F-statistic	2.643829	Durbin-Watson stat	1.935187
Prob(F-statistic)	0.003665		

This second time period yields very different OLS results. Focusing on the parameter estimates on the four lagged DFF variables, we observe that none of the four coefficients are significantly different from zero given that all the t-statistics are less than two in absolute value. To investigate further, I employ the same redundant variable test as in the earlier time period. The results for the period from 1994q1 to 2012q2 are observable in Table 4.4.

Table 4.4, DFF Redundant Variable Test, Second Sample:

Redundant Variables: DFF(-1) DFF(-2) DFF(-3) DFF(-4)

F-statistic	1.071904	Prob. F(4,57)	0.3789
Log likelihood ratio	5.366965	Prob. Chi-Square(4)	0.2517

Recall that the null hypothesis is that all the DFF coefficients are jointly equal to zero. The probability of 0.3789 leads to the failure of the rejection of the null hypothesis. This means that in the period from 1994q1 to 2012q2, all four DFF variables can be considered redundant variables, a result clearly opposite of the results in the earlier "Bernanke and Gertler" time period. The implication is clear: DFF contains useful explanatory power in the earlier sample period, but lost its information content in the latter sample period.

Granger Causality

To investigate further, I employed bivariate Granger causality tests on the variables DFF and DLRGDP over both sample periods. The results of the test from the first time period are below in Table 4.5.

Table 4.5, DFF and DLRGDP Granger Causality Results, First Sample:

Pairwise Granger Causality Tests
Date: 01/23/13 Time: 16:03
Sample: 1970Q1 1993Q4
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
DFF does not Granger Cause DLRGDP	96	7.89006	2.E-05
DLRGDP does not Granger Cause DFF		3.54915	0.0099

From 1970q1 to 1993q4, the observable results are consistent with the traditional beliefs of monetary policy. In this period, we reject both null hypotheses at very high significance levels. By looking at the values associated with the F-statistic and probability, it is clear that the null hypothesis that DFF does not Granger cause DLRGDP is rejected. The same is true for the second null hypothesis, DLRGDP does not Granger cause DFF. By rejecting both of these null hypotheses we can see that the difference of the federal funds rate had a significant influence on real GDP growth, and vice-versa, consistent with the redundant variable results in the previous section.

We now update the sample, and perform the exact same methodology on the time period of 1994q1 to 2012q2. The results of this test are seen in Table 4.6.

Table 4.6 DFF and DLRGDP Granger Causality Results, Second Sample:

Pairwise Granger Causality Tests
Date: 01/23/13 Time: 16:04
Sample: 1994Q1 2012Q2
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
DFF does not Granger Cause DLRGDP	74	0.43760	0.7810
DLRGDP does not Granger Cause DFF		1.12263	0.3536

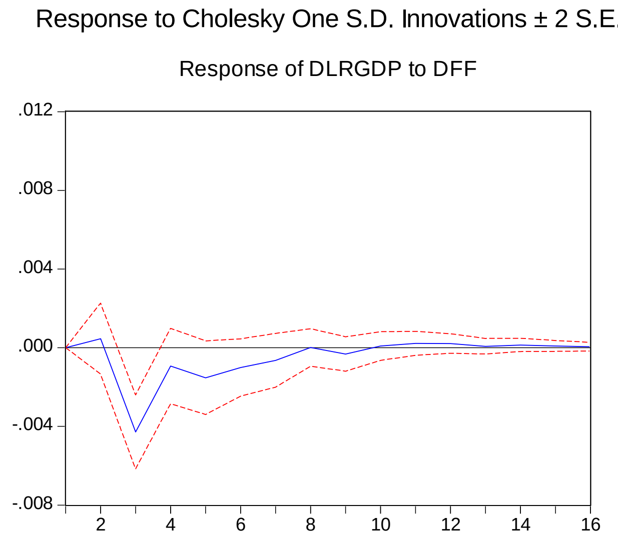
Casual observation of Table 4.6 reveals dramatically different results relative to the earlier sample period. These tests lead to the conclusion that DFF does not have a significant impact on DLRGDP in this time period. In particular, we fail to reject the null hypothesis that DFF does not Granger cause real GDP growth at very high confidence levels, consistent with the notion that DFF has lost its information content in the latter period.

Vector Autoregression Model

For the final analysis, I ran VARs to determine the impact of DFF on DLRGDP. Following Bernanke and Gertler, in this model, DLRGDP, DLGDPDEF, and DFF are included as endogenous variables with four lags, and DLOIL is included as an exogenous variable (note that we use the differences of these variables to avoid the econometric problems associated with non-stationary time series). The impulse response function of this VAR for the period of 1970q1 to

1993q4 is shown in Figure 4.3 below. In this figure, and in all subsequent impulse response functions, the horizontal axis will represent quarters.

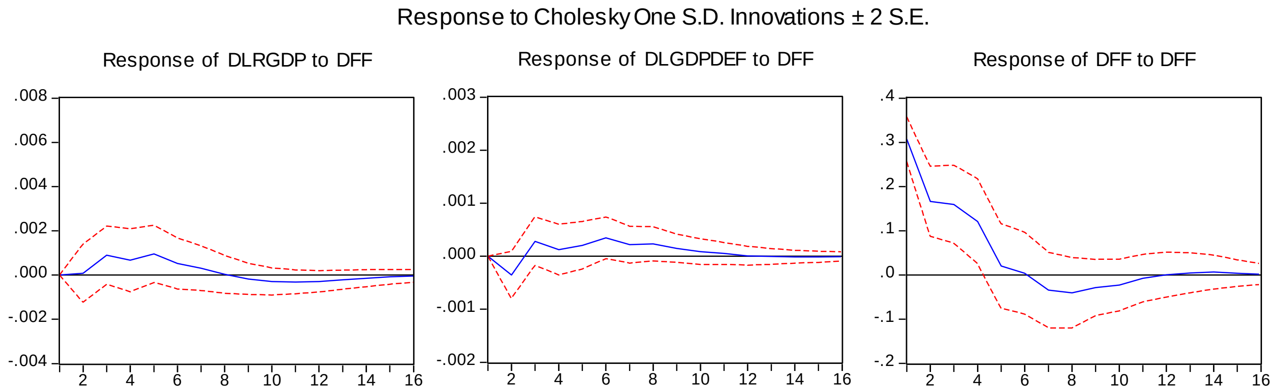
Figure 4.3:



As evident in the figure displaying the response of DLRGDP to DFF, real GDP growth is lowered as a result of the positive shock to the difference of the federal funds rate. In this period, DLRGDP's reaction to a positive shock to DFF is as traditional expectations would predict: DLRGDP falls after a six month lag (two quarters), and it returns to its original level after approximately two years. This shows that in the period from 1970q1 to 1993q4, monetary policy, as defined as shocks to DFF, had a measurable effect on influencing real GDP growth, consistent with our previous results.

Updating the data set to a time period from 1994q1 to 2012q2 alters these results dramatically. Using methods identical to those used above, I created VARs, and ran impulse response functions with the updated data set. Figure 4.4 shows the results from 1994q1 to 2012q2.

Figure 4.4, 1994q1 to 2012q2 Impulse Response Functions:

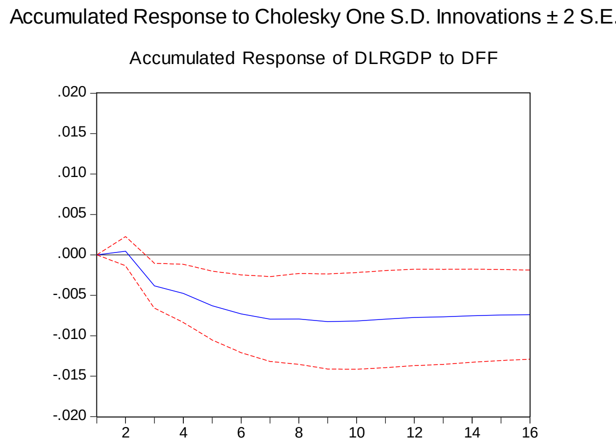


Focusing on the left hand panel, the results, again, are completely different than the results found in the 1970q1 to 1993q4 period. We no longer observe DLRGDP reacting to a positive one standard deviation shock to DFF. Not only has the six month policy lag disappeared, but we fail to see any significant effect on DLRGDP at all. By examining the figures above, we can see that positively shocking the difference of the federal funds rate is not effective in lowering real GDP growth, because zero is completely contained within the 95 percent confidence interval throughout the response period. These results further confirm my hypothesis that monetary policy conducted by the Federal Reserve is becoming less effective, perhaps even neutral.

Accumulated Response Results

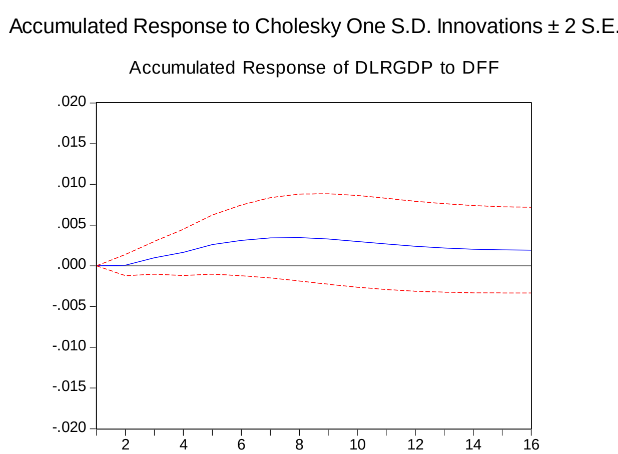
To demonstrate the robustness of these findings, in addition to standard impulse response functions, I include accumulated impulse response functions. An accumulated response shows the sum of all the impulse responses, and when employing accumulated response functions on growth variables, as we do here, they measure the influence on the level of the growth variable, in this case, the level of real GDP. In Figure 4.5, we can observe the accumulated response of DLRGDP to DFF from 1970q1 to 1993q4. Again, the horizontal axis of all accumulated response functions will be in terms of quarters.

Figure 4.5, First Sample Accumulated Response of DLRGDP to DFF:



In this period, the accumulated response of DLRGDP to DFF shows how over every period, positive shocks to the difference of the federal funds rate cause the level of real GDP growth to fall over time. As we can see in Figure 4.5, a one standard deviation shock to DFF lowers the level of real GDP growth significantly, and for a relatively long period (at least 16 quarters). This is consistent with the results above. Using this same methodology, we can examine how these responses change. The accumulated response from 1994q1 to 2012q2 is displayed in Figure 4.6.

Figure 4.6, Second Sample Accumulated Response of DLRGDP to DFF:



Again, the results in the second sample are dramatically different from those in the first sample. In particular, when examining DFF in each period, zero is completely contained within the 95 percent confidence interval. In this, we fail to see a significant change in the level of real GDP growth after one standard deviation period shocks to the difference of the federal funds rate. These findings further confirm the results of the previous section.

By using VARs and impulse response functions to replicate, update, and expand upon the results presented in Bernanke and Gertler's "Inside the Black Box: The Credit Channel of Monetary Policy Transmission," our results clearly indicate that the effectiveness of monetary policy, as measured by changes in the difference of the federal funds rate, has become impossible to detect in the second period. Utilizing the same methodology in two distinct time periods, 1970q1 to 1993q4 and 1994q1 to 2012q2, we discover two very different sets of results: monetary policy works as traditionally expected in the first time period, but in the second time period, policy is much less effective, and is in fact almost neutral.

Chapter 5

Discussion

In the empirical results section, we observe two very different sets of results over the last forty plus years. In the first period, from 1970q1 to 1993q4, monetary policy follows the expectations of traditional theory, which state that changes in monetary policy affect real GDP, with a lag, with the effects being short-run (they eventually die out). In the second period, however (1994q1 to 2012q2), these traditional results vanish. In other words, monetary policy becomes ineffective. From 1994q1 to 2012q2, policy fails to have a significant influence on real GDP, and its effects are practically neutral. This significant change in effectiveness leads to one prominent question: why has monetary policy become less effective? To answer this, I will begin by explaining the term structure of interest rates, the expectations theory, and the liquidity premium theory. I will then introduce and discuss some prominent theories, including the "conundrum" as detailed by Alan Greenspan and other ideas regarding the breakdowns in the term structure. In addition, I will offer policy suggestions for the future.

The term structure of interest rates details the relationship between interest rates on bonds with different terms to maturity (Mishkin, 2009, p. 123). The term premium exists because the long-term interest rates are often more volatile than short-term rates. This concept has given rise to some popular theories regarding the term structure of interest rates, including the expectations theory and the liquidity premium theory. Now, it is important to note that monetary policy's effectiveness in terms of influencing real output is based primarily on the belief that it has an influence over long-term interest rates. The Federal Reserve has a significant influence over short-term interest rates (i.e., the federal funds rate), which through the term structure of interest rates, affects long term interest rates (i.e., the 10-year treasury).

According to Frederic Mishkin, the expectations theory of the term structure states that, "The interest rate on a long-term bond will equal an average of the short-term interest rates that people expect to occur over the life of the long-term bond" (Mishkin, 2009, p. 132). From this theory, we can observe the following, Equation 5.1.

Equation 5.1:

$$i_{nt} = [i_t + i^e_{t+1} + i^e_{t+2} + \ldots + i^e_{t+(n-1)}] / n$$

Where:

i_{nt} = Today's interest rate for the n^{th}-period (long-term interest rate).

i_t = Today's interest rate (short-term interest rate).

i^e = The expected interest rate (short-term future interest rate).

n = The number of time periods.

Equation 5.1 is known as the Pure Expectations Theory of the term structure (PET), and offers a powerful explanation for the fact that the interest rates of bonds with different maturities tend to move together over time. Here, we can see that an increase in short-term interest rates today would tend to lead to an increase in short-term rates in the future. This in turn would raise the future expected interest rate, which would then lead to an increase in long-term interest rates, which demonstrates short-term and long-term interest rates moving together (Mishkin, 2009, p. 133). The influence on long-term interest rates depends on whether the change today is perceived to be permanent or temporary, with the perception of a permanent change in short-term interest rates influencing the long-term interest rates by more than the perception of a temporary change. In recent years, by holding quarterly press conferences, the Federal Reserve has attempted to increase its transparency, which in turn helps enable its ability to manage expectations. The concept of the expectations theory is incredibly important when it comes to monetary policy, because historically, the relationship between the federal funds rate and the 10-year treasury rate has been one of the most accurate forecasters of economic activity.

A closely related theory, the liquidity premium theory of the term structure, offers additional insight to the relationship between short and long-term interest rates. In addition to the relationship detailed in Equation 5.1 above, the liquidity premium theory adds in a variable known as the liquidity premium. The addition of the liquidity premium and the liquidity premium theory is shown in Equation 5.2.

Equation 5.2:

$$i_{nt} = \{[i_t + i^e_{t+1} + i^e_{t+2} + \ldots + i^e_{t+(n-1)}] / n\} + l_{nt}$$

Where:

l_{nt} = The liquidity premium for the *n*-th period of time *t*.

All other variables are the same as those defined in Equation 5.1.

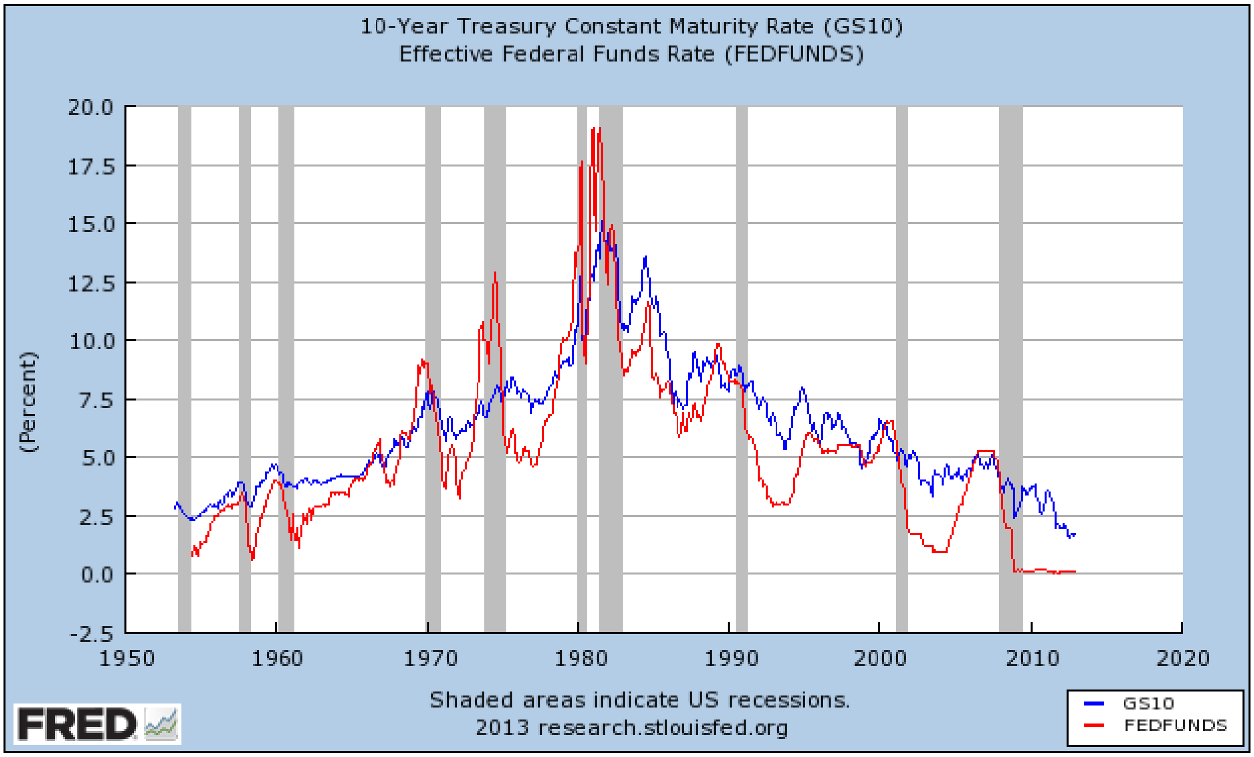
With this equation, we observe the liquidity premium, which is added on to the standard expectations theory. In this case, a positive liquidity premium tends to be associated with long-term bonds (Mishkin, 2009, p. 137). This theory, along with the expectations theory, has given policy makers greater insight into the relationship between short and long-term interest rates. But, if there is a correlation between this relationship and the results found in the empirical results section, something has clearly gone awry in the sense that conventional monetary policy no longer has the significant influence on real GDP growth that it once possessed.

As shown in the expectations and liquidity premium theories, historically, long-term interest rates (i.e., 10-year treasuries) and short-term interest rates (i.e., the federal funds rate) moved together. Typically, this meant than when the federal funds rates decreased, the 10-year treasury rate would decrease, and when the federal funds rate increased, the 10-year treasury rate would increase. Recently though, some scholars, like Alan Greenspan, have suggested that this is no longer the case. After the 2001 recession, we can observe what appears to be a breakdown between this relationship. Preceding and following the 2001 recession, and up until 2004, the Federal Reserve was lowering the federal funds rate. In the latter half of this period, the 10-year treasury rate failed to decrease along with the federal funds rate. Later in 2004, the Federal Reserve began a campaign to raise the federal funds rate. Despite this though, we again failed to see the 10-year treasury rate respond in the traditional manner, even though the Federal Open Market Committee raised the target for the federal funds rate seventeen meetings in a row.

In an attempt to explain this phenomenon, in 2005 Alan Greenspan appeared before a congressional panel and according to Martin Wolk, "…ruminated on what he previously described as a 'conundrum' — long-term interest rates that have remained low and even fallen despite the Fed's yearlong campaign to raise short-term rates" (Wolk, 2005). In his testimony, Greenspan states, "Long-term interest rates have trended lower in recent months even as the Federal Reserve has raised the level of the target federal funds rate by 150 basis points. This development contrasts with most experience, which suggests that, other things being equal, increasing short-term interest rates are normally accompanied by a rise in longer-term yields. The simple mathematics of the yield curve governs the relationship between short and long-term interest rates. Ten-year yields, for example, can be thought of as an average of ten consecutive one-year forward rates. A rise in the first-year forward rate, which correlates closely with the federal funds rate, would increase the yield on ten-year U.S. Treasury notes even if the more distant forward rates remain unchanged" (Thornton, 2012).

In practice, the concept of Greenspan's "conundrum" can be observed between 2004 and 2006. During this time period, the Federal Reserve increased the federal funds rate seventeen times (Labonte and Makinen, 2008). Also during this period, while the federal funds rate was increasing from 1% in 2004 to 5% in 2006, the 10-year treasury rates remained relatively constant. See Figure 5.1 below for more details.

Figure 5.1, Term Structure of Interest Rates:



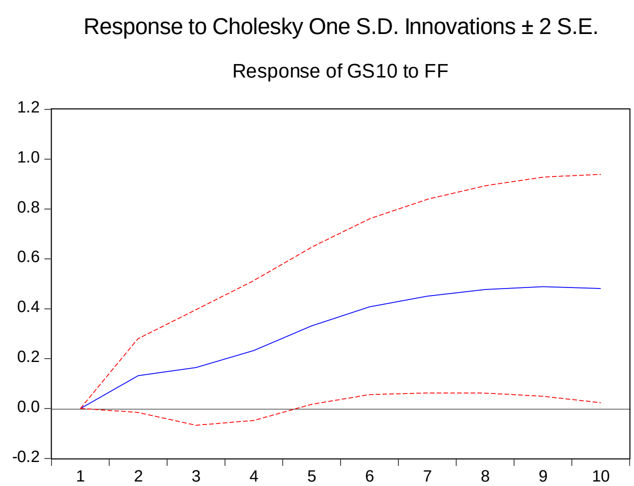
Source: Federal Reserve Economic Database

From after the 2001 recession, and up to the present, this "conundrum" has persisted in the economy. But, we have to ask, what could have changed to result in this? There are a few possible explanations.

Reexamination of Equation 5.2, the liquidity premium theory of the term structure, allows for some interesting observations regarding the liquidity premium. In the past, it has been assumed that as a bond's maturity increases, so does the liquidity premium (because of increased volatility). With the proposed "conundrum" though, this might not be the case. From 2004 to 2006 specifically, the federal funds rate was increasing, but the 10-year treasury rate was remaining practically constant. This would lead us to believe that in this period, the liquidity premium of bonds was actually decreasing. Similar observations can be made from 2006 up to the present. In each year, it seems that the liquidity premium is moving in the opposite direction as the federal funds rate. If in fact the liquidity premium has been fluctuating in this way, the usefulness of the relationship between the federal funds rate and the 10-year treasury rate as an economic indicator has diminished severely.

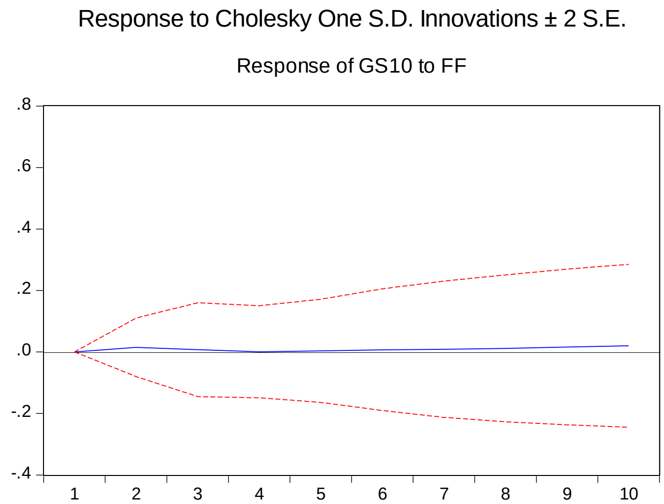
With that being said, if this is actually the case, the interest rate channel of the transmission mechanisms would be much less effective, assuming that long-term interest rates are more important in terms of influencing real economic activity. Conventional monetary policy in particular, has relied heavily on the increasing/decreasing of the federal funds rate leading to similar reactions in the 10-year treasury rates. To depict this relationship over time, we ran impulse response functions on the federal funds rate (FF) and the 10-year treasury rates (GS10). This relationship in the period from 1970q1 to 1993q4 is detailed in Figure 5.2.

Figure 5.2, 1970q1 to 1993q4 Response of GS10 to FF



In this time period, we can observe that positively shocking the federal funds rate leads to an increase in the 10-year treasury rate. This of course is consistent with the expectations theory. Updating the time period yields some different results. See Figure 5.3 below.

Figure 5.3, 1994q1 to 2012q2 Response of GS10 to FF



In this case, we fail to observe results typically predicted by the expectations theory. Unlike the results found in Figure 5.2, zero is completely contained within the 95 percent confidence interval, and positively shocking FF leads to no significant change in GS10. Figures 5.2 and 5.3, along with the information presented in Figure 5.1, give us evidence that we are in fact living in the economic environment of the "conundrum."

Once we reached the zero lower bound in December of 2008, since they could not lower the federal funds rate anymore, the Federal Reserve began conducting unconventional monetary policy. Unconventional monetary policy (including Quantitative Easing 1, Quantitative Easing 2, and Operation Twist) targets long-term interest rates, largely in an attempt to influence the 10-year treasury interest rate. In the economic environment of the "conundrum," though, the relationship between the federal funds rate, the 10-year treasury rate, and real output is incredibly difficult to detect.

This realization, along with our ever- changing global economy, makes the use of monetary policy even more complex. With increased globalization and international interdependence, the Federal Reserve plays a smaller role than it once did as an influencer of real output. Perhaps it is time for the Federal Reserve to shift its focus from influencing real output, to targeting inflation and providing increased financial stability in the economy. At the very least, policymakers should consider focusing on monetary policies that influence factors other than the federal funds rate and 10-year treasury rates, since this relationship has clearly deteriorated. Overall, changes in the global economy should spark changes in future policy. Accepting these changes, and the new roles they provide, could prove vital for the future success of monetary policy conducted by the Federal Reserve.

Chapter 6

Conclusion

This thesis offers an examination of the effectiveness of monetary policy over the last forty years. By utilizing accurate data and well accepted analytical methods, this paper replicated and updated the results presented in Ben Bernanke and Mark Gertler's "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." By doing so, I was able to establish a strong foundation on which to base my methods. In the first period examined, 1970q1 to 1993q4, we found that monetary policy had a measurable impact on real GDP growth. In this period, policy followed traditional expectations and essentially, was effective. During the second time period (1994q1 to 2012q2), however, we fail to observe this effectiveness. Here we see that changes in the federal funds rate did not have any measurable impact on real GDP growth. Further examination of the second time period reveals that policy is practically neutral. This evidence lends credibility to this paper's hypothesis that policy conducted by the Federal Reserve is becoming increasingly neutral over time.

Examining these two time periods allowed for an accurate look at the effects of monetary policy over the last four decades. The results presented clearly show that in the transition between the first and second period, policy has lost its significance. But what does this mean for the future? The economic environment of the "conundrum" could lead to significant changes in monetary policy in the future. With the likely breakdown in the term structure of interest rates, the future effectiveness of conventional monetary policy is placed in serious doubt. This all leads to the notion that unconventional monetary policy (directly targeting interest rates on long-term securities) could be here to stay.

With such economic uncertainty moving forward, including the "conundrum," it seems that now more than ever, the Classical school of economic thought is becoming increasingly more relevant. With technology becoming more sophisticated, our society has access to nearly perfect information. With this, along with increasing globalization, many of the assumptions necessary for the effectiveness of the Keynesian model (i.e. menu costs, sticky prices, and imperfect information), can no longer be made. Because of this, it seems that a more laissez-faire approach to policy might be more effective in the long run.

In regards to future research, I feel it is vital to keep testing the effectiveness of monetary policy over time. We live in a world with an ever-changing economy, and the only way to learn more of its intricacies is by conducting research similar to that which is presented in this paper. As the Federal Reserve continues to try new unconventional monetary policies, these policies are becoming the norm. Having the federal funds rate set at the zero lower bound until at least 2014 makes unconventional monetary policy the only way in which the Federal Reserve can utilize the most popular transmission mechanism, the interest rate channel. With that said, we could end up seeing an economic environment where unconventional monetary policy becomes conventional. With economic inconsistencies like the "conundrum," whether or not the effectiveness of these policies increases in the future cannot yet be determined, but if the results presented in this paper have any indication of future trends, it is likely that they will not.

Overall, the results outlined in this paper should serve as an eye opener in terms of the effectiveness of monetary policy. Its ability to significantly influence real GDP growth over time has fallen drastically since 1994, and the measurable effects of recent monetary policies are almost, if not completely neutral. The development of a complex global economy has led to many changes in policy over the last few decades, and with the increasing neutrality of policy, now might be the time to reevaluate the implementation of monetary policy in our economy.

Appendix A

Stationarity Test

To test for the stationarity of variables, I conducted a unit root test. I first examined the whether or not FF has a unit root.

Null Hypothesis: FF has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic based on SIC, MAXLAG=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.102561	0.2440
Test critical values:	1% level	-3.468980	
	5% level	-2.878413	
	10% level	-2.575844	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FF)
Method: Least Squares
Date: 01/23/13 Time: 16:29
Sample: 1970Q1 2012Q2
Included observations: 170

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FF(-1)	-0.044333	0.021085	-2.102561	0.0370
D(FF(-1))	0.314630	0.076640	4.105293	0.0001
D(FF(-2))	-0.204448	0.077888	-2.624915	0.0095
D(FF(-3))	0.189865	0.076306	2.488195	0.0138
C	0.227236	0.147730	1.538188	0.1259

R-squared	0.128829	Mean dependent var	-0.051706
Adjusted R-squared	0.107709	S.D. dependent var	1.020268
S.E. of regression	0.963757	Akaike info criterion	2.793015
Sum squared resid	153.2565	Schwarz criterion	2.885244
Log likelihood	-232.4063	Hannan-Quinn criter.	2.830440
F-statistic	6.100045	Durbin-Watson stat	2.009153
Prob(F-statistic)	0.000133		

Here, we see that the augmented Dickey-Fuller test statistic (-2.102561) is not significant enough to reject the null hypothesis that FF has a unit root at any test critical value. This shows that FF is non-stationary, and that Bernanke and Gertler's methods featured a major flaw. To correct this, I took the first order difference of FF. I ran another unit root test with DFF to verify this correction.

Null Hypothesis: DFF has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on SIC, MAXLAG=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.741633	0.0000
Test critical values:	1% level	-3.468980	
	5% level	-2.878413	
	10% level	-2.575844	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DFF)
Method: Least Squares
Date: 01/23/13 Time: 16:30
Sample: 1970Q1 2012Q2
Included observations: 170

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DFF(-1)	-0.924774	0.094930	-9.741633	0.0000
D(DFF(-1))	0.185362	0.075930	2.441221	0.0157
C	-0.047100	0.075610	-0.622940	0.5342

R-squared	0.411082	Mean dependent var	0.000529
Adjusted R-squared	0.404029	S.D. dependent var	1.274433
S.E. of regression	0.983851	Akaike info criterion	2.822805
Sum squared resid	161.6498	Schwarz criterion	2.878143
Log likelihood	-236.9384	Hannan-Quinn criter.	2.845261
F-statistic	58.28550	Durbin-Watson stat	1.938388
Prob(F-statistic)	0.000000		

With DFF (the difference of FF) the unit root test produces an augmented Dickey-Fuller test statistic of -9.741633. This T-stat is significant enough to reject the null hypothesis that DFF has a unit root at all test critical values. From this information, we can interpret that DFF is a stationary variable. This solves the problem of the unit root contained within FF, and fixes the error in Bernanke and Gertler's analysis.

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ACADEMIC VITA

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Education

The Pennsylvania State University, University Park, PA *Expected May 2013*
Bachelor of Science in Economics – Schreyer Honors College
Minor in Business

Honors

Dean’s List, College of the Liberal Arts Scholarship Recipient

Activities

Department Honors Program in Economics 2012-2013
- Selected to participate in the Department’s honors program.

Penn State Knights of Columbus Grand Knight (President) 2012-2013
- Coordinated and led group meetings and organized service and social activities.

Penn State Knights of Columbus Deputy Grand Knight (Vice-President) 2011-2012
- Facilitated recruitment of thirteen new members and set up service trips.

Catholic Campus Ministry Lector
- Publicly spoke in front of large audiences for four years at Penn State.

Professional Experience

Edward Jones Investments *6/2012 – 8/2012*
Financial Advisor Intern *Oil City, PA*
- Interacted with clients and potential clients on a daily basis through appointments and meetings.
- Completed a rigorous curriculum including financial training modules and efficiency projects.
- Coordinated a client seminar on asset protection, and facilitated branch operations.

Bates White Economic Consulting *Spring, Fall 2012*
REU Researcher *University Park, PA*
- Collected information, created spreadsheets, and ran economic models to quantify data.
- Generated results with EViews and reported my findings in a detailed research report.