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The Twisting Fed: How Changing Open Market Operation Compositions Affect Long-Term Interest Rates and Subsequently Influence Capital Expenditures

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by

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Abstract

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The Federal Reserve has been highly active in the past decade in its attempts to lower long-term interest rates and spur economic growth. This thesis will investigate how the Federal Reserve's actions have influenced long-term Treasury yields and whether the manipulation of the long-term interest rate helps stimulate economic growth through capital investment.

To examine how the Fed's actions affect long-term yields we study the maturity composition of the Fed's Open Market Operations (OMOs). As the trend of proportional purchases shift farther out along the yield curve, we expect the long-term interest rate to decrease.

The impact of shifting long-term interest rates on economic growth will be examined through its influence upon capital investment. An altered version of Chirinko's (1993) Neoclassical Investment Model is used to demonstrate this relationship. The key explanatory variables of this investment model are output and the user cost of capital. The determination of the user cost of capital includes interest rates, which is the channel through which we will test the impact of differing interest rates on capital investment.

We find that the Federal Reserve is successful in lowering the long-term interest rate through its Quantitative Easing and Operation Twist programs. We also find that total capital investment increases by 2.9% in response to a 1-percentage point reduction in the 10-year interest rate on average.

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CHAPTER ONE

INTRODUCTION

The Federal Reserve System is one of the custodians of the U.S. economic health through the management of low inflation and unemployment rates. One of its major tools for stimulating the economy during recessionary periods and for controlling inflationary trends is participation in direct open market operations (OMOs) at the discretion of the Federal Open Market Committee (FOMC). The purchase and sale of government treasuries and, more recently, mortgage-backed securities and other forms of debt, are a means of conducting monetary policy through the manipulation of interest rates.

When it comes to controlling interest rates, the primary focus of the Fed has been the Federal Funds Rate, also known as the overnight rate The federal funds rate functions as the mechanism to determine a bank's cost of borrowing from other financial institutions on a short-term basis—mostly overnight—to ensure the cash on hand is sufficient for its reserve requirements. The FOMC determines the desired federal funds rate, also called the target value, and then generates the necessary shift of the federal funds rate towards the target value by altering the money supply in the United States through OMOs.

The federal funds rate is important to the economy because if it is cheaper for a bank to borrow cash to cover its reserve ratio, the bank will be more likely to lend past the reserve ratio limit. A lower federal funds rate is expected to have a stimulating effect on the economy; the opposite is true for a higher federal funds rate. To maneuver the federal funds rate, the Fed purchases and sells short-term securities, which directly

impacts their yields. The shift of the federal funds rate towards the target value also impacts the interest rates of longer-term securities.

The FOMC announced on December 16, 2008 that it would lower the federal funds target value to between zero and ¼ percent. The FOMC cited "deteriorating labor market conditions…consumer spending, business investment, and industrial production" as the reason for this change.[1] Further monetary stimulus via the federal funds rate has not been possible since the target was set to its lower bound of essentially zero, so the Fed searched for alternative actions to lower interest rates and stimulate the economy. It decided to purchase longer-term securities through open market operations. This was the case during the 2008 quantitative easing 2 (QE2) and the 2011 Operation Twist programs.

During QE2 and Operation Twist, the Fed has attempted to stimulate the economy through open market operations that target long-term interest rates. QE2 has consisted of multiple announcements that resulted in the purchase of roughly $900 billion "longer-term Treasury securities…at a pace of $75 billion per month."[2] QE2 was primarily funded by printing money and the sale of bank reserves, a security similar to treasuries.[3] Operation Twist differs from QE2 in a fundamental way: rather than increasing the money supply in the economy, the program aims to shift the Fed's balance sheet composition towards more long-term holdings. The increased holdings of long-term treasuries in relation to short-term treasuries are expected to increase the demand for long-term treasuries and therefore drive the yield down on longer-term treasuries.

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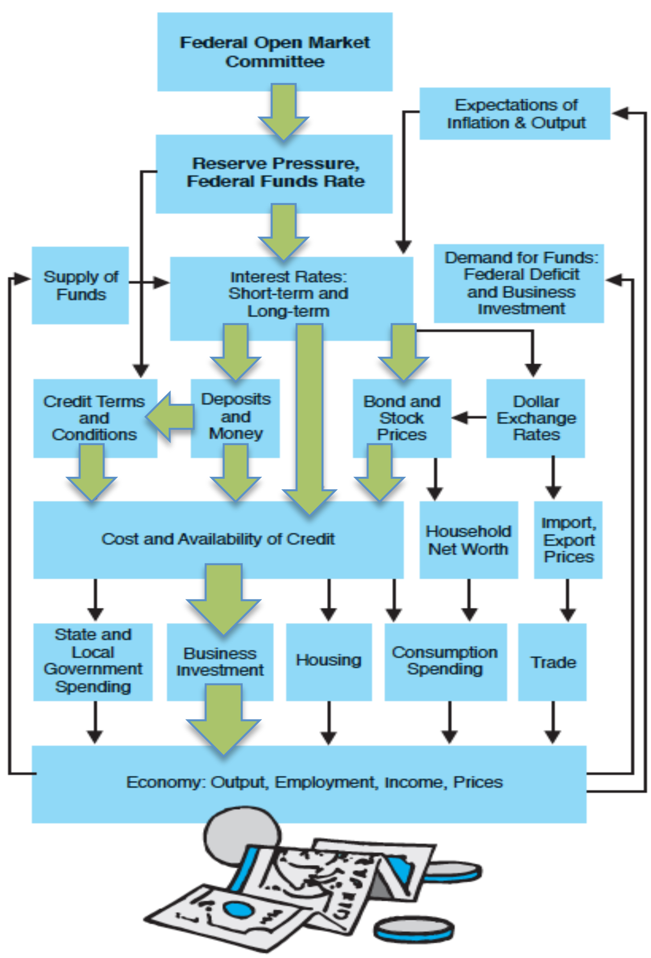
[1] http://www.federalreserve.gov/newsevents/press/monetary/20081216b.htm
[2] http://www.federalreserve.gov/newsevents/press/monetary/20101103a.htm
[3] Alon and Swanson, *Operation Twist and the Effect of Large-Scale Asset Purchases* article

A lower federal funds target rate allows financial institutions to lend money more freely, but lower long-term interest rates are meant to influence other economic variables, such as the cost of credit. Mortgage rates are typically based on the 10-year treasury yield, so a lower interest rate lowers the cost of borrowing for homeowners. Similarly, corporate business investment decisions are typically made with a long-term horizon in mind; therefore, borrowing costs relevant to corporate debt issuances are, in part, based on long-term Treasuries.

The various channels through which the FOMC's actions impact the economy are displayed below in Akhtar's (1997) diagram:

The Transmission of Monetary Policy



The above diagram demonstrates the interconnected channels through which the FOMC is able to influence the economy. The green, bolded arrows delineate the paths through which this paper wishes to address how alterations in the interest rates impact the United States economy; that is, through changes in capital investment. Essentially, increases by the Fed of the long-term interest rate are expected to result in "higher corporate bond rates, [which] increase borrowing costs, restraining the demand for additional plant, equipment," and other capital goods (Akhtar 1977, 10). Conversely, a decrease by the Fed of the long-term interest rate is expected to increase demand for capital through the same channels. There are a number of different paths through which changes in the interest rate can impact the *Cost and Availability of Credit* box in the diagram above, but the key focus is to understand how interest rates impact the cost of investment, which subsequently affects capital investment and the overall economy.

This thesis will consist of two separate but related components. First, we will analyze the impact of the Fed's OMOs on long-term interest rates. Specifically, we will analyze how the composition of the Fed's purchase and sale of treasuries of varying maturities influences the long-term interest rate. This analysis will be made through the comparison of the proportion of long-term versus short-term treasury holdings on a week-to-week basis during the December 2002-October 2011 period. Secondly, this paper will strive to identify the magnitude of the impact of long-term interest rate changes on corporate capital expenditures across eighteen sectors in the United States using an economic model based on the Neoclassical Investment Model.

The remainder of this paper will be structured as follows. Chapter Two will review prior economic literature pertinent to 1) the structure of the Treasury market

and the Federal Reserve’s impact on interest rates, and 2) the Neoclassical Investment Model and prior estimates of how changing interest rates and the user cost of capital influence capital expenditures. Chapter Three will introduce and explain the theoretical and empirical frameworks used in this thesis. Chapter Four will present the data and discuss the empirical results. Chapter Five will provide concluding remarks.

CHAPTER TWO

REVIEW OF LITERATURE

This section will review the relevant literature and theory supporting the necessity for this study. Subsection 2.1 will outline the Preferred-Habitat Theory and its relevance to understanding the effect of yields across maturities and how an alteration in the term structure of government debt may impact interest rates. Subsection 2.2 will conduct a survey of studies related to how monetary policy, especially programs such as Operation Twist and QE2, affect interest rates. Finally, subsection 2.3 will present prior studies focused on how interest rates are related to user cost of capital, and how user cost of capital is subsequently related to capital investment.

2.1 The Preferred Habitat Theory

The preferred-habitat theory is a framework used to explain and predict the interaction between interest rates across term structures. It is an extension of the expectations theory, which essentially posits that longer termed securities are based on an estimation of the yield of future short-term securities. The Preferred-Habitat Theory attempts to explain the demand for different maturities with the understanding that yield may not be the primary or singular reason an investor chooses to buy a specific maturity bond.

The key behind this theory is that "there are investor clienteles [whose] preferences for specific maturities" are not solely based on yields (D'Amico and King 2010, 1). There are three types of agents in this theory: the government, preferred habitat investors, and arbitrageurs. The government influences the supply of bonds through its

policies of issuance. Preferred-habitat investors, such as institutional investors, have preferences for bonds of specific maturities" (Greenwood and Vayanos 2010, 6). Arbitrageurs are the third set of agents; they attempt to "exploit differences in yields, buying that segment and shorting other segments to hedge their risk exposure" (Greenwood and Vayanos 2010, 8). While each agent plays an important role in affecting the bond markets, it is the actions of the arbitrageurs that are the key to this theory.

The theory explains that shocks to one maturity have effects across all term lengths:

> Suppose, for example, that the short rate increases, becoming attractive relative to investing in bonds. [Preferred-Habitat] Investors do not take advantage of this opportunity because they prefer the safety of the bond that matures at the time when they need to consume. But arbitrageurs do take advantage by shorting bonds and investing at the short rate.[1]

The result of the example described above would be an increase in the yield of bonds and a dampening effect on the increased short rate. This relationship is applied across government securities, which explains how arbitrageurs bring "yields in line with each other, spreading the local effect of supply over the entire term structure" (Greenwood and Vayanos 2010, 8). This also explains how the government and Federal Reserve can impact bond prices at different maturities by altering the supply of securities at a few maturities.

The Preferred-Habitat Theory also explains how the alteration of the average maturity of government securities impacts yields. An increase in the average maturity of government securities, say by an issuance of long-term bonds, reduces yields across the term structure.

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[1] Greenwood and Vayanos 2010, 8.

> Arbitrageurs accommodate the shock by increasing their holdings of long-term bonds and reducing those of short-term bonds. Even though the two transactions have the same market value, arbitrageurs' overall exposure to the short rate increases because long-term bonds have higher duration than short-term bonds.[2]

The shift towards holding more long-term securities reduces the demand for short-term securities, which causes short-term interest rates to increase. A longer average return horizon of a portfolio typically requires a higher return in itself because it is riskier and reduces the short-term liquidity and maneuverability of an investor. In this situation, the increased yield of the short-term securities puts added upward pressure on the asking yield by arbitrageurs for longer-term securities due to greater exposure to higher short-term rates, which implies a greater risk association. Conversely, if the Fed reduces the supply of long-term bonds through open market purchases, the opposite effect occurs. This explains why the Fed wishes to reduce the supply of long-term bonds through the Large Scale Asset Purchase (LSAP) program and Operation Twist programs; they hope it will reduce interest rates.

The Preferred-Habitat Theory is important to D'Amico and King (2010) as they studied the Fed's $300 billion treasury purchase program implemented in 2009. Their goal is to better explain price elasticities and substitutability of Treasuries as well as the ability of large-scale asset purchases to reduce overall yields and improve market functionality. D'Amico and King opt to utilize the preferred-habitat theory rather than the expectations model because of their desire to explore the yield's reaction to the LSAP. The preferred habitat-theory is more useful for this objective than the expectations model because the expectations model does not include a variable measuring yields. They

[2] Greenwood and Vayanos 2010, 11.

believed that the preferred-habitat theory could help explain how “withdrawing Treasury supply through programs like the LSAP would be able to affect the level and slope of the yield curve (implying a change in term premiums)” (D’Amico and King 2010, 9). The avenue of this effect can be examined as a *flow* or *stock* effect on interest rates.

D’Amico and King study the short term and long-term impacts of the 2009 LSAP on treasury yields in the short and long run timeframes. They characterize a *flow* effect as the immediate “response of [security] prices to the ongoing purchase operations” of the FOMC (D’Amico and King 2010, 2). A stock effect reflects the longer-term reaction of the treasury yield through “persistent changes in price that results from movements along the Treasury demand curve and includes the market reaction due to changes in expectations about future withdraws of supply” (D’Amico and King 2010, 2). Through these two lenses, the paper analyzes the immediate and lasting impacts of the LSAP on yields across maturity lengths.

The $300 billion Treasury purchase program was a small portion of the 2009 LSAP and an even tinier portion relative to the total size of the Treasury market. The Treasury program constituted a mere 8% of the total market size (D’Amico and King 2010, 1). Despite the small size of the plan, D’Amico and King found that the yield curve’s response, on average, to “each operation was on the order of -3.5 basis points for the sector being purchased”(flow effect), and realized a statistically significant decline across the yield curve (stock effect) with the largest yield reduction “of about 50 basis points in the 10- to 15-year sector” (D’Amico and King 2010, 16 and 22). This clearly demonstrates that the FOMC successfully lowered treasury yields through the LSAP, but the question of whether the effect was worth the expense continues to be hotly contested.

The Federal Reserve hopes that its open market purchases can have influential ripple effects that reduce credit costs in markets beyond the treasury yield curve. In the January 2009 FOMC press release, the Fed announced its readiness to continue to purchase longer-term treasury securities in the event that it proves "particularly effective in improving conditions in private credit markets" (FOMC Jan 2009)[3]. D'Amico and King find evidence that this hypothesis may have some validity because the "purchases of 'near substitutes' had almost as large effects on [the security's] yield as did purchases of the security itself, pointing to a very high degree of substitutability among these securities" (D'Amico and King 2010, 21). While this demonstrates substitutability across treasury securities of differing maturities, the link between government debt and the private debt is less clear.

In theory, corporate debt, like all debt, is priced based on the perceived risk a lender will inherit from purchasing the bond. Treasury securities are typically considered to be risk-free debt, or as close to risk-free as possible. Treasuries have been shown to be substitutable to those of similar maturities, but Treasuries are "not perfect substitutes for other types of debt…" because of the "exceptional liquidity and safety that are associated with the Treasury market" (D'Amico and King 2010, 3). Corporate debt, which is inherently riskier than government debt, must therefore offer a higher yield to convince investors to purchase the bonds.

Krishnamurthy and Vissing-Jorgensen (2008) conduct an in-depth study of the yield spread between government and corporate debt. They examine "a high-grade corporate bond, which [they] assume to be an asset that is similar to the Treasury

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[3] http://www.federalreserve.gov/newsevents/press/monetary/20090128a.htm

bond,…and express the difference in yields between this corporate bond and the Treasury bond" (Krishnamurthy and Vissing-Jorgensen 2008, 8). They investigate the idea of Treasuries as a risk-free asset and introduce the concept that the yield differential between AAA corporate-issued debt and government-issued debt is characterized by a convenience factor. The convenience factor includes the "surety of Treasuries, the superior trading liquidity of Treasuries, and their use in satisfying regulatory mandates" (Krishnamurthy and Vissing-Jorgensen 2008, 44). These convenience benefits, as well as the common risk-free ideal associated with Treasuries, make Treasuries attractive to many investors despite their relatively low returns.

The disparity between the convenience and perceived risk that an investor associates with a Treasury security compared with a corporate bond security is the mechanism that helps determine market prices for corporate debt. The FOMC hopes that lower Treasury yields, the baseline off of which corporate debt is priced, will create a ripple effect through the corporate world via lower lending costs in the private credit markets. This would hypothetically offer an incentive for companies to borrow money and invest in capital expansion, which is expected to foster greater economic growth.

The preferred-habitat theory is relevant to this study because it helps to analyze how a change in the yield of Treasury securities at one maturity impacts the yield of securities at other maturities. Under the assumptions that 1) a decrease in the supply of securities at a particular maturity causes a shift down for the yield of that maturity and 2) a shift down in the yield of one maturity impacts the yields of maturities all along the yield curve, we believe that as the composition of maturities in the FOMC's OMOs swing to include a greater proportion of long-term treasuries in relation to short term, the

long-term interest rate will decrease. Following the preferred-habitat theory explained in Greenwood and Vayanos (2010), this will maintain downward pressure on short-term Treasuries because as the yield goes down on the long term treasuries (due to reduced supply, so price of bond increases as yields decreases), the perceived risk of these bonds is decreasing. The long-term treasury risk is essentially an accumulation of short-term treasury risk, so the risk on the short-term treasuries is perceived to be reduced.

2.2 Other Studies of Monetary Policy Affecting Interest Rates

Berument and Froyen (2005) use impulse response and variance decomposition functions to study how the federal funds rate impacts longer-term nominal interest rates in the United States. The study takes a two-pronged approach by studying the data in various groupings of time periods. First, they conduct time variation analysis on the whole sample period from 1975-2002 and on two sub periods within the total sample period. The two sub periods span January 1975-October 1979 and November 1982-August 2002. The sample is divided into these two subsections because of a "widely acknowledged shift in monetary policy on October 6, 1979" (Berument and Froyen 2005, 739). Furthermore, the time between the two sub periods is not included to avoid the "turbulent period often referred to as the 'monetarist experiment'" from October 1979-November 1982 (Berument and Froyen 2005, 739).

The second approach that Berument and Froyen (2005) use is to break their sample period into sub periods based on the monetarist regime. These monetary regimes refer to the "tenure of Federal Reserve Board Chairmen: Burns (January 1975-August 2002); Volcker (August 1979-August 1987); and Greenspan (August 1987-August 2002)" (Berument and Froyen 2005, 739). Berument and Froyen hypothesize that the

public investment community has different interpretations of the Fed's actions and expected future actions based on the perceived philosophy and direction of the Federal Reserve Chairman.

Berument and Froyen note that much of prior research related to how innovations in the federal funds rates affect longer-term yields draw conflicting conclusions. Some argue that the federal funds rate and longer-term interest rates move in opposite directions while others argue that they are positively associated. The results of Berument and Froyen (2005) support the conflicting nature of these prior studies. They find that for the overall period, "the responses of the 10-year rate to the federal funds rate are in the same direction but are smaller in magnitude than are the responses of the 1-year rate" (Berument and Froyen 2005, 746). For the sub periods January 1975-October 1979 and November 1982-August 2002, they find that innovations in the federal funds rate resulted in the long-term rate moving in the same direction, but to a "smaller and less persistent [magnitude] in the post relative to the pre-1979 sub period" (Berument and Froyen 2005, 750). In the post-1982 sub period they find that, "a positive innovation in the federal funds rate leads… to a short-lived increase [in short and long-term interest rates] followed by a longer period where these longer-term rates decline relative to their initial values" (Berument and Froyen 2005, 750). The varying results from prior studies may occur due to the failure to account for the significant change in monetary policy in 1979.

The impact of monetary policy also varies across different Federal Chairman regimes. The Burns sub period ended in 1979, so the 1-year and 10-year treasury moved in the same manner that the results for the pre-1979 sub-period above suggest. Volcker and Greenspan, however, served as Chairmen after 1979. The Volcker period was

characterized by “relatively larger and more persistent movement of the long-term rate in the same direction as the innovation in the federal funds rate and less evidence of a reversal of this effect than do those for the Greenspan period” (Berument and Froyen 2005, 750). Berument and Froyen (2005) conclude that the Fed’s increased focus on inflationary goals after 1979 “firmly anchored the inflationary expectations of market participants” so that monetary shocks had “less effect on expected future…interest rates” (Berument and Froyen 2005, 750). This study demonstrates that the Federal Reserve can alter the yields in the bond market through its traditional channels of the federal funds rate and open market operations, but it also impacts the Treasury Security market through participants’ expectations.

Swanson (2011) studies the implications of the original Operation Twist and relates its effects to the potential effects of the Federal Reserve’s more recent efforts to stimulate the economy through QE2. Swanson utilizes a high frequency case study to analyze the impact of six major announcements regarding the Fed and its OMO policies and policy shifts that came during the course of the 1961 Operation Twist. Specifically, he looks at the reaction of the Treasury yields within a one to two day window of these major announcements to determine if the plan impacted long-term interest rates. The changes of the Treasury yields in such a short timeframe demonstrate the influence of each announcement because “financial markets would not leave large riskless profitable trading opportunities unexploited for more than a few hours, let alone one or two days” (Swanson, 2010).

Swanson analyzes the overall impact of Operation Twist as well as the effect of the six individual announcements over the course of the program. To understand the

effect of the whole Operation Twist, Swanson takes two approaches. First, he studies the first four announcements together. They provide “a reasonable estimate of the initial effects of Operation Twist” because they occurred within the first three weeks of the program’s initial announcement (Swanson 2010, 19). The announcements indicate an increase in the Federal Reserve’s dedication to selling short term and purchasing long-term government securities. Swanson defines the *initial effect* of the program as “what the total effect *could have been* with no future policy reversals or mixed signals” by the Fed (Swanson 2010, 20). Secondly, Swanson looks at the total effect of all announcements in the Operation Twist program, which demonstrates the impacts of policy reversals and mixed signals regarding the Fed and Treasury’s resolve to support the endeavor.

Swanson finds that the total initial effect, which he attributes to data through the first four announcements, is moderate at about 15 bp with a high level of statistical significance. The total affect of the program, including all six announcements, is not statistically significant except at the 10-year, 30-year, and 3-year maturity levels. Furthermore, he finds the program had a much smaller effect on the longer-maturity interest rates. Swanson also notes that a 15 bp decline in the 10-year Treasury yield is not very large; it is similar in magnitude to a typical fluctuation in the 10-year yield over the course of one quarter. However, it “should be noted that a 15 bp decline in the 10-year Treasury yield would be a typical response to a 100bp surprise cut in the federal funds rate target” (Gurkaynak, Sak, and Swanson, 2005).

2.3 User Cost of Capital and Investment

Chirinko, Fazzari, and Meyer (1999) explore the responsiveness of business capital formation to the user cost of capital. They utilize a dataset containing 26,000 observations of firm-level data, which represents "48% of aggregate U.S. non-residential fixed investment and 43% of sales of final and intermediate goods" in the middle year of the sample period, which was 1987 (Chirinko, Fazzari, and Meyer 1999, 4). With this massive data source, they utilize a model based on firm-level demand for capital and demand for investment to estimate the effect of the user cost of capital on capital formation.

Through various tests, Chirinko, Fazzari, and Meyer decide to exclude cash flow from their model. This is a variable used in many user cost of capital models, but they discover that including the statistic "lowers the effect of sales growth," because of supposed positive correlation between sales growth and cash flow, and of user cost of capital on capital formation (Chirinko, Fazzari, and Meyer 1999, 13). They explain the reduction in the effect of the user cost of capital on capital formation as stemming from 'income effects' that change the behavior of a financially constrained firm.

The results of these tests demonstrate that the user cost of capital elasticity estimates are negative, which indicate that holding all else constant, as the user cost of capital increases, investment decreases. The consensus among the various versions of the regression model demonstrates that the user cost of capital elasticity is -0.25. This supports the theory that "higher user costs do indeed reduce capital formation." (Chirinko, Fazzari, and Meyer 1999, 26). However, the user cost of capital elasticity is

significantly lower than values discovered in prior research. Furthermore, this study demonstrates that “price incentives have a quantitatively smaller impact on capital formation” than many believed and that there is only a “modest effect of interest rates on investment” (Chirinko, Fazzari, and Meyer 1999, 26). These results call into question the effectiveness of lowering the long-term interest rates to spur the economy.

Dwenger (2010) focuses his research on how the elasticity of the cost of borrowing impacts capital investment. He uses a dynamic framework to estimate the user cost of capital using German firm-level data from 1987-2007. The firm-level user cost of capital is then inserted into a distributed lag (DL) model, based off of Neoclassical principles, and an error correction model (ECM) to estimate the responsiveness of investment to the user cost of capital. Dwenger’s results for the DL model demonstrate an elasticity of -0.56. The ECM, which “separates the immediate and long-term effects of a change in sales or user cost of capital,” estimates that “an increase in the user cost of capital by 1 percent will decrease capital by about 1.3 percent” (Dwenger 2010, 14 and 19). The purpose of Dwenger’s study is to ultimately discover “whether taxes matter for business investment spending” through the user cost of capital variable in his investment model (Dwenger 2010, 1). He concludes that the DL model shows a low response of investment to changes in the user cost of capital, but the ECM demonstrates the potential for policy, such as tax reforms, to significantly alter investment through the user cost of capital variable.

Coulibaly and Millar (2009) focus on South Africa to estimate the elasticity of the user cost of capital using both DL and cointegration models. The dataset of quarterly data from 24 manufacturing industries from 1970 through 2000 offers a unique study of the

user cost of capital's effect on investment. Coulibaly and Millar believe that the size of South Africa makes this data set more relevant to the study because the small and isolated position of the country suggests that interest rates and capital goods prices may be exogenous (Coulibaly and Millar 2009, 3). Furthermore, the economic sanctions on South Africa from 1985 to 1994 offer an opportunity to examine how endogeneity attenuates estimates of the user cost of capital elasticity (Coulibaly and Millar 2009, 20). Coulibaly and Millar estimate statistically significant user cost elasticity between -0.80 and -1.0. This study is important in that it is one of the first to demonstrate such a high user cost of capital elasticity for a "broad measure of business capital that includes both equipment and structures" (Coulibaly and Millar 2009, 20). Furthermore, the study found that during the embargo period "when the user cost became less influenced by exogenous factors, the estimated user cost elasticity fell considerably" and then recovered to former levels when the embargo was lifted (Coulibaly and Millar 2009, 20). This demonstrates that exogeneity may play a significant role in the reason for low estimates of the user cost of capital elasticity found in other studies.

CHAPTER THREE

EMPIRICAL MODEL

The introduction and explanation for the empirical models used in this paper will be presented in this section. Subsection 3.1 will demonstrate the methodology and framework used to analyze how the Federal Reserve's actions through their open market operations affect long-term interest rates. Section 3.2 will survey other empirical investment models and introduce the empirical model used in this study to understand how fluctuating long-term interest rates impact capital investment across 18 sectors in the United States economy. Finally, the subsection 3.3 will discuss the sources of data and reasoning for the time periods observed.

3.1 Framework to Analyze Proportional OMO Innovations

The impact of the composition of the Fed's open market operations (OMOs) on long-term interest rates are analyzed through a direct comparison of the proportion of the Fed's OMOs at each maturity and long-term (10-year) interest rates. The object is to determine a relation between shifts in the proportional composition of the Fed's OMOs and shifts in the long-term interest rates over the past decade. It should be noted that this is an observational, intuitive exercise with no concrete statistical conclusions as would be found in an empirical model; however, the presentation and analysis of graphs and trends may shed light on the impact the Fed has on long-term interest rates.

To test my hypothesis, we will create a graphical representation (see Exhibit A) of the relationship between the maturity composition of the FOMC's OMOs as well as the short and long-term treasury yield trends. The short-term interest rate trend is included in

the graph for comparative purposes. The purpose of this exercise is to demonstrate that as the Federal Reserve shifts the term structure of government debt to the longer end through its open market operations, there will be a reduction in long-term interest rates. The study focuses on the weekly changes of the Fed's balance sheet rather than the total holdings on its balance sheet because the Fed's holdings are so massive that observation of changes in its holdings on a weekly basis would be miniscule relative to the total balance sheet as to be nearly irrelevant. Furthermore, a typical Treasury investor is not necessarily interested in the total holdings of the Fed; instead, an investor's decisions are based more on the changes in the Fed's policies and actions that will influence interest rate shifts in the market. Urich and Wachtel argue that the weekly announcement of the money supply "often leads to changes in interest rates" because it leads "market participants to revise expectation" of Fed policy and future economic conditions (Urich and Wachtel 1981, 1063). Similarly, the observation of the proportion of securities purchased and sold at each maturity level on a weekly basis can be a proxy that signals the Fed's plans and therefore impacts expectations of the investing public. To quantify the impact of the proportional data and better understand the relationship between the proportional data and the interest rate, a graph demonstrating the overall volume of securities purchased and sold over the sample period is included.

The data for the OMOs, broken into four maturity lengths, represent the weekly changes of the Federal Reserve's balance sheet at each maturity. A negative number represents a net sale of Treasuries at that maturity for the week. A positive number implies that the FOMC was a net purchaser of Treasuries at that maturity for the week.

The analysis of the impact of the Fed's OMOs on long-term interest rates in terms

of the proportion of short-term versus longer-term treasuries being bought and sold requires the creation of a special index. The proportional data must take both the purchase and sale of each security type into consideration; however, the proportion of each maturity length purchased or sold during a week cannot mathematically be demonstrated in a typical pie chart or in percentage terms of the daily value of securities traded because of the negative number associated with net sales of a Treasury maturity. We create an index to circumnavigate this issue and allow the creation of meaningful graphical representations to demonstrate the proportionality of the Fed's OMOs across different maturities. The next five paragraphs will discuss and explain the derivation and meaning of this index's values.

The absolute value of all maturities' flow of weekly activity is calculated (summed) to demonstrate the Fed's total weekly activity across all maturities in the market. This then allows the calculation of the percent of total weekly activity (including buying and selling) that each maturity is accountable for in each period. The proportional data is then represented in the form of a stacked bar graph with each maturity length having a designated colored bar.

Each date along the x-axis has a bar of height 0 or 1. If a date has a bar value of 0 (there is no bar visible), then it demonstrates that the FOMC refrained from participation in the Treasury markets that week. All other instances will show a bar of height 1; however, the bar may sit anywhere within the -1 to +1 scale based on its proportion of purchases and sales for the given week. A total bar value, including all colored bars stacked, of +1 for a particular date shows that the FOMC only purchased securities that week. Similarly, a total bar value of -1 in a week demonstrates that the FOMC only sold

securities that week. Any other total bar value between -1 and 1 represents a week where the Fed both bought and sold Treasuries.

The size of each color in a bar allows a viewer to roughly observe the proportion of the weekly OMOs made up of each Treasury maturity. If a certain color is in the positive range, it demonstrates that the Fed was a net purchaser of securities at that maturity that week. Alternatively, if a specific colored bar is negative for a week, the Fed was a net seller of securities at that maturity.

The graphs will also include interest rate trends for particular Treasuries to demonstrate the effect of changing proportions of OMOs on the yields. The proportional OMO data (stacked bar graphs) and yield trend data (line graphs) will simultaneously be demonstrated through the use of two y-axes. The y-axis on the left will represent the scale we have created to demonstrate the proportion each maturity accounts for of the period's OMO. The y-axis on the right will display the scale for the interest rate of the yields for each week.

The graph representing the volume of each maturity bought or sold each week will be demonstrated in a grouped bar chart (see Exhibit B). Each bar will represent the total dollar volume of each maturity purchased or sold in a given week.

3.2 Survey of Empirical Investment Models, Neoclassical Model is Used

The effect of long-term interest rate changes on capital expenditures across industries requires a more complex econometric model than the observation of the Fed's impact on the long-term interest rate. This model includes Investment (I) as the dependent variable and takes the general form of a Neoclassical Investment model. This

subsection is presented in three further subsections. Subsection 3.2A will survey various investment models considered for this analysis, subsection 3.2B will examine the evolution and reasoning of the Neoclassical Investment Model, and subsection 3.2C will outline and describe the specific model we use in this study.

3.2A Survey of Investment Models

The Neoclassical Investment Model is one of five prevalent models of capital expenditures. In addition to the Neoclassical Model, Kopcke (1993) describes these models: the Accelerator Model, the q Model, the Cash Flow Model, and the Autoregression Model.

The Accelerator Model proposes that the "demand for new capital goods, investment, depends on changes in the rate of production" (Kopcke 1993, 11). Current and lagged capital stock as well as a short history of output are the only variables included. The theory behind the model suggests that businesses may "avoid overreacting to temporary changes in the demand for their products…[by] extrapolating [output expectations] from the course of sales in the past" (Kopcke 1993, 11). Furthermore, the Model suggests that the ratio of capital stock to output tends towards a long-run constant.

The q Model focuses on the cost of a capital asset at market value versus its replacement value. The ratio of these two values is known as "q." The theory claims that values of q "exceeding unity foster investment spending, while values of q well below unity discourage capital formation" (Kopcke 1993, 12). Businesses make decisions to invest by considering the expected marginal returns on the new capital assets against the costs of procuring them. While this model is theoretically sound, it is not popular among

economists because "separating marginal returns from average returns on assets…can compromise the quality" of the forecast (Kopcke 1993, 13).

The Cash Flow Model recognizes that a company's cash flow is crucial to the determination of its investment strategy. From 1960 to 1989, "the purchases of plant and equipment by nonfinancial corporations have essentially equaled their cash flow" (Kopcke 1993, 16). The model demonstrates this relationship between investment and the ratio of cash flow to prices of capital goods. Greater cash flows allow for an expansion of a firm's capital budgets, which implies an increase in investment. Growing cash flows also suggest increasing returns on assets, which increases the demand for capital (Kopcke 1993, 17).

The Autoregression Model relies solely on historic trends of capital expenditures. It differs greatly from the other four models because it does not include any of the typical indicators found in Investment Models, namely output, prices, profits, and taxes. The theory driving this model suggests "the trends and cyclical dynamics of recent capital spending…are sufficiently stable to describe the course of spending in the future" (Kopcke 1993, 17).

Kopcke's (1993) description of the Neoclassical model demonstrates its effectiveness at estimating the relationship between investment and other important economic variables. In his explanation of the model, he mentions that it "allows the optimal ratio of output to the stock of capital to vary with prices, interest rates, and tax codes" (Kopcke 1993, 13). The basic theory driving this model is that real business investments are a function of the firm's expected profitability in relation to the cost of purchasing this capital as well as the expected demand for the goods to be produced.

Furthermore, this model differs greatly from other models in that it recognizes that target investment is not a long-run constant; instead, it is a fluctuating, continuously moving target as firm operating circumstances change over time.

Kopcke notes that “no one approach consistently dominates the others,” and all models fit his data relatively well. However, despite various benefits and drawbacks of the Accelerator, q, Cash Flow, and Autregression Investment Models, none are appropriate for this study because they do not allow for the observation of the long-term interest rate’s effect on capital investment. The Neoclassical Investment Model is chosen for this study because it is a widely accepted model of investment that offers an avenue through which the relationship between interest rates and investment may be studied.

3.2B Development of the Neoclassical Model of Investment

Jorgenson (1961) formulates the basis for the modern Neoclassical Model of Investment. In his paper, he works to create a model that combines the two prevailing theories at the time of its publication: growth and development. In a development model, “emphasis is laid on the balance between capital accumulation and the growth of population” while a growth model focuses on “the balance between investment and saving [as] all-important [while] the growth of population is treated as constant or shunted aside” (Jorgenson 1961, 310). Joining these two theories into a single model allows the analysis of how multiple sectors of an economy interact in terms of wages, population growth, output, capital accumulation, and investment among other variables.

Jorgenson uses a Cobb-Douglas model for the basis of his derivation and the construction of the Neoclassical Model. The two sectors in his hypothetical economy are

farming and manufacturing. He explains that farming is a labor-intensive industry while manufacturing is a capital-intensive industry. Therefore, as the population increases throughout the farming industry past the threshold of the required population to work the land, people move towards cities to search for work. This shift, caused by an overflow of labor in the agricultural sector, supplies the labor needed for the manufacturing sector. This is important for the development of the investment model because:

> Once the share of labor in manufacturing output is distributed to workers in the form of food and consumption goods, and agricultural workers have received the proportion of manufacturing output which must be traded for food, the remainder of manufacturing output is available for capital accumulation, or more properly, for investment.[1]

In this way, Jorgenson demonstrates the process through which capital accumulation theoretically occurs. Furthermore, it shows how the factors of output are tied together in the economy through the expansion of the Cobb-Douglas production function. The relationship that he develops for capital stock and labor with output becomes the basis for the Neoclassical Investment model.

Jorgenson continues the development of his theory behind the Neoclassical Investment Model in his 1963 study. The basis for the theory is that the "relationship between inputs, including the input of capital services, and output is summarized in a production function" where the firm attempts to maximize its net worth (Jorgenson 1963, 247). Net worth is characterized by the relationship of revenues less direct taxes. For the determination of net worth, Jorgenson uses quantity and price variables for two inputs—labor and investment—and output. Let revenues be represented by R, Q be the quantity of output, L be the quantity of the input variable labor, and I be the rate of investment.

[1] Jorgenson 1961, 323

Furthermore, let P^O represent the price of output, P^S the wage rate of labor, and P^I the price of capital. Net revenue is therefore characterized by the equation:

$$R = P^O Q - P^S L - P^I I.$$

The formula for direct taxes determines the input, taxes, and depreciation costs of a firm. Jorgenson derives a formula for the direct taxes of a firm by applying τ, the rate of direct taxation, to the whole revenue formula as well as replacing the expression for capital investment I with the expression:

$$I = (v\delta + wr - x)K$$

Where v is the proportion of capital replacement chargeable against income for tax purposes, w is the proportion of interest, and x is the proportion of capital losses chargeable against income. In this relationship, K is capital stock, δ is the rate of replacement, and r is the rate of interest. According to the above alterations to the revenue formula, direct taxes, say D, of a firm is demonstrated by the relationship:

$$D = \tau\,[P^O Q - P^S L - (v\delta P^I + wrP^I - xP^I)K].$$

The derivation of a firm's revenues and direct taxes then allow for the formula of net worth, W:

$$W = (P^O Q - P^S L - P^I I) - (\tau[P^O Q - P^S L - (v\delta P^I + wrP^I - xP^I)K])$$

Jorgenson then derives the marginal productivity conditions for output with respect to labor and output with respect to capital where the "rate of growth of capital stock is investment less replacement" (Jorgenson 1963, 249). The marginal productivity of output with respect to capital is of interest in deriving the Neoclassical Model of Investment:

$$\frac{\partial Q}{\partial K} = \frac{P^I\left[\frac{1-\tau v}{1-\tau}\delta + \frac{1-\tau w}{1-\tau}r - \frac{1-\tau x}{1-\tau}\frac{\dot{P}^I}{P^I}\right]}{P^O}$$

Jorgenson further assumes that capital gains are not included as taxes because they will be reinvested; therefore, the above equation may be reduced to:

$$C = P^I \left[\frac{1-\tau v}{1-\tau}\delta + \frac{1-\tau w}{1-\tau} r\right]$$

Where C = user cost of capital, or "the rental of one unit of capital service per period of time" (Jorgenson 1963, 249). The user cost of capital is the means through which this study will observe the impact of interest rates on capital investment.

Continuing under the general assumption that firms are profit driven, Jorgenson notes that firms wish to control the amount of capital that maximizes their earnings. The desired capital is represented by K^*. If the "production function is Cobb-Douglas with elasticity of output with respect to capital, γ," the desired amount of capital can be represented by the formula (Jorgenson 1963, 249):

$$K^* = \gamma \frac{P^I Q}{C}.$$

The relationship between the desired capital, output, and the user cost of capital make up the Neoclassical Investment model because the change from a firms' actual capital towards its desired capital represents the investment made by the firm.

There are two basic types of investment that comprise a firm's total investment: replacement (I^r_t) and net (I^n_t) investment. Replacement investment is "proportional to the capital stock available at the beginning of the period" and represents the cost of replacing the capital that depreciated over the period (Chirinko 1993, 1878). This relationship is demonstrated in the formula:

$$I_t^r = \delta K_{t-1}.$$

Net investment “is determined by a distributed lag on new orders, which equal in a given period the change in the desired capital stock” (Chirinko 1993, 1878). This relationship is demonstrated by the formula:

$$I_t^n = \sum_{i=0}^{n} B_j \, \Delta\boldsymbol{K}_{\boldsymbol{t-i}}^*$$

The sum of I_t^r and I_t^n represents the total investment undertaken by the firm in a period. With the addition of an error term u and the addition of γ for elasticity, we obtain the Neoclassical Model of investment:

$$I_t = \alpha + \delta K_{t-1} + \gamma \sum_{i=0}^{n} \beta_i \, \Delta\left(\frac{Q_{t-i}}{C_{t-i}}\right) + u_t$$

The above model, found in Chirinko 1993, will be modified slightly for use in this study.

3.2C The Econometric Model Used In This Study

The Neoclassical Model found in Chirinko (1993) will be slightly modified in two ways. In the first modification, the elasticity measurement, γ, will be removed because it is considered in many prior studies (Dwenger 2010, for example) to be close to unity. Regarding the second modification, the Neoclassical Model discussed above treats “replacement investment” as a fixed proportion of the existing capital stock. However, this treatment is problematic for at least two reasons. Firstly, as Chirinko (1993, p. 1880) points out, “[t]he validity of constant geometric depreciation has been the subject of numerous empirical investigations providing mixed support for this assumption.” Secondly, even if the depreciation rate *were* fixed, it is not clear why firms would replace existing capital stock automatically and without regard to actual economic conditions, such as the existence of capital overhang.

Therefore, in common with several empirical studies of Neoclassical Investment functions, we use the following modified version of Chirinko's model, for our regressions in this study.

$$\boldsymbol{I_t = \alpha + \sum_{i=0}^{n} \beta_i \Delta\left(\frac{Q_{t-i}}{C_{t-i}}\right) + u_t}$$

This model will be run three separate times for the Equipment and Software, Fixed Assets, and Structures investment types using data from eighteen sectors. The investment (*I*) and output (*Q*) data are given by the data, but the user cost of capital (*C*), is calculated through a simplified version of Jorgenson's model for the user cost of capital. The simplified version to be used is depicted below:

$$C_t = \frac{P_t^I}{P_t^Y} \times \frac{(r_t + \delta_t)}{1 - \tau_t}$$

Where P_t^I and P_t^Y are the input and output prices of goods at time t for their respective sectors. The interest rate, r_t, and corporate tax rate, τ_t, data are applied across all industry sectors and investment types for each time t. The depreciation rate, δ_t, is specific to each time period, industry sector, and investment type. The inclusion of sector- and investment type-specific data for all of the independent variables would have been preferable; however, it was not possible to find tax or price data of that specificity. The variables for investment tax credit and the discounted value of tax depreciation allowances found in Jorgenson's model for the user cost of capital are excluded because the specific data could not be obtained; however, the real corporate tax rate is assumed to be acceptable for characterizing the costs associated with taxes and credits and should not significantly impact the efficacy of the model.

The coefficients of the model introduced above are described in this paragraph. The term α is a constant. The estimated value of α in the regression equation suggests the level of investment if Q/C were zero. The term β_i is the coefficient that links the ratio of output and user cost of capital to investment in a given period. The coefficient β_i is expected to be positive because, theoretically, a decrease of the user cost of capital in relation to output signifies an increase in return on investment. Firms will be more willing to invest when relative returns increase, and total investment will tend to rise. Furthermore, holding all else constant, an increase in output will cause an increase in investment.

The term Q/C is positively associated with investment, meaning that Q/C and investment are expected to move in the same direction. It is through this relationship of output and the user cost of capital that we draw our hypothesis: Higher interest rates will lead to a higher user cost of capital. This higher user cost of capital will then reduce the value of the term Q/C, which will result in lower capital investment.

3.3 Data and Reason for Period Selection

The data for the analysis of the Fed's impact on the 10-year interest rate includes a breakdown of the FOMC's weekly open market operations by maturity length found on the Federal Reserve Data Download Program and interest rate trends found on the Federal Reserve Economic Data (FRED) database. Graphs of the S&P500, Dow Jones Industrial, and NASDAQ stock indices as well as the 10-year Treasury were found on Yahoo! Finance. This portion of the study uses roughly ten years of weekly data from 2002-2012. The time period selection is limited primarily by the data available—the

detailed breakdown of OMOs by maturity length data only extends back to 2002. However, the purpose of this part of the study is most importantly to analyze the Fed's impact on the long-term interest rate over the course of the last decade. During this period, the Fed's major operations focused largely on the long-term interest rates with programs such as QE2 and, more recently, Operation Twist. Therefore, we believe this to be an ample and appropriate sample period.

The data for the Neoclassical Model of Investment used in this study includes real capital investment and depreciation for Software and Equipment, Fixed Assets, and Structures investment types, real output, real input prices, and real output prices for eighteen sectors in chain-index form (2005=100) from the US Department of Commerce, Bureau of Economic Analysis. The number of observations for each investment type is calculated by multiplying the number of years of data by the number of sectors used in the regression. The data set is on an annual basis from 1977 through 2010, but due to the use of lags, the number of observations is based on the periods 1984-2010, 1984-2010, and 1990-2010 for Equipment and Software, Fixed Assets, and Structures investment types respectively. The number of observations are displayed in Table 3.1. Structures has fewer observations because of the greater number of lags used in the regression, which restricts the number of years of data included.

The descriptive statistics for the regressions run in this study are displayed below:

Table 3.1: Descriptive Statistics

	Equip and Software		**Fixed Assets**		**Structures**	
	Mean	Standard Dev	Mean	Standard Dev	Mean	Standard Dev
Investment	64.99	34.67	72.59	32.27	111.86	63.52
Q/C	9.13	62.72	19.93	104.10	38.33	159.17
Q/C Lagged 1 Year	8.87	57.27	19.92	95.10	38.24	144.29
Q/C Lagged 2 Years	8.66	43.38	19.12	72.57	36.76	114.87
Q/C Lagged 3 Years	8.46	40.78	17.31	67.99	34.52	109.21
Q/C Lagged 4 Years	7.49	40.32	15.27	67.08	35.65	106.05
Q/C Lagged 5 Years	7.34	39.01	15.46	64.49	39.41	101.29
Q/C Lagged 6 Years					39.84	90.26
Q/C Lagged 7 Years					40.46	88.83
Q/C Lagged 8 Years					33.02	81.33
Q/C Lagged 9 Years					30.23	80.16
Q/C Lagged 10 Years					22.16	72.23
Q/C Lagged 11 Years					21.53	69.30
Observations:	486		486		378	

CHAPTER FOUR

EMPIRICAL RESULTS

Chapter 4 will present the empirical results for this study. Section 4.1 will analyze the proportional purchase and sale of the Fed's open market operations (OMOs) over the past decade. Section 4.2 will present the regression results as well as charts and tables necessary to analyze the elasticity of investment with respect to changes in the 10-year interest rate.

4.1 How Changing Proportional OMOs Impacts Long-term Interest Rate

This section will survey the FOMC actions across the past decade and analyze pertinent announcements of programs related to long-term Treasuries. We then compare the enacted monetary policies to the proportional and volume trends of OMOs to understand how the proportional purchase or sale of securities may impact long-term interest rates.

The Fed was relatively inactive in the Treasury market prior to 2007 aside from periodic adjustments to the federal funds rate; however, the Fed became very involved in the Treasury market after the financial markets began to slide downward as a result of the burst housing bubble. The Fed's major Treasury activities began in 2008 as it sold off high levels of short-term treasuries in both proportional and volume terms. The year began with a reduction in the federal funds rate by "75 basis points to 3-1/2 percent".[1] Twelve months later, the Fed lowered the target rate a number of times; the federal funds

[1] http://www.federalreserve.gov/newsevents/press/monetary/20080122b.htm

target rate finally settled at essentially 0 by December 2008.[2] The large proportional amount of short-term treasuries sold during this period, especially in the first six months of the year, in Exhibit A, can be attributed to the creation of the Term Auction Facility (TAF) program, which undertook responsibility for the "auction [of] term funds to depository institutions against the wide variety of collateral that could be used to secure loans at the discount window."[3] The Fed utilized the TAF as a means to introduce liquidity into a stagnating economy. The Fed hoped that setting the federal funds rate at zero and making credit available to lending agencies would jump-start the free-falling economy.

The economy began to recover in early 2009, though slowly. To help spur the economic recovery, the Fed decided to lower credit costs for businesses; however, the Fed's typical means of lowering credit costs, the federal funds rate, was already held at its lower bound of 0 to ¼ percent. To achieve lower credit costs, the Fed implemented the first round of what became known as the Large-Scale Asset Purchase (LSAP) program, a $300 billion program to purchase longer-term Treasuries and thereby drive down interest rates. This program was announced in March 2009 and lasted for approximately six months. The graphs in Exhibit A and B clearly demonstrate this policy shift by the increased proportional and volume purchases of longer-term Treasury securities, namely in the 5- to 10-year and greater than 10-year Treasury maturity groups. Purchases of the 1- to 5-year Treasuries by the FOMC also significantly increased in proportional and volume terms. The less than 1-year Treasuries were the only maturity section sold with any regularity in proportional and volume terms during this period. The 10-year interest

[2] http://www.federalreserve.gov/newsevents/reform_mbs.htm
[3] http://www.federalreserve.gov/newsevents/press/monetary/20071212a.htm

rate increased during this period of monetary easing, rising from just under 3% to just under 4%, but it began to decline shortly after the $300 billion purchase program ended in October of 2009.

The financial markets continued to recover in 2010, and The FOMC was relatively inactive for the first three quarters of the year. During this time, the Fed announced it would be "winding down its Term Auction Facility" by March 8th.[4] More importantly, the Fed announced that it would "keep constant the Federal Reserve's holdings of securities at their current level by reinvesting principal payments from agency debt and agency mortgage-backed securities [(MBS)] in longer-term Treasury securities" in August.[5] This policy announcement is observed in Exhibit A through the increased proportional purchase of longer-termed securities, especially in the 5- to 10-year maturity group. The volume of longer-term treasuries purchased also began to pick up at this point.

Three months later, on November 3, the Fed made a splash in the market with its announcement of round two of the LSAP, which was to purchase a further $600 billion in longer-term securities over the next three quarters.[6] The impact of this program is observed in Exhibit B—the volume of longer-term securities being purchased nearly tripled, which was the result of the decision to reinvest the principle from the agency debt and MBS purchase programs in longer-term securities. The 5- to 10-year Treasuries continued to be the most purchased maturity group, followed by the 1- to 5-year maturity group. There are few purchases of the greater than 10-year maturity group and very little

[4] http://www.federalreserve.gov/newsevents/press/monetary/20100127a.htm
[5] http://www.federalreserve.gov/newsevents/press/monetary/20100810a.htm
[6] http://www.federalreserve.gov/newsevents/press/monetary/20101103a.htm

activity in the under 1-year maturity groups. It is difficult to see a definite shift in the proportionality of the Fed's purchases in Exhibit A resulting from the initiation of the $600 billion program because the Fed had already begun purchasing proportionally large amounts of long-term assets due to its prior announcement to reinvest the principle of short-term securities in longer-term Treasuries.

By June 2010, the FOMC completed the $600 billion injection of liquidity into the Treasuries market via longer-term securities. The Fed announced it would "maintain its existing policy of reinvesting principal payments from its securities holdings" in longer-term Treasuries for the foreseeable future.[7] As a result, the longer-term purchases by the FOMC observed in Exhibit A and Exhibit B remain high in proportional and, to a lesser extent, volume terms through the end of the displayed time period.

In June 2011, the Fed announced Operation Twist in the attempt to further lower longer-term interest rates. The plan called for the FOMC to purchase "$400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less."[8] This caused a rise in the already relatively high proportional purchases of longer-term securities, though the volume of OMOs declined.

Observation of the proportional purchase and sales of Treasury securities by the Fed since it began meaningful OMOs around 2007 results in mixed results. During the time from each program's announcement to its conclusion, the longer-term interest rate has tended to rise, which is an unexpected result. This reaction may occur for a number of reasons, such as equity market, arbitrageur, or Treasury Department influences.

[7] http://www.federalreserve.gov/newsevents/press/monetary/20110622a.htm
[8] http://www.federalreserve.gov/newsevents/press/monetary/20110921a.htm

The major stock indices, including the Dow Jones Industrial Average, S&P 500, and the NASDAQ (all depicted in Exhibit C), seem to follow a nearly identical trend as the 10-year interest rate (also found in Exhibit C) over the past decade. It may be that the fluctuations of the financial equity markets, which reflect the health of the United States economy, significantly impact interest rates. For example, as the housing market bubble burst and the stock markets tumbled from June 2007 through March 2008, Treasury interest rates also plummeted. The 10-year interest rate fell from a high of around 5% to just above 2% over this span. This trend may be attributed to the investor mentality of *flight to safety* or *flight to quality*, which refers to an investor's shift from potentially high-risk, high-growth investments to low-risk, low-growth investments in order to preserve wealth in an especially turbulent, uncertain market. Government Treasuries are considered among the safest, low-risk investments. The uncertain and rapidly declining equity markets following the housing bubble caused many investors to move their assets to government securities; therefore, the increased demand for Treasuries may be credited with driving interest rates down considerably. The risks and trends of the equity markets may have a more significant impact on interest rates than monetary policy because of investors' perception of Treasuries as a safe haven. The fact that each of the Fed's large monetary stimulus policies were announced and implemented while the stock markets were trending upwards may help explain why the 10-year interest rate rose during the programs rather than fell as was expected.

The tendencies of arbitrageur investors in the Treasury security space may be partly to blame for the rise, rather than decline, of the 10-year interest rate over the course of the monetary stimulus programs. The Federal Reserve's announcement of a plan to

purchase billions of dollars worth of longer-term securities over a short-term period, typically around six months, immediately impacted the expectations of investors. Arbitrageurs, who attempted to take advantage of any price differential they observed, were likely to react to this announcement by buying up long-term bonds and then selling these holdings following each weekly sale of Treasuries by the FOMC desk. This is because each of the Fed's large purchases of Treasuries was expected to further drive down the yield. The arbitrageur therefore earned a profit on the margin between the principle price before and after each of the FOMC's sales of Treasuries.

The United States government, through the Treasury Department, could have undermined the Federal Reserve's attempts to lower the long-term interest rates. If the Fed announced a multi-hundred-billion dollar plan to purchase securities of a certain maturity, the Treasury may have decided to auction more bonds at the same maturity during the specified plan period. This would have resulted in more beneficial borrowing costs for the government, but it would counteract the goals of the Fed. The sale of more Treasuries by the government would increase the supply of securities in the open market while the Fed simultaneously attempted to lower interest rates by decreasing supply. While this remains a potential issue, the Fed typically convened with the Treasury Department to secure assurances that the Treasury would refrain from undermining the Fed's operations.

The examination of the proportional purchase and sale of Treasuries of different maturities resulted in mixed results. The monetary policies implemented to reduce the long-term interest rate typically resulted in an increase in the 10-year interest rate over the course of each program. However, the long-run effects of these operations did seem

to be successful in lowering the 10-year interest rate from June 2007 to the present. Over this period, the proportion of longer-term treasuries purchased by the Fed far outpaced purchases of short-term Treasuries. To better demonstrate this, we created another bar graph demonstrating the proportional maturity of Treasuries held on the Fed's balance sheet.

The bar graph demonstrating the proportional maturity of Treasuries held on Fed's balance sheet is displayed in Exhibit D. This graph clearly shows the trends of the Fed's operations and how they have impacted the Fed's holdings. The most notable trend of the graph is that around the end of 2007, the proportion of short-term holdings dropped off steeply. At the end of 2007, the Treasuries with a maturity of less than one year accounted for nearly 50% of the Fed's balance sheet of government Treasuries. This statistic dropped to 11% by June 2009 and continued to decline. Conversely, the 1- to 5-year maturity group grew from 30% of the Fed's balance sheet to just over 40% from the end of 2007 to June 2009 period. The 5- to 10-year maturity group increased from 10% to 30% of the balance sheet during this period, and the holdings of Treasuries with maturity longer than 10 years jumped from 10% to 20% of the Fed's balance sheet. The 10-year interest rate decreased from about 4.1% to about 3.3% during this period that is characterized by an intense adjustment of the term structure of the Fed's Treasury holdings.

After June 2008 the Fed continued to shift its proportional holdings to longer-term Treasuries, albeit at a slightly slower pace. The 5- to 10-year maturity group reached 35% of the Fed's holdings by September 2011, the final month reported in this study, and the 10-year interest rate shrank to 2.0%. The significant shift of the overall maturity of the

Fed's Treasury holdings combined with the increase in proportional purchases of longer-term securities in the post-2007 era demonstrates that the Federal Reserve has been successful in significantly reducing the long-term interest rate over an extended period of time even though the short-term response of the interest rate does not react as expected.

It is clear that the Fed is able to manipulate the long-term interest rate, even if it does not respond as quickly as expected; however, the question remains whether the Fed is justified in spending nearly $1 trillion over the course of nearly five years to reduce the 10-year interest rate by 2%. The next section will attempt to shed light on this question by testing how a 1-percentage point lower 10-year interest rate would impact capital investment.

4.2 Interest Rate Elasticity of Investment Using the Neoclassical Model

To present the findings of this study, we begin with the analysis of the regression results from the Neoclassical Investment Model in subsection 4.2A. Subsection 4.2B presents the results of an *ad hoc* regression equation that keeps output and user cost of capital separate. Finally, we demonstrate the impact of a 1-percentage point decrease in the 10-year interest rate on investment in subsection 4.2C using the Neoclassical Investment Model.

4.2A Neoclassical Model

The initial regressions run using the Neoclassical Investment Model return results of high statistical significance, low residuals, and appropriately signed coefficients; however, the Durbin Watson (DW) statistic is extremely low, suggesting positive serial

correlation. The presence of autoregressive behavior suggests that an important independent variable may be excluded from the model or the functional form may be inappropriate. One standard procedure used to address autoregressive behavior is the Chochrane-Orcutt method, denoted by the AR(1) specification in EViews. We rerun the regression with the first order autoregressive error specification (AR(1)) to test for potential autoregressive behavior in the error terms. We hope the newly generated model exhibits a DW statistic within the acceptable range as described by Gujarati (2003).[9]

The inclusion of AR(1) in the Neoclassical Investment Model improves the DW statistic to 1.6, 1.6, and 2.3 for the Equipment and Software, Fixed Assets, and Structures investment types respectively. These DW statistics fall in the "zone of indecision" as characterized by Gujarati (2003). While this is not ideal, they are acceptable statistics and the functional form of the model is still considered valid because it is supported by prior research, such as Chirinko (1993). The statistical significance of the coefficients, the signs of the coefficients, and the Adjusted R-squared for each investment type remain acceptable. Therefore, the estimation equation that includes the AR(1) specification is used in this study. The results are displayed below in Table 4.1:

[9] For further details regarding Gujarati's discussion of autocorrelation, the Durbin-Watson statistic, and the range of acceptable DW statistics, see pages 454-472 and 970-971 in *Basic Econometrics*, 2003.

Table 4.1: Regression Results for Neoclassical Model

	Equip and Software	Fixed Assets	Structures
Q/C Base Year	0.017 (0.008)**	0.014 (0.005)***	0.027 (0.014)**
Q/C Lagged 1 Year	0.034 (0.014)**	0.024 (0.009)***	0.041 (0.023)*
Q/C Lagged 2 Years	0.047 (0.018)***	0.032 (0.012)***	0.061 (0.033)*
Q/C Lagged 3 Years	0.041 (0.018)***	0.035 (0.012)***	0.099 (0.039)**
Q/C Lagged 4 Years	0.028 (0.015)**	0.029 (0.01)***	0.113 (0.043)***
Q/C Lagged 5 Years	0.016 (0.011)	0.022 (0.008)***	0.133 (0.044)***
Q/C Lagged 6 Years			0.127 (0.044)***
Q/C Lagged 7 Years			0.136 (0.043)***
Q/C Lagged 8 Years			0.107 (0.041)***
Q/C Lagged 9 Years			0.097 (0.038)**
Q/C Lagged 10 Years			0.114 (0.035)***
Q/C Lagged 11 Years			0.057 (0.026)**
AR(1)	1.034 (0.006)***	1.019 (0.006)***	0.901 (0.019)***
Adjusted R-Squared	0.93	0.90	0.74

Standard errors are in parenthesis.
***significant at 1%, **significant at 5%, *significant at 10%

The regressions of the three types of investment are displayed above and provide interesting and statistically significant results. The Equipment and Software, Fixed Assets, and Structures investment types have Adjusted R-squared values of 0.93, 0.90, and 0.74 respectively, demonstrating that the estimated equations explain roughly 93%, 90% and 74% of the relationship variance between investment and the ratio of output to user cost of capital. The signs for all coefficients across the three regressions are positive,

which is to be expected. This is because as the ratio of output to user cost of capital increases, investment is expected to increase. Furthermore, each regression contains a majority of statistically significant coefficients at the 5% level or better.

Equipment and Software has four statistically significant lags and the Fixed Asset investment type has five statistically significant lags, while the Structures investment regression includes eleven statistically significant lags. The number of statistically significant lags demonstrates how long the relationship between Q/C and Investment is relevant in the dataset. In the Neoclassical Model, the jump from current capital stock (K) to optimal capital stock (K^*) is theoretically assumed to be immediate; however, lags are added to the model to account for the fact that there are frictions in investment. A greater number of periods of statistically significant lags demonstrate greater frictions to investment. The differing levels of friction are partly due to adjustment costs.

Adjustment costs are the costs of the time, alterations, and other various financial obligations and hurdles that arise over the course of the implementation of a capital good. Higher adjustment costs are positively correlated with a greater number of lags because a firm, understanding the amount of unexpected costs associated with particular investments, may require more years of historical financial data to be sure the firm's projection of future market conditions, which the investment decision is based on, is not a short-term fluke. It can then be stated that Structures are associated with the highest adjustment costs and therefore firms will be most hesitant to invest in this type of capital good unless they are very certain their projections are accurate. Equipment and Software and Fixed Assets are typically cheaper to invest in and require less time to implement, which explains the fewer statistically significant lags. Firms require less market certainty

to invest in Equipment and Software and Fixed Assets relative to Structures. Also, the liquidation or disposal costs of Structures may be higher than both Equipment and Software and Fixed Assets, which is also reflective of higher adjustment costs. The presence of eleven statistically significantly lags may seem excessive, especially compared to the four and five years for Equipment and Software and Fixed Asset investment types, but the difference in the results suggest greater role for uncertainty and adjustment costs in regard to investment in Structures.

The trend of the magnitudes of the lagged coefficients provides interesting insight into a firm's decision-making process for each investment type. Graphs in Exhibit E demonstrate the trend of the coefficients for all statistically significant results. Graphs of all three investment types result in a general 'hump' shape. This characteristic suggests that the ratio of output to the user cost of capital (Q/C) at time t-1 has a greater impact on investment at time t than the Q/C at time t. Furthermore, the Q/C at time t-2, two years ago, has a greater impact on investment than the ratio at time t-1. This trend continues until it reaches a maximum, and then the magnitude begins to decline. The point where the coefficient reaches its maximum demonstrates, on average, the optimal time period on which a firm bases its investment decision.

The graph for Equipment and Software Coefficients shows that magnitudes of the coefficients of Q/C rise from 0.017 in the base year to its peak of 0.047 in the second lagged year. The Fixed Assets Coefficients graph depicts the magnitude rising from 0.014 to its maximum of 0.035 between the base year and the third lag. Structures, as expected, requires the most lags to reach the maximum magnitude of its coefficient, which is 0.136 after seven lags. The number of lagged years that it takes to reach the peak of the

coefficient's magnitude suggests the sensitivity of investment to historic Q/C. The largest coefficient in each trend demonstrates which Q/C influences investment the most, which suggests it is the optimal historic economic data that a firm should look at to make investment decisions on average. They also, of course, reflect the nature of adjustment costs in each category.

4.2B *Ad Hoc*, Unrestricted Investment Model

We also run regressions for each investment type where the model regresses output and the user cost of capital as separate variables against capital investment. In the Neoclassical model, the impact of output and the user cost of capital on investment must travel through the same coefficient. Separating the two independent variables allows for the observation of the unrestricted effect of output and user cost of capital on capital investment. The justification for using this model comes from Ramanathan's description of the Partial Adjustment Model.

> Because of 'frictions' in the market, the gap between the actual and the desired levels [of investment] cannot be closed instantaneously but only with some lag and random shocks. Suppose only a fraction of the gap is closed each period. In this case, the [investment] at time *t* would equal that at time *t*-1, plus an adjustment factor, plus a random error term.[10]

The derivation of the Partial Adjustment Model reduces to the basic formula:

$$Y_t = \beta_1 + \beta_2 Y_{t-1} + \beta_3 X_t + u_t$$

The key to this model is that the addition of an adjustment coefficient accounts for the advancement a firm makes from capital stock Y to optimal capital stock Y^* in the given

[10] Ramanathan 2002. Page 442

period. The adjustment coefficient manifests itself in the lagged dependent variable being on the right side of the equation.[11]

The results from the 'unrestricted' model are displayed below:

Table 4.2: Regression Results for Partial Adjustment Model

	Equip and Software	Fixed Assets	Structures
C	3.350	11.206	94.048
	(1.978)*	(2.763)***	(41.124)
Output	0.183	0.285	0.459
	(0.036)***	(0.051)***	(0.330)
User Cost of Capital	-15.733	-43.392	-26.278
	(3.366)***	(5.773)***	(23.249)
Investment, Lagged 1 Year	0.847	0.686	-0.339
	(0.029)***	(0.048)***	(0.338)
AR(1)	0.325	0.479	0.907
	(0.051)***	(0.069)***	(0.015)***
Adjusted R-Squared	0.95	0.93	0.87

Standard errors are in parenthesis.
***significant at 1%, **significant at 5%, *significant at 10%

The regression results from the Partial Adjustment Model all have high Adjusted R-squared statistics of 0.95, 0.93, and 0.87 for Equipment and Software, Fixed Assets, and Structures respectively. This demonstrates that each regression explains about 95%, 93%, and 87% of the variance of the data respectively. The estimated coefficients are robustly statistically significant for the Equipment and Software estimations, but the results are not statistically significant for the Structures estimation. The output coefficients for the three investment types are positive, and the user cost of capital coefficients are negative. The positive sign of the output coefficient demonstrates that as output increases,

[11] For further detail and explanation regarding the Partial Adjustment Model, see Ramanathan's *Introductory Econometrics with Applications,* Fifth Edition, 2002. Page 442.

investment will also increase on average. The negative sign of the user cost of capital coefficients suggest that as the user cost of capital increases, investment will decrease on average. Despite the lack of statistical significance in the Structures estimate, the overall analysis of the unrestricted regression estimations of the effects of output and the user cost of capital on investment qualitatively supports the results from the Neoclassical Investment Model. The two models are both generally statistically significant and agree on the interaction of the user cost of capital and output with the dependent variable, investment; however, we decide to use the Neoclassical Investment Model to study the elasticity of the user cost of capital in detail because it has greater prior theoretical backing to support the results.

4.2C Elasticity of Investment to the 10-Year Interest Rate

To test for the elasticity of investment to the 10-year interest rate, we recalculate the user cost of capital variable using interest rates 1-percentage point lower than they actually are. The newly calculated user cost of capital is inserted into the regression equation generated from the original Neoclassical Model regression. The goal is to simulate what the capital investment would be for each year if the interest rate were 1-percentage point lower. The difference between the actual investment and the generated investment with a 1-percentage point lower interest rate represents the elasticity of investment with respect to changes in the 10-year interest rate.

On average, we find that a 1-percentage point decrease in the 10-year interest rate results in a $121.4 billion increase in total capital investment, which is a 2.9% increase.

Equipment and Software investment exhibited the least elasticity to a 1-percentage point decrease in the 10-year interest rate with a reaction of $0.9 billion, or 0.10%, increase in capital investment on average. Fixed Asset investment jumps $7.7 billion, or 0.37%, on average. Capital investment in Structures exhibits the largest shift from a 1-percentage point decrease in the 10-year interest rate with an increase of $85.0 billion, which is a 7.69% change on average. This logically makes sense, given the higher costs of capital structures, which therefore typically requires a greater dependency borrowing. As a result, shifts in borrowing costs impact Structures-related investment decisions to a higher degree. It is also interesting that Structures is most affected by a change in the 10-year interest rate because past studies have struggled to find statistically significant estimates of the user cost of capital elasticity using data for investment in Structures. This may have resulted in a severe underestimation of the benefits to the US economy of lowering long-term interest rates. Note, however, that this is a ceteris paribus experiment. That is, the positive effects on investment of a reduction in interest rates might be outweighed by the negative effects on investment from a reduction in output.

The elasticity of investment to the 10-year interest rate clearly differs significantly across investment types. It also varies between industries. Table 4.3 ranks the industries based on how much a 1-percentage point reduction of the 10-year interest rate impacts capital investment from the greatest to least affected.

Table 4.3: Industries Ranked By the Response of Investment to a 1-Percentage Point Reduction of the 10-Year Interest Rate

Equipment and Software	Investment % Change	Fixed Assets	Investment % Change	Structures	Investment % Change
1. Utilities	0.31%	1. Real estate and rental and leasing	1.38%	1. Real estate and rental and leasing	10.73%
2. Transportation and warehousing	0.14%	2. Utilities	0.83%	2. Utilities	10.52%
3. Mining	0.13%	3. Educational services	0.67%	3. Educational services	9.84%
4. Accommodation and food services	0.11%	4. Arts, recreation, entertainment	0.47%	4. Health care and social assistance	9.39%
5. Real estate and rental and leasing	0.11%	5. Accommodation and food services	0.47%	5. Administrative and waste management services	8.08%
6. Manufacturing	0.10%	6. Health care and social assistance	0.42%	6. Transportation and warehousing	7.96%
7. Arts, recreation, entertainment	0.10%	7. Mining	0.33%	7. Management of companies and enterprises	7.89%
8. Health care and social assistance	0.10%	8. Transportation and warehousing	0.33%	8. Professional, scientific, and technical services	7.88%
9. Agriculture, forestry, etc.	0.09%	9. Retail trade	0.32%	9. Construction	7.43%
10. Construction	0.08%	10. Agriculture, forestry, etc.	0.22%	10. Finance and insurance	7.40%
11. Retail trade	0.07%	11. Information	0.20%	11. Wholesale trade	7.35%
12. Wholesale trade	0.06%	12. Management of companies and enterprises	0.19%	12. Agriculture, forestry, etc.	7.12%
13. Educational services	0.06%	13. Finance and insurance	0.18%	13. Accommodation and food services	6.97%
14. Information	0.06%	14. Manufacturing	0.18%	14. Arts, recreation, entertainment	6.97%
15. Administrative and waste management services	0.05%	15. Wholesale trade	0.15%	15. Retail trade	6.96%
16. Finance and insurance	0.05%	16. Administrative and waste management services	0.12%	16. Information	6.95%
17. Professional, scientific, and technical services	0.04%	17. Construction	0.11%	17. Manufacturing	5.78%
18. Management of companies and enterprises	0.03%	18. Professional, scientific, and technical services	0.08%	18. Mining	3.23%

It is clear that the impact of interest rate changes has varying effects on capital investment across different industries. Some industries are relatively highly capital intensive in all investment types, such as *Utilities* and *Real estate and rental and leasing,* which rank in the top five of industries in each of the three investment types. The data suggests that different industries may have different capital needs in one or two investment types with a lesser demand in others. For instance, *Mining* ranks as the second highest industry for investment elasticity to interest rate changes for Equipment and Software and seventh for Fixed Assets. However, it ranks last for Structures investment type. This demonstrates the fact that the *Mining* industry, on average, uses Equipment and Software and Fixed Asset types of capital to a much greater extent than Structures to carry out its business. If a firm uses a certain investment type of capital more, a change in the costs of credit, the 10-year Treasury in this case, will impact the capital investment of that investment type to a much greater extent.

CHAPTER FIVE

CONCLUSIONS

This study observes that the Federal Reserve has managed to lower interest rates through programs aimed at shifting the proportional maturity structure of the Fed's Treasury position towards the long end. Furthermore, we find statistically significant results, using the Neoclassical Model of Investment, demonstrating that lower long-term interest rates help to increase capital investment.

We find that the elasticity of investment with respect to a 1-percentage point reduction in the 10-year interest rate, specifically the 10-year Treasury yield to be a 0.10%, 0.37%, and 7.69% increase in each investment type respectively on average. Our estimation of the elasticity of investment with respect to the 10-year interest rate is not comparable to past estimations in terms of the orders of magnitude. This is because former research projects focus on the *user cost of capital* elasticity of investment. We are among the first to specifically calculate the *long-term interest rate* elasticity of investment; therefore the two estimates of elasticity are based on two different measurements. However, the direction of the elasticities of the user cost of capital found in past studies, such as Chirinko et. al (1999), Dwenger (2010), and Coulibaly and Millar (2007), support our findings qualitatively. This is important given the more prominent role the Federal Reserve has taken in managing interest rates in recent years.

One of the most important contributions of this study is the finding of a statistically significant Neoclassical Model of Investment for Structures investment type, which very few prior studies have been able to generate. This is especially important

given the magnitude to which Structures investment type reacts to changes in interest rates and therefore the user cost of capital in comparison to other investment types.

The question remains whether the billions of dollars spent on lowering the long-term interest rate meets some pertinent cost-benefit test. In the period from March 2009, when the date of the first Long-term Treasury purchase program was announced, through the present, the 10-year interest rate has fallen by roughly 1-percentage point from 3% to 2%. The Fed spent $900 billion in the purchase of longer-term Treasuries to accomplish this. In comparison to the $121.4 billion increase in investment, it appears that the benefits of lowering the long-term interest rate through open market operations do not justify the prodigious expense. However, greater positive benefits from lowering interest rates to the economy may exist through channels that this study does not consider.

There is much left to examine in this area. Future studies may look at whether programs, such as Operation Twist, that rely on a shift of the Fed's holdings from short to longer-term securities with no additional injection of liquidity into the markets have a greater bang-for-buck impact on capital investment trends than directly purchasing long-term Treasuries. It would also be interesting to further understand the marginal impact of monetary stimulus as well as a greater understanding of how lower long-term interest rates help different sectors in the economy—do the lower credit costs allow companies to spend more on capital investments, do the lower credit costs simply allow its customers to borrow more to finance their purchases and therefore impact the investment model through output, or is it a combination of these two scenarios that results in greater investment in each sector from lower interest rates.

We acknowledge that there are shortcomings to this study. It would be preferable to have all data for the calculation of the user cost of capital at the industry and investment-type level; however, data of this specification were not available for taxes or prices. More in-depth manipulations of the empirical model estimations may reduce any remaining autocorrelation behavior from the model. Moreover, our elasticity calculations are *ceteris paribus* exercises. It is beyond the scope of this thesis to compare the effectiveness of the kind of monetary policy that we have studied in this thesis with, for example, a fiscal policy that might have directly affected the numerator of our estimated investment function.

Despite these shortcomings, the observational results of the Fed's proportional OMOs and balance sheet holdings over the last decade suggest that the Fed has been successful in shifting the long-term interest rates down. Furthermore, the results demonstrated by the Neoclassical Model of Investment provide support for the hypothesis that a reduction in interest rates tends to result in increased capital investment. Therefore, it appears the Federal Reserve has successfully managed to stimulate the economy through lower credit costs, though it also appears that the cost of lowering interest rates are much higher than the observed increase in capital expenditures.

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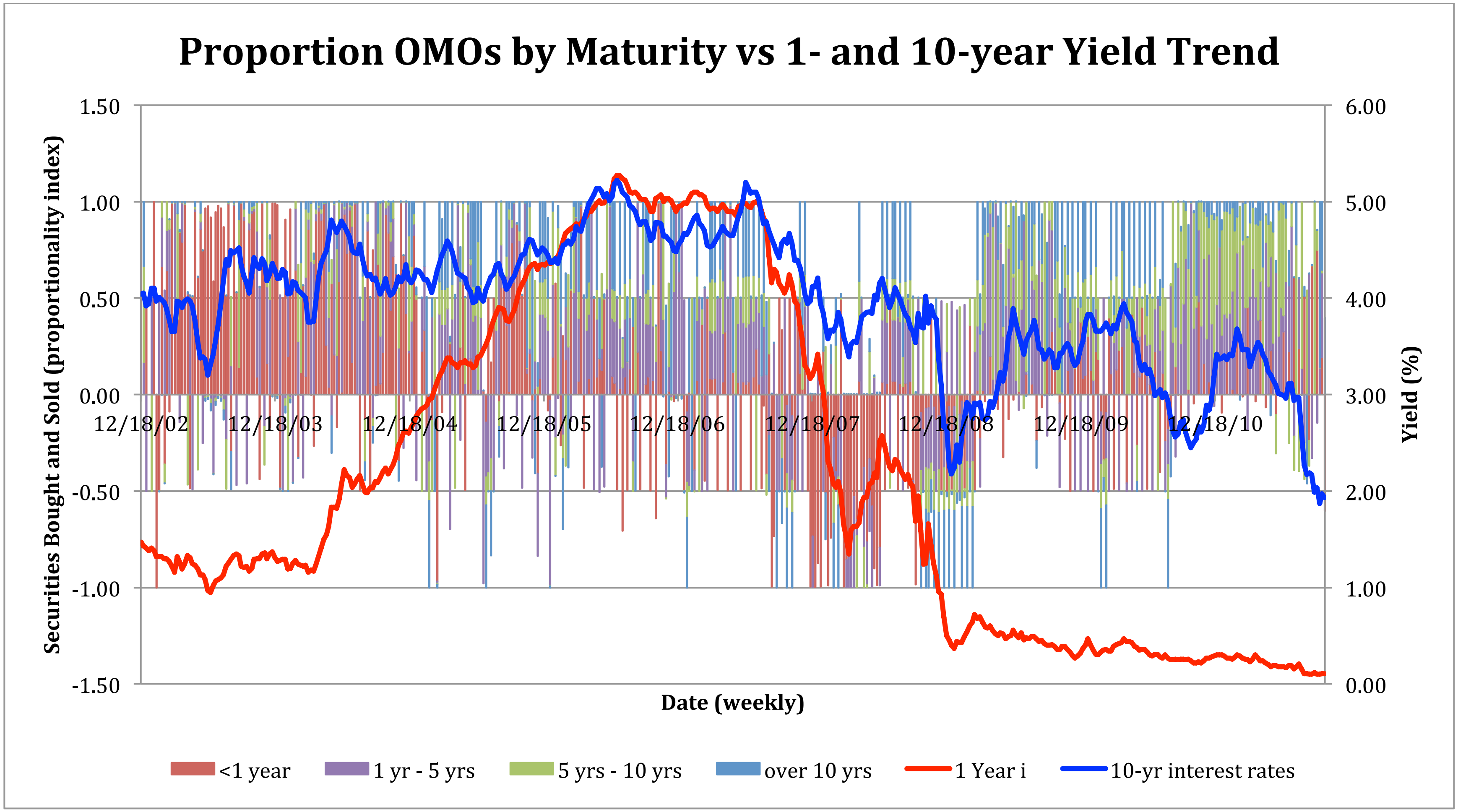
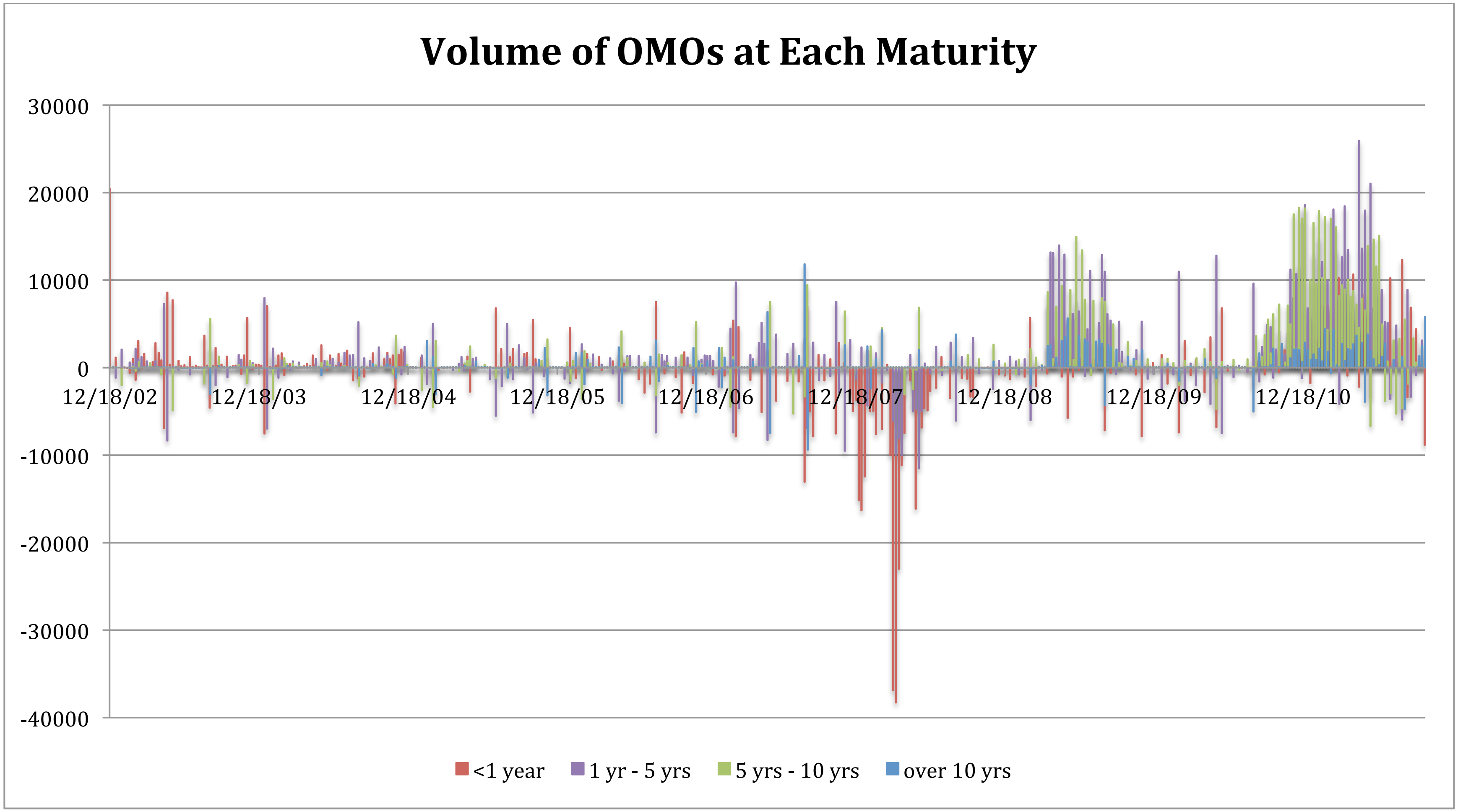
Exhibit A



Proportion OMOs by Maturity vs 1- and 10-year Yield Trend
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
6.00
5.00
4.00
3.00
2.00
1.00
0.00
12/18/02
12/18/03
12/18/04
12/18/05
12/18/06
12/18/07
12/18/08
12/18/09
12/18/10
Securities Bought and Sold (proportionality index)
Yield (%)
Date (weekly)
<1 year
1 yr - 5 yrs
5 yrs - 10 yrs
over 10 yrs
1 Year i
10-yr interest rates

Exhibit B



Volume of OMOs at Each Maturity
30000
20000
10000
0
-10000
-20000
-30000
-40000
12/18/02
12/18/03
12/18/04
12/18/05
12/18/06
12/18/07
12/18/08
12/18/09
12/18/10
<1 year
1 yr - 5 yrs
5 yrs - 10 yrs
over 10 yrs

Exhibit C: Major Stock Indices and 10-Year Treasury

Dow Jones:

S&P 500:

Nasdaq:

10 Year Treasury:

*Index charts from Yahoo! Finance.

Exhibit D

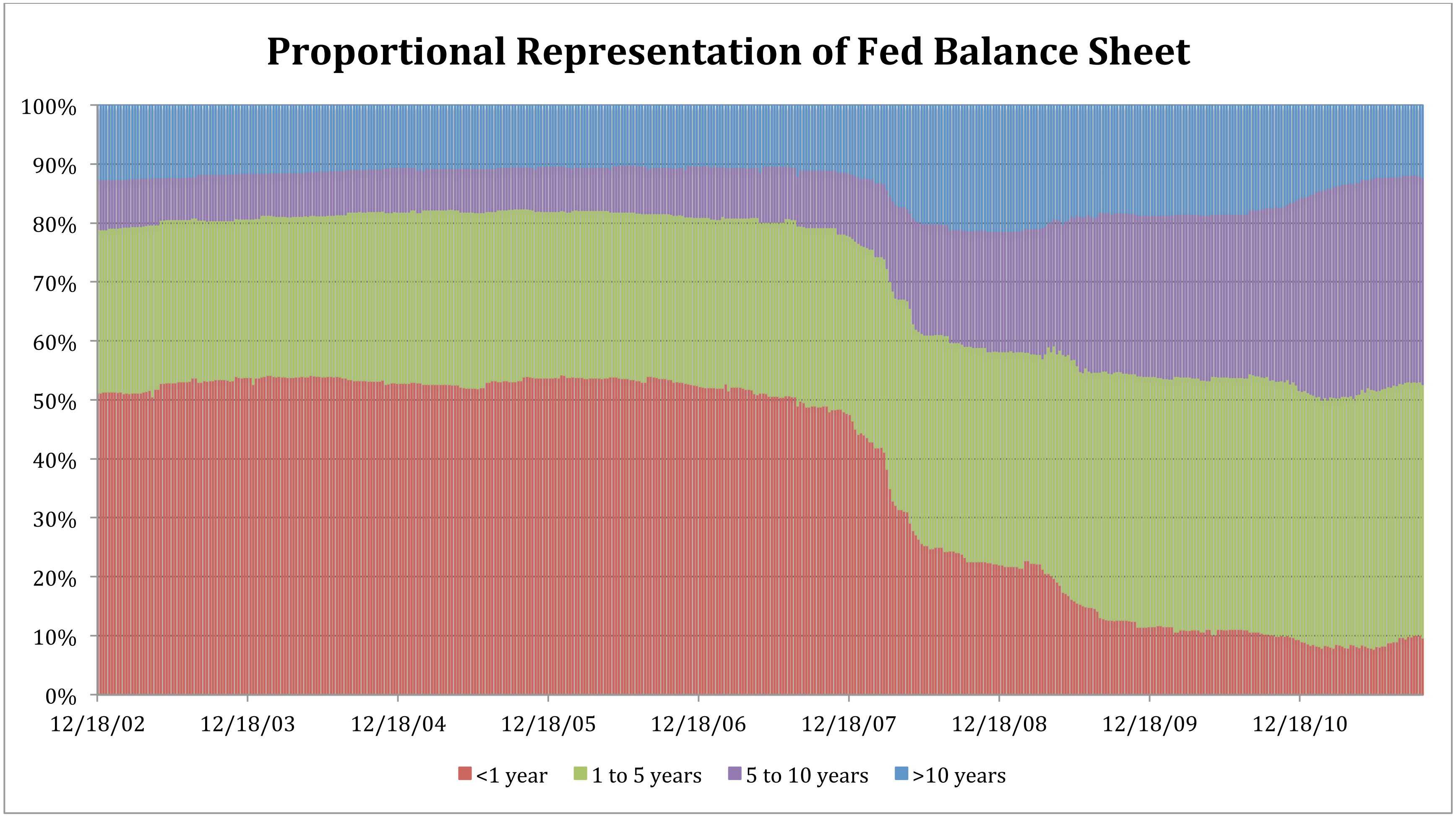

Proportional Representation of Fed Balance Sheet
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
12/18/02
12/18/03
12/18/04
12/18/05
12/18/06
12/18/07
12/18/08
12/18/09
12/18/10
<1 year
1 to 5 years
5 to 10 years
>10 years

Exhibit E: Coefficient Trends of Each Investment Type