How the Removal of Deposit Rate Ceilings Has Changed Monetary Transmission in the US: Theory and Evidence

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Abstract

Establishing the existence and nature of changes in the conduct and transmission of monetary policy is key in understanding the remarkable macroeconomic performance of the US since the mid 1980s. This paper presents evidence on a phenomenon of disintermediation occurring during the major recessions in the 1960s and 1970s, but absent ever since. Using a novel data set, I show that disintermediation is closely linked to the existence of deposit rate ceilings under regulation Q. In a monetary DSGE model that incorporates deposit rate ceilings as occasionally binding constraints, the regulation alters the behavior of money aggregates and exacerbates the drop in economic activity following a monetary tightening. The results of a time-varying coefficient VAR lend support to the main theoretical predictions of the model. In a counterfactual experiment, the presence of deposit rate ceilings explains *two thirds* of the decline in output volatility since the early 1980s.

JEL classification: E3, E4, E5, G21, G28
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1 Introduction

Output and inflation volatility in the US have dropped considerably since the early 1980s, which suggests a fundamental change in the dynamics of the economy.[1] So far, no consensus has emerged on the fundamental causes of this Great Moderation. Many, such as Clarida, Gali and Gertler (2000) and Cogley and Sargent (2001, 2005), focus on shifts in monetary policymaking, arguing that the Federal Reserve has become more successful in fighting inflation and stabilizing economic activity. Others, such as Bernanke and Mihov (1998) and Sims and Zha (2006), find little evidence for a break in the conduct of monetary policy. The focus of this paper is on one aspect of monetary policymaking for which structural change is a historical fact: Regulatory deposit rate ceilings and their removal in the early 1980s.

After the banking collapse of the 1930s, US legislators imposed a regulatory structure on the US banking sector aimed at restoring financial stability. The Banking Act of 1933 introduced regulation Q of the Federal Reserve, prohibiting interest payments on demand deposits and imposing interest rate ceilings on time and savings deposits at commercial banks. The purpose of the regulation was to shelter banks from excessive competition, discourage risky investment policies and prevent future bank failures. Most of the ceilings were phased out between 1980 and 1986.

This paper provides evidence, based on data constructed from historical Federal Reserve releases, that binding deposit rate ceilings gave rise to a phenomenon of "disintermediation": Unable to raise deposit rates above the legal ceilings, banks could not compete effectively with market instruments and failed to manage their liabilities in the same way as without binding regulations. Disintermediation potentially has real effects if the resulting shortage of loanable funds forces banks to cut back on lending to borrowers that rely on intermediated finance. In

[1] The evidence on the Great Moderation is discussed by Kim and Nelson (1999), as well as McConnell and Perez-Quiros (2000) and Blanchard and Simon (2001).

that case, regulation Q affects the monetary transmission mechanism and may have contributed to business cycle volatility during the 1960s and 1970s. This hypothesis deserves attention, since in contrast with the post-1980 years, every recession during this period is associated with outflows in all deposit categories at US banks.

To formalize the argument, I construct a theoretical DSGE model that incorporates occasionally binding interest rate ceiling constraints and solve it numerically. Attention is restricted to monetary policy innovations in order to relate to the debate on changes in monetary policy as an explanation for the Great Moderation. Comparing the impulse responses to an unanticipated decrease in the money supply with and without a binding constraint, the model yields several testable predictions: In the presence of a binding ceiling, the spread between market interest rates and the ceiling widens; real deposit holdings display a disintermediation effect; the liquidity effect of a monetary tightening is larger; the contraction in business lending is more severe; inventories/sales ratios are lower; and finally, the output decline is more pronounced.

I confront the theoretical predictions with the data by estimating a structural VAR while allowing for time-variation in the autoregressive coefficients. The empirical model captures the nonlinearities of binding deposit rate ceilings by exploiting information contained in the spread between market interest rates and the regulatory ceilings. In response to an identified positive innovation in the Federal Funds rate, binding ceilings exacerbate the contraction in output. Moreover, the response of the spread, the monetary aggregates and real lending are consistent with the theoretical predictions. These findings lend support for a structural change in the monetary transmission mechanism since the early 1980s that is due to the disappearance of regulation-induced disintermediation effects. The results also imply a role for regulation Q in shaping macroeconomic outcomes during the 1960s and 1970s in the US. A counterfactual experiment, in which the effects of regulation Q are removed from the 1960s-1970s data, indicates that two thirds of the reduction in output volatility can be explained by the effects of deposit rate ceilings.

The literature has produced several alternative explanations for the decline of output volatility in the US. According to the "good luck" hypothesis, the Great Moderation is mostly due to reductions in the volatility of exogenous disturbances (see Stock and Watson (2002) and Ahmed, Levin and Wilson (2004)). Another hypothesis, put forward by Kahn, McConnell and Perez-Quiros (2002), is that improvements in inventory management and information technology are responsible. However, Stock and Watson (2002) and Ramey and Vine (2005) question this point of view on empirical grounds. Although acknowledged by Blanchard and Simon (2001) and Stock and Watson (2002), the role of financial innovation and deregulation in the late 1970s and early 1980s has received relatively little attention. According to the general financial markets deregulation hypothesis, improved access to credit markets has enhanced the ability of consumers to smooth income shocks and has lessened the sensitivity of business spending to fluctuations in sales and cash flow. Dynan, Elmendorf and Sichel (2006) provide empirical evidence in support of this explanation. Some previous research has focussed on the impact of deposit rate ceilings in this context. For instance, Duca (1996) and McCarthy and Peach (2002) argue that a regulation-induced disintermediation effect of interest rate hikes leads to sharp contractions in residential construction and housing sales. Duca (2005) also finds regulation-Q effects in the market for consumer credit.

The rest of the paper is organized as follows: Section 2 presents evidence of the disintermediation phenomenon during the 1960s and 1970s; Section 3 describes the monetary DSGE model and its quantitative properties. Section 4 lays out the empirical strategy, and discusses the estimated impulse responses and the counterfactual experiment. Section 5 concludes.

2 Disintermediation and Deposit Rate Ceilings

Regulation-induced disintermediation occurs when depository institutions experience drops in deposit inflows because legal ceilings prevent the payment of the higher interest rates offered on market instruments. This phenomenon was described by, for instance, Ruebling (1970) as well as Cook (1978) and Gilbert and Lovati (1979). In this paper, I distinguish two major components of the liability side of depository institutions' balance sheets: *Core deposits*, consisting of all checkable and savings deposits; and *managed liabilities*, which are defined as the sum of small and large denomination time deposits, dollar-denominated deposits issued by foreign banks (also known as eurodollar deposits), and security repurchase agreements. Core deposits have traditionally been, and still are, quite interest-sensitive, with rising interest rates leading to outflows as agents substitute towards higher yielding alternatives. By varying the rate of interest offered on other types of deposits, banks can control the total deposit inflow and "manage" their liabilities. To the extent that investors substitute towards these alternatives, banks are able to maintain the pool of loanable funds. The larger the spread between rates on alternative saving instruments and the rates offered by depository institutions, the bigger the opportunity cost of holding deposits. If regulations constrain interest rates paid on managed liabilities, banks, not being able to offer competitive yields, may fail to offset losses in core deposits. The disintermediation effect occurs when, for these reasons, binding regulatory ceilings cause slowing or negative growth in all deposit categories.

Figure 1 plots real growth of core deposits and managed liabilities at US depository institutions from 1960 to 2005. From the late 1970s onwards, there is a negative correlation between the two series, which suggests that banks have successfully counteracted losses in core deposits. Before, however, the picture is quite different: Every NBER-dated recession is associated with slowing or negative growth in *both* core deposits and managed liabilities. If this fact is to be explained by a regulation-induced disintermediation effect, it needs to be the case that the ceilings constituted binding constraints at those instances. Note for example, that there is one early episode (1966 and early 1967) of negative growth in core deposits during which banks were able to expand their use of managed liabilities.

To identify the periods in which regulation Q was binding, I constructed a monthly data set from historical issues of the Federal Reserve's Annual Statistical Digest.[2] I refer the interested reader to Appendix A for a more detailed background on regulatory adjustments and financial market innovations that have influenced deposit rate regulation over time.

Core Deposits - Figure 2 plots real growth of core deposits against the difference between the 3-month T-bill rate and the ceiling on savings deposits from 1960 until the removal in 1986. The figure shows a stable negative relationship between the spread and deposit growth. It also reveals how on each occasion up to 1983, a positive spread is associated with drops in core deposit growth. In fact, every NBER-dated recession is associated with troughs in core deposit growth and peaks in the ceiling spread. Finally, note that the large spike in core deposit growth in 1983 is due to the nationwide authorization of a string of new transaction and savings deposit instruments (including ATS, NOW, Super-NOW and MMDA accounts). The ceilings on core deposits were lifted in March 1986.

Managed Liabilities - To assess the relevance of deposit rate ceilings on managed liabilities, it is important to first have a look at their composition. Figure 3 depicts the components of managed liabilities as a share of the total. Although steadily declining over time, small denomination time deposits (STDs) have traditionally constituted the largest share of managed liabilities. Because of the creation of large negotiable certificates of deposit (CD), by the mid 1960s, the share of large time deposits (LTDs) had risen from 10% to almost 40% of managed liabilities. After 5 years of subsequent decline, 1970 marked a turning point, after which the share of LTDs has remained relatively stable at about 25%, until recently climbing back up to 40%. The volumes of Eurodollar deposits and Repurchase Agreements have historically remained relatively small compared to the volume of time deposits.

[2]The Annual Statistical Digest is published by the Board of Governors of the Federal Reserve System and documents ceiling adjustments on the various types of deposits. A monthly data set is available from the author.

Although usually higher than those for savings deposits, maximum rates also applied to time deposits. Figure 4 plots the real growth rate of small and large time deposits, together with the spreads between the relevant market rates and the ceilings for various maturities. Real growth in small term deposits, depicted in the left panel of Figure 4, was negative during 1960, when the spread on all maturities was positive. A series of upward adjustments of the ceilings in 1962, 1963, 1964 and 1965 brought STD rates back in line with market rates. The revisions initiated an expansion in STDs during the course of 1966 and early 1967. This counteracted the contemporaneous drop in core deposits on which the ceilings were still binding. In contrast, at the onset of the recessions in 1969-1970 and 1973-1975, market rates exceeding the ceilings had brought about significant reductions in STD growth. The authorization of Money Market Certificates and Small Saver Certificates in 1978 and 1979 explains why the growth in STDs remained relatively stable while interest rates soared in the early 1980s (see Appendix A). In September 1983, the ceilings on small time deposits were eliminated.

Real growth of LTDs, shown in the right panel of Figure 4, also displays evidence of disintermediation effects. Major ceiling rates adjustments in the first half of the 1960s ensured that banks could offer competitive rates as the market for LTDs expanded. However, positive spreads towards the end of the 1960s caused a dramatic fall in the amount of LTDs outstanding, also explaining the decline in their relative use, evident in Figure 3. The contraction in LTDs outstanding even led to the removal of ceilings for certain smaller maturities in 1970. In 1973, regulation-Q ceilings were lifted on all LTDs.

The analysis of bank liabilities and deposits rate ceilings leads to the following conclusions: *First*, on multiple occasions, there have been contemporaneous contractions in core deposits and managed liabilities growth during the 1960s and 1970s. In contrast, after the late 1970s, the correlation between the growth rates of both deposit categories is consistently negative. *Second*, the contractions in deposits coincide exactly with periods in which market rates exceeded the deposit rate ceilings imposed under regulation Q, thus providing evidence for a regulation-induced disintermediation effect. *Third*, episodes in which disintermediation appears to have taken place include the periods surrounding the 1960 and 1970 recessions. Also the 1973-1975 recession seems to have been associated with disintermediation, despite the earlier removal of ceilings on large time deposits. Regulatory changes and innovations in banking explain why the impact of the deposit rate ceilings was reduced towards the end of the 1970s, even though regulation Q was not formally removed until the early 1980s.

3 Effects of Disintermediation: A Monetary DSGE Model

If the regulation-induced disintermediation observed in the data has forced banks to cut back on lending to borrowers that depend on intermediated finance, it has potentially also exacerbated the business cycle. This section develops a Dynamic Stochastic General Equilibrium model in which interest rate regulations, incorporated as occasionally binding constraints, affect the transmission of stochastic shocks primarily by affecting the availability of bank credit: Binding ceilings reduce the demand for deposits and constrain the pool of loanable funds. I restrict attention to monetary shocks to relate to the debate on changes in monetary policy as an explanation for the Great Moderation. The model also incorporates inventory investment decisions, because the availability of short-term credit directly affects firms' optimal inventory response to a monetary-induced drop in sales. Since most short-term business credit consists of bank loans, the disintermediation effect could alter the sensitivity of inventory investment to cash flow fluctuations and the ability of firms to smooth production. Therefore, disintermediation could also be relevant for the inventory explanation of the Great Moderation.

There are several additional reasons to narrow the discussion to the monetary transmission mechanism: *First*, disintermediation occurs when nominal market interest rates exceed the deposit rate ceilings. The monetary authority exerts control over nominal rates by varying the supply of base money. So regulation-Q effects are either induced by the systematic response of policy to non-monetary shocks or otherwise by unexpected shifts in monetary policy itself. However, the debate on the stability of the systematic conduct of monetary policy has not yet been settled. Narrowing attention to money shocks permits the common practice of modelling money as an exogenous stochastic process and mitigates the need of taking a stance on time variation in monetary policy rules. *Second*, the most direct consequence of the disintermediation effect for the real economy operates through the availability of loanable funds, a channel of transmission that is traditionally associated with monetary policy. *Third*, despite a wide range of methodologies, the empirical literature on monetary transmission has reached considerable agreement about the qualitative effects of monetary policy shocks on the main macroeconomic variables. Accordance with this consensus imposes a great deal of discipline on both the theory and the empirical testing procedures and therefore adds to the plausibility of the results.

3.1 A Monetary DSGE Model of Deposit Rate Ceilings

The model is a standard money-in-the-utility-function model, with a few twists. Apart from the regulation-Q price controls and the possibility of inventory investment, the model features a finance constraint: Firms must finance working capital expenses by taking out a bank loan. This assumption is an often-used short-cut to creating dependency on the availability of loanable funds in monetary models, see for instance Christiano and Eichenbaum (1992) or Fuerst (1992). Furthermore, I assume that prices are set before the realization of the current shock. This price-setting friction allows for more realistic effects of monetary shocks on interest rates and real variables. The economy contains a household sector, a firm sector, a banking sector and a government and the only source of uncertainty is a shock to the money supply.

The Household - The economy is inhabited by an infinitely-lived representative household that starts every period $t = 0, ..., \infty$ with the economy's entire last period money stock M_t. The household decides to deposit an amount $M_t - Q_t$ in a bank and keep Q_t as nominal cash balances. Deposits earn a gross nominal deposit rate R_t.

The specification of household preferences is identical to Christiano and Eichenbaum (2005).

Lifetime utility is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) - \frac{\Psi}{2} h_t^2 + \frac{\Omega}{1 - 1/\phi} \left(\frac{Q_t}{P_t} \right)^{1-\frac{1}{\phi}} \right] , \tag{1}$$

where E_0 is the time 0 conditional expectation operator; c_t is the period t value of a consumption index to be defined below; h_t is hours worked in period t; and P_t is the period t consumption-based money price index. The parameters of the utility function are the discount factor, $1 > \beta > 0$; the time allocation parameter, $\Psi > 0$; the utility weight of real cash balances, $\Omega > 0$; and the interest rate elasticity of the demand for cash, $\phi > 0$.

There is a continuum of differentiated final consumption goods, indexed by $j \in (0, 1)$, that enter the household utility function through the index c_t, given by

$$c_t = \int_0^1 \left[\left(\frac{n_{jt}}{n_t} \right)^{\frac{\xi}{\epsilon}} s_{jt}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} dj \ .$$

Here, s_{jt} is the amount of good j purchased by the household for consumption in period t, whereas n_{jt} denotes the *total stock* of good j that is available for sale in period t. This specification of the consumption index implies that, at a given price, finished goods inventories facilitate sales. This modelling approach is followed by, for instance, Bils and Kahn (2000) and is also related to models that incorporate inventories as a factor of production, such as Kydland and Prescott (1982) and Christiano (1988). Note that here, following Jung and Yun (2006), the stock of good j available in stores generates higher utility for the household only to the extent it is higher than the economy-wide average level $n_t = \int_0^1 n_{jt} dj$. The parameters of the consumption goods index c_t are the elasticity of demand with respect to stock available for sales, $\xi > 0$; and the price elasticity of demand for good j, $\epsilon > 1$.

Letting P_{jt} denote the price of good j, intratemporal cost minimization implies the following demand function for the j-th good:

$$s_{jt} = \left(\frac{n_{jt}}{n_t} \right)^{\xi} \left(\frac{P_{jt}}{P_t} \right)^{-\epsilon} c_t \ , \tag{2}$$

where the utility-based price index P_t is given by

$$P_t = \left(\int_0^1 \left(\frac{n_{jt}}{n_t} \right)^{\xi} {P_{jt}}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} .$$

Household assets evolve according to

$$M_{t+1} = R_t(M_t - Q_t) + D_t + W_t h_t + Q_t - P_t c_t \ . \tag{3}$$

The first term on the right hand side, $R_t(M_t - Q_t)$, denotes total interest earnings on deposits held with the banks. Without loss of generality, asset markets are not modelled explicitly and D_t simply represents combined period t dividend payments from the household and banking sector. The third term, $W_t h_t$ is total labor earnings, where W_t is the period t nominal wage. Finally, Q_t are cash balances and $P_t c_t$ is total consumption expenditure. The intertemporal decision problem of the household consists of choosing sequences of cash holdings, consumption levels and labor effort, contingent on the history of realizations of the shock, in order to maximize lifetime utility as defined in (1), subject to the constraint defined in (3).

The Firms - Each final consumption good $j \in (0, 1)$ is produced by a monopolistic firm using labor as the only input. The technology for period t production for each firm j is given by

$$y_{jt} = \begin{cases} h_{jt}^{\alpha} - \theta & \text{if } h_{jt}^{\alpha} \geq \theta \\ 0 & \text{otherwise} \end{cases} , \tag{4}$$

where $\theta > 0$ is a fixed cost of production and $1 > \alpha > 0$ and h_{jt} is labor input by firm j. There is no entry or exit in the market for good j. Each firm's stock of goods available for sale in period t is

$$n_{jt} = n_{jt-1} - s_{jt-1} + y_{jt} \ , \tag{5}$$

where s_{jt-1} are period $t-1$ sales of good j.

It is assumed that workers must be paid in advance and that firms must borrow the wage bill by lending L_{jt} from a bank. As a result, each firm j faces a financing constraint $W_t h_{jt} \leq L_{jt}$. Loans are repaid at the end of the period at the gross interest rate r_t. Firms set prices in period t before the current realization of the shock and see V_t, the marginal value of one unit of cash to the household in period t, as exogenous. Noting that, as long as $r_t > 1$, the financing constraint holds with equality, the objective of each firm j is to choose sequences of prices and production levels contingent on the realization of uncertainty in order to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t V_t \left[P_{jt} s_{jt} - r_t W_t h_{jt} \right] \ ,$$

taking into account the demand function for its differentiated final consumption good, given by (2), and subject to (4) and (5).

The Banks - The representative bank receives deposits $M_t - Q_t$ and receives X_t as a cash injection from the government. Hence, bank lending is restricted by the availability of funds as follows

$$L_t \leq M_t - Q_t + X_t \ .$$

The market for business loans is competitive and as long as $r_t \geq R_t > 1$, the intermediary lends all the available funds to the firms. Government regulation stipulates the following restriction on interest rates paid on deposits:

$$R_t \leq R^q \ ,$$

where $R^q > 1$ is an exogenous deposit rate ceiling. This inequality captures regulation Q in a simple and straightforward manner. The banks' net cash position at the end of each period t is distributed as dividends to the household, the ultimate owner of the banks. Entry and exit in the banking sector is ruled out.

The Government - The money stock evolves according to $M_{t+1} = M_t + X_t$. Define $\mu_t \equiv M_{t+1}/M_t$ as the growth rate of money in period t, which evolves according to the univariate stochastic process

$$\ln(\mu_t) = (1-\rho)\ln(\mu) + \rho\ln(\mu_{t-1}) + \chi_t \; , \tag{6}$$

where $\mu > 1$ is the average gross growth rate of the money stock, $1 > \rho > 0$ measures the persistence and χ_t is a normal i.i.d. random variable with mean zero and variance $\sigma^2 > 0$. Christiano, Eichenbaum and Evans (1998) provide arguments in favor of this simple representation of monetary policy for evaluating the effect of monetary shocks in theoretical models.

Market Clearing and Equilibrium - An equilibrium is a set of sequences of prices and quantities such that all agents maximize their objective functions and goods, labor and asset markets clear. Appendix B provides a more detailed equilibrium definition.
Note that loan market clearing implies that

$$W_t h_t = M_{t+1} - Q_t \; . \tag{7}$$

Competition in the market for loans ensures that $R_t = r_t$ as long as the regulation Q-constraint is not binding. Else, in the case where the interest rate constraint binds, it must be the case that $r_t > R_t = R^q$.

3.2 Parametrization and Numerical Solution Methodology

Parametrization - Following standard practice, I choose parameter values to obtain certain properties of the steady state of a *non-stochastic* version of the model. All the values used for generating the results are summarized in Table 1. The time period in the model corresponds to one quarter. The parameters can be partitioned into three groups. The *first* group contains the household's preference parameters, namely β, Ψ, Ω, ϕ, ϵ and ξ. The discount factor is $\beta = 1.03^{-0.25}$, implying an annualized real interest rate of 3% in the non-stochastic steady state. The value for the time allocation parameter Ψ normalizes the steady-state value of hours worked h to unity. The value for the utility weight Ω yields a ratio of cash balances to the total money stock Q/M equal to 0.3. The interest rate elasticity of money demand ϕ is 0.24. Obtaining reliable estimates for this parameter is difficult because of structural changes in financial markets. I take the value estimated by Teles and Zhou (2005), who use a relatively stable monetary aggregate, MZM, and a more accurate measure of the opportunity cost. The value of 0.24 is higher than the one estimated by Christiano and Eichenbaum (2005) but lower than those obtained by Lucas (1988) and Chari, Kehoe and McGrattan (2000). Next, the value of the price elasticity of demand ϵ yields a steady state non-competitive markup of 20% (see Rotemberg and Woodford (1995)). Finally, the value for ξ matches the average inventories/sales ratio in manufacturing and trade in US postwar data. The *second* group contains the technology parameters, θ and α. The choice of $\alpha = 0.64$ corresponds to the labor income share in the data and the fixed cost θ is set to ensure that firms make zero excess profits in the non-stochastic steady state. The *third* group are the parameters governing the money growth process. I borrow these values from Christiano and Eichenbaum (1992): The average quarterly gross growth rate is $\mu = 1.012$, the autoregressive parameter ρ is 0.3 and the standard deviation of the monetary shock is $\sigma = 0.012$.

Numerical Solution Methodology - I compute the model solution by solving the system of Euler equations describing the equilibrium behavior of the various macroeconomic variables, which is given in Appendix B. The numerical method is based on time iteration, as described by Coleman (1990). The main advantages of the procedure are its straightforward application to non-Pareto optimal economies and the fact that convergence is usually achieved. Time iteration also does not rely on discretization of the state space, but instead requires interpolation techniques that preserve the continuous nature of the state space. In addition, as showed by Rendahl (2006), time iteration is relatively easily to implement in the presence of inequality constraints.[3] However, time iteration is generally slow. Therefore the iterative scheme is augmented by the

[3] In fact, Rendahl (2006) proves numerical convergence for the case of Pareto optimal economies.

application of the method of endogenous gridpoints, developed by Carrol (2006). This method reduces the number of nonlinear equations that need to be solved numerically in every iteration. The model features two endogenous state variables, n_t and p_t, and one exogenous state χ_t. All functions are approximated by a linear interpolation scheme based on a grid of the state space. The grid contains 20 nodes for both endogenous state variables, and 9 nodes for the shock. Taking expectations requires integration over the continuous state space. The integrals with respect to the normal density are approximated using Gauss-Hermite quadrature with 10 quadrature nodes (see Judd (1998)).

3.3 Quantitative Properties of the Model

Figure 5 plots the response of some of the main variables to a one-standard-deviation (1.2%) unexpected decrease in the money growth rate in period $t = 1$. The solid line represents the model without deposit rate ceiling (R^q is set arbitrarily high), the striped line represents the model with a ceiling R^q of 1.02. The response of the net interest rate $r_t - 1$, inflation P_t/P_{t-1} and the interest rate-ceiling spread $r_t - R^q$ are in levels, whereas those for production y_t, the inventories/sales ratio $(n_t - c_t)/c_t$, real lending L_t/P_t, real cash balances Q_t/P_t and real deposits $(M_t - Q_t)/P_t$ are all in percentage deviations from the state prior to the shock. This initial state, at $t = 0$, is the one to which the economy converges when the value of the exogenous shock is set to $\chi_t = 0$ for an arbitrarily long period. Note that this state does not correspond to the steady state of the non-stochastic version of the model. For instance, in the absence of a ceiling on the deposit rate, $r_0 = R_0 = 1.0192$ is slightly below its non-stochastic steady-state level of $\mu/\beta = 1.0195$ because of Jensen's inequality. When a ceiling of $R^q = 1.02$ is imposed, the market interest rate is 1.0202, which is higher than μ/β. This is because, in those states of the world where the ceiling is binding, a higher loan rate r_t is required to clear the market for loanable funds, as the ceiling decreases the opportunity cost of holding cash and lowers the demand for deposits. For the consumption Euler equation to hold, interest rates also need to be higher in states of the world where the ceiling is not binding. The fact that interest rates increase on average with regulation Q is interesting in itself, since one of the motivations during the 1960s and 1970s to keep the ceilings below the market interest rates was to *lower* loan rates charged by banks. In the current setting, this reasoning breaks down. Because of the finance constraint, the higher interest rates raise the marginal cost of hiring labor and therefore lower output and consumption relative to the regulation-free model. Note that for $R^q = 1.02$, the ceiling is binding in the initial state. Hence, in simulations, deposit rates are at the ceiling more often than not, which is the case in 1960s and 1970s data.

In response to a negative money growth shock, both models display a “liquidity effect”, i.e. market interest rates rise after a money tightening. To see why, write the real supply of loanable funds in the economy as

$$\frac{L_t^s}{P_t} = \frac{X_t}{P_t} + \left(\frac{M_t}{P_t} - \left(\frac{R_t - 1}{\Omega c_t} \right)^{-\phi} \right) . \tag{8}$$

Loanable funds come from two sources: The first term in equation (8) represents the exogenous injections by the government, the second term reflects the endogenous supply of deposits by the households derived from the household's first order condition with respect to cash balances. The demand for deposits depends positively on the deposit rate R_t and negatively on consumption through the equalization of the marginal utilities of holding cash and consuming. Using the firms' first order condition for labor, loan demand can be written as

$$\frac{L^d}{P_t} = \alpha \frac{MC_t}{P_t} \frac{y_t + \theta}{r_t} . \tag{9}$$

Loan demand depends negatively on the cost of borrowing r_t and the markup P_t/MC_t and positively on production y_t, all of which determine the size of the real wage bill in equilibrium. The monetary shock leads to a leftward shift of the loan supply curve through a decrease in X_t. Because prices do not adjust immediately, clearing of the loan market is achieved by a reduction in demand through increases in r_t and MC_t/P_t and a decrease in y_t. In the regulation-free model, an endogenous reaction of deposit demand through an increase in R_t and a decrease in c_t counteracts the decrease in the supply of funds. The two lower right panels of Figure 5 show

how households substitute out of cash balances and into interest-bearing deposits. Despite this shift into deposits, the net effect for the loan market is a decrease in L_t/P_t and an increase in the borrowing cost r_t. In the model with a binding regulation-Q constraint, there is no first order effect on deposit demand through an increase in R_t. The cash position of the household changes only through the decrease in c_t. This is the model equivalent of the disintermediation effect of deposit rate ceilings. As a result, a larger part of the adjustment must occur through increases in r_t and MC_t/P_t and the decrease in y_t. The immediate consequence of disintermediation is thus to amplify the liquidity effect of a monetary contraction.

In both models, a monetary tightening leads to a fall in hours worked and output: On the one hand, higher borrowing costs increase the marginal cost of hiring labor, which leads to a leftward shift of the labor demand curve; On the other hand, the labor supply curve shifts rightward because of a drop in consumption. Both effects contribute to a decline of the real wage W_t/P_t, and because prices do not react in the period of the shock, necessarily also of the nominal wage W_t. Nevertheless, the net result is a decline in h_t, which implies that the marginal cost of hiring labor, R_tW_t/MC_t has risen. Because borrowing costs rise more with a binding regulation-Q ceiling, the decline in output is much more pronounced than for the regulation-free model.

To understand the response of inventories, it useful to consider the firms' first order condition for inventory investment, which in a symmetric equilibrium leads to the following relation:

$$P_t \xi \frac{s_t}{n_t} + \beta E_t \left[\frac{V_{t+1}}{V_t} MC_{t+1} \right] \left(1 - \xi \frac{s_t}{n_t} \right) = MC_t \ . \tag{10}$$

Adding an extra unit to the stock of goods available for sale is associated with a marginal cost MC_t, and yields an increase in sales of $\xi s_t/n_t$, valued at P_t. To the extent the extra unit adds to inventories and is not sold, production is shifted from $t+1$ to t, saving the firm the present discounted value of tomorrow's marginal production cost MC_{t+1}. For notational ease, let $z_t = MC_t/P_t$ denote the inverse of the markup charged over marginal cost and $z_t^e = \beta E_t \left[z_{t+1} P_{t+1} V_{t+1} / P_t / V_t \right]$ the expected discounted value of next period's inverse markup. Using

(10), the inventories/sales ratio can be written as

$$\frac{i_t}{c_t} \equiv \frac{n_t - c_t}{c_t} = \xi \left(\frac{1 - z_t^e}{z_t - z_t^e} \right) - 1 \,. \tag{11}$$

Note that the inventories/sales ratio is increasing in today's markup, and decreasing in the expected markup tomorrow. The reason is that, since the return to inventory investment is largely the ability to boost current sales, firms wish to build up the stock of goods available for sale at times when profit margins are high. The marginal cost of producing one additional good is

$$MC_t = \frac{r_t W_t}{\alpha} (y_t + \theta)^{\frac{1-\alpha}{\alpha}} \,. \tag{12}$$

The drop in y_t and W_t contributes to a decrease in MC_t whereas the increase in r_t tends to increase MC_t. The net effect in both models, however, is a decrease in marginal cost and, since prices are sticky, and increase in P_t/MC_t. In the next period, prices adjust and there is a drop in the markup. The countercyclical reaction of today's markup and the lower markup tomorrow are the reason why firms wish to increase the inventories/sales ratio, which is achieved both through a drop in c_t and an increase in the stock of inventories. Because borrowing costs rise more in the model with regulation Q, the increase in the profit margin is smaller and the positive response of inventories is reduced relative to the regulation-free model.

Since the shock to monetary growth rate is persistent, in period 2 inflation falls. Whereas the supply of loanable funds on behalf of the government is still low, equilibrium in the market for funds is now attained mainly through the drop in prices, even to the extent that, in real terms, lending increases in period 2. Through the household's consumption Euler equation, consumption and therefore sales rise in period 2. Afterwards, as the effect of the money shock dies out, consumption reverts to the initial state. Because of the price adjustment, now markups are small relative to tomorrow's, which leads firms to decrease the stock of inventories relative to sales. Note how, because of the ceiling, the liquidity effect in the regulation-Q model is quite persistent. This additional gradual decline in borrowing costs further raises next period's markup relative to today's, and therefore the inventories/sales ratio is reduced more in the regulation-Q model. As markups and sales stabilize, inventory levels return to the initial state.

The model response to a contractionary monetary shock is qualitatively consistent with the consensus view: Interest rates rise; aggregate output, employment, the price level and monetary aggregates fall. Admittedly, the model is too simple to replicate the precise timing and persistence encountered in the data. Nevertheless, it provides several clear predictions about the impact of deposit rate ceilings after a contractionary monetary shock. First and foremost, the drop in aggregate output is more pronounced with a binding regulatory ceiling. But to assess whether a stronger output response after a monetary tightening can be explained by the presence of regulation Q, the following additional facts should be observed in the data: With a binding ceiling,

1 the spread between market rates and the regulatory ceilings widens;

2. the response of real deposit holdings displays a disintermediation effect;

3. the liquidity effect, i.e. the negative effect of monetary aggregates on interest rates, is stronger;

4. the contraction in real lending is more severe;

5. inventories/sales ratios are lower relative to the unconstrained case.

If the data support these facts, then there is evidence for a role of ceiling regulations in the monetary transmission mechanism and in shaping the macroeconomic outcomes of the 1960s and 1970s in the US.

4 Confronting the Theory with the Data

To evaluate the theoretical predictions empirically, I estimate impulse responses to an identified monetary policy innovation in a structural Vector Autoregressive Model (VAR). The objective is to compare the impulse responses for two separate situations: One in which deposit rate ceilings are binding, the other in which they are not. Implicitly, this means that the autoregressive coefficients in the VAR must display time variation. The presence of time-varying coefficients generally complicates the estimation process because of the large number of coefficients to be estimated relative to a limited number of observations, and because of the need to define a law of motion for the coefficients. Researchers focussing on time variation in monetary VARs have traditionally relied either on subsample analysis (see for instance Bernanke and Mihov (1998) and Boivin and Giannoni (2006)) or on Bayesian estimation of more sophisticated econometric models (see Cogley and Sargent (2005) and Sims and Zha (2006)). Instead, the empirical strategy adopted in this paper is to exploit information about the presumed source of time variation. The assumption is that the observations on the interest-rate ceiling spreads contain sufficient information to capture, in an asymmetric fashion, the impact of binding deposit rate ceilings. The structural economic model underlying the time-varying VAR contains only few additional parameters relative to a stable VAR, such that estimation is straightforward.

4.1 Empirical Model and Estimation Strategy

Model Specification - Let $\mathbf{y}_t$ be a $(n \times 1)$ vector of time series including a price index PI_t; a commodity price index $Pcom_t$; a measure of economic activity Y_t; the federal funds rate FF_t; and a monetary aggregate MZM_t, all of which are variables that are commonly included in monetary VARs. In this paper, $\mathbf{y}_t$ also contains some additional variables of interest, namely the real volume of managed liabilities ML_t; the real volume of loans LNS_t; and the inventories/sales ratio In_t, such that $n = 8$ and $\mathbf{y}_t = [Pcom_t \;\; FF_t \;\; PI_t \;\; Y_t \;\; In_t \;\; MZM_t \;\; LNS_t \;\; ML_t]'$. Let $\mathbf{x}_t = [1 \; \mathbf{y}'_{t-1} \; ... \; \mathbf{y}'_{t-p}]'$ be a $((np{+}1){\times}1)$ vector containing a constant and the lagged observations, where p denotes the number of lags. Because I use monthly data, $p = 12$ in all the estimations.

Let S_t be the period t observation of the spread between the market interest rate and the legal deposit rate ceiling and let $\bar{S}_t \equiv \max(S_t, 0)$, i.e. $\bar{S}_t$ equals the value of the spread whenever that value is positive, and zero otherwise. Let $s_t = [S_{t-1} \; ... \; S_{t-p}]'$ be a $(p \times 1)$ vector of the current and lagged observations of the spread and correspondingly, $\bar{s}_t = [\bar{S}_{t-1} \; ... \; \bar{S}_{t-p}]'$. The dynamics of $\mathbf{y_t}$ and S_t are assumed to be captured by

$$A\mathbf{y}_t + C\bar{S}_t \quad = \quad B\mathbf{x}_t + D\bar{s}_t + \Sigma\epsilon_t \; , \tag{13a}$$

$$A^s\mathbf{y}_t + S_t \quad = \quad B^s\mathbf{x}_t + D^s s_t + \sigma^s\epsilon_t^s \; . \tag{13b}$$

The model coefficients are contained in the matrices $A_{(n\times n)}$, $B_{(n\times(np+1))}$, $C_{(n\times 1)}$, $D_{(n\times p)}$, $A^s_{(1\times n)}$, ${B^s}_{(1\times(np+1))}$, ${D^s}_{(1\times p)}$, a positive definite, diagonal matrix $\Sigma_{(n\times n)}$ and the scalar $\sigma^s > 0$. I further assume that A and $A - CA^s$ are invertible matrices and, without loss of generality, that the structural shocks ϵ_t are i.i.d. $\sim N(0, I_n)$ and ϵ_t is i.i.d. $\sim N(0,1)$. In other words, I include the variables $\bar{S}_t$ and $\bar{s}_t$ into an otherwise standard structural model with the purpose of capturing the nonlinear effects of disintermediation.

Equation (13a) can be reformulated as a VAR with time-varying coefficients. To see this, substitute (13b) into (13a) and, for simplicity, also define $\hat{S}_t = B^s\mathbf{x}_t + D^s s_t + \sigma^s\epsilon_t^s$. Then equation (13a) is equivalent to

$$\text{(VAR1):} \qquad \mathbf{y}_t = G_t\mathbf{x}_t + F_t\bar{s}_t - \mathcal{I}_t C\hat{S}_t + \mathbf{u}_t \; ,$$

where $G_t = (A - \mathcal{I}_t CA^s)^{-1} B$, $F_t = (A - \mathcal{I}_t CA^s)^{-1} D$ and where $\mathcal{I}_t$ is a dummy variable that takes on the value of 1 if regulation Q is binding in period t. The relationship between the fundamental shocks and the VAR-disturbances is given by $(A - \mathcal{I}_t CA^s)\,\mathbf{u}_t = \Sigma\epsilon_t$. For comparison, define two further models nested by the specification VAR1:

$$\text{(VAR2): } C = 0 \text{ ,} D = 0, \qquad \mathbf{y}_t = G\mathbf{x}_t + \mathbf{u}_t \ ,$$
$$G = A^{-1}B \ , \ A\mathbf{u}_t = \Sigma\epsilon_t \ ,$$
$$\text{(VAR3): } C = 0 \ , \qquad \mathbf{y}_t = G\mathbf{x}_t + F\bar{s}_t + \mathbf{u}_t \ ,$$
$$G = A^{-1}B \ , F = A^{-1}D \ , A\mathbf{u}_t = \Sigma\epsilon_t \ .$$

Specification VAR2 assumes $C = 0$, $D = 0$, and corresponds therefore to the standard time-invariant monetary VAR widely used in the literature. Assuming only $D = 0$, VAR3 corresponds to the standard VAR in which the elements of $\bar{s}_t$ are added as extra explanatory variables.

Identification - Recovering the structural parameters of VAR1-VAR3 is impossible without additional identification assumptions. In correspondence with a large part of the literature on monetary VARs, I base the strategy for estimating the effects of a monetary shock on the recursiveness assumption, together with the assumption that the federal funds rate is a good measure of monetary policy. Bernanke and Mihov (1998) and Christiano, Eichenbaum and Evans (1999) provide arguments why this strategy is reasonable. Suppose that the monetary policy is characterized by the rule

$$FF_t = f(\Omega_t) + \epsilon_t^m \ , \tag{14}$$

where $f(\cdot)$ is a linear function and Ω_t is the information set of the monetary authority. A monetary shock, denoted by ϵ_t^m, is a shock orthogonal to the elements of Ω_t. The information set Ω_t contains the current value of the spread S_t and the commodity price index $Pcom_t$, as well as all of the lagged values contained in $\mathbf{x}_t$ and s_t. Given the use of monthly data, this definition of a monetary shock therefore reasonably assumes that the Federal Reserve has within-month data on commodity prices, which are set in auction markets, and market interest rates. The Federal Reserve does however not see current values of output, the price level, the money stock or any of the other variables in $\mathbf{y_t}$. The recursiveness assumption is not sufficient for identification and, following common practice, I further assume that A is a lower triangular matrix with diagonal elements equal to one. In practice, this implies that the coefficients in VAR2 and VAR3 can be obtained by standard OLS and subsequent Choleski decomposition of the estimated variance-covariance matrix. For standard cases as VAR2 and VAR3, Christiano, Eichenbaum and Evans (1999) show that the additional assumptions imposed by the lower triangularity of A is without consequence for the estimated impulse response to a monetary shock.

Estimation of VAR1 requires some more restrictions, since A^s and $\hat{S}_t$ are unknown. *First*, I assume that Y_t, PI_t, $Pcom_t$ and In_t are predetermined relative to ϵ_t^s, which implies that the corresponding elements of C are zero. In other words, a financial market shock to S_t does not affect output, prices, inventories and sales within the same month. *Second*, I assume that there is no contemporaneous relation between S_t on the one hand and Y_t, PI_t, $Pcom_t$ and In_t on the other hand, which implies that the corresponding elements of A^s are zero. Note, however, that shocks to $Pcom_t$ still affect S_t within the same period indirectly through the effect on FF_t.

Estimation Procedure - With the above identification scheme, VAR1 can be estimated in the following two steps:

1. Obtain estimates of A^s and $\hat{S}_t$ by instrumental variables estimation of equation (13*b*), using Y_t, PI_t, $Pcom_t$ and In_t as instruments;

2. Use these to estimate the coefficients in A, B, C, D and Σ with conventional maximum likelihood techniques.

Because only 4 additional coefficients need to be estimated in the VAR1 specification relative to the stable version in VAR3, the ML-step never proved problematic. Note that in the VAR1 model, the lower triangularity assumption does matter for the impulse response to a monetary shock. Fortunately, changing the ordering of the variables in $\mathbf{y}_t$ led only to small changes in the estimated impulse response functions in practice, which suggest that the results are at least invariant to this subset of identification restrictions.

4.2 Data and Sample

Data Series - The series included in $\mathbf{y_t}$ are log PCEPI less food and energy for PI_t; the log index of sensitive materials prices for $Pcom_t$; the log of interpolated real GDP for Y_t; the effective federal funds rate for FF_t; the log of money at zero maturity for MZM_t; the log ratio of real inventories to real sales in trade and manufacturing for In_t; the log of commercial and industrial loans, deflated by the price index, for LNS_t and the log of the volume of managed liabilities, deflated by the price index, for ML_t.[4] The series used for S_t is the spread between the average of the 3 and 6 month T-bill rates and the regulatory ceiling on time deposits with maturity between 3 and 6 months.

The choice of variables is motivated by a number of considerations. $Pcom_t$ is usually included in VARs to mitigate the so-called "price puzzle", the finding that prices rise persistently after a contractionary monetary shock. Real GDP constitutes the broadest measure of economic activity. I repeated the estimations with the log index of industrial production, which is available at monthly frequency, but obtained very similar results. Money zero maturity is the preferred money stock measure because of its stability, because it does not include any of the components of ML_t, and because it is a good data equivalent of Q_t/P_t in the theoretical model.[5] I use C&I loans rather than total bank loans, since business loans are the more appropriate measure in testing for a credit channel affecting production. Moreover, recent research by Denhaan, Sumner and Yamashiro (2005) stresses the importance of distinguishing between the components of banks' loan portfolios. Finally, ML_t is a good data equivalent of real deposit holdings $(M_t - Q_t)/P_t$ in the theoretical model.

An issue in VAR estimation is whether or not to remove time trends. The inventory to sales ratio displays a clear low frequency shift, most likely due to changes in management techniques during the early 1980s. Also, innovations in financial markets have caused much higher trend growth in the series for managed liabilities before 1980s than afterwards. Since

[4]Detailed descriptions and the sources of all series can be found in the data Appendix C.2.

[5]Money zero maturity (MZM) roughly equals $M2$ but excludes small time deposits. See Teles and Zhou (2005) for evidence on the stability of the MZM measure.

these low frequency movements are outside the scope of this paper, they are removed from the ML_t and In_t series with a HP filter. The smoothing parameter is 86,400, as opposed to the conventional choice of 14,400, such as not to remove too much business cycle variation. Finally, note that using alternative measures of the spread S_t did not significantly change the results.

Sample - The monthly data set covers the period 1959:1-2004:4, spanning a period of about 45 years and containing a total of 544 observations for each series in $\mathbf{y_t}$. However, the estimation of the VAR is conducted using only a subset of the available data points, including the periods 1960:1-1978:6 and 1983:10 to 2004:4. This means that 63 observations (1978:7 to 1983:9) are dropped during the estimations.[6] Also note that in the estimation of equation in (13b), necessarily only the first subsample is used. There are 121 data points for which the spread is positive. The omission of a range of intermediate observations is motivated by two considerations. *First*, the break date of June 1978 marks the permission of retail money market certificates MMCs. As explained in Appendix A, these and other subsequent new instruments offered market-determined interest rates and greatly facilitated the ability of banks to raise funds. The second break date, October 1983, marks the elimination of the remaining ceilings on small time deposits. The omitted data points comprise the relevant transition period during which the effects of the regulation gradually vanished. A *second* reason for the omission is the short-lived experiment of nonborrowed reserve targeting adopted by the Federal Open Market Committee from 1979 to 1982, which resulted in excessive volatility of the federal funds rate during this period. As shown by Bernanke and Mihov (1998) and Sims and Zha (2006), this period constitutes a significant regime shift that invalidates the use of a single policy indicator over the entire sample. However, Bernanke and Mihov (1998) conclude that using the funds rate prior to 1979 and after 1982 produces reasonable results.

[6]These data ranges take into account the loss of observations due to the inclusion of lagged terms.

4.3 Impulse Responses and Counterfactual Experiment

Figure 6 plots the estimated impulse response to a one-standard-deviation (0.23%) shock to the Federal Funds rate in the VAR1 model, occurring in period $t = 1$. The solid line represents the case where the deposit rate ceiling is non-binding in period 1 and all periods following the shock, i.e. the dummy variable $\mathcal{I}_t$ takes on the value of 0 in all periods. The dashed line represents the case where the regulation-Q constraint is binding in $t = 1$ and all subsequent periods, i.e. $\mathcal{I}_t$ equals 1 in all periods. For comparison, the dotted line represents the results for the time-invariant specification in VAR2.

According to Figure 6, the responses of the main economic aggregates to an unanticipated monetary policy tightening are qualitatively in line with the established facts: the rise in FF_t is persistent; there is a sustained drop in Y_t and, after an initial delay, also in the price level PI_t; the money stock MZM_t goes down, which points to a liquidity effect. Also, in correspondence with the theoretical model of this paper, the inventories/sales ratio rises after the shock and, as prices start to adjust, reverts back to trend and eventually declines in the long run. At the same time, Figure 6 reveals some important differences between the responses with and without a binding regulation-Q constraint. A first observation is that a binding ceiling exacerbates the output decline. Moreover, the difference in the output response is quantitatively quite large and occurs mainly at 6 to 18 months after the shock. The extent to which this finding can be explained by presence of the regulation Q depends on whether the other variables behave according to the theoretical predictions of the model:

First, an unanticipated funds rate hike of 23 basis points causes the spread between the market rate and the regulatory ceiling to widen up to 16 basis points in the third month after the shock. Thus, the pass-through from the funds rate to the spread is considerable.

Second, without constraint, the real volume of managed liabilities ML_t expands relative to trend, peaking 9 months after the shock. With binding deposit rate ceilings, ML_t *declines* until 6 months after the shock, after which there is a reversion back to trend. In the longer run, the real volume of managed liabilities drops in both cases. The difference during the first year after the shock constitutes evidence that a money tightening induces a disintermediation effect and is consistent with the second theoretical prediction.

Third, the negative response of money holdings MZM_t is much less pronounced with binding regulation than without. In the former case, the drop in MZM_t is also more short-lived, occurring mostly during the first year after the shock. To some extent, this is because the FF_t increase is somewhat less persistent with binding regulation. Nevertheless, the results are in line with the conjecture that the binding regulatory ceilings significantly disrupt the relation between money demand and interest rates. It is therefore also consistent with the third theoretical prediction, that negative monetary shocks are associated with a larger liquidity effect under regulation Q.

Fourth, although real lending to firms increases immediately after the shock, before declining in the longer run, the initial increase is much more short-lived with a binding ceiling.[7] Moreover, the contraction in real lending in the longer run is much more pronounced. In general, it is very hard to draw firm conclusions about the direction of casuality between lending and economic activity from this type of evidence. Some researchers, such as Romer and Romer (1990), see the lack of a drop in lending that precedes the decline in output as evidence against a causal role for bank credit. However, the fact that business lending, at least initially, expands after a monetary shock can be explained by the desire of firms to finance an inventory build-up and smooth production. What is more important to the argument of this paper is the *difference* between the responses with and without binding regulation, for which the theory provides a rationale. The evidence is therefore seen as consistent with the fourth theoretical prediction, that the reduction in firm lending after a monetary tightening is more severe when the regulatory constraint is binding.

Fifth, the response of the inventories/sales ratio in the first few months after the shock is initially slightly negative with a binding ceiling and remains below the regulation-free response for several months. This is in line with the theory, according to which firms postpone production

[7] The finding of an initial increase in business lending is consistent with previous results in the literature (see for instance Denhaan, Sumner and Yamashiro (2005)).

to a greater extent because larger increases in borrowing cost negatively affect current profit margins. But admittedly, the difference is quantitatively rather small. Moreover, it seems as if the inventory build-up lasts longer with the regulation-Q constraint, which seems more at odds with the theory.[8] One possible explanation is that technological improvements in inventory management since the early 1980s influence the results for the non-binding case. A second contributing factor potentially lies in the reaction of the price level. Without the ceiling, the price level starts to adjust downwards after about 12 months after the shock. In contrast, the fall in prices occurs much later with the binding constraint, after about 24 months. To the extent that the price response implies a faster adjustment of markups in the non-binding case, this could be reflected in a swifter adjustment of inventories.

Overall, at least four of the five theoretical predictions find support in the data. The evidence thus seems broadly consistent with an economically significant role of the disintermediation effect in the monetary transmission mechanism during the 1960s and 1970s. Whether the difference in the responses with and without binding deposit rate ceiling are also statistically significant can be further examined by testing whether the coefficients contained in C, D are significantly different from zero. Table 2 presents the asymptotic likelihood ratio test statistics. The results in the first row compare the unrestricted, time varying-coefficients model to the standard stable monetary VAR. The null hypothesis, that $C = 0$ and $D = 0$ is strongly rejected by the data. A second and third hypothesis, that only the coefficients of C, resp. D are zero, are also firmly rejected.

To gain some further insight in the role of the regulation-induced disintermediation effect, Figure 7 examines the response to an identified one-standard-deviation positive shock to the interest rate-ceiling spread. The rise in the spread causes an immediate decline in managed liabilities ML_t, reflecting substitution out of time deposits. Interestingly, this decline is associated with a relatively quick drop in real lending to firms. This observation constitutes additional evidence that the disintermediation effect negatively affected the ability of banks to lend during

[8] This is in line with McCarthy and Zakrajsek (2003) who find, using subsample analysis, a smoother and shorter-lived response of inventories/sales ratios after a contractionary monetary shock in recent samples.

the 1960s and 1970s. The response of output displays a swift and fairly persistent decline shortly after the shock. There is also a short-run decrease in the inventories/sales ratio. More so than for the monetary shock, the inventories response to a spread shock is in line with the hypothesis that firms postpone production because increases in borrowing cost negatively affect current profit margins. In any case, the evidence points to considerable real effects of a spread shock in accordance with a channel of transmission operating through bank lending. Note, how the money stock increases immediately after the shock. This potentially reflects a reaction of the Federal Reserve to counteract the negative spread shock by a money supply expansion. There is a slight increase in the price level, and no clear pattern in the response of the Federal Funds rate, which could be consistent with this conjecture.

Given that the above results suggest a considerable degree of time variation in the AR coefficients of the VAR, it is informative to make a comparison with the results from the standard VAR2 specification with stable coefficients. An interesting question is how the failure to explicitly take into account the regulation-induced disintermediation effects of the 1960s and 1970s biases the estimated responses in the basic VAR. In other words, to what extent does the omission distort our understanding of the effects of a monetary shock in more recent samples? Perhaps the most obvious observation concerns the behavior of monetary aggregates. For one, the VAR2 specification tends to underestimate both the short and long-run interest elasticity of money demand. The fundamentally different response of ML_t also makes evident why the MZM money definition, which roughly corresponds to M2 *excluding* small time deposits, is a more useful measure of the money stock as a macroeconomic indicator. In addition, not taking into account the disintermediation effect leads to overestimation of the contractionary effect on output of a monetary tightening. Another issue concerns the measurement of the monetary policy innovations. Figure 8 reports the 3-month centered, equally-weighted moving average of the estimated shocks for the VAR1 and VAR2 models. Several researchers, such as Boivin and Giannoni (2002), have found monetary policy shocks to be significantly more volatile in the 1960s and 1970s than after the mid 1980s. Table 3 reports the standard deviations of the estimated policy shocks for the periods 1960:1-1978:6 and 1983:10-2004:4. For the VAR2 specification, the shocks are indeed found to be about 30% more volatile in the earlier sample. In contrast, the volatilities in the two subsamples are virtually identical in the VAR1 model.

Business Cycle Volatility: A Counterfactual Experiment - This section returns to the bigger question, to what extent has the disintermediation effect contributed to business cycle volatility during the 1960s and 1970s? The answer involves estimating how the economy would have evolved, had the regulation Q not been in place. I perform a counterfactual experiment using the estimated VAR1 model. The structural shocks obtained from the data are fed into the VAR system, but with the dummy variable $\mathcal{I}_t$ equal to zero in every period. This implies that the spread no longer plays any role for the dynamics of $\mathbf{y_t}$. Figure 9 reports the true and simulated HP-filtered paths of real GDP for the 1960:1-1978:6 sample period.[9] The figure shows how all three of the NBER-dated recessions would have been considerably milder. The regulation Q effect seems to be the weakest for the 1960 recession. In contrast, the experiment suggests that 1970 recession would not even have occurred without regulation Q in place. Recall from Section 2 that positive market rate-ceiling spreads caused a severe contraction in the volume of large time deposits towards the start of the 1969-1970 recession, which eventually led to the removal of certain ceilings while the recession was already well under way. This intervention suggests that policymakers at the time indeed considered disintermediation to be an important contributing factor. Also the 1973-1975 recession would have been considerably less severe without regulation Q in place. By and large, most of the differences between the true and simulated series occur during the 1970s. This is primarily because, in contrast to the early 1960, the continuous upward revisions of the ceilings were much less sufficient to keep pace with rising market interest rates in that period. Table 4 reports the standard deviation of HP-filtered real GDP. In accordance with the evidence on the Great Moderation, output volatility in the data is about twice as large in the 1960:1-1978:6 than in the 1983:10-2004:4 sample. Removing the effect of the regulation-Q ceilings, the output volatility in the 1960:1-1978:6 sample drops from 1.17% in the data to 0.77%

[9]The HP-filter employs a smoothing parameter of 14,400.

in the counterfactual experiment. In other words, the experiment suggests that more than two thirds of the reduction in the Great Moderation can be explained by removing the effects of deposit rate ceilings in the data.

5 Conclusion

Assessing the role of changes in the monetary transmission mechanism is essential for understanding the performance of the US economy since the mid 1980s. This paper has provided evidence for a disintermediation phenomenon in the 1960s and 1970s that is linked to the existence of deposit rate ceilings under regulation Q. In a monetary DSGE model that incorporates interest rate ceilings as occasionally binding constraints, I showed how a binding constraint changes the behavior of monetary aggregates and aggravates the output decline after a monetary tightening primarily through a credit channel. In addition, I argued that the main predictions of the model are supported in the data by estimating a time-varying coefficients VAR that captures the nonlinearities implied by binding regulation.

In the debate on the stability of monetary VARs, my empirical results suggest a significant amount of time variation in the autoregressive coefficients that is due to changes in the financial landscape, and to regulation-induced disintermediation effects in particular. Regarding the causes of the Great Moderation, my counterfactual experiment indicates that two thirds of the reduction in output volatility can be explained by the removal of deposit rate ceilings in the early 1980s. Even if this number seems large, it does suggest that financial markets deregulation and innovation deserve more attention in future research as an explanation for the outstanding performance of the US economy over the last couple of decades.

A Appendix: A Brief History of Regulation Q

Until the second half of the 1950s, regulation Q was of limited significance in US banking, as the legal ceilings remained well above market rates and the average rates paid on savings and term deposits. However, the gradual rise of interest rates in the 1950s made the ceilings bind for the first time since their inception. In order to provide banks with greater flexibility in competing for funds, in 1957 legislators decided to raise the ceilings for the first time in over 20 years. Nevertheless, the continuing updrift in market rates throughout the 1960s and 1970s meant banks were frequently unable to offer competitive yields. The recurrent problems in the banking sector stirred reactions by both regulators and banks: On the one hand the maximum rates payable on various types of deposits were frequently revised; on the other hand, banks actively sought to decrease their reliance on heavily regulated sources of funds through innovation.

The rising interest rates necessitated frequent adjustments of the ceilings. As an illustration, Figure 10 depicts the ceiling on savings deposits at commercial banks, together with the interest rate on 3-month Treasury bills. The figure shows how the maximum rate payable was revised upwards on multiple occasions: To 3.5% in 1962, 4% in 1964, 4.5% in 1970, 5% in 1973, 5.25% in 1979 and finally to 5.5% in 1984. Similar revisions were made for the other deposit categories. But despite all these adjustments, market rates repeatedly rose above the ceilings. Quarterly surveys conducted by the Federal Home Lone Bank Board during the 1970s confirm that the vast majority of banks were indeed paying the maximum rates.[10] One major regulatory change occurred during the recession of 1970, when ceilings on certain types of large time deposits were suspended. The suspension took place after the volume outstanding of these instruments had shrunk dramatically because ceilings had hampered banks to compete effectively. Later, in May 1973, all large denomination time deposits were freed of interest rate restrictions. Towards the end of the 1970s, the regulatory attitude started to move more in pace with developments in the financial markets. Finally, the Monetary Control Act (MCA) of 1980 initiated the phaseout of regulation Q. In practice, the remaining ceilings on small term deposits were eliminated in

[10]See Cook (1978) for a discussion of the survey results.

October 1983, and those on savings deposits in March 1986.

After the experience of the late 1950s, depository institutions started to reduce their reliance on heavily regulated sources of funds. The binding ceilings unleashed a cat-and-mouse game between banks and regulators: Banks would develop a new instrument, after which the Federal Reserve would declare it a deposit and subject it to regulation Q. Before 1960, almost all deposits at US banks consisted of demand and savings deposits. Figure 11, which plots the ratio of managed liabilities to core deposits, shows the shift in deposit categories throughout the 1960s and 1970s. One of the key innovations in this respect was the creation in 1961 of large denomination negotiable CDs by a New York bank, together with the creation of a secondary market. The advantage of the negotiable CD was that it was a liquid, interest-bearing asset that was marketable when nearing maturity. This contrasted with standard time deposits which could not bear interest at maturities below 30 days. Within a couple of years, total domestic negotiable CDs outstanding had risen dramatically. Another innovation were the Eurodollar deposits, which, falling outside of the jurisdiction of the Federal Reserve, were not subject to regulatory ceilings. After interest rates had risen well above the maximum rates during the 1973-1975 recession, banks put strong pressure on legislators for deregulation. In June 1978, the use of retail money market certificates (MMCs), a new category of 6-month time deposits was permitted. The ceiling rate on newly issued MMCs was adjusted weekly to the current discount yield on 6-month T-bills and then remained constant until maturity. Similarly, 1979 saw the introduction of small saver certificates (SSCs), which had large maturities but also paid market-determined interest rates. The subsequent growth in the use of MMCs and SSCs, which were effectively ridden of interest rate ceilings, greatly improved the ability of banks to compete with money market instruments from 1978 onwards. In fact, Gilbert and Lovati (1979) observe how the authorization of MMCs by Federal regulators arose precisely in an attempt to reduce the extent of disintermediation.

B Theoretical Appendix

Attention is confined to symmetric equilibria in which $P_{jt} = P_t$, $N_{jt} = N_t$, $y_{jt} = y_t$, $h_{jt} = h_t$ and $s_{jt} = s_t$ for all $j \in (0,1)$. In addition, the state space is confined to yield equilibria where all net nominal interest rates are positive, and it is verified that the inequality in (4) never binds. Although the method used to solve the model allows to take into account the zero bound on nominal interest rates as well as the inequality in (4), both are irrelevant for the choice of parameters discussed in Section 3.2 and are therefore ignored in the equilibrium definition below.

It is useful to scale the model's nominal quantities by the beginning-of-period money stock and define $[p_t\ q_t\ w_t] \equiv [P_t\ Q_t\ W_t]/M_t$. In addition, let z_t be the inverse markup due to imperfect competition in the goods markets. An equilibrium is conveniently defined as a set of sequences of quantities $\{y_t, h_t, c_t, n_t, q_t\}_{t=0}^{\infty}$ and prices $\{p_t, r_t, R_t, z_t, w_t\}_{t=0}^{\infty}$ such that in every period t and given the initial conditions $p_0, n_0 - c_0$ and the period t history of realizations of χ_t, the system of equations, given by (A.1)-(A.11) is satisfied.

Household

$$\Psi h_t = \frac{1}{c_t}\frac{w_t}{p_t} \quad \text{(A.1)}$$

$$1 = \beta E_t\left[\frac{c_t}{c_{t+1}} R_{t+1} \frac{p_t}{p_{t+1}\mu_t}\right] \quad \text{(A.2)}$$

$$R_t = 1 + \Omega\left(\frac{q_t}{p_t}\right)^{-\frac{1}{\phi}} c_t \quad \text{(A.3)}$$

Policy

$$R_t = \min(r_t, R^q) \quad \text{(A.4)}$$

$$\ln(\mu_t) = (1-\rho)\ln(\mu) + \rho\ln(\mu_{t-1}) + \chi_t \quad \text{(A.5)}$$

Firms

$$y_t = h_t^{\alpha} - \theta \quad \text{(A.6)}$$

$$n_t = y_t + n_{t-1} - c_{t-1} \quad \text{(A.7)}$$

$$\frac{w_t}{p_t} = \alpha \frac{z_t}{r_t}\frac{y_t + \theta}{h_t} \quad \text{(A.8)}$$

$$1 = \frac{\epsilon}{\epsilon - 1} E_t \beta\left[\frac{c_{t+1}}{c_{t+2}} z_{t+2}\right] \quad \text{(A.9)}$$

$$\left(\xi\frac{c_t}{n_t} - z_t\right) = \beta E_t\left[\frac{c_t}{c_{t+1}} z_{t+1}\right]\left(\xi\frac{c_t}{n_t} - 1\right) \quad \text{(A.10)}$$

Loan Market

$$q_t = \mu_t - w_t h_t \quad \text{(A.11)}$$

The first set of equilibrium conditions summarizes the household's optimal behavior. Equation (A.1) determines labor supply by equating the marginal disutility of working to the real wage, weighted by the marginal utility of consumption $1/c_t$. The household's saving and consumption behavior is governed by the standard Euler condition, given by equation (A.2). Equation (A.3) specifies the demand for cash.

Equation (A.4) stipulates the regulation-Q restriction on the deposit rate and (A.5) specifies monetary policy.

Equation (A.6) specifies the production technology and (A.7) states that the current aggregate stock of final consumption goods available for sale equals the sum of newly produced goods and inventories carried over from the previous period. Labor demand is determined by equating the real wage with the marginal product of labor, as in (A.8). Equation (A.9) determines the typical firm's optimal price-setting behavior, with prices set as markups over expected discounted future marginal costs. Similar to Jung and Yun (2006), the possibility of inventory investment leads firms to take into account marginal cost two periods ahead rather than one. Finally, equation (A.10) dictates the firms' optimal inventory accumulation and is identical to the first-order condition of inventory investment in the partial equilibrium setting of Bils and Kahn (2000).

Finally, clearing in the market for loans requires that the nominal wage bill equals the total volume of loanable funds, as in equation (A.11).

C Data Appendix

C.1 Data used in Figures 1-4 and 10-11

The data on the ceiling rates on the various types of deposits was constructed from the Annual Statistical Digest published by the Board of Governors of the Federal Reserve System. The monthly time series are available from the author. Market interest rates are from Federal Reserve release H.15: Selected Interest Rates. The seasonally adjusted data on deposits is from Federal Reserve release H.6: Money Stock Measures. The following series were used to construct Figures 1-4.

Figure 1: Annualized growth in managed liabilities is the year-on-year growth in the sum of small and large time deposits, repurchase agreements and eurodollar deposits at all depository institutions, deflated by the Personal Consumption Expenditures price index; annualized growth in core deposits is year-on-year growth in savings and checkable deposits at all depository institutions in the US, deflated by the Personal Consumption Expenditures price index.

Figure 2: Spread is the difference between the 3-month Treasury Bill rate and the ceiling on savings deposits at commercial banks with maturity less than 12 months; annualized growth in core deposits is year-on-year growth in savings and checkable deposits at all depository institutions in the US, deflated by the Personal Consumption Expenditures price index. Core deposits include Money Market Deposit Accounts.

Figure 3: Components of managed liabilities are small time deposits, large time deposits, repurchase agreements and eurodollar deposits at all depository institutions, each divided by the sum of small and large time deposits, repurchase agreements and eurodollar deposits at all depository institutions.

Figure 4: Annualized growth in small term deposits is year-on-year growth in small term deposits (STDs) at all depository institutions, deflated by the Personal Consumption Expenditures price index; Spreads are the differences between 1) 3-month T-bill and ceiling on STDs with maturity from 30 to 89 days, 2) average of 3-month and 6 month T-bill rate and the ceiling on

STDs from 90 to 179 days, 3) average of 6-month T-bill rate and 1 year T-security rate and the ceiling on STDs from 180 days to 1 year, 4) average of 1-year and 2-year T-security rate and the ceiling on STDs from 1 year to 2 years. Annualized growth in large term deposits is year-on-year growth in large term deposits (LTDs) at all depository institutions, deflated by the Personal Consumption Expenditures price index. Spreads are the differences between 1) 3-month T-bill rate and ceiling on LTDs with maturity from 30 to 59 days, 2) 3-month T-bill rate and the ceiling on LTDs from 60 to 89 days, 3) average of 3-month and 6-month T-bill rate and the ceiling on LTDs from 90 to 179 days, 4) average of 6-month T-bill rate and 1-year T-security rate and the ceiling on LTDs from 180 days to 1 year.

Figure 10: Ceiling on savings deposits at commercial banks with maturity less than 12 months; 3-Month Treasury Bill rate (secondary market).

Figure 11: The ratio of managed liabilities is the sum of small and large time deposits, repurchase agreements and eurodollar deposits at all depository institutions divided by the sum of savings and checkable deposits at all depository institutions.

C.2 Additional Data used in VARs

Price Index: *Personal Consumption Expenditures Chain-Type Price Index Less Food and Energy*, Federal Reserve Bank of St.Louis, http://research.stlouisfed.org/

Commodity Price Index: *Index of Sensitive Materials Prices*, Business Cycle Indicators, The Conference Board Series, http://www.conference-board.org

Real GDP: *Real Gross Domestic Product, Seasonally Adjusted Annual Rate*, U.S. Department of Commerce: Bureau of Economic Analysis (NIPA), http://www.bea.gov/

Inventories/Sales Ratio: *Ratio of Manufacturing and Trade Inventories (Chained 2000 $) to Manufacturing and Trade Sales (Chained 2000 $)*, Business Cycle Indicators, The Conference Board Series, (mnemonics A0M070 and A0M057) http://www.conference-board.org

Federal Funds Rate: *Effective Federal Funds Rate*, The Federal Reserve System's H.15 release, http://www.federalreserve.gov/releases/h15.

Commercial and Industrial Loans: *Commercial and Industrial Loans at All Commercial Banks*, H.8 Statistical Release of the Federal Reserve System, http://www.federalreserve.gov/releases/h8.

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Table 1: Parameter Values of the Theoretical Model

Household Preferences		
β	$1.03^{-0.25}$	Household discount factor
Ψ	0.64	Time allocation parameter
Ω	$4.38e^{-5}$	Utility weight of real cash balances
ϕ	0.24	Interest rate elasticity of money demand
ϵ	5.79	Price elasticity of demand for goods
ξ	0.08	Sales stock elasticity of demand for goods
Technology		
α	0.64	Labor input elasticity of production
θ	0.18	Fixed cost of production
Monetary Policy		
μ	1.012	Average money growth rate
ρ	0.3	Persistence of the shock
σ	0.012	Standard deviation of the shock

Table 2: Asymptotic Likelihood Ratio Tests

Unrestr. Model	Restr. Model	H_0	Statistic	Df	$\chi^2(df)$ P-value
VAR1	VAR2	$C = 0, D = 0$	463.74	100	< 0.01
VAR1	VAR3	$C = 0 \mid D \neq 0$	264.21	4	< 0.01
VAR3	VAR2	$D = 0 \mid C = 0$	199.53	96	< 0.01

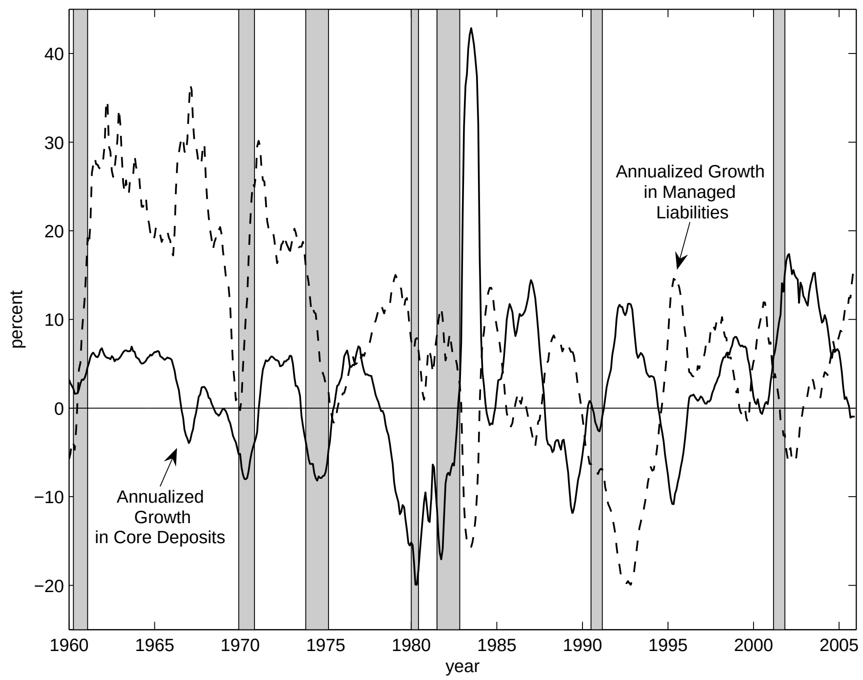

Figure 1: Annualized Real Growth in Core Deposits and Managed Liabilities.
Monthly data (Jan 1960-Dec 2005). Grey areas indicate NBER-dated recessions (peak-to-through). Data: See Appendix C.1.

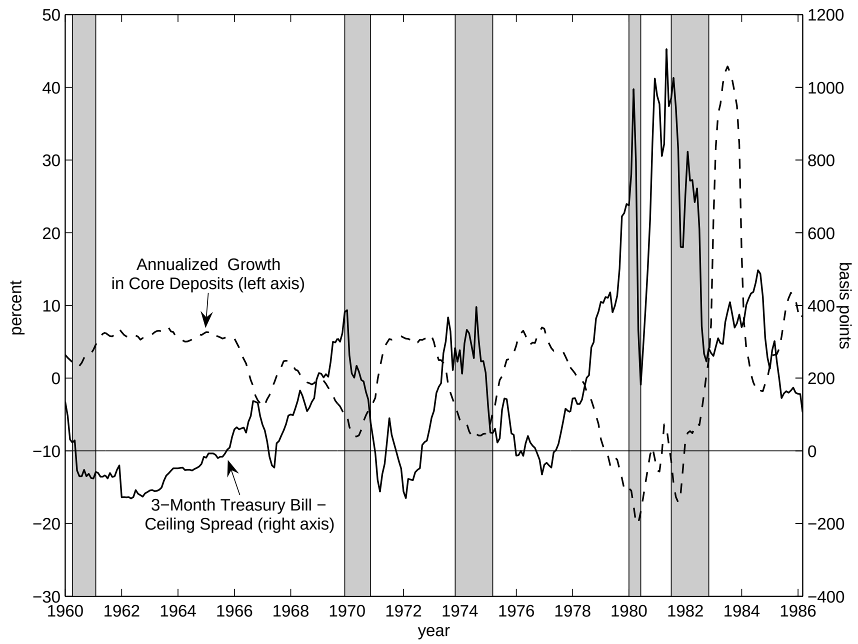

Figure 2: Annualized Real Growth in Core Deposits and 3-Month Treasury Bill - Ceiling Spread.
Monthly data (Jan 1960- Mar 1986). Grey areas indicate NBER-dated recessions (peak-to-through). Data: See Appendix C.1.

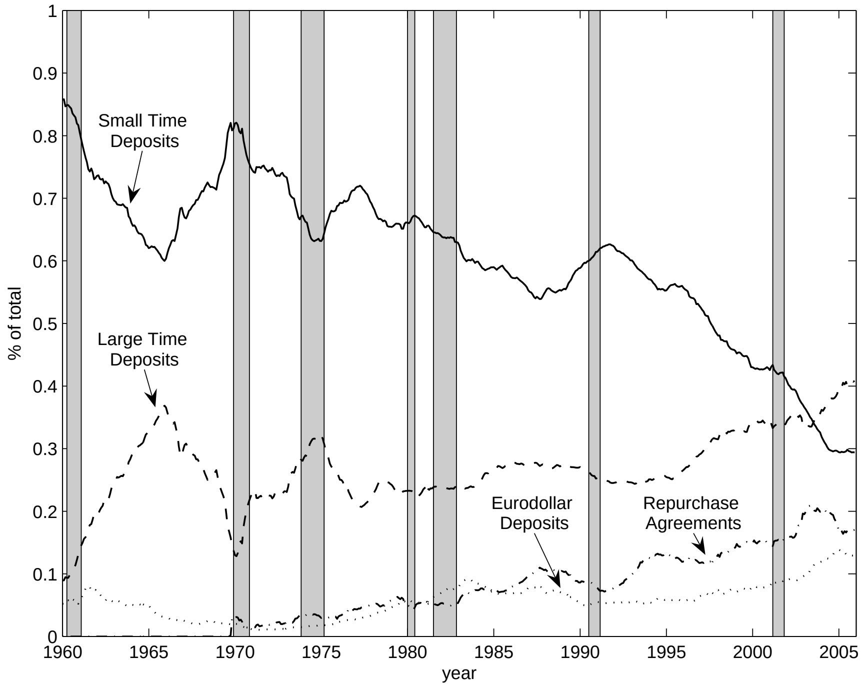

Figure 3: Components of Managed Liabilities.
Monthly data (Jan 1960-Dec 2005). Grey areas indicate NBER-dated recessions (peak-to-through). Data: See Appendix C.1.

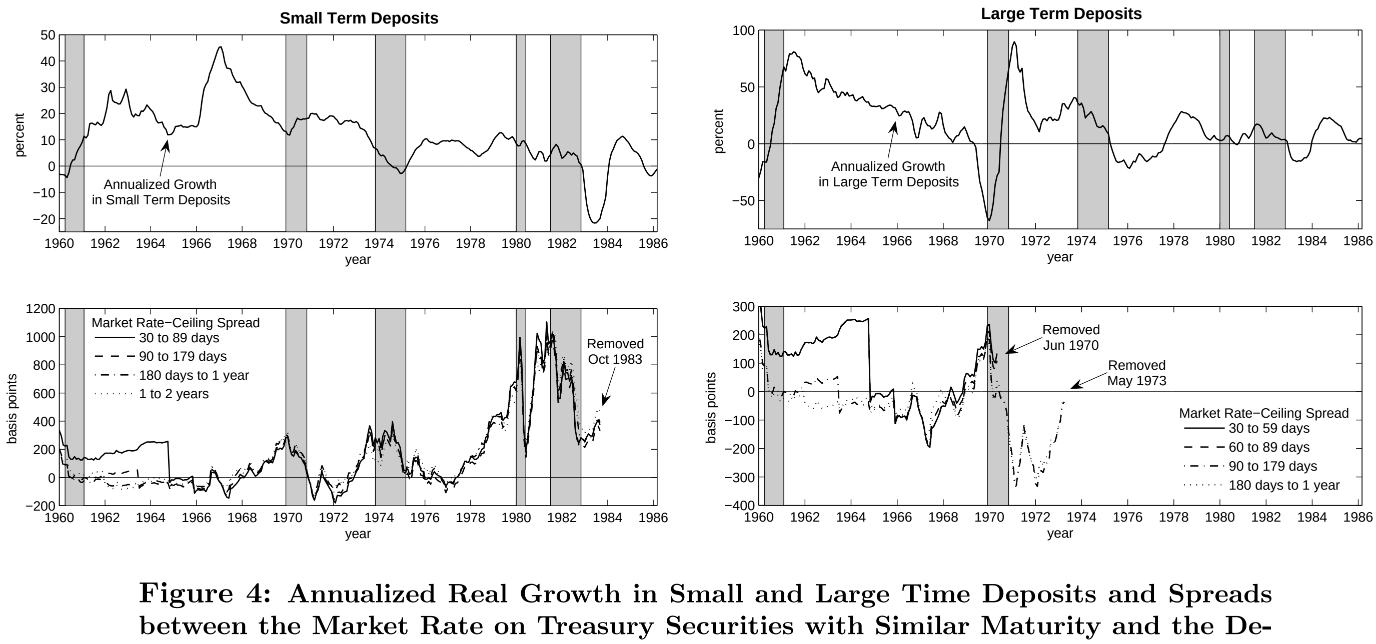

Figure 4: Annualized Real Growth in Small and Large Time Deposits and Spreads between the Market Rate on Treasury Securities with Similar Maturity and the Deposit Rate Ceiling.
Monthly data (Jan 1960-Mar 1986). Grey areas indicate NBER-dated recessions (peak-to-through). Data: See Appendix C.1.

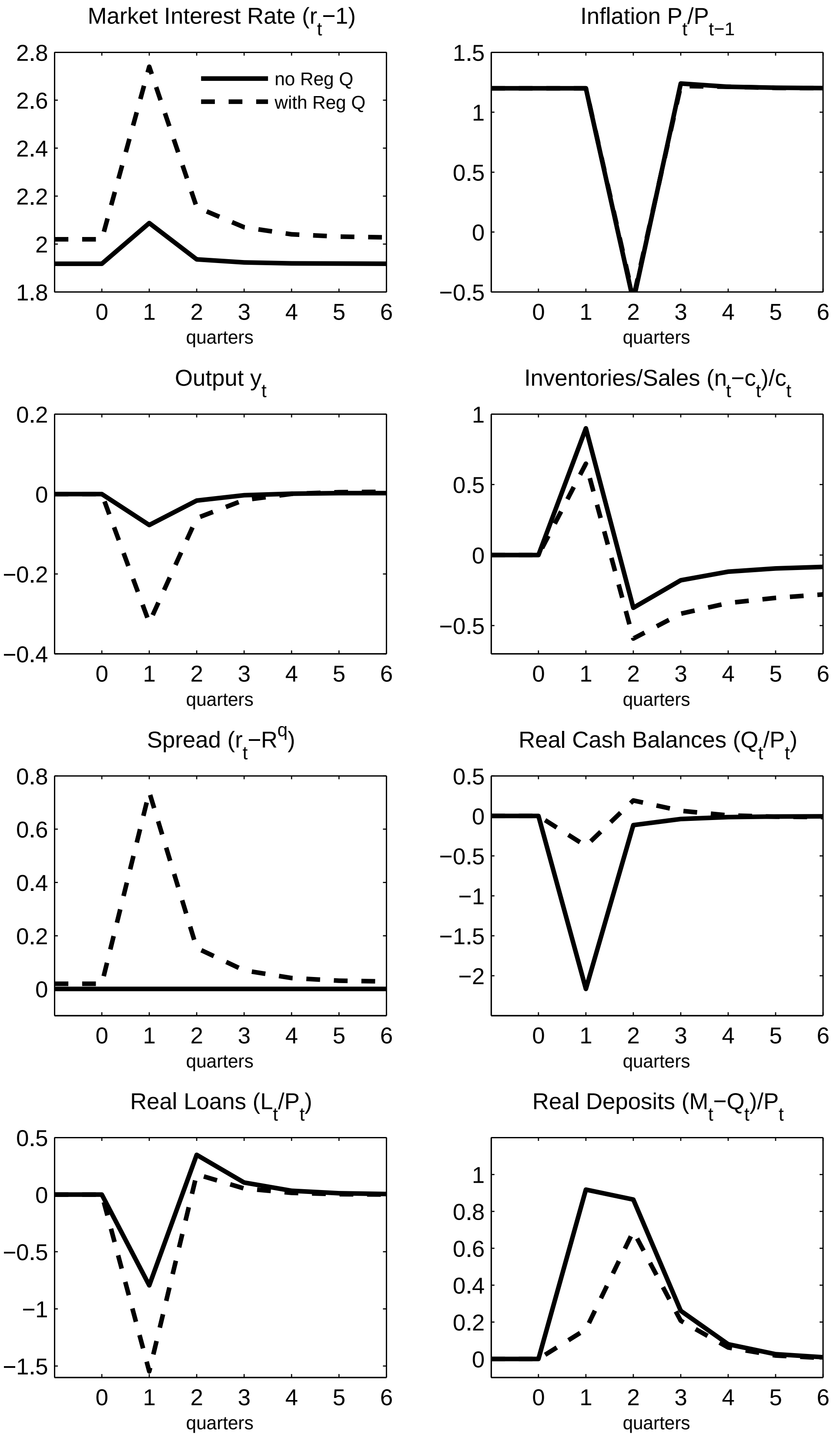

Figure 5: Theoretical Response to a One-St.-Dev. Negative Money Growth Shock. The shock occurs in period 1. The solid line depicts the response without regulation Q and the dashed line depicts the response with binding regulation Q.

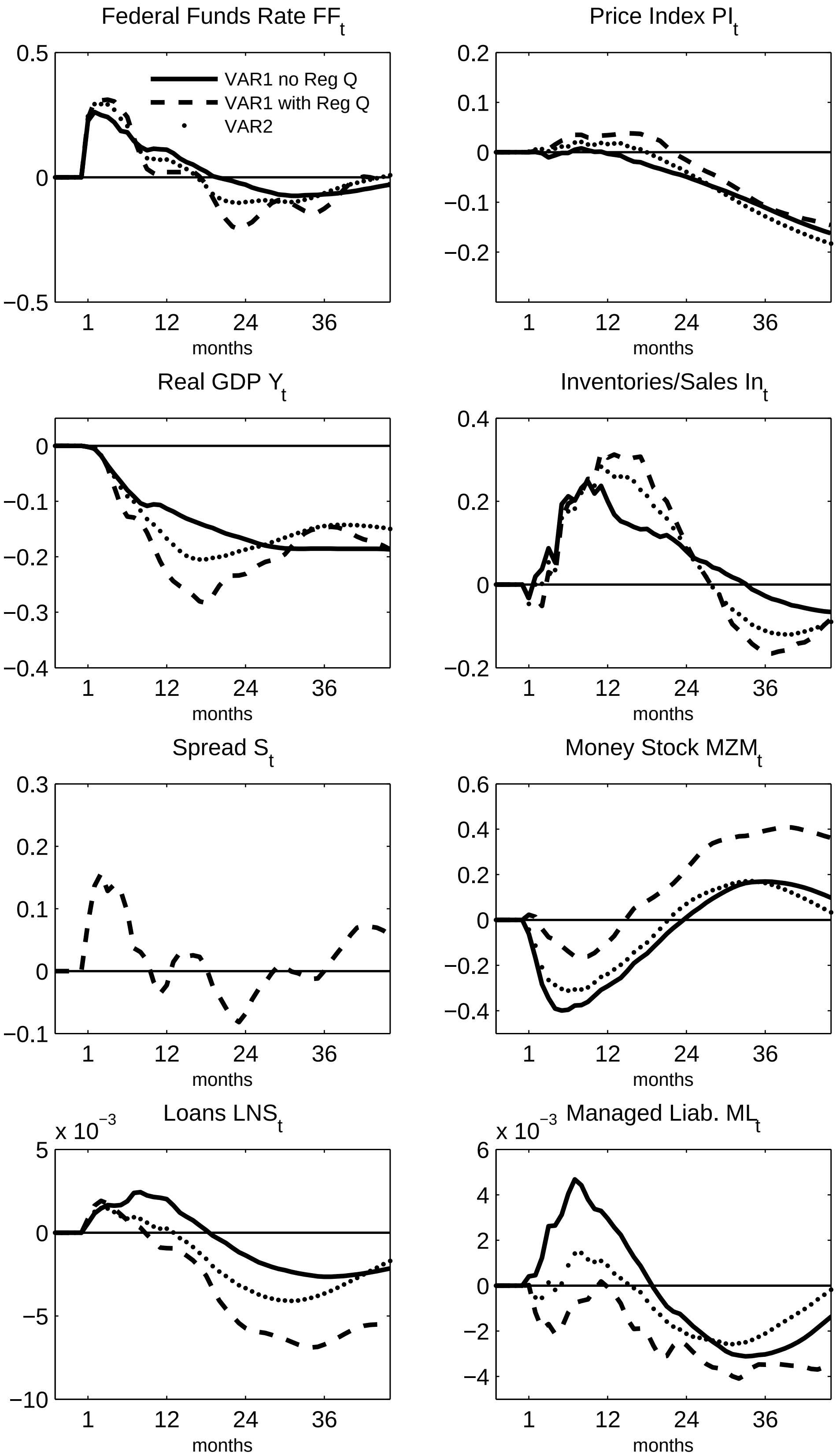

Figure 6: VAR1/VAR2 Response to a One-St.-Dev. Positive Funds Rate Shock. The shock occurs in period 1. VAR1 is the model with time varying coefficients. VAR2 is the standard stable monetary VAR. The solid line depicts the response without regulation Q and the dashed line depicts the response with binding regulation Q.

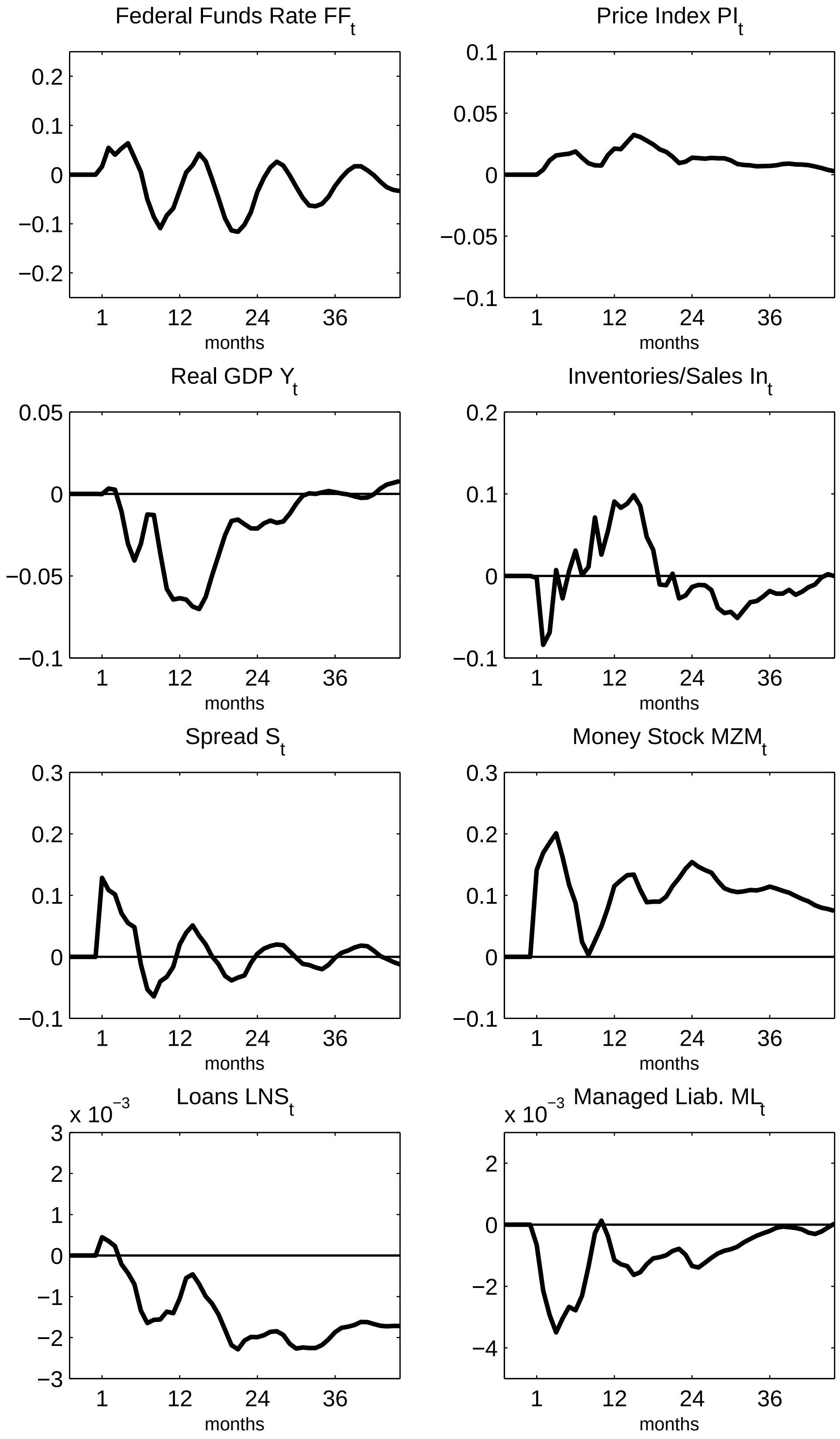

Figure 7: VAR1 Response to a One-St.-Dev. Positive Spread Shock.
The shock occurs in period 1.

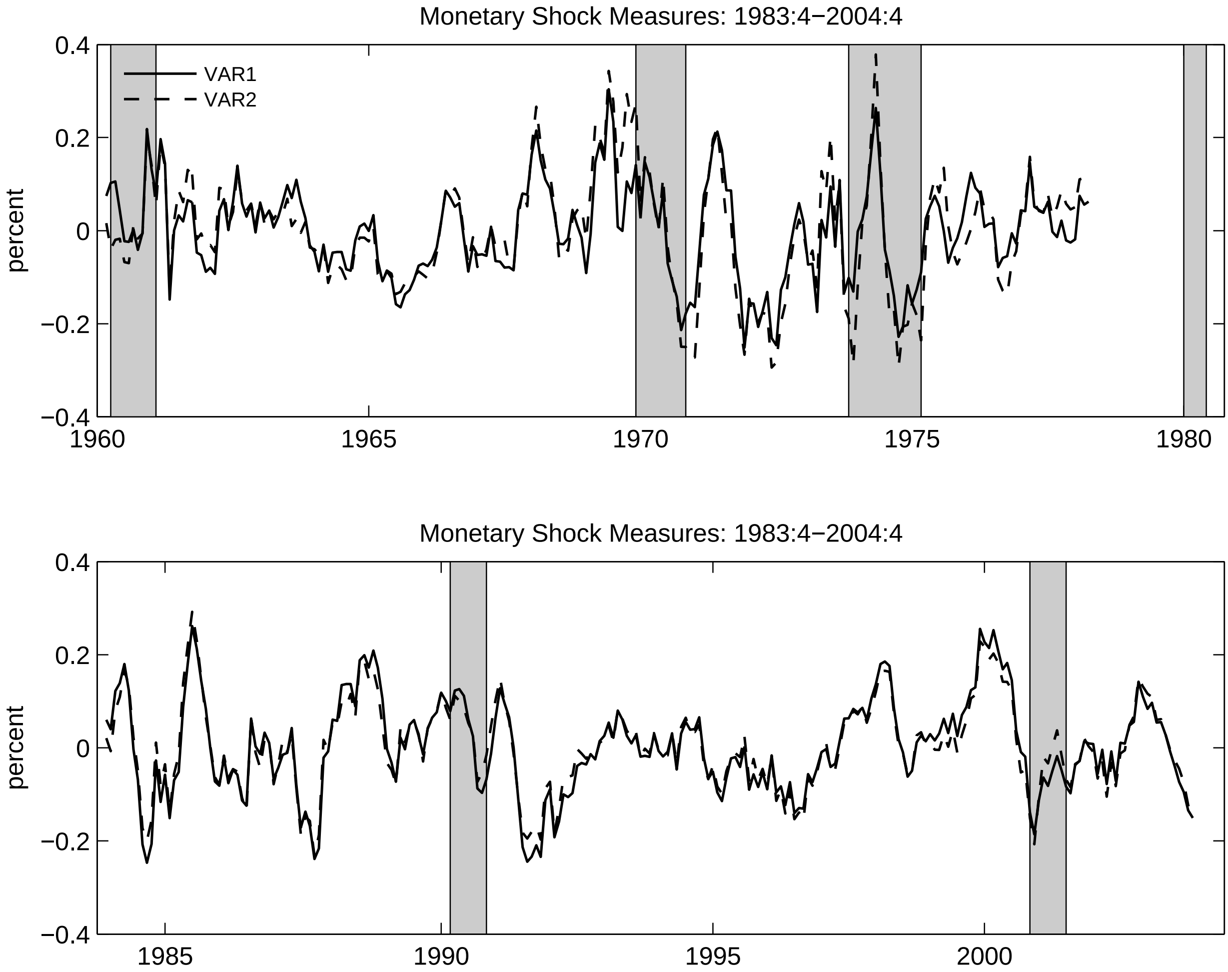

Figure 8: 3-Month Centered, Equally-Weighted Moving Average of Monetary Policy Shock Measures.
Grey areas indicate NBER-dated recessions (peak-to-through).

Table 3: Standard Deviation of Monetary Shock

Model	Sample	St.Dev.
VAR1	1960:1-1978:6	0.10%
VAR1	1983:10-2004:4	0.10%
VAR2	1960:1-1978:6	0.12%
VAR2	1983:10-2004:4	0.09%

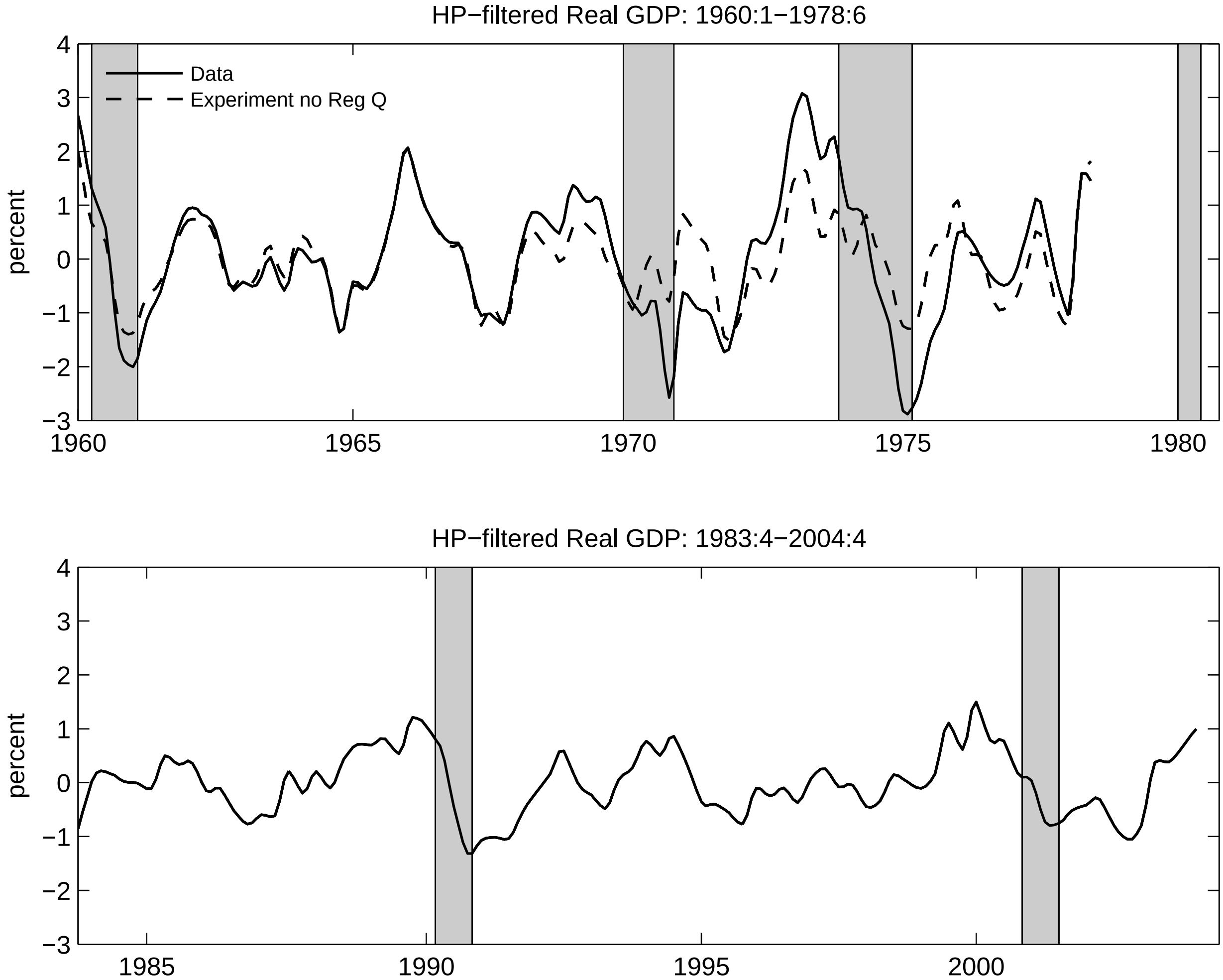

Figure 9: Real GDP Counterfactual Experiment.
Grey areas indicate NBER-dated recessions (peak-to-through). The solid line depicts the true data and the dashed line depicts the simulated path of real GDP for the experiment without regulation Q.

Table 4: Standard Deviation of HP-filtered Real GDP

Series	Sample	St.Dev.
Data	1960:1-1978:6	1.17%
Experiment no Reg Q	1960:1-1978:6	0.77%
Data	1983:10-2004:4	0.58%

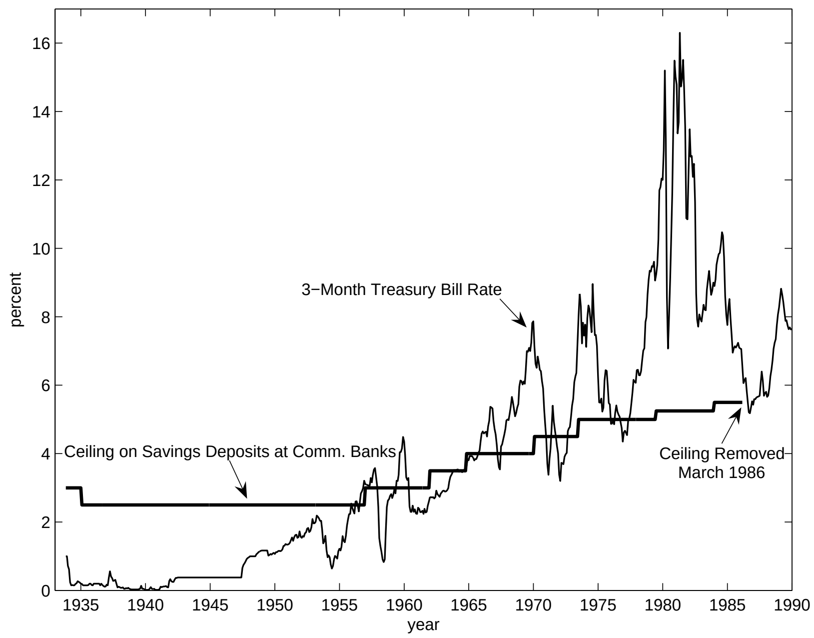

Figure 10: 3-Month T-Bill Rate and Ceiling on Savings Deposits at Commercial Banks.
Monthly data (Nov 1933-Dec 1989). Data: See Appendix C.1.

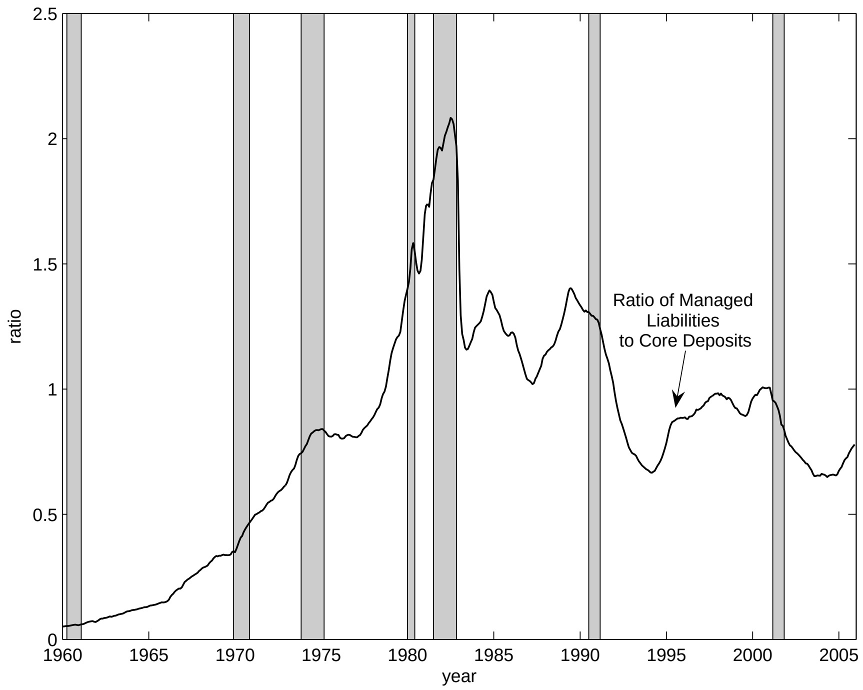

Figure 11: Ratio of Managed Liabilities to Core Deposits.
Monthly data (Jan 1960-Dec 2005). Grey areas indicate NBER-dated recessions (peak-to-through). Data: See Appendix C.1.