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Essays on the Implications of the Zero Lower Bound and the Impact of Trade Openness on Output Volatility

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in previously published or accepted papers that I first authored. I mention here that Chapter 2 of this dissertation is a reprint of the article " Consumption and Money Uncertainty at the Zero Lower Bound", which is published in Economics Bulletin, volume 36, issue 1, March 2016. The text of Chapter 3 of this dissertation is a reprint of the article "The asymmetric impact of trade openness on output volatility" as it appears the Empirical Economics, volume 49, issue 3, published November 2015.

In the loving memory of my father.

To my mother and sister Raeda.

To my wife Hanaa.

&

My children: Dana, Laith, and Sameer.

To my brother−in−law Ashraf.

Love you all.

ABSTRACT OF THE DISSERTATION

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Our focus lies on the implications of recent monetary policy rules that operate under the zero lower bound. Time varying parameters show how changes in these parameters affect the impact of macroeconomic shocks. In addition to our analysis on the uncertainty that surrounds the economy within a zero lower bound regime. Our dissertation focuses on output uncertainty in an open economy; this is measured by the realized volatility.

Chapter 1 proposes a New Keynesian Markov Switching model where the coefficient of risk aversion switches between high and low risk regimes. Risk aversion is of primary interest because when the nominal interest rate hits the zero lower bound (ZLB) in New Keynesian models, the coefficient of risk aversion becomes the sole determinant in the relationship between output and inflation expectations. Results yield that risk-aversion plays a crucial role in the impact of macroeconomic shocks. This is especially true when the economy is constrained by the ZLB. We find sub-

stantial asymmetric impact of positive versus negative macroeconomic shocks at the ZLB. Given that the Federal Reserve cannot lower the nominal interest rate below zero as a response to negative inflation and aggregate demand shocks. However, it is granted more flexibility to respond to positive shocks.

In Chapter 2, we examine the impact of the zero lower bound (ZLB) on the uncertainty of personal consumption and money stock. We calculate the second conditional moments as a proxy for uncertainty. This chapter implements a multivariate GARCH model on U.S. personal consumption and real money balance from January 1980 to December 2014.Our main findings suggest that when constrained by the zero lower bound, consumption uncertainty declines. And, we note that real money uncertainty increases significantly.

While the core of our dissertation thus far has focused on the implications of recent monetary policy rules that operate under the zero lower bound. Chapter 3 highlights our investigation into the impact of trade openness on output volatility and how this impact may be affected by the country's level of development. We use a panel data set for 33 countries for the years of 1980 through 2009. A standard deviation of quarterly real GDP over a 5-year span is used as the dependent variable. Controlling for the country and period-specific effects, the main results are as follows:: trade openness increases the output volatility. And, the output volatility of countries with a higher level of development is less affected by trade openness.

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Chapter 1

Markov Switching Risk Aversion and Asymmetries at the Zero Lower Bound

1.1 Introduction

There is a vast literature that studies the role of risk aversion coefficient on macroeconomic shocks. Recent New Keynesian Dynamic Stochastic General Equilibrium (DSGE) papers [Christiano et al. (2011), Gali (2008), and Walsh (2010)] treat the risk-aversion coefficient as a constant over time regardless of the state of the economy. This assumption may lead to underestimation or overestimation of the effects of shocks on the economy - particularly when the nominal interest rate is at the zero

lower bound (ZLB). This constraint occurs when the short-term nominal interest rate is at or near zero , but should remain nonnegative.

In a standard New Keynesian model, aggregate demand curve is negatively sloped. This implies that the output gap is inversely related to inflation expectation. Additionally, positive technology shocks are expansionary in the standard versions of these models. However, when the nominal interest rate is at the ZLB, technology shocks become contractionary due to the positively slopped aggregate demand. For example, when a negative inflation shock hits the economy and the Central Bank does not adjust its policy rate more than one-for-one with inflation, as prescribed by the Taylor rule (1993), the real interest rate rises, leading to a contraction in real activity. Research on the implications of the zero lower bound has been mainly theoretical The lack of sufficient data has made it difficult to empirically analyze the effects of the zero lower bound because the short-term nominal interest rate has only been at or near zero for approximately five years. For this reason, this paper examines the implications of the ZLB from a theoretical angle. This paper proposes a New Keynesian model that captures several possibilities at the ZLB. In particular, it considers the possibility of a risk-aversion coefficient that switches between high and low risk regimes, as well as the potential asymmetric impact of positive and negative macroeconomic shocks.

A typical new Keynesian aggregate demand curve such as that implemented by Gali (2008) can be written as follows:

$$\tilde{y}_t = E_t\tilde{y}_{t+1} - \frac{1}{\sigma}(i_t - E_t\pi_{t+1} - \rho) \tag{1.1}$$

The monetary authority follows the Taylor rule:

$$i_t = \rho + \Phi_\pi\pi_t + \Phi_y\tilde{y}_t + v_t \tag{1.2}$$

In equation (1.1), the role of the risk-aversion σ on the relationship between inflation expectations $E_t\pi_{t+1}$ and output gap $\tilde{y}_t$ is substantially minimized whenever the inflation coefficient Φ_π is more than 1 in equation (1.2). However, when the nominal interest rate i_t is at the zero bound, the relationship between inflation expectation and output gap changes its sign and magnitude. Thus, the risk-aversion measure becomes an increasingly important driver of this relationship[1].

As commonly found in the literature, risk premium spikes during economic recessions. Licata (2013) suggests that time varying risk aversion is motivated by time-varying risk premia. Our paper investigates how macroeconomic shocks impact the economy when risk aversion switches between two regimes: high risk during recessions and low risk in expansions. The main goal is to study the potential distinct impact

[1]The output gap responds to inflation expectation by $-0.5/\sigma$ if $\Phi_\pi = 1.5$ and the economy is not at the ZLB. However, when nominal rate i_t is at the zero bound, inflation expectation affects output gap by a positive fraction of $1/\sigma$

of these shocks across recessions or expansions at the ZLB. This paper expands on the work of Davig and Leeper (2007), Farmer, Waggoner, and Zha (2011), Liboshi (2015), Cho (2012) and Licata (2013). These authors use a Markov-switching new Keynesian model in the context of rational expectations (MSRE) and optimal monetary policy. We use these models in the context of the zero lower bound constraint. For example, in Cho's (2012) work, the agent's utility function is regime-dependent in which the log-linearized demand curve relates the current output gap to the future expected output gap. The coefficient of this relationship is a fraction of the next period expected to current risk-aversion[2].

Reducing the government deficit dominated discussions of the political parties in the United States during the summer of 2011. The debates and disagreements led to a cloud of uncertainty that hovered over the U.S. economy. Individuals anticipated that a mild economic recession could take place as a result of the uncertainty. This situation is referred to as the United States Fiscal Cliff. This meant the government had to act fast by cutting spending and increasing taxes. With the U.S. government aiming to reduce its deficit, the decline in output was expected to be larger when monetary policy rate is not adjusted in response to these shocks. This means that government multipliers are larger at the ZLB [Christiano, Eichenbaum, and Rebelo (2011), and Eggertsson (2011)].

[2]See Section 2 for more details

We use this as motivation to contribute to the literature by studying how the presence of such governmental shocks along with other macroeconomic shocks at the zero lower bound affect measures of household risk-aversion. This is an important question since changes in risk aversion alter the extent to which changes in the real interest rate affect economic activity.

This paper is comprised of two parts. First, it uses a simple econometric analysis to investigate whether nominal interest rate affects household consumption growth more or less intensively during a recessionary period than during expansions. From this, we show that the coefficient of risk-aversion within the households' optimization conditions takes two different values depending on the state of the economy. Next, we test the impact of both positive and negative demand and inflation shocks. We allow the new Keynesian model parameters to vary with respect to the assigned values for the risk-aversion coefficient. The risk-aversion coefficient is random and follows a probability matrix.[3]

Our results indicate the following findings. During recessions as dated by the NBER , the impact of the federal fund rate on consumption growth is weaker. This result implies that the coefficient of risk-aversion increases during recessions. This paper argues that negative shocks are increasingly likely to be associated with higher risks. The effects of these shocks provide more realistic predictions when a higher coefficient of risk aversion is assigned to the calibrated model. Hence, the difference

[3]The risk-aversion transition probabilities match the turning points of the US business cycle [Chauvet and Hamilton (2006)]

between the impacts of shocks in and out of the ZLB is not overly exaggerated. The empirical results of this paper also yield that prior to the nominal interest rate becoming substantially low; the federal fund rate increasingly affects consumption growth. Hence, our calibrated results concurrently reveal that the impact of the interest rate shock on inflation and output is less during the zero lower bound periods. In and out of the zero lower bound, negative inflation and output shocks are asymmetric in their magnitude and intensity within a low risk regime. Negative inflation and output shocks tend to reduce output at the ZLB. In particular, negative inflation decreases output twice as much as it increases output in normal times. On the other hand, in a high risk regime, within the constraints of the ZLB, the asymmetry of shocks on output is reduced.

In September of 2015, the Federal Reserve stated that in the near future, it plans to increase the Federal Fund rate as inflation increases to its objective of 2%. From this, the paper concludes that there is a substantial possibility that the Federal fund rate would rise with positive inflation and output shocks. Complementary to the statement above, our main findings on the impact of positive shocks yield identical impulse response functions in and out of the ZLB. This is because the nominal interest rate does not hit the zero as a response to positive shocks. With regards to the risk-aversion level, the impact of positive demand shocks on output is nearly identical in high and low risk regimes. In respect to the value of the coefficient of risk-aversion, the impact of positive inflations shocks on output is asymmetric. The impact of

positive inflations shocks on output is weaker in a high risk regime. Both positive inflation and demand shocks impact inflation in about the same manner in both risk regimes. More specifically with macroeconomic shocks being positive, the interest rate does not hit the ZLB. This grants the Fed greater flexibility to adjust its policy rate against the possibility of future upcoming negative shocks.

This paper is organized as follows: Section 2 describes the proposed small scale New Keynesian Markov-switching Risk Aversion model (MSRA). Section 3 shows the empirical analysis. Section 4 provides our models calibration. Section 5 shows the main findings from the calibration of the MSRA model. Section 6 concludes. Section 7 includes a list of tables and figures

1.2 The model

1.2.1 Markov-Switching Risk-Aversion (MSRA) model

We assume an infinitely-lived household representative maximizes future discounted utility. Utility is divided into two components: positive with respect to consumption and negative with respect to labor.

$$E_0\left[\sum_{t=0}^{\infty}\beta^t U(C_t, S_t, N_t)\right] \tag{1.3}$$

The budget constraints

$$\begin{aligned} \int_0^1 P_t(i)C_t(i)di + Q_tB_t &= B_{t-1} + W_tN_t + T_t \\ C_t &\equiv \left(C_t(i)^{1-\frac{1}{\epsilon}} di \right)^{\frac{\epsilon}{1-\epsilon}} \\ \lim_{T\to\infty} E_t(B_T) &\geq 0 \end{aligned} \tag{1.4}$$

The household representative consumes a continuum quantity of goods $C_t(i)$ where i lies in the interval of [0,1].β is the household discounting factor. $P_t(i)$ is the price of good i; N_t is the supply of labor for a nominal wage rate W_t. B_t represents one-period bonds purchased at a discounted price of Q_t. T_t denotes a lump-sum tax and ϵ is the elasticity of substitution between differentiated goods. S_t refers to a marginal utility shifter component that follows a Markov-switching model. Separable utility function takes the following form:

$$\begin{aligned} U_t &\equiv \frac{C_t^{1-\sigma_{(S_t)}}}{1-\sigma_{(S_t)}} - \frac{N_t^{1-\phi}}{1-\phi} \\ S_t &= \{0, 1\} \end{aligned} \tag{1.5}$$

where $\sigma_{(S_t)}$ measures risk-aversion or the inverse elasticity of intertemporal substitution that is contingent on the current state of the economy. In the formula above, $S_t = 1$ whenever NBER classifies time t as a recession. S_t on the other hand equals 0 in expansion . ϕ is the inverse of the elasticity of labor supply. A continuum number of firms indexed by $i \in [0, 1]$ produce according to the production function of

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{1.6}$$

A_t refers to technology. And, we assume that firms reset their prices by a probability of $1-\xi$. And the labor share is given by $(1-\alpha)$. Each firm is assumed to have chosen optimal price P^* to maximize future discounted profits:

$$max \ \sum_{k=0}^{\infty} \xi^k E_t \Big\{ Q_{t,t+k} \Big(P_t^* Y_{t+k|t} - \Psi_{t+k}\big(Y_{t+k|t}\big) \Big) \Big\} \tag{1.7}$$

subject to

$$Y_{t+k|t} = \Big(P_t^* / P_{t+k} \Big)^{-\epsilon} C_{t+k} \tag{1.8}$$

where k=1,2,3,... and $Q_{t,t+k} \equiv \beta^k C_t^{\sigma_{S_t}} C_{t+1}^{-\sigma_{S_{t+1}}} \left(\frac{P_t}{P_{t+k}} \right)$ is a stochastic discounting factor, and Ψ is a cost function[4]. P_t is the aggregate price level. The gross inflation rate $\Pi_t \equiv \frac{P_t}{P_{t-1}}$. With regards to the equilibrium conditions, the bond investment $B_t = 0$. And, the good market clearing conditions implies that $Y_t(i) = C_t(i)$ and $Y_t = C_t$.

The new Keynesian IS curve

The log-linearized household optimal conditions combined with the optimal conditions of firms -along with the market clearing conditions yield the following[5]:

$$\tilde{y}_t = E_t \left[\frac{\sigma_{(S_{t+1})}}{\sigma_{(S_t)}} \tilde{y}_{t+1} \right] - \frac{1}{\sigma_{(S_t)}} \big(max\{0, i_t\} - E_t \pi_{t+1} - \rho \big) + \varepsilon^y_{t\,(S_t)} \tag{1.9}$$

[4]The aggregate output $Y_t \equiv \left(\int_0^1 Y_t(i)^{1-\frac{1}{\epsilon}} di \right)^{1-\frac{1}{\epsilon}}$ and $Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t$.

[5]The paper does not fully show the derivations of the new Keynesian model. See Gali (2008) for details on how to derive the main new Keynesian equations

where $\tilde{y}_t$ is the output gap and $\tilde{y}_t \equiv ln(\frac{Y_t}{Y})$. The nominal interest rate $i_t \equiv -ln(Q_t)$ and natural rate of interest $\rho = -ln\beta$. The future inflation rate $\pi_{t+1} \equiv ln\left(\frac{\Pi_{t+1}}{\Pi}\right) \equiv lnP_{t+1} - lnP_t$, and ε_t^y represents the aggregate demand shock. A constant risk-aversion[Gali (2008)] implies that $\sigma_{(S_{t+1})} = \sigma_{(S_t)} = \sigma$. Nevertheless, as the economy switches between states of expansion and recession. Similarly, we assume that the risk-aversion coefficient switches between high risk regime (recession) and low risk regime (expansion) with a transition matrix as follows:

$$P = \begin{bmatrix} Pr(S_{t+1} = 0|S_t = 0) & Pr(S_{t+1} = 1|S_t = 0) \\ \\ Pr(S_{t+1} = 0|S_t = 1) & Pr(S_{t+1} = 1|S_t = 1) \end{bmatrix} = \begin{bmatrix} P_{00} & P_{01} \\ \\ P_{10} & P_{11} \end{bmatrix} \tag{1.10}$$

The elements of the stochastic matrix P characterize the probability at which the economy (risk-aversion) goes through a transition from one state to another. If the economy remains at one state, the matrix in equation (1.10) turns into an identity matrix. Under the assumption that the coefficient of risk aversion is a regime-independent and constant over time, each of the diagonal elements of P matrix will equal one. Practically, the transition matrix is described by the equation below:

$$\sum_{j=0}^{1} P_{ij} = 1 \tag{1.11}$$

Incorporating the first part of IS equation (1.9) with the transition matrix yields:

$$E_t\left[\frac{\sigma_{(S_{t+1})}}{\sigma_{(S_t)}}\tilde{y}_{t+1}\right] = E_t\left[\Theta_{(S_t)}\tilde{y}_{t+1}\right] \tag{1.12}$$

where

$$\begin{aligned}
\left[\Theta_{(S_t)}|_{S_t=1}\right] &= \begin{cases} 1 & \text{With probability} \quad P_{11} \\ \sigma_0/\sigma_1 & \text{With probability} \quad P_{10} \end{cases} \\
\left[\Theta_{(S_t)}|_{S_t=0}\right] &= \begin{cases} 1 & \text{With probability} \quad P_{00} \\ \sigma_1/\sigma_0 & \text{With probability} \quad P_{01} \end{cases} \\
& \sigma_0 < \sigma_1
\end{aligned} \tag{1.13}$$

Because of the ZLB, the nominal interest rate in equation (1.9) follows inequality constraints that should take on a nonnegative value. In addition, the demand shock $\varepsilon^y_{t\,(S_t)}$ follows a Markov-switching chain. I define the new Keynesian IS curve in two regimes as follows:

$$\begin{bmatrix} \tilde{y}_t|_{S_t=0} \\ \\ \tilde{y}_t|_{S_t=1} \end{bmatrix} = E_t \Bigg\{ \begin{bmatrix} P_{00} & P_{01} \\ \\ P_{10} & P_{11} \end{bmatrix} \begin{bmatrix} 1 & \sigma_0/\sigma_1 \\ \\ \sigma_1/\sigma_0 & 1 \end{bmatrix} \begin{bmatrix} \tilde{y}_{t+1}|_{S_t=0} \\ \\ \tilde{y}_{t+1}|_{S_t=1} \end{bmatrix} \Bigg\} \tag{1.14}$$

$$- \begin{bmatrix} \frac{1}{\sigma_0}\big(max\{0, i_t\} - E_t\pi_{t+1} - \rho\big) \\ \\ \frac{1}{\sigma_1}\big(max\{0, i_t\} - E_t\pi_{t+1} - \rho\big) \end{bmatrix} + \begin{bmatrix} \varepsilon^y_{t0} \\ \\ \varepsilon^y_{t1} \end{bmatrix}$$

The shock ε^y_i follows AR(1) process:

$$\begin{bmatrix} \varepsilon^y_{t0} \\ \\ \varepsilon^y_{t1} \end{bmatrix} = \begin{bmatrix} \rho^y_0 & 0 \\ \\ 0 & \rho^y_1 \end{bmatrix} \begin{bmatrix} \varepsilon^y_{t-1,0} \\ \\ \varepsilon^y_{t-1,1} \end{bmatrix} + \begin{bmatrix} \zeta^y_0 \epsilon^y_{t0} \\ \\ \zeta^y_1 \epsilon^y_{t1} \end{bmatrix} \tag{1.15}$$

These shocks are i.i.d with a mean of zero and are independent of one another. It is additionally assumed that the persistence parameter of the demand shock ($\rho^y_0 > \rho^y_1$) in expansion is greater than that in a recession. The shock ($\zeta^y_0 < \zeta^y_1$.) is more volatile during recessions. The intuition behind the asymmetry of demand shock persistence relies on the assumption that the probability of switching between expansions is larger than the probability of switching between recessions [Chauvet and Hamilton (2006)]. According to Iiboshi (2015), the standard deviation of demand shocks are larger when the interest rate hits the ZLB. Negative demand shocks are generally associated with

recessionary periods. As implied by Taylor rule, the policy rate responds to output gap and inflation by positive coefficients. Hence -as a result of negative shocks, the nominal interest rate reaches the ZLB more frequently.

The new Keynesian Phillips curve

A forward looking New-Keynesian Phillips curve that relates the current inflation to the output gap and future expected inflation

$$\pi_t = \beta E_t \pi_{t+1} + k_{(S_t)} \tilde{y}_t + \varepsilon_t^P$$

$$k_{(S_t)} \equiv \lambda\Big(\sigma_{(S_t)} \frac{\phi + \alpha}{1 - \alpha}\Big) \tag{1.16}$$

$$\lambda \equiv \frac{(1-\xi)(1-\beta\xi)}{\xi} \frac{1-\alpha}{1-\alpha+\alpha\epsilon}$$

where ξ measures the degree of price sickness, and $k_{(S_t)}$ measures the price flexibility. While $k_{(S_t)}$ is inversely related to price stickiness, it is positively affected by the risk-aversion. The impact of output gap on inflation in Phillips curve is different across risk-aversion regimes. We assume that the inflation (cost-push) shock is i.i.d with a mean of zero and a standard deviation ζ^P. This shock follows a univariate AR (1) stochastic process with a persistence parameter of ρ^p:

$$\varepsilon_t^P = \rho^p \varepsilon_{t-1}^P + \zeta^P \epsilon_t^p \tag{1.17}$$

While inflation shocks remain controversial, positive aggregate demand shocks remain expansionary with or without the ZLB. Hence, unlike the demand shocks, our model is simplified in assuming that supply (inflation) shock persistence and volatility are independent of the risk-aversion regimes. Farmer et *al.* (2011) allow most of the parameters in the new Keynesian model to vary from one regime to another. For the purposes of this paper, we do not allow all the parameters to follow a Markov-switching chain with the exception of those that rely on the value of the risk-aversion coefficient.

1.2.2 Monetary policy

The Federal Reserve tries to achieve maximum employment and stable prices by targeting the nominal short term interest rate. Typically, the Fed follows the Taylor principle by adjusting the nominal interest rate as follows:

$$i_t = max\Big\{0, \;\; r + \phi_i[i_{t-1} - r] + (1 - \phi_i)\big[\phi_\pi \pi_t + \phi_y \tilde{y}_t\big] + \varepsilon_t^m\Big\} \tag{1.18}$$

The nominal short term interest rate i_t is bounded below by zero . It implies that $i_t \geq 0$. The parameter $\phi_i \in (0, 1)$ measures the degree of interest rate smoothing[6]which demonstrates that the monetary policy continues to respond to economic conditions at the ZLB. This is due to a current decline in output and inflation contributing to a lower future interest rate. This is a double-edged sword. First, a current decline in

[6]See Clarida, Gali, and Gertler (1998) for more details on interest smoothing.

inflation may worsen the Fed's ability to adjust its policy rate -especially if this decline is followed by another decline in future prices at the ZLB. Yet, on the other hand, a positive shock in current inflation grants the Fed the ability to counter upcoming negative shocks. r is the natural rate where $r \equiv \rho \equiv -log(\beta)$.

The coefficients ϕ_y and ϕ_π are positive. The value of these coefficients in Davig and Leeper (2007) depend on monetary policy regimes. Unlike the work of Davig and Leeper, our models deals with these coefficients under inequality constraints in monetary policy. The values of these coefficients either obey the traditional Taylor rule (1993) or are useless when the nominal interest rate is at the zero . We further assume that the monetary policy shock ε_t^m is i.i.d and it follows AR(1) process:

$$\varepsilon_t^m = \rho^r \varepsilon_{t-1}^m + \zeta^m \epsilon_t^m \tag{1.19}$$

where ρ^r captures the persistence in monetary policy shock and ζ^m represents the standard deviation of this shock.

1.3 Simple empirical analysis

1.3.1 OLS estimation

In this subsection, a simple ordinary least squares (OLS) estimation is used to discriminate between high and low risk-aversion. To further motivate our empirical

model, the consumption growth derived from the work of Farmer, Waggoner, and Zha (2011) can be empirically estimated by the following regression[7]:

$$E_t\big(g_{t+1}|_{S_t}\big) = \delta_1(S_t) + \delta_2(S_t)i_t + \delta_3(S_t)E_t\pi_{t+1} \tag{1.20}$$

where $g_{t+1} \equiv ln\Big(\frac{C_{t+1}}{C_t}\Big)$, $\delta_1(S_t) \equiv -\rho/\sigma_{(S_t)}$, $\delta_2(S_t) \equiv 1/\sigma_{(S_t)}$, and $\delta_3(S_t) \equiv -1/\sigma_{(S_t)}$. The parameters in equation (1.20) are time-varying given that the risk-aversion is not constant and can vary over time. From this, one can conclude that non-parametric methods are superior to models which assume that data follows a particular distribution. Instead of relying on non-parametric methods, we feel it suffices to distinguish the particular impact of the nominal interest rate on consumption in times of recessions versus expansions. We apply the following formula to remove the expectations operator:

$$\begin{aligned} E_tX_{t+1} &= X_{t+1} + \vartheta_{t+1} \\ \vartheta_{t+1} &= -[X_{t+1} - E_tX_{t+1}] \end{aligned} \tag{1.21}$$

where ϑ_{t+1} is the error term. A dummy variable is added to represent the state of the economy. An interaction term between this dummy and the lagged nominal interest rate is added to the first lag of equation (1.20). From this, we estimate the following:

$$\begin{aligned} g_t &= \delta_1 + \delta_2 i_{t-1} + \delta_3\pi_t + \delta_4\eta_{t-1} + \vartheta_t \\ \eta_t &= (D_t \times i_t) \end{aligned} \tag{1.22}$$

[7]The authors use Gali(2008)'s new Keynesian IS curve with time subscript on the risk-aversion coefficient.

where the current consumption growth,g_t , is 100 times of the first log difference between consumption at time t and $t-1$, i_{t-1} stands for the lagged nominal rate of interest, and π_t is the inflation rate. Furthermore, we add the lagged variable η_{t-1} which represents the nominal rate rate multiplied by a dummy variable D_t, where:

$$D_t = \begin{cases} 1 \quad \text{if} \quad \text{NBER recession} \\ \\ 0 \quad \text{if} \quad \text{Otherwise} \end{cases} \tag{1.23}$$

δ_4 governs whether or not the nominal interest rate affects growth differently during recessionary periods. Risk-aversion σ_1 is assumed to be greater in times of recession than in times of expansion σ_0. For this reason, δ_2 is dependent on the current state of the economy. This suggests that $[\delta_{21} \equiv 1/\sigma_1] < [\delta_{20} \equiv 1/\sigma_0]$ in equation (1.20). With all that has been taken into consideration, one might ask what does a significant δ_4 imply?.The interest rate plays a crucial role in the allocation of household consumption between time t and t+1. Depending on the state of the economy, the magnitude of this effect remains asymmetric. If consumption is reduced one day and increases the next day, we experience an increase in consumption growth. Hence, if the interest rate increases; one gets more reward in their investment. For this reason, growth will increase. Thus, if we are given a higher interest rate, our behavior will innately cause us to consume less for a greater consumption tomorrow. Our argument, therefore −is as follows. For illustrative purposes, suppose that consumption

growth is related to the nominal interest rate by a coefficient of 1[8]. Now, lets discriminate between two situations: expansion and recessions. As mentioned before, one is assuming that the interest rate is increasing by one percent and we are in a state of expansion; then this coefficient would be less than one in recession. This means that consumption growth would increase further in expansions than in times of economic recessions -given the same nominal interest rate. In other words, if one aims to save money in the bank, an increase in interest rate will attract one to make this investment; however, at the same time, that which makes one invest more despite an increase in interest rate remains contingent on the fact that less risk is involved.

The underlying aim in introducing equation (1.24) serves to capture the effect of the interest rate on consumption growth in and out of the ZLB. Theoretically, the interest rate is supposed to stimulate consumption growth. Yet, empirically, we must question if the effect of the interest rate on consumption growth displays asymmetric magnitude with respect to the sub-samples before and after the ZLB. Thus, I add the dummy variable non-zero lower bound (NZLB) to represent the series prior to the Fed's encounter with the ZLB. An interaction term I_t is added between this dummy and the nominal interest rate,

[8]That is the coefficient of risk-aversion $\sigma = 1$

$$g_t = \delta_1 + \delta_2 I_{t-1} + \delta_3 \pi_t + \vartheta_t$$

$$I_t = (NZLB_t \times i_t)$$

where (1.24)

$$NZLB_t = \begin{cases} 1 & \text{if Out of the ZLB} \\ 0 & \text{if Otherwise} \end{cases}$$

The interest rate from equation (1.24) has been dropped because it is highly collinear with the interaction term I_t. This generates unreliable coefficients of individual regressors.

1.3.2 Data

The empirical models in this paper employ quarterly data from 1980Q1 − 2014Q2. The consumption c_t is the US real personal consumption expenditures(in logs). It is seasonally adjusted and measured in billions of chained 2009 dollars. Quarterly nominal interest rate, i_t is the average of the monthly federal funds rate. The inflation rate is 400 times the first difference of GDP chain-weighted price index P_t (in logs), $\pi_t = 400 * (lnP_t - lnP_{t-1})$. The dummy variable D_t takes 1 if the National Bureau of Economic Research(NBER) refers to quarter t as a recession. This variable takes 0 in non-recessionary periods. All empirical models variables are drawn directly from the Federal Reserve Economic Data - FRED (St. Louis Fed).

1.4 Calibration

It is noteworthy to mention that this paper is mainly theoretical. We assume that the risk-aversion parameter follows a Markov-switching chain and we calibrate the model based on this assumption. Rather than estimating the probability matrix directly from the data, we rely on the literature by importing the probability matrix. Chauvet and Hamilton (2006) estimate a transition probability matrix at which the economic switches between expansion and recession state. Th paper argues that recessions are associated with higher risk-aversion, and expansions on the other hand are associated with low risk. This allows us to use the probability matrix of switching between states of the economy in the content of Markov-switching risk aversion. Alternatively and in the near future, we will estimate out transition probabilities of risk-aversion by relying of real time data. Table 1.1 of the Tables and Figures section offers the model parameters. We assign high risk-aversion σ_1 with a value of 3; and the low coefficient of risk-aversion σ_0 -a value of 1. From Framer et *al.*(2009), we extract the autoregressive (AR) coefficients, we place higher persistence in the aggregate demand shock ($\rho_0^y = 0.83, \rho_1^y = 0.68$); along with a lower standard deviation ($\zeta_0^y = 0.18, \zeta_0^y = 0.27$) during expansions. The AR coefficients of price and monetary policy shocks are set up to assume that they are independent of risk-aversion regimes. I import the AR coefficients of inflation shock ρ^P, monetary policy shock ρ^r, and their standard deviations ζ^P and ζ^m from Holden and Paetz (2012); alongside our use of interest rate smoothing parameter ϕ_i, price elasticity ϵ, and the price stickiness pa-

rameter ξ . The transition probabilities P_{00} and P_{11} are drawn from the empirical results of Chauvet and Hamilton (2006). The remainders of the parameters encompassed in this paper are taken from Gali (2008). All the parameters are calibrated based on quarterly frequency.

1.5 Main results

1.5.1 OLS regressions

The main empirical results of regression equations (1.22) and (1.24) can be found in tables 1.3 and 1.4 of the Tables and Figures section. Table 1.3 notes that the first lag of the federal fund rate affects consumption growth by a significant positive coefficient of 0.053. On the other hand, current inflation reduces consumption growth significantly by a negative coefficient of -0.072. The above result is consistent with the standard negatively sloped new Keynesian IS curve. Throughout 1980Q1$-$2014Q2, the negative coefficient corresponding to the inflation rate reveals a positive relationship between previous period consumption and current inflation.

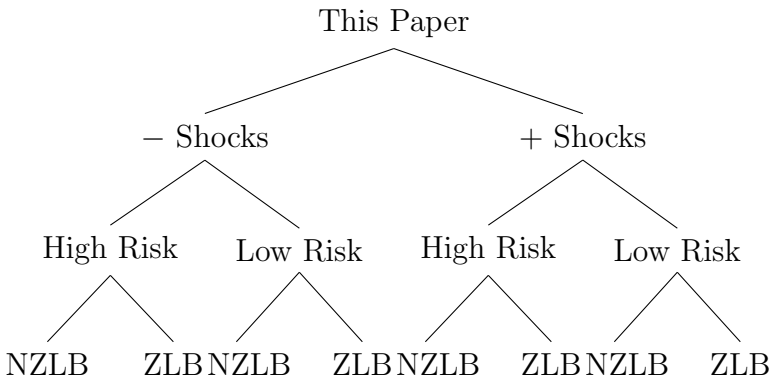
The negative coefficient -0.077 in equation (1.22) is statistically significant. This asserts that the relationship between interest rate and consumption growth is weakened in times of recession. In both our theoretical and empirical models, we mention that the relationship between the nominal interest rate and consumption growth should be inversely related to the coefficient of risk-aversion. This is confirmed in the

results yielded in Table 1.3; thus supporting this paper's use of the Markov-Switching risk-aversion.

Results concerning the zero interest rate policy regime are found in Table 1.4. Here, we see that the positive coefficient δ_2 in equation 1.24 is significant. The interaction term I_t is a variable that represents the interest rate before the year 2009. The same interaction term takes a value of zero from the year 2009 and beyond. From this, we prove that the interest rate plays a minimal role in consumption growth when the nominal interest rate is tied to the zero bound.

1.5.2 Impulse response functions

Figures 1.1−1.12 in the Tables and Figures section demonstrate the impulse responses of output gap, inflation, and interest rate to macroeconomic shocks. From these, multiple scenarios arise −all of which are addressed in the following tree:



We believe that positive demand shocks are associated with low risk; thus these shocks do not force the nominal interest rate to reach the zero bound. Our empirical analysis demonstrates that negative demand shocks are related to a higher risk-aversion;

therefore imposing the ZLB on the nominal interest rate.

In Figure 1.1, output increases due to negative monetary shocks for at least 10 quarters. When the ZLB binds, the impact of the negative demand shock on output is more aggressive. Inflation shock reduces output within the ZLB. The magnitude of this effect is larger when the monetary policy is not constrained by the ZLB. For instance, when inflation experiences a negative shock, the aggregate supply shifts left. This leads to larger output at the equilibrium with no constraints in standard models.

On the other hand, inflation shock leads to larger contractions in output when the aggregate demand curve is upward slopping and flatter at the zero bound[9]. In Figure 1.2, the inflation responds more negatively to demand shocks at the ZLB. This decreases the Fed's ability to offset negative shocks. In Figure 1.4, whenever the economy is characterized by high-risk aversion, the impact of negative inflation shock on output is minimized. Figure 1.4−1.6 show impulse response functions to negative shocks in a high-risk aversion regime. When the ZLB is ruled out, negative demand shocks have a large effect on output. Figure 1.5 shows that impulse response of inflation to the negative interest rate and demand shocks display asymmetry with respect to the level of risk-aversion

The response of economic activity with respect to high and low risk-aversion; and positive shocks in and out of the ZLB are analyzed in Figures 1.7−1.12. The solid and dashed lines in these figures are identical. In Figure 1.7, one can see that the

[9]In Figure 1.1, the aggregate demand curve is flatter as a result of low-risk aversion

position of the ZLB is not crucial because the response of output to interest and inflation shocks stay the same regardless.

The coefficient of risk-aversion may be assigned to larger values when the economy is faced with positive inflation shocks. Figures 1.7 and 1.10 have nearly identical responses of output to positive demand shock. Even though different parameters are assigned to demand shocks that are contingent on the risk-aversion regime; the output in both high and low risk regimes are affected symmetrically by positive demand shocks. Extensive literature on macroeconomic shocks neglects selecting the appropriate risk-aversion. Bearing this in mind, our paper extends on this literature by demonstrating that risk-aversion plays a crucial in the transmission of macroeconomic shocks. Namely when these shocks are negative and the zero bound constraints binds.

1.6 Conclusion

The paper investigates the impact of macroeconomic shocks through the implementation of a new Keynesian model with a coefficient of risk-aversion that follows a Markov-switching chain. Empirically, we demonstrate that risk-aversion jumps during recessions. This influences the impact of shocks in a zero lower bound environment. In general, the paper imports a probability matrix at which the economy switches between high and low risk regimes. Then, we investigate the impact of shocks in two different current states of the economy: expansions and recessions. The findings of this paper have several significant implications for both fiscal and monetary pol-

icy. On the firsthand, if the federal fund rate remains low for an extended period of time; the Fed has no room to stabilize prices and economic growth. Furthermore, household risk-aversion needs to be taken into consideration when monetary and fiscal policy adjustments are made. Primarily because, risk-aversion determines how intense negative shocks are in a zero interest rate monetary policy regime.

With all that that paper investigates, its important to note that we face a few noteworthy limitations. Because data related to the ZLB is limited; robust empirical results are difficult to conduct. Furthermore, aggregate consumption is substantially unpredictable; therefore making it difficult to make judgments on household risk-aversion from the data available on aggregate consumption growth. Future research will focus on micro-founded data by which a household-level survey will be used. This survey will aid in the estimation of a new Keynesian model that implements a Markov-switching risk aversion on an individual level.

1.7 Tables and Figures

Table 1.1: Calibrated parameters

Parameter	Value	Interpretation
β	0.995	discounting factor
α	0.33	non-labor share
ϵ	6	price elasticity
σ_0	1	low risk-aversion coefficient
σ_1	3	high risk-aversion coefficient
ϕ	1.0	inverse elasticity of labor supply
ρ_0^y	0.83	AR-coefficient aggregate demand shocks in expansions
ρ_1^y	0.68	AR-coefficient aggregate demand shocks in recessions
ρ^P	0.70	AR-coefficient inflation shocks
ρ^r	0.70	AR-coefficient monetary policy shocks
ζ_0^y	0.18	S.D. aggregate demand shock innovations during expansions
ζ_1^y	0.27	S.D. aggregate demand shock innovations during recessions
ζ^P	0.10	S.D. inflation shock innovations
ζ^m	0.10	S.D. monetary policy shock innovations
ξ	0.75	the degree of price stickiness
ϕ_i	0.20	interest rate smoothing parameter
ϕ_π	1.5	reaction coefficient of inflation
ϕ_y	0.125	reaction coefficient of output
P_{00}	0.95	transition probability from expansion to expansion
P_{11}	0.78	transition probability from recession to recession

Table 1.2: Summary statistics (1980.Q1 - 2014.Q2)

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**
$g_t^a\%$	0.722	0.621	-2.274	1.96
P_t^b	77.650	17.90	42.955	1.8.621
$i_t^c\%$	5.252	4.031	0.0733	17.78
${\pi_t}^d\%$	2.708	1.762	-0.624	11.086
D_t^e	0.1304	0.3380	0	1
$NZLB_t^f$	0.8478	0.3604	0	1

[a] Is the first difference of real personal consumption (in logs), $[100 * (lnC_t - lnC_{t-1})]$. [b] Is the the GDP chain-weighted price index, Index 2009=100. [c] Is the federal funds rate, the averaged of three months. [d] $\pi_t\%$=[400*(ln$P_t - lnP_{t-1}$)].
[e] NBER based Recession Indicator that takes 1 in recessions and 0 otherwise
[f] $NZLB_t$ represents the period before the ZLB, where $NZLB_t = 1$ for any quarter before 2009, and 0 otherwise

Table 1.3: OLS estimation of equation (1.22) (1980.Q1−2014.Q2)

Variable	**Coefficient**
Constant	0.710180***
	(0.093796)
Lagged Federal fund rate (i_{t-1})	0.052849***
	(0.018000)
Inflation rate (π_t)	−0.072330*
	(0.039022)
Interaction term[a]($\eta_{t-1} = D_{t-1} \times i_{t-1}$)	−0.076760***
	(0.017186)
R^2	0.165
N	138

[a] D_t takes 1 during NBER recessions. Numbers between parenthesis are the standard errors. ***significant at 1%; **significant at 5%; *significant at 10%.

Table 1.4: OLS estimation of equation (1.24) (1980.Q1−2014.Q2)

Variable	**Coefficient**
Constant	0.804974***
	(0.098059)
Inflation rate (π_t)	−0.089873**
	(0.042142)
Interaction term[a]($I_{t-1} = NZLB_{t-1} \times i_{t-1}$)	0.030483*
	(0.018355)
R^2	0.033182
N	137

[a] $NZLB_t$ takes 1 out of the zero lower bound. Numbers between parenthesis are the standard errors. ***significant at 1%; **significant at 5%; *significant at 10%.

Figure 1.1: Output impulse responses to negative monetary, inflation, and demand shocks in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

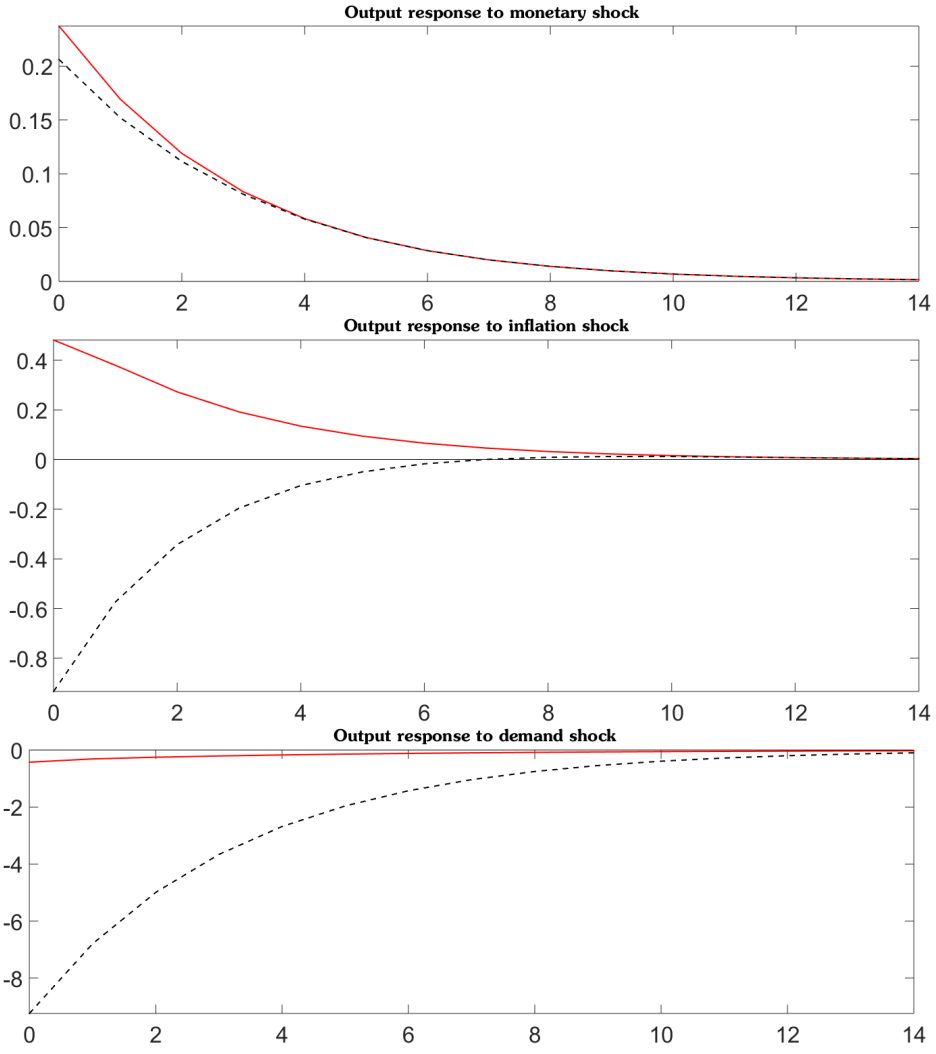


Figure 1.2: Inflation impulse responses to negative monetary, inflation, and demand shocks in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

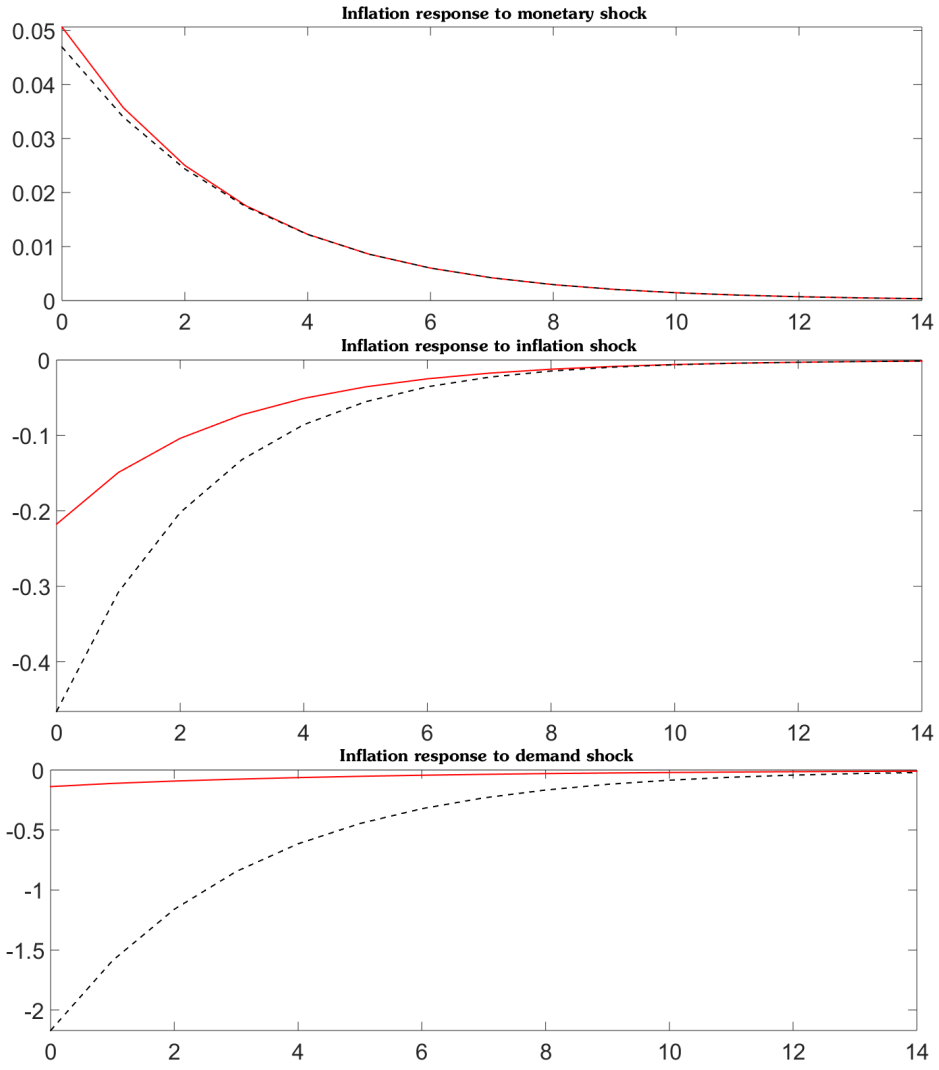


Figure 1.3: Interest rate impulse responses to negative monetary, inflation, and demand shocks in in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

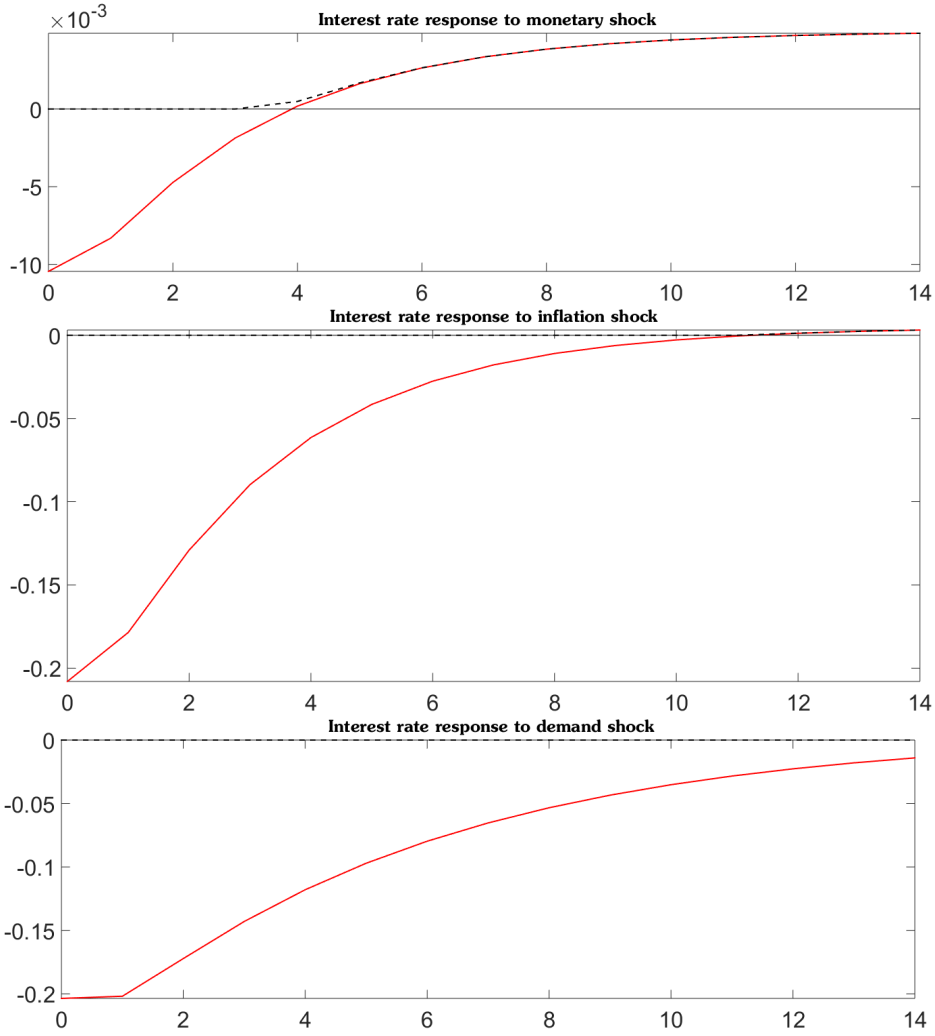


Figure 1.4: Output impulse responses to negative monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.

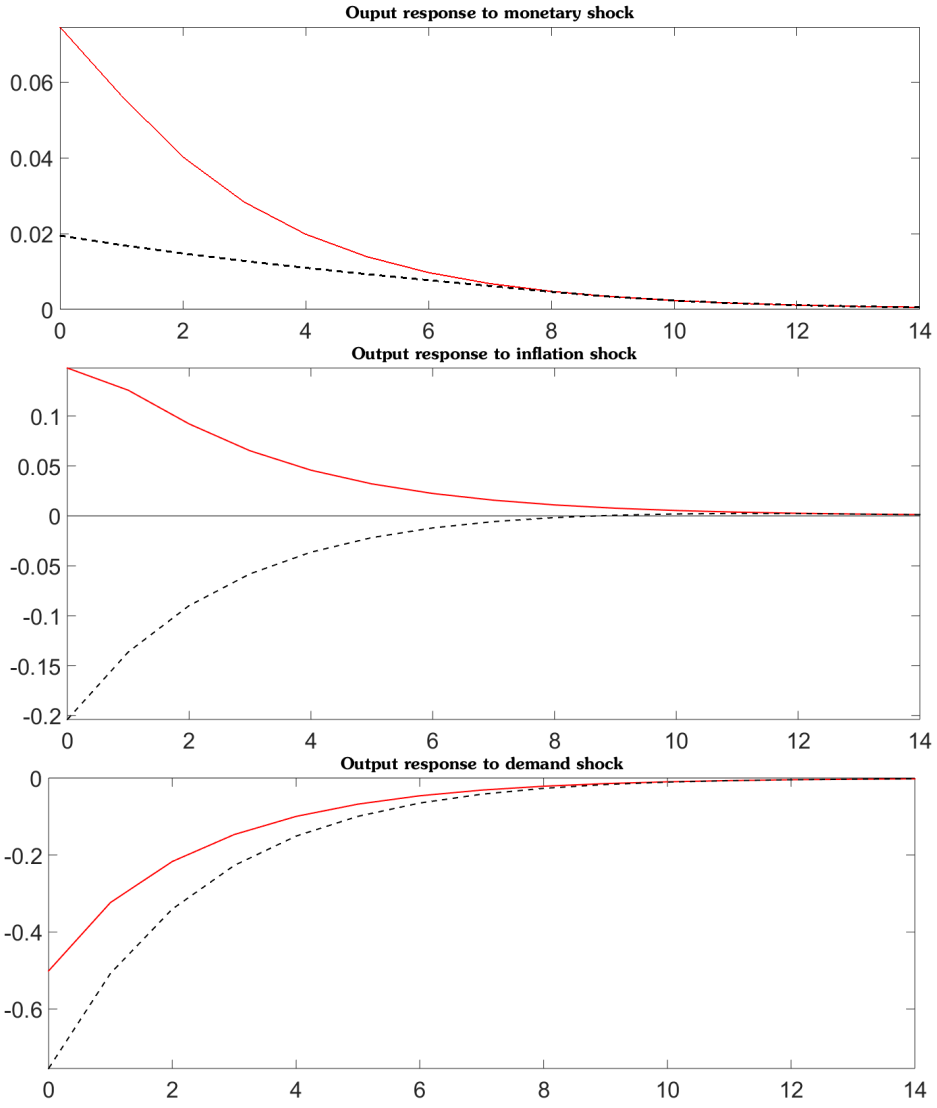


Figure 1.5: Inflation impulse responses to negative monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.

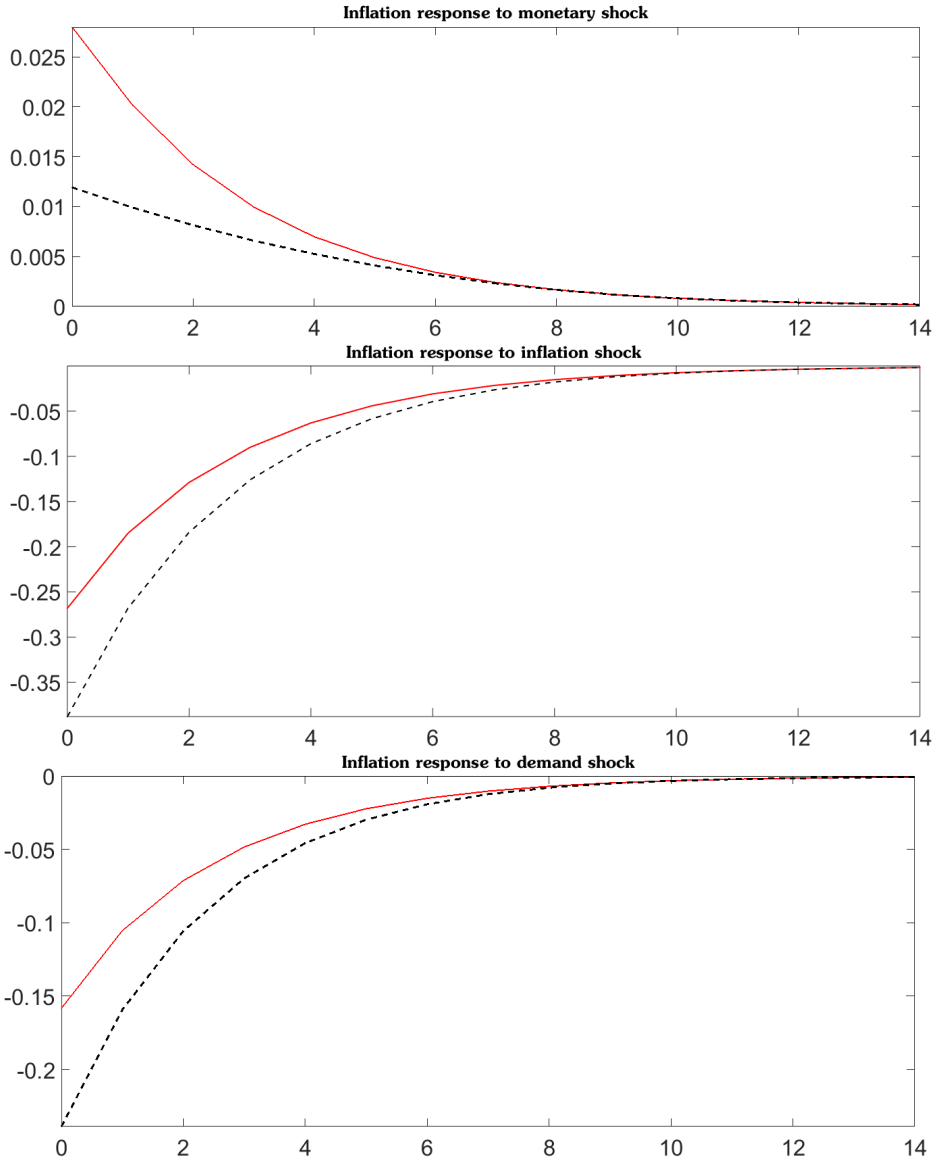


Figure 1.6: Interest rate impulse responses to negative monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.

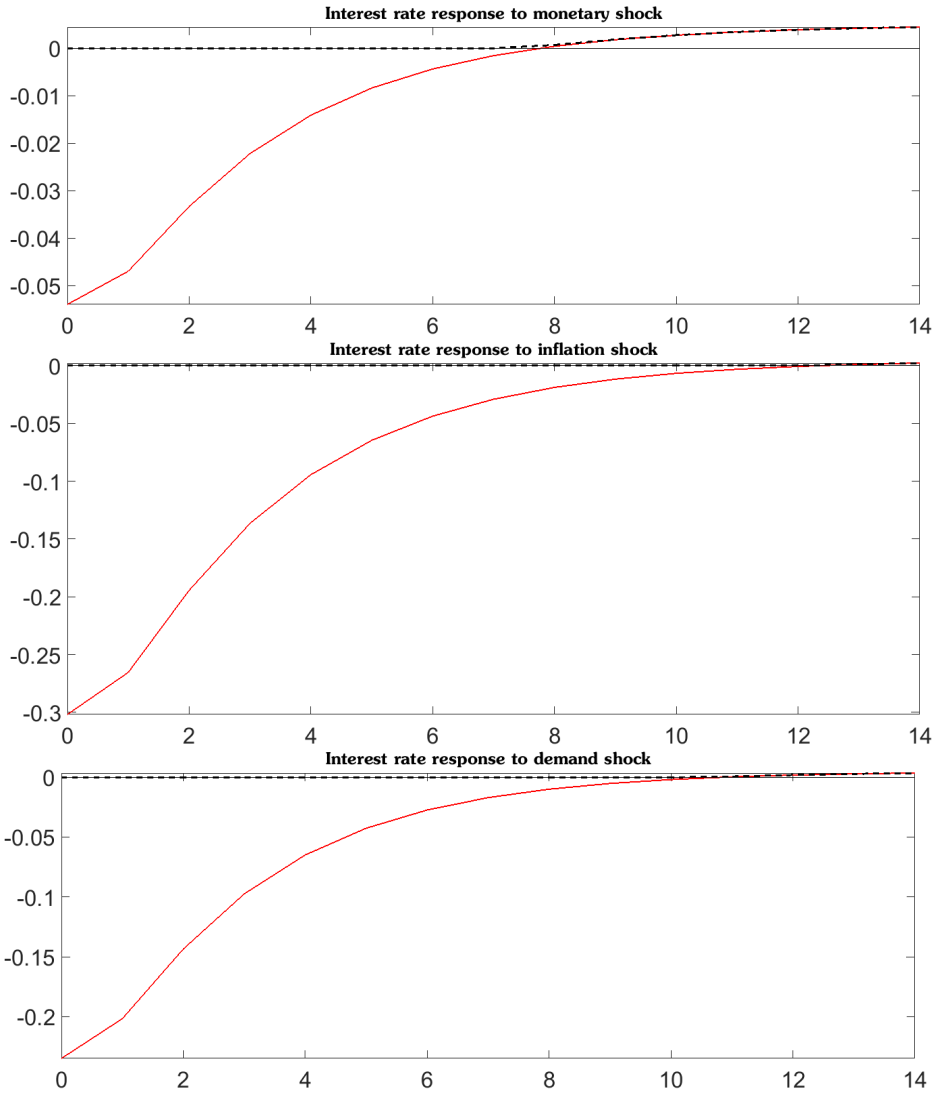


Figure 1.7: Output impulse responses to positive monetary, inflation, and demand shocks in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

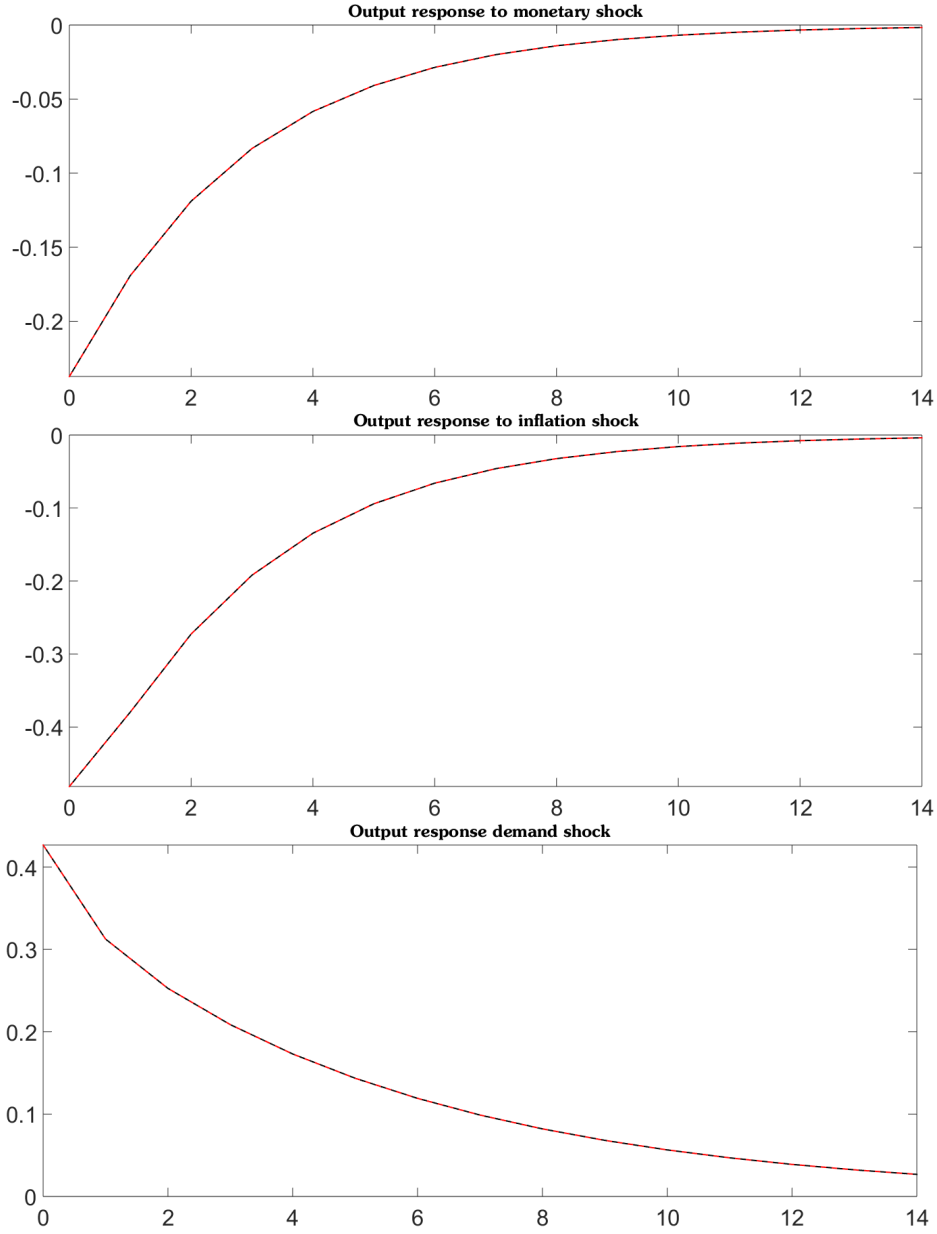


Figure 1.8: Inflation impulse responses to positive monetary, inflation, and demand shocks in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

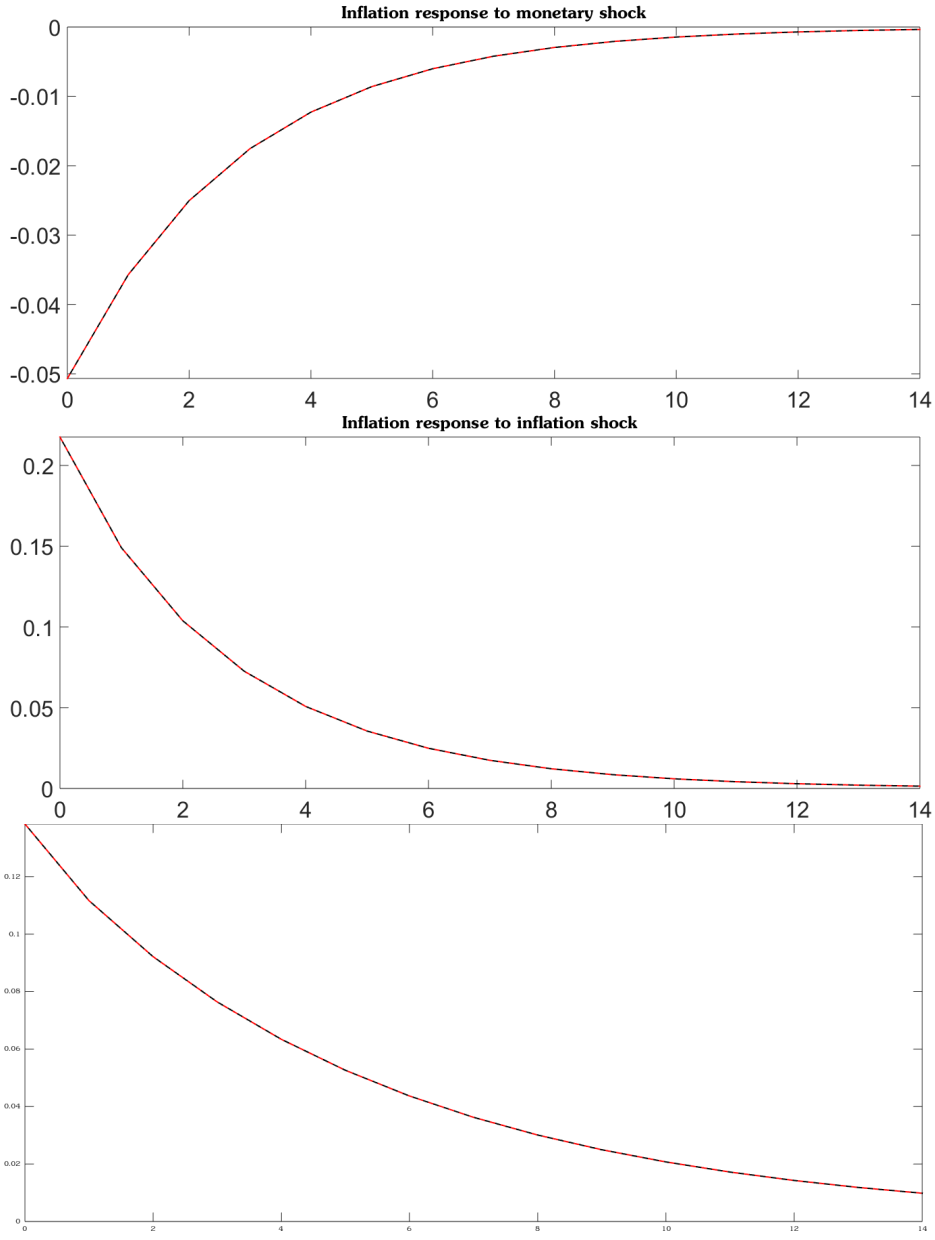


Figure 1.9: Interest rate impulse responses to positive monetary, inflation, and demand shocks in a low-risk current state($S_t = 0$), where current $\sigma = 1$. The dashed black line enforces the ZLB, while solid red lines don't.

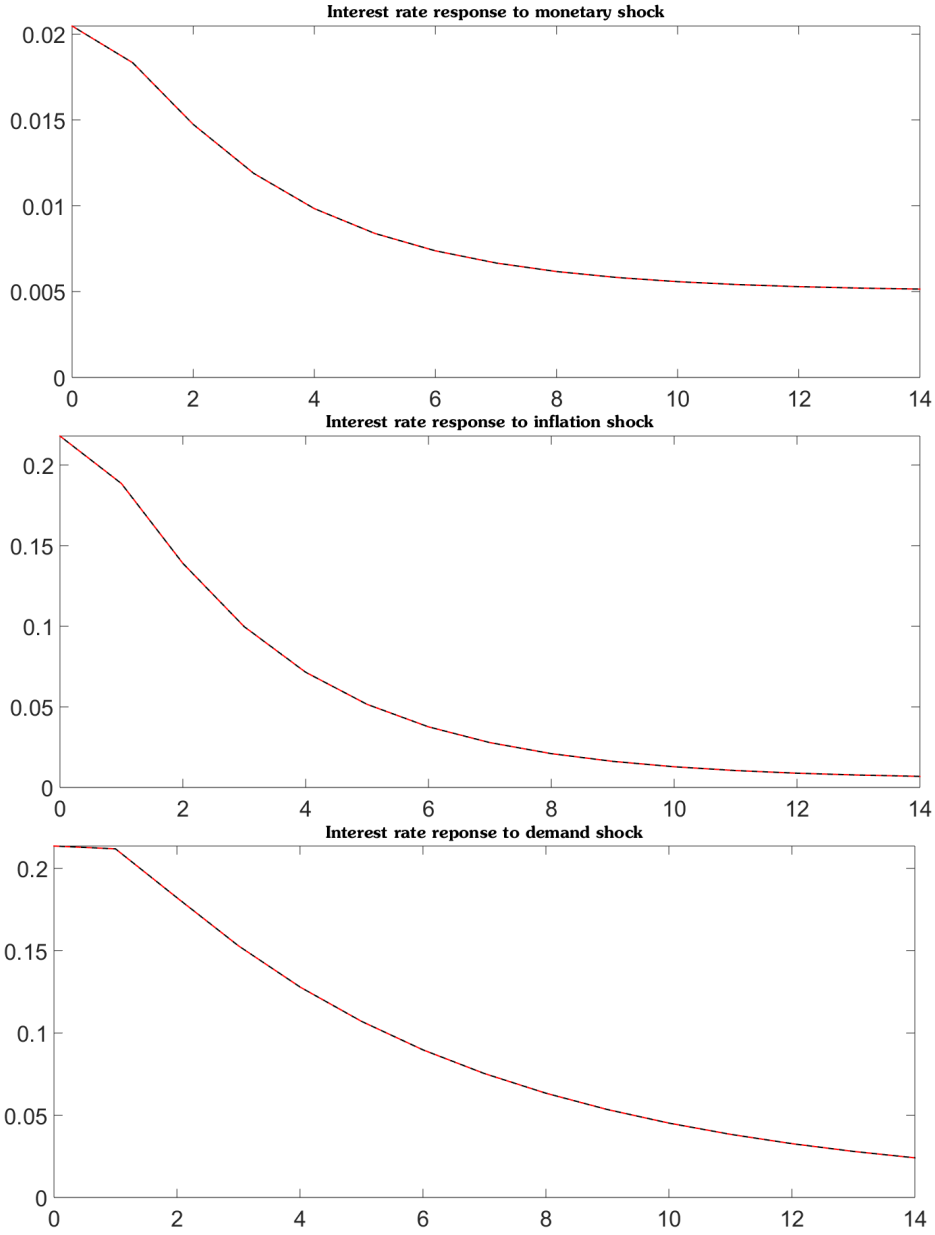


Figure 1.10: Output impulse responses to positive monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.

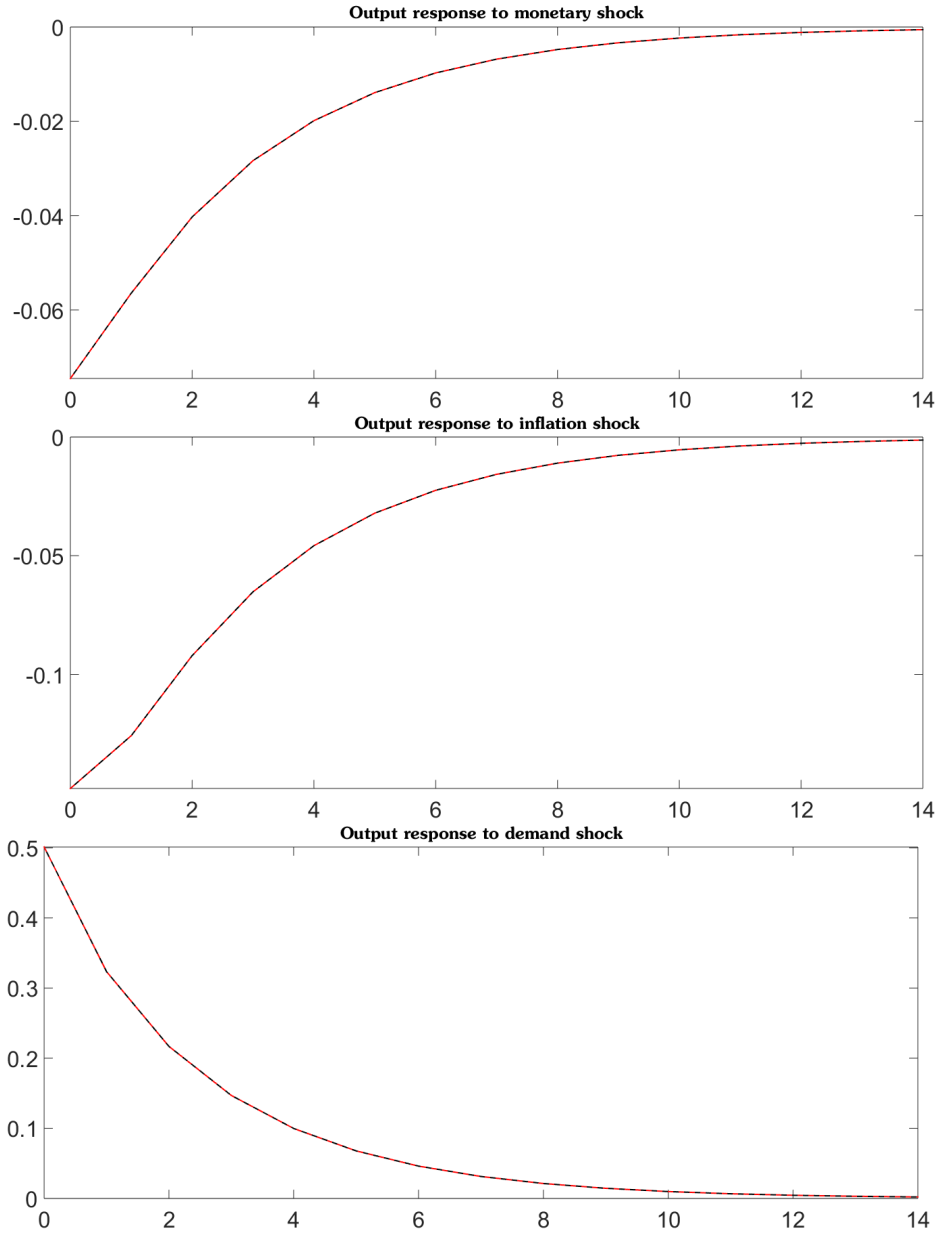


Figure 1.11: Inflation impulse responses to positive monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.

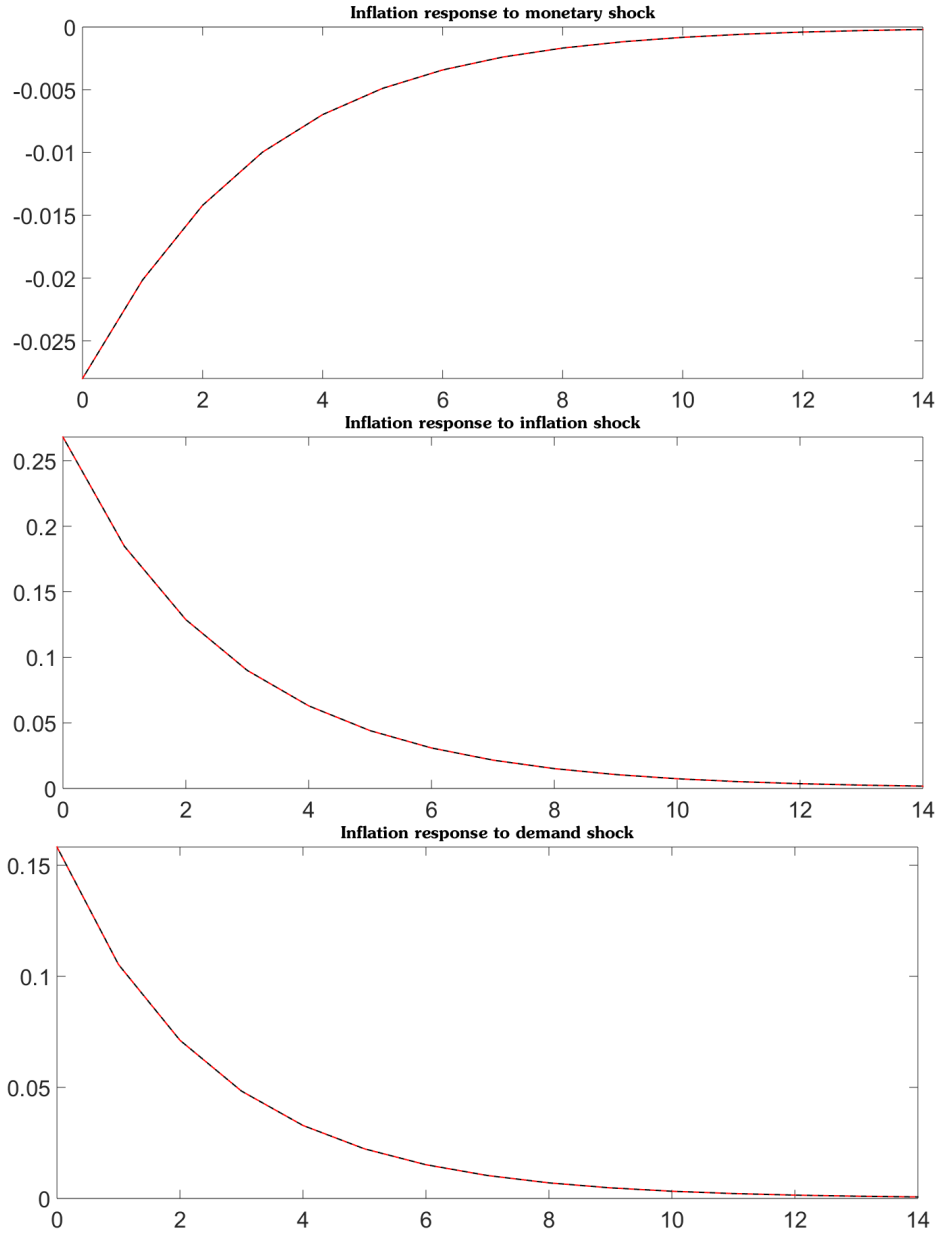
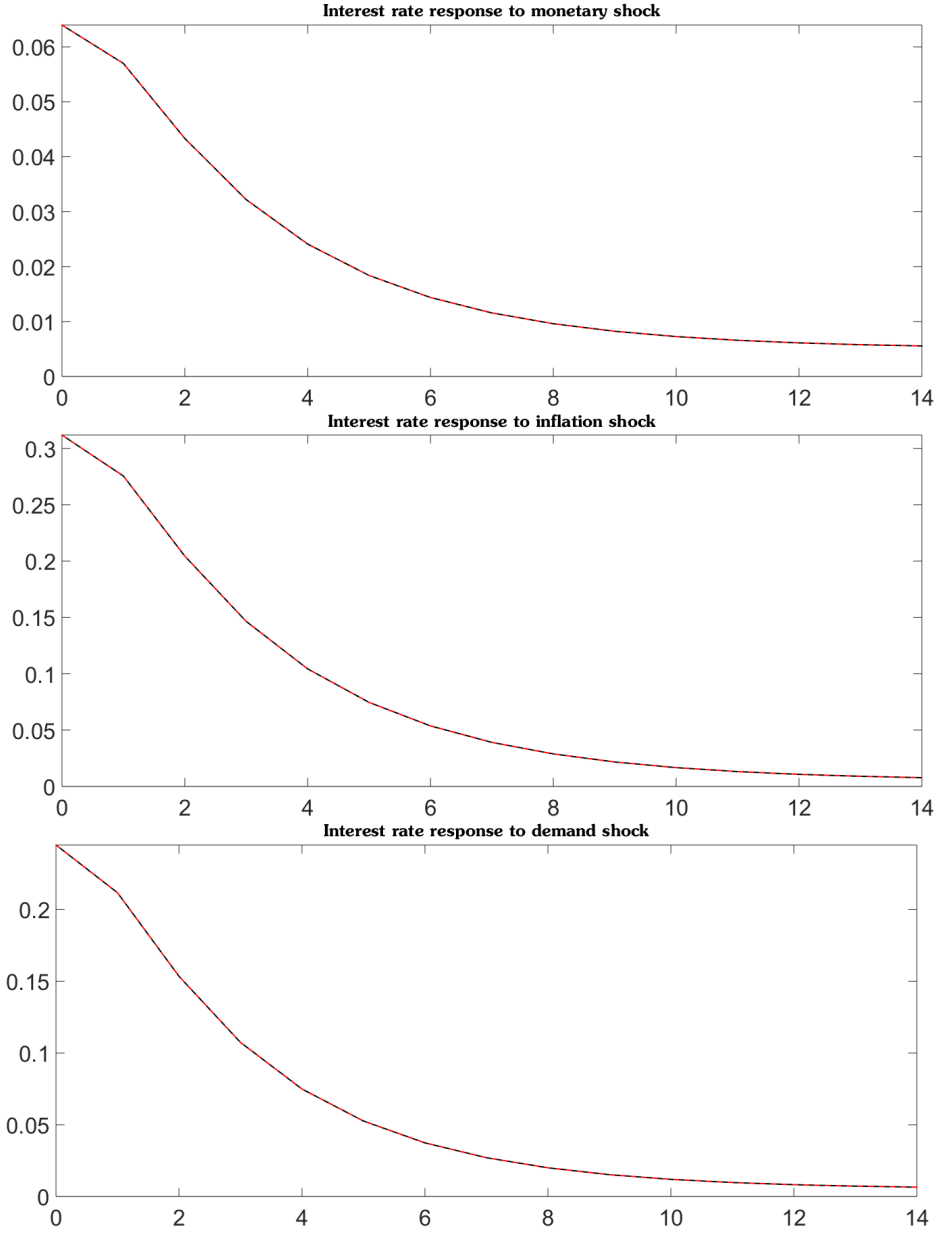


Figure 1.12: Interest rate impulse responses to positive monetary, inflation, and demand shocks in a high-risk current state($S_t = 1$), where current $\sigma = 3$. The dashed black line enforces the ZLB, while solid red lines don't.



Chapter 2

Consumption and Money Uncertainty at the Zero Lower Bound

2.1 Introduction

This paper studies uncertainty measured by conditional volatility at the zero lower bound. Uncertainty measured by conditional volatility is a negative feature of the U.S. economy through which the instability of the economy become transparent. Our interest focuses on consumption uncertainty. We examine if a zero interest rate regime affects the Fed's ability to fully offset shocks and achieve optimal policy. From a theoretical background, we demonstrate that both money uncertainty and consumption

uncertainty are related to the nominal interest rate. To empirically illustrate this, the paper implements a multivariate GARCH model on U.S. personal consumption and real M1 from January 1980 to December 2014. Recent literature uses second conditional moments as a proxy of uncertainty. Engle's (1982) introduction of the GARCH model serves as a powerful tool in modeling economic uncertainty. Economists such as Chiriac and Voeb (2010), Fountas, Karanasos, and Kim (2006), Grier and Perry (2000), Grier, Henry, Olekalns, and Shields (2004) utilize this framework to model inflation and output volatility.

During the era of the Great Depression, economic uncertainty reached a record breaking high (Mathy, 2014). This triggered a reduction in employment, investment and output. With the recent financial crisis of 2008, the Federal Reserve reduced the federal fund rate to nearly zero. Even though the federal fund rate is constrained by the zero lower bound, the Federal Reserve continuously aims to control inflation and output growth through unconventional policies. The Fed purchases governmental securities in order to keep it's policy rate low for an extended duration of time. Lowering the nominal interest rate reduces the opportunity cost of holding money. In Sidrausky (1967) model, the marginal rate of substitution between personal consumption and the quantity of money relies on the nominal interest rate. Hence, the opportunity cost of holding money reaches its lowest levels when the nominal interest rate is at the zero lower bound. This can have a potential effect on the relationship between consumption and money.

The quantity of money, rather than the price of money can affect the economy if the Federal Reserve commits to a low interest rate for an extended period of time. This is due to the Federal Reserves reliance on open market operations during which money stock changes to maintain the federal fund rate at a very low level. From the perspective of the individual, the returns they get on their deposits made at commercial banks become less appealing when the short-term interest rate is lowered. To best illustrate, the zero lower bound, Figure 2.1 provides series on the federal fund rate and the nominal interest rate given by the 3 month treasury bills.

The remaining sections of this paper are organized as follows: Section 2 offers the related literature. Section 3 provides a theoretical background and introduces the empirical model. Section 4 describes the data and Section 5 yields the results of this paper. Section 6 offers the paper's conclusion and Section 7 includes a list of tables and figures.

2.2 Related literature

Most economist neglect to include a theoretical background for their GARCH empirical models; thus without properly establishing a connection between the empirics and theory, the results can become misleading. For this reason, this paper strives to use empirical methods directly driven by the money in the utility function (MIU) developed by Sidrauski (1967).

In Sidrauski's model, households gain utility from money services with the op-

portunity cost of holding money being given by the nominal interest rate. Thus, the zero lower bound has its direct impact on the marginal rate of substitution between consumption and money services. Friedman (1969) argues that the optimal interest rate should equal zero. For Friedman, the marginal cost of creating additional money is zero; here the optimality condition implies that the opportunity cost of holding money has to be equal to the social cost of creating money. Nevertheless, it remains critical to examine the extent to which the zero optimal value of the nominal interest rate contributes to the volatility of economic variables.

According to Basu and Bundick (2014), the zero lower bound creates risk and uncertainty that leads to precautionary savings by households. Complementary to these findings, Plante et al. (2014) suggests that the ZLB generates a strong correlation between macroeconomic uncertainty and real GDP growth. Others such as Canzoneri, Cumby, and Diba (2007); Hartzmark (2013); Crowder and Hoffman (1996) show that higher moments of consumption and output can be functions of the nominal interest rate. These researches don't include money stock in their models, even though money is assumed to be more sensitive to changes in the nominal interest rate.

The zero lower bound can affect the economy through different channels. On the one hand, Christiano, Eichenbaum, and Rebelo (2011) and Woodford (2011) suggest that the fiscal policy is more effective than the monetary policy at the zero lower bound. In contrary, Swanson and Williams (2014) argue that the effectiveness of monetary and fiscal policy is the same -regardless of the economy being in or

out of the ZLB. For Swanson and Williams (2014), the output gap can be written as a function of the entire future path of the nominal interest rate, instead of the current rate. That is −the current rate can hit zero; however, the future nominal rate is unconstrained with the ZLB. Furthermore, Wieland (2012) demonstrates that negative supply shocks can be expansionary at the ZLB.

What is the role of the Central Bank at the zero lower bound? If the nominal interest rate reaches the zero lower bound, the Federal Reserve will face a challenge in stabilizing prices. Ireland (2001) suggests that real money balances can eliminate the impact of the ZLB which the central banks use to control prices. In addition, Ireland articulates that agents are worse off under a zero nominal interest rate. Strong empirical evidence suggests that the real money balance increases the marginal utility of consumption (Koenig, 1990). The role of the Central Bank revolves around manipulating the money stock in a low and consistent nominal interest rate environment. The Central Bank uses the Forward Guidance tool. In this tool, the Central Bank promises to commit to a low interest rate for an extended period of time. For Coenen and Warne (2014), forward guidance can possibly be a successful policy in downsizing the risks to price stability.

2.3 The model

2.3.1 Theoretical background

In closing the last section, we introduce related literature that enhances our stance on the impact of the zero lower bound on the uncertainty of personal consumption and money. Now, we turn our analysis over to methodology; here we provide our main empirical model with a brief introduction into the theory behind it -this helps encourage our empirical analysis and provide a sense of insight for our results. The purpose of this section is to derive the uncertainty model GARCH from the optimal conditions of the household maximization problem. The research in this paper is empirical. Our use of a theoretical model demonstrates the correlation among variables from a theoretical angle. In our theoretical section, we implement the Money in the Utility Function (MIU) by Sidrauski (1967), Walsh (2010); Bhattacharjee and Thoenissen (2007). In this function, households maximize the following future discounted utility:

$$E_0\Big[\sum_{t=0}^{\infty}\beta^t U(C_t, M_t/P_t, N_t)\Big] \tag{2.1}$$

subject to budget constraints:

$$P_tC_t + M_t + Q_tB_t \leq B_{t-1} + W_tN_t + M_{t-1} \tag{2.2}$$

Where N_t represents households supply of labor $-$ with W_t being nominal wage and M_t stands for nominal money balance. β is a discounting factor between zero and one. C_t is consumption, and P_t denotes the aggregate price index. B_t represents risk-less discounted bonds purchased at time t and maturing at time $t+1$. Each bond yields one unit of money at maturity with its price being Q_t where $Q_t = exp(-i_t)$. We use a non-separable utility function with respect to money and consumption. In this model, we follow Benchimol and Fourcans (2012)[1]:

$$U_t \equiv \frac{1}{1-\sigma}\left((1-b)C_t^{1-v} + b\Big(\frac{M_t}{P_t}\Big)^{1-v}\right)^{\frac{1-\sigma}{1-v}} - \frac{N_t^{1-\phi}}{1-\phi} \tag{2.3}$$

Households gain positive utility from consumption C_t and real money services M_t/P_t. However, they get negative utility from work N_t. σ is households coefficient of risk-aversion or the inverse of the intertemporal elasticity of substitution. v is the inverse of the elasticity of money holdings with respect to the interest rate. b is a positive scaler and ϕ^{-1} is the elasticity of work with respect to real wage.

The first order conditions are given by equation (2.4):

$$\begin{aligned} Q_t = \beta E_t\left[\frac{U_c'\Big(C_{t+1}, M_{t+1}/P_{t+1}, N_{t+1}\Big)}{U_c'\Big(C_t, M_t/P_t, N_t\Big)}\Pi_{t+1}^{-1}\right] \\ \frac{U_m'\Big(C_t, M_t/P_t, N_t\Big)}{U_c'\Big(C_t, M_t/P_t, N_t\Big)} = 1 - Q_t \end{aligned} \tag{2.4}$$

[1]Preference, money, and hours worked shocks are included in the authors' model.

Where the top part of equation (2.4) represents the Euler equation. This is the marginal rate of substitution between consumption at time t and t+1. The bottom part of equation (2.4) equals the opportunity cost of holding money. Plugging the marginal utilities in equation (2.4) yields:

$$e^{-i_t} = \beta E_t \left[\frac{C_{t+1}^{-v}}{C_t^{-v}} \frac{\left((1-b)C_{t+1}^{1-v} + b\left(\frac{M_{t+1}}{P_{t+1}}\right)^{1-v}\right)^{\frac{1-\sigma}{1-v}-1}}{\left((1-b)C_t^{1-v} + b\left(\frac{M_t}{P_t}\right)^{1-v}\right)^{\frac{1-\sigma}{1-v}-1}} \Pi_{t+1}^{-1} \right] \tag{2.5}$$

$$\frac{b(M_t/P_t)^{-v}}{(1-b)C_t^{-v}} = 1 - Q_t$$

The gross inflation rate is given by Π_t, where $\Pi_t = Pt/P_{t+1} = 1 + \pi_t$. Equation (2.5) relates consumption, price level, and money stock to the nominal interest rate. The log-linearized Euler equation and opportunity cost of holding money can be written as[2]:

$$i_t = \theta_0 + \theta_1(E_t c_{t+1} - c_t) + \theta_2(E_t m_{t+1} - m_t) + \theta_3 E_t \pi_{t+1} \tag{2.6}$$

$$\lambda_0 m_t + \lambda_1 c_t = \lambda_3 i_t$$

where $c_t = log\left(\frac{C_t}{C}\right)$ and $m_t = log\left(\frac{M_t/P_t}{M/P}\right)$. These variables represent the deviations of their logs from steady state[3]. For simplicity, the parameters of the households optimality conditions are reduced to a set of θ and λ coefficients . We follow Canzoneri, Cumby, and Diba (2007); Fuhrer (2000), and Hartzmark (2013) by assuming that

[2]The reader is encouraged to see Benchimol and Fourcans (2012) for more details on how to derive equation (2.6) from (2.5).

[3]Values without time subscript refer to the steady state

the Euler equation follows a conditional log-normality. For this reason, we include uncertainty measures and log-linearize the Euler equation in (2.5) as follows:

$$i_t = \theta_0 + \theta_1(E_t c_{t+1} - c_t) + \frac{\theta_1^2}{2} V_t c_{t+1} + \theta_2(E_t m_{t+1} - m_t) + \frac{\theta_2^2}{2} V_t m_{t+1} + \theta_3 E_t \pi_{t+1}$$
$$+ \frac{\theta_3^2}{2} V_t \pi_{t+1} + \theta_1\theta_2 Cov_t(c_{t+1}, m_{t+1}) + \theta_1\theta_3 Cov_t(c_{t+1}, \pi_{t+1}) + \theta_2\theta_3 Cov_t(m_{t+1}, \pi_{t+1}) \tag{2.7}$$

The above equation is estimated by the moment generating function[4]. V_t is the conditional variance, and Cov_t is the conditional covariance. We use this equation to show that consumption and money uncertainty are both functions of the nominal interest rate. Alternatively, the interest rate drives the relationship between consumption, real money balance, and their uncertainty.

2.3.2 Empirical model

This section examines whether the second moments of consumption and money are affected by the level of the nominal interest rate. In addition, we focus on whether or not these moments behave asymmetrically within a money regime that is constrained by a remarkably low interest rate. Our empirical model is motivated by Fuhrer (2000) and Canzoneri (2007) who show that the Euler equation can be written as a vector autoregressive. We use a multivariate GARCH model that links consumption, real money, and their uncertainty to the nominal interest rate. Our adaptation of

[4]The moment-generating function for a normal random variable $X : E[e^{bX}] = b\mu + \frac{1}{2}b^2\sigma$

the GARCH model complements the work of Engle and Sheppard (2001) and Engle (2002). The mean equations of the multivariate GARCH model are presented in the form of Vector autoregression VAR (P) as follows:

$$\begin{aligned} Y_t &= \Lambda + \sum_{s=1}^{P} \Psi_s Y_{t-s} + \Xi_t \\ \Xi_t|\Omega_{t-1} &\sim N(0, H_t) \end{aligned} \tag{2.8}$$

where 0 is a null vector, and Ω_{t-1} is a past information set. H_t is a time varying variance−covariance matrix. Y_t is 2×1 a vector of dependent variables, and Ξ_t is 2×1 a vector of error terms

$$Y_t = \begin{bmatrix} c_t \\ m_t \end{bmatrix}, \quad \Lambda = \begin{bmatrix} a_c \\ a_m \end{bmatrix}, \quad \Psi_s = \begin{bmatrix} \psi_{cc,s} & \psi_{cm,s} \\ \psi_{mc,s} & \psi_{mm,s} \end{bmatrix}, \quad \Xi_t = \begin{bmatrix} \varepsilon_{c,t} \\ \varepsilon_{m,t} \end{bmatrix}$$

We implement a multivariate GARCH model with a dynamic conditional correlation DCC-GARCH as proposed by Engle and Sheppard (2001). In this model, the variance−covariance matrix H_t can be written as:

$$H_t = D_t R_t D_t \tag{2.9}$$

where D_t is the 2×2 diagonal matrix of time varying standard deviations from GARCH models with $\sqrt{h_{kk,t}}$ on the $k^{th.}$ diagonal. R_t is a dynamic correlation matrix. In the DCC-GARCH model[5],

$$h_{kk,t} = s_k + \alpha_k \varepsilon^2_{k,t-1} + \beta_k h_{kk,t-1} \qquad k = c, m \tag{2.10}$$

The conditional covariance between consumption and money is written as:

$$h_{cm,t} = \rho_{cm,t} \sqrt{h_{cc,t} h_{mm,t}} \tag{2.11}$$

where the diagonal elements $h_{cc,t}$ and $h_{mm,t}$ follow univariate GARCH processes and $\rho_{cm,t}$ follows the dynamic process specified in Engle (2002).

Bollerslev (1990) proposed a constant conditional correlation model CCC-GARCH in which the matrix R_t is assumed to be time-invariant which implies that:

$$H_t = D_t R D_t \tag{2.12}$$

and

$$h_{cm,t} = \rho_{cm} \sqrt{h_{cc,t} h_{mm,t}} \tag{2.13}$$

[5]The paper places more emphasis on the money and consumption uncertainty(conditional variance), not on the correlation between these variables

To avoid unidentified parameters in the DCC-GARCH, the paper tests the constancy of conditional correlation by performing two tests. The first test is derived from the seminal work of Engle and Sheppard(2001). Here, the null hypothesis is written as:

$$H_0 : R_t = R \quad \forall t \in T \tag{2.14}$$

The null hypothesis is tested against H_a where $H_a : vech(R_t) = vech(R)+\beta_1 vech(R_{t-1})+ \beta_2 vech(R_{t-2}) + ...\beta_p vech(R_{t-p})$ and p is the number of lags.

The second constant correlation test is the Lagrange multiplier statistic, LMC, as introduced by Tse (2000). We implement these tests to support the use of appropriate multivariate GARCH models. In rejecting the null hypothesis, we demonstrate that the correlations among variables are subject to time-varying[6]. If we reject the null hypothesis; then the use of dynamic conditional correlation GARCH is seen as more suitable for the analysis of our paper. In equation (2.6) of the theoretical background section of our paper, we indicate that a correlation between money and consumption exists. Hence, as the nominal interest rate varies, the marginal rate of substitution between consumption and money stock will change. When the Federal Reserve adjusts its policy rate against prices and real activity fluctuations to achieve maximum employment and stabilize prices, consumption and money change accordingly. The demand for money service increases due to the U.S. monetary authority reduction of

[6]The paper examines the constancy of conditional correlation to verify which multivariate GARCH model fits the data so that model parameters are not unidentified.

the nominal interest rate. Maintaining the nominal interest rate at low target levels requires the Fed to apply expansionary monetary policy. This policy is often known as Quantitative Easing where the Fed purchases financial assets from commercial banks and other financial institutions. . We motive the DCC-GARCH model by testing the constancy of the conditional correlation −which reveals that consumption and money are driven by the dynamics of the nominal interest rate. Our paper investigates the potential impact of the nominal interest rate level on consumption and money stock uncertainty. The lagged nominal interest rate is added i_{t-1} to equation (2.10) as follows[7]:

$$h_{kk,t} = s_k + \alpha_k \varepsilon^2_{k,t-1} + \beta_k h_{kk,t-1} + \delta_k i_{t-1} \qquad k = c, m \tag{2.15}$$

The paper additionally examines the uncertainty surrounding consumption and real money stock in a zero nominal interest rate regime. We do this by including a dummy variable I_t. This dummy variable takes 1 after the Fed encounters the ZLB constraint[8]. We include another dummy variable $\mathcal{T}_t$ which controls the effects on uncertainty generated by recessions.

[7]Previous literature uses the level of the interest rate as an explanatory variable in the conditional variance equations. [Henry and Olekalns (2005); Gruber and Vigfusson (2012)]

[8]Lamoureux and Lastrapes (1990) apply similar models in which a dummy variable is added to the variance equation of the GARCH model.

The latter dummy variable takes 1 whenever the National Bureau of Economic Research (NBER) dates time t as a recessionary period.

$$h_{kk,t} = s_k + \alpha_k \varepsilon^2_{k,t-1} + \beta_k h_{kk,t-1} + \gamma_k I_{t(t\geq 01.2009)} + \eta_k \mathcal{T}_t$$

$$I_t = \begin{cases} 1 & \text{if} \quad t \geq \text{Jan.2009} \\ 0 & \text{if} \quad t < \text{Jan.2009} \end{cases} \qquad \mathcal{T}_t = \begin{cases} 1 & \text{if} \quad \text{NBER recession} \\ 0 & \text{if} \quad \text{Otherwise} \end{cases} \tag{2.16}$$

Without including the recessionary dummy variable $\mathcal{T}_t$, the coefficient γ may be incorrectly interpreted. For example, during the Great Recession of 2008-2009, consumption recorded an unusually sharp contraction. Subsequently, as a result of larger recessionary fluctuations, −a statistically significant γ may result in the event of an omitted variable $\mathcal{T}_t$. NBER dates the duration of the Great Recession from January 2008 to June 2009. During the time span within the economic recession of 2008-2009, we distinguish the behavior of consumption and money uncertainty within a nearly zero interest regime by including this recessionary dummy variable. Finally, an estimation for the multivariate GARCH model is provided by applying the Maximum Likelihood[9].

[9]See Engle and Sheppard (2001) for more details on the estimation methods.

2.4 Data

Our variables are taken from the Federal Reserve Economic Data (FRED). These variables include: money stock (M1), monthly nominal personal consumption expenditure, Consumer Price Index (CPI), NBER recessions indicators, the federal fund rate, and the 3-month Treasury bill. M1 and consumption are in billions of U.S dollars. Real money balance is the nominal money stock divided by the Consumer Price Index. We apply the Hodrick-Prescott (HP) filter to take the cyclical component of consumption c_t and real money stock m_t. By de-trending the variables of consumption and real money stock, the data is transformed to become stationary. The nominal interest rate i_t is the 3-month Treasury bill. We implement an Augmented Dickey Fuller test to examine the unit root up to 10 lags. This test produces a p-value of 0.0000 for consumption and real money. Thus this implies that the unit root is rejected for both variables. Table 2.1 provides descriptive statistics for the main variables used in this research.

Our data is based on monthly frequency which ranges from January 1980-December 2014. Additionally, we implement a White diagnostic test to examine whether consumption and real M1 residuals display heteroskedasticity. From this, we conclude that the null hypothesis of homoscedasticity is rejected with a p-value=0.000 for each variable. Figure 2.2 in our Tables and Figures section plots the HP cyclical components of consumption and real money balances. In our section to follow, we turn our discussion over to our main findings.

2.5 Main Empirical Results

The constant correlation test results are shown in Table 2.2. Under the null hypothesis, the conditional correlation between consumption and money stock is constant. However, in Table 2.2, the constant correlation test suggests that we can safely reject the null hypothesis in favor of a multivariate GARCH with dynamic conditional correlation (DCC-GARCH). In selecting the number of VAR lags used, we rely on the Akaike Information Criterion; the mean equation (2.8) is estimated with 4 lags[10].

Table 2.3 reports the impact of the nominal interest rate on consumption and money conditional volatility. The lagged nominal interest rate is added to the variance equations. In addition, in this table, we use the 3 month treasury bill as a short term risk-less nominal rate.

Consumption uncertainty is positively affected by the level of the nominal interest rate with a coefficient of 0.113. Personal consumption expenditures is less volatile and smoother when the economy experiences a lower nominal interest rate. On the other hand, real money stock exhibits a negative relationship with a coefficient of -0.234 between the nominal interest rate and its uncertainty $-$with more magnitude in comparison to consumption uncertainty.

From the results mentioned above, one is left to ponder whether consumption uncertainty increases when the nominal interest rate reaches its lowest levels at the ZLB? To adequately answer the question we raised above, we add a dummy variable

[10]AIC is described by Ivanov and Kilian (2005) to be the best method for monthly data lag order selection.

to the variance equations as it appears in Table 2.4. This table aims to show whether the zero nominal interest rate environment contributes to consumption and money uncertainty. It appears from this table that both consumption and money uncertainty increases significantly during recessions. With regards to consumption uncertainty at the ZLB, our results reveal a negative significant coefficient of the dummy variable I_t that equals -0.79. However, a significant increase with respect to money uncertainty is seen throughout the period in which the nominal interest rate is at or near zero. These results indicate the Fed's promise to maintain the nominal rate consistently low for an extended period of time resulted in lower fluctuations in personal consumption. However, when the nominal interest rate is pushed to the zero, a higher volatility in real money stock is noted. In Figure 2.3, the conditional standard errors of money stock display notable spikes within the zero lower bound −especially in the Quantitative Easing periods. In targeting the nominal interest rate, The Fed can accommodate all shocks to money demand with equivalent shocks to money supply. Hence, when the Fed follows a nearly zero interest rate policy; consumption volatility decreases at the cost of a significantly increased volatility of money shock.

2.6 Conclusion

This paper studies the implications of the ZLB on uncertainty of consumption and money stock. We employ a dynamic conditional correlation type of multivariate GARCH model (DCC-GARCH). In this model, the nominal interest rate and dummy

variables are added to the variance equations. The model is implemented on monthly data within the U.S. that ranges from January 1980 to December 2014. Our empirical findings suggest that consumption uncertainty displays a notable decrease in the months following January 2009. Within the same period of time, our results indicate that money uncertainty increases. The primary focus of this study lies in assessing the extent at which a monetary policy regime within the ZLB may influence the uncertainty that surrounds personal consumption. In conclusion, this paper proposes that the Fed's attempt to keep the federal fund rate at a low target results in lower consumption volatility at the expense of higher volatility in money stock.

2.7 Tables and Figures

Table 2.1: Summary statistics (1980.01−2014.12)

Variable	Mean	Standard Deviation	Min	Max
c_t	1.71×10^{-11}	0.0081	−0.025742	0.026441
m_t	$-\ 5.78\times10^{-11}$	0.020455	−0.076967	0.070487
$\text{Fed}_t(\%)$	5.179071	4.070646	0.07	19.1
$\text{i}_t(\%)$	4.686667	3.571948	0.01	16.3

Fed_t is the federal fund rate and i_t is 3-Month Treasury Bill.

Table 2.2: Constant correlation test

Test	Stat	P-value
Tse (2000)		
LMC	75.5812	0.0000000
Engle and Sheppard (2001)		
5 lags	144.903	0.0000000
10 lags	148.392	0.0000000

Stat is the test statistic of the non-constant correlation.
P-value is calculated for the null hypothesis H0: $R_t = R$

Table 2.3: Dynamic conditional correlation multivariate GARCH including the First Lag of the Nominal Interest Rate.

	Variance equations (2.15)			
	Consumption variance, $h_{c,t}$		Money stock variance , $h_{m,t}$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
constant	−13.58521 ***	0.4236789	−11.54428***	0.5949923
$\varepsilon^2_{c,t-1}$	0.1650034 ***	0.0412326	———	———
$\varepsilon^2_{m,t-1}$	———	———	0.3132255***	0.0746904
$h_{c,t-1}$	0.7182717 ***	0.0683992	———	———
$h_{m,t-1}$	———	———	0.65544***	0.0791658
i_{t-1}	0.1132174 ***	0.035852	−0.2342142***	0.0706924

***significant at 1%; **significant at 5%; *significant at 10%. .

Table 2.4: Dynamic conditional correlation multivariate GARCH within the zero lower bound.

	Variance equations (2.16)			
	Consumption variance, $h_{c,t}$		Money stock variance , $h_{m,t}$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
constant	−13.17557 ***	0.3619935	−12.87203***	0.4051186
$\varepsilon^2_{c,t-1}$	0.1213627***	0.0332584	———	———
$\varepsilon^2_{m,t-1}$	———	———	0.2401187***	0.0626496
$h_{c,t-1}$	0.7450905 ***	0.0568198	———	———
$h_{m,t-1}$	———	———	0.6718309***	0.0657819
$I_{t(t\geq 01.2009)}$	−0.7942867 ***	0.3141533	1.486595 ***	0.3856828
$\mathcal{T}_t$	1.345503 ***	0.3333198	1.946544 ***	0.3891582

***significant at 1%; **significant at 5%; *significant at 10%. .

Figure 2.1: The Federal Fund Rate and 3-Month Treasury Bill before and after the ZLB.

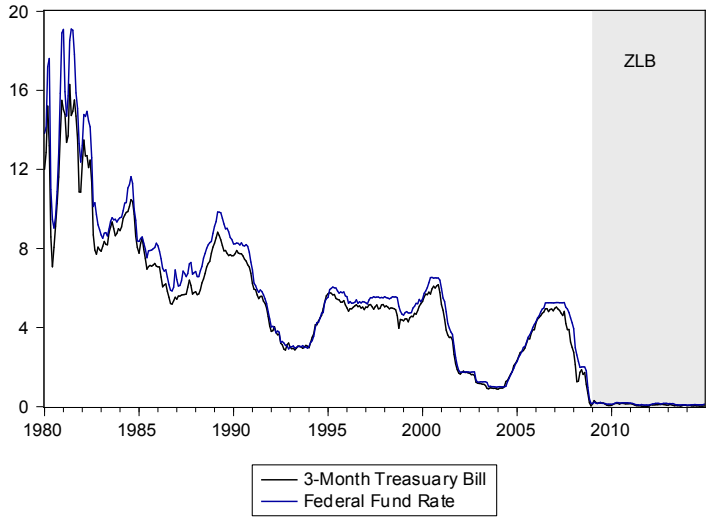


Figure 2.2: Consumption and real M1 from 1980.01 to 2014.12. The area shaded green represents NBER recessions.

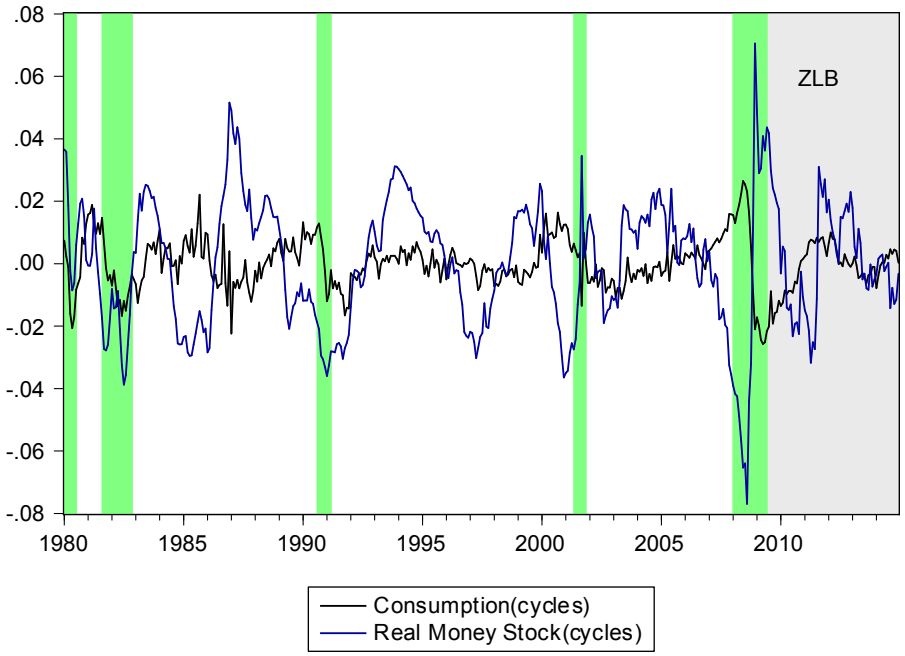
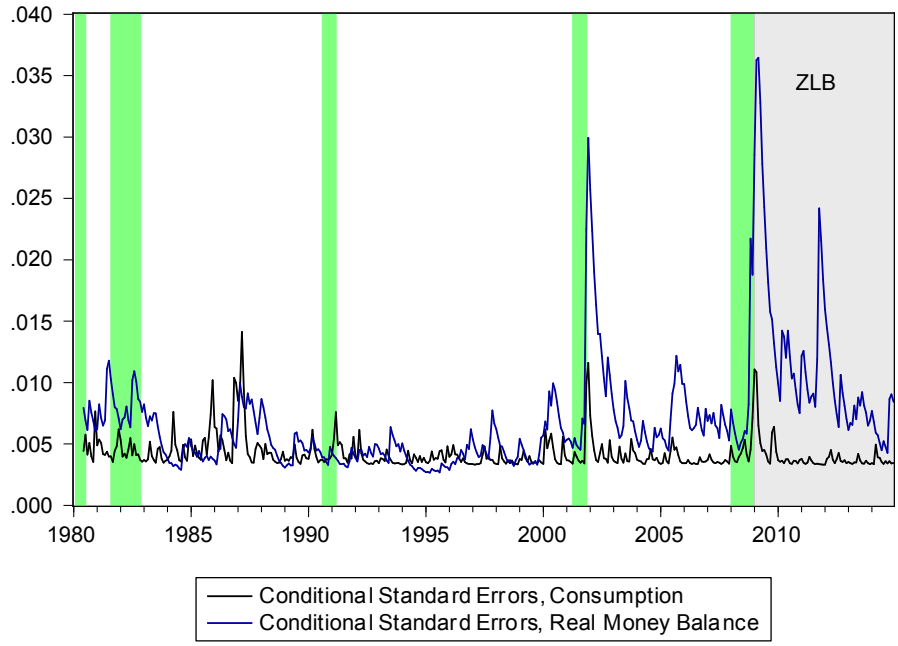


Figure 2.3: The conditional standard errors of consumption and real M1. The area shaded green represents NBER recessions.



Chapter 3

The Asymmetric Impact of Trade Openness on Output Volatility

3.1 Introduction

Output volatility affects the aggregate economic growth, the stock market, and economic forecasting. This paper examines the impact of trade openness on output volatility. In addition, the paper investigates whether this impact is asymmetric or not. Recent empirical papers on the impact of trade openness on output volatility argue that this relationship is theoretically ambiguous, but empirically testable.

The literature that is relevant to discussing the relationship between openness and business cycle volatility is rapidly growing. However, many studies failed to use the right methodology, which can lead to an incorrect outcome. Karras (2006) finds

that trade openness has a significant negative impact on output volatility. Karras calculates the average of trade openness and the standard deviation of output from 1951 to 1998, a time span that is too wide to yield accurate results. In contrast, this analysis uses a panel data for 33 countries. Time is divided into 5-year periods, as this was seen as a more appropriate measure for business cycle volatility.

Calderón and Schmidt-Hebbel (2008) employ an annual panel data for 82 countries from 1975 to 2005. In relying on annual data and by accounting for year- and country-fixed effects, the authors find that trade openness reduces the standard deviation of real GDP growth rate. However, unlike Calderón and Schmidt-Hebbel and other papers in the literature that use annual data on output; our research uses quarterly data on log of real GDP, as this allows for a more precise estimation for output variability.

Studies such as those conducted by Calderón and Schmidt-Hebbel (2008) and Bekaert *et al.*(2006) focus on the standard deviation of output or consumption over a 5-year period. Splitting the series into 5-year periods is better suited for this type of analysis for two reasons: First, it gives more distance for output variability. Second, it is more consistent with the NBER recessions.

Giovanni and Levchenko (2009) argue that sectors more open to international trade are more volatile. While Yanikkaya (2002) argues that trade barriers and regulations affect the openness-economic growth relationship. Examples of these barriers include: taxes, methods of payment, and tariffs.

The paper contributes to the existing literature the following: We use quarterly data on real GDP to account for the output volatility, in which more observations are included in each of the 5-year periods. In addition, this paper includes country- and time-fixed effect, and control variables such as size of the economy, financial openness, real exchange rate, inflation rate, and nominal short-term interest rate. Finally, and most importantly, this research shows how the country's level of development determines the degree of the impact of trade openness on output volatility. The remainder of this paper is organized as follows: Section 2 describes the data. Section 3 provides empirical models; and Section 4 presents the results and the conclusion of our research. Section 5 includes a list of tables and figures

3.2 Data

Our data are a panel for 33 countries from 1980 to 2009. Data on real GDP, real exchange rate, inflation rate, and nominal short-term interest rate is quarterly. While data on trade openness, financial openness, country size, and human development index are annual, the following variables are extracted from Smith and Gales (2011): real GDP, real exchange rate, inflation rate, and nominal short-term interest rate. Trade openness and country size variables are taken from Penn World Table 7.1, while financial openness is taken from Chinn-Ito Financial Openness Index (2011) and the human development index is drawn from the United Nations Development Programme.

Table 3.1 in the "Tables and Figures" section provides the list of countries used in the sample. And Table 3.2 provides the data source.

3.3 Empirical model

The output volatility is represented by the standard deviation of log(RGDP)[1], the 5-year standard deviation of output is defined as follows::

$$\sigma_{yit} = \sqrt{\frac{1}{20}\sum_{q=1}^{20}(y_{qit} - \bar{y}_{it})^2} \tag{3.1}$$

The variable σ_{yit} is the standard deviation of the log of real GDP for country i in period t, where i=1,2,3...33 and t=1,2,..6. Because there are 30 years, time is divided into six periods, with each being 5 years in length. We divide the sum of squared deviations by $\frac{1}{20}$ because we have 20 quarters in a period of 5 years. y_{qit} is the output for quarter q in country i within the period t. And $\bar{y}_{it}$ is the average of 5 years output for that particular country i.

The trade openness is the sum of exports, EX, and imports, IM, as a fraction of GDP:

$$OPEN_{it} = \frac{EX_{it} + IM_{it}}{GDP_{it}} \times 100 \tag{3.2}$$

[1] $Log(RGDP_{it}) = Log(\frac{GDP_{it}}{CPI_{it}})$, where CPI_{it} is the Consumer Price Index for country i in time t.

The country size is defined as the aggregate Gross Domestic Product of a country i at time t relative to the USA.[2]

$$Size_{it} = \frac{GDP_{i,t}}{GDP_{US,t}} \tag{3.3}$$

OLS fixed effects regression,

$$\sigma_{yit} = \mu_i + \tau_t + \beta_{it} OPEN_{it} + \Psi_{it} Z_{it} + \varepsilon_{it} \tag{3.4}$$

where σ_{yit} is the standard deviation of the log of real GDP for country i in period t, μ_i, and τ_t are country- and time-fixed effects, respectively, and OPEN_{it} is the log of openness as defined in (2)[3]. Z_{it} is a vector of control variables: country size, financial openness, real exchange rate, inflation rate, and nominal short-term interest rate. ε_{it} is an error term. OLS fixed effects difference in difference regression,

$$\sigma_{yit} = \mu_i + \tau_t + \beta_{it} OPEN_{it} + \gamma_{it} HDI_{it} + \chi_{it} (HDI \times OPEN)_{it} + \Psi_{it} Z_{it} + \varepsilon_{it} \tag{3.5}$$

Equation (3.5) has the same variables as Eq.(3.4), except we add a development variable and an interaction term. The variable HDI_{it} refers to the human development

[2]Total PPP Converted GDP, G-K method, at current prices (in milions $)

[3]Since t represents a period of 5 years and the openness is given by annual data, first we take the logs of openness, and then we calculate the average of logs over 5 years, that is the average of the logs, not the log of the averages

index, and the interaction term (HDI$\times$ OPEN)$_{it}$ counts for investigating if there is asymmetric impact of trade openness on output volatility[4].

3.4 Results and conclusion

Table 3.3 reports the results of the baseline regression. These results show a positive impact of log of trade openness on output volatility, with a coefficient of 0.029814 and significant at a 1% level. These results differ from Calderón and Schmidt-Hebbel (2008) and Karras (2006), where both studies find a negative significant impact of trade openness on output variability.

Our results are robust because of the inclusion of controls and country characteristics. In Karras's paper (2006), the results change dramatically when country size is added to the simple linear regression. This alters the sign of the openness coefficient from insignificant positive to significant negative.

Table 3.3 shows that the larger the size of the economy, the less the output volatility. The coefficient equals -0.03331 and significant at a 1% level. None of the other control variables are significant. Additionally, the adjusted R-squared is sufficiently large: 0.708. Taking into consideration, the country- and time-fixed effects -our main result as indicated in Table 3.3 shows that trade openness increases the output volatility.

Table 3.4 includes the human development index and a continuous interaction

[4]Note that the interaction term here is a continuous variable

term between this variable and the log of trade openness. The coefficient of the log of trade openness is positive and significant. The developed countries experience higher jumps and drops in output than developing countries, but this coefficient is insignificant. However, the coefficients of the inflation rate and the nominal short-term interest rate are both significant.

The coefficient of the interaction term between human development and trade openness is significant negative: -0.084158. This indicates that output volatility in more developed countries is less affected by trade openness than countries that are less developed. Table 3.4 demonstrates that the output volatility coming from trade openness is weaker in developed countries than that in developing countries. These results are reasonable. Because developed countries have more complicated economic structures and different output volatility sources, while developing countries depend more on international trade.

3.5 Tables and Figures

Table 3.1: Countries in The Sample and The Average Human Development Index HDI

Country	Average HDI*	Country	Average HDI
ARGENTINA	0.7221	MEXICO	0.6720
AUSTRALIA	0.8801	NETHERLANDS	0.8460
AUSTRIA	0.8043	NORWAY	0.8705
BELGIUM	0.8290	NEW ZEALAND	0.8474
BRAZIL	0.6416	PERU	0.6492
CANADA	0.8551	PHILIPPINES	0.6048
CHINA	0.5456	SOUTH AFRICA	0.6142
CHILE	0.7222	SAUDI ARABIA	0.6959
FINLAND	0.8157	SINGAPORE	0.8024
FRANCE	0.8066	SPAIN	0.7865
GERMANY	0.8188	SWEDEN	0.8406
INDIA	0.4581	SWITZERLAND	0.8528
INDONESIA	0.5671	THAILAND	0.6076
ITALY	0.7922	TURKEY	0.6081
JAPAN	0.8331	UNITED KINGDOM	0.8154
KOREA	0.7656	USA	0.8686
MALAYSIA	0.6770		

* Average HDI: is the simple average of Human Development Index over the years of 1980-2009.

Table 3.2: Data Sources, 1980-2009

Variable	Frequency	Source
Real GDP	Quarterly	Smith, L.V. and A. Galesi (2011)
Real Exchange Rate	Quarterly	Smith, L.V. and A. Galesi (2011)
Inflation Rate	Quarterly	Smith, L.V. and A. Galesi (2011)
Nominal Short-Term Interest Rate	Quarterly	Smith, L.V. and A. Galesi (2011)
Trade Openness	Annual	Penn World Table 7.1 (PWT 7.1)
Financial Openness	Annual	Chinn-Ito Financial Openness Index(2011)
Country Size	Annual	Penn World Table 7.1 (PWT 7.1)
Human Development Index	Annual	United Nations Development Programme Human Development Report, 2014

Table 3.3: OLS Fixed Effects Regression
Dependent Variable: Standard Deviation of the Log of Real GDP
Sample of 33 countries, 1980-2009 (5-year period observations)
Counting for country and time fixed effects

Variable	Coefficient
Log(trade openness)	**0.029814***** (0.010086)
Log(Country size)	**−0.03331***** (0.00959)
Financial openness	**0.001701** (0.00222)
Real exchange rate	**0.012857** (0.00955)
Inflation rate	**0.07084** (0.09607)
Nominal short-term interest rate	**−0.10171** (0.10797)
Number of observations	189
Adjusted R^2	0.708
F	11.85***

Notes: Robust standard errors in parentheses. ***significant at 1%; **significant at 5%; *significant at 10%.

Table 3.4: OLS Fixed Effects Difference in Difference
Dependent Variable: Standard Deviation of the Log of Real GDP
Sample of 33 countries, 1980-2009 (5-year period observations)
Counting for country and time fixed effects

Variable	Coefficient
Log(trade openness)	**0.08231*****
	(0.0183147)
Human Development Index	**0.05445**
	(0.14547)
Human Development Index × Log(trade openness)	**−0.084158*****
	(0.02784)
Log(Country size)	**−0.02354****
	(0.01095)
Financial openness	**0.00203**
	(0.00213)
Real exchange rate	**0.00592**
	(0.00934)
Inflation rate	**0.16938***
	(0.09470)
Nominal short-term interest rate	**−0.19557***
	(0.10547)
Number of observations	189
Adjusted R^2	0.7244
F	12.11***

Notes: Robust standard errors in parentheses. ***significant at 1%; **significant at 5%; *significant at 10%.

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