ASSET PRICES AND MACROECONOMIC POLICY

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ABSTRACT

ANTHONY M. DIERCKS: Asset Prices and Macroeconomic Policy.
(Under the direction of Patrick Conway and M. Max Croce)

My dissertation work focuses on the relationship between asset pricing and macroeconomic policy. Asset prices play a fundamental role in the daily lives of most people as they face important choices about saving in the form of cash, bank deposits, bonds, stocks, or even real estate. Asset prices are connected to macroeconomic policy through monetary and fiscal policy's impact on interest rates together with taxation and government spending. The three projects within my dissertation focus on the policy implications of macro models that are consistent with financial market data and the channels through which policy impacts asset prices. Many previous studies have sought to determine the optimal behavior of monetary policy while abstracting from asset pricing considerations, and their predominant conclusion is that it is optimal for monetary policy to concentrate mainly on stabilizing inflation. In the first chapter, my contribution is to show that monetary policy puts more emphasis on stabilizing output compared to previous studies when the model replicates key features of financial markets. In the second chapter, I investigate the channels through which fiscal policy impacts financial markets using a news decomposition. I find that the effects are highly dependent upon the stance of monetary policy, and this is rationalized with a standard DSGE model. In the third chapter, I investigate the effects of monetary policy responding to government debt, and find there exists a significant tradeoff between reducing inflation risk and increasing taxation risk.

and only, Margot Bellmer, who has sacrificed and been nothing but supportive and encouraging of me in reaching my goals.

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CHAPTER 1

INTRODUCTION

My dissertation work focuses on the relationship between asset pricing and macroeconomic policy. Asset prices play a fundamental role in the daily lives of most people as they face important choices about saving in the form of cash, bank deposits, bonds, stocks, or even real estate. Asset prices are connected to macroeconomic policy through monetary and fiscal policy's impact on interest rates together with taxation and government spending. The three projects within my dissertation focus on the policy implications of macro models that are consistent with financial market data and the channels through which policy impacts asset prices.

In my first chapter, "Asset Pricing and the Welfare Effects of Monetary Policy," I construct a novel asset pricing-oriented New Keynesian model to evaluate the welfare effects of monetary policy. To match asset pricing facts, I incorporate recursive preferences and long-run risk in productivity. When combined, I find these characteristics lead to policy recommendations that place significantly greater weight on output and less weight on inflation compared to the existing literature. Greater weight is placed on stabilizing output because the welfare costs of recessions are much higher upon matching the equity premium. At the same time, a low risk-free rate suggests that agents are very patient and forward looking, implying that monetary policy can more effectively and persistently reduce the average markup with higher inflation volatility. The difference in welfare between the implementation of complete inflation stabilization (as is often suggested in prior literature) versus the optimal policy in the asset pricing framework is over \$3,000 for each individual.

In work with William Waller, "Taxes, Spending, and Market Returns," we study fiscal policy's effects on financial markets by decomposing changes in current equity and bond returns into news

about cash flows and news about discount rates. Our main empirical findings suggest that fiscal policy's effects are highly dependent upon the stance of monetary policy. For the Post-1980 era, tax increases lead to lower cash flow news and lower discount rates. However, the discount rate news dominates so that higher taxes are associated with higher equity returns. In contrast, for the Pre-1980 era, we find the effects on cash flows and discount rates flip signs so that higher taxes are associated with lower equity returns. The change in the relationship between taxes and equity returns can be fully rationalized within the context of a standard New Keynesian DSGE model by slightly altering just one parameter, the weight monetary policy places on output in the interest rate reaction function.

In the third chapter, "Inflating Away Debt: Trading Off Inflation Risk and Taxation Risk," I evaluate the effects of monetary policy reacting to the debt-output ratio in a simple interest rate rule using a model that prices risk consistent with the data. In contrast to my job market paper, this paper focuses on the interaction of fiscal and monetary policy when taxes are distortionary. In this setting, a Taylor rule in which the inflation target increases with the debt-output ratio (thus inflating away debt) can improve welfare, but only at debt levels above 200%. At such high debt levels, taxes are forced to adjust more to deal with greater interest payments, causing higher tax and equity risk. By allowing for greater inflation in response to higher debt, monetary policy can bring greater certainty to the tax rate and reduce consumption risk, which improves welfare.

CHAPTER 2

ASSET PRICING AND THE WELFARE EFFECTS OF MONETARY POLICY

2.1   Introduction

As we continue to recover from the Great Recession, monetary policy makers are confronted with the decision of when to start raising interest rates and by how much. Underlying these choices is a concern about the trade-off between inflation and output. On one side there are "inflation hawks" who suggest that the primary goal of monetary policy should be price stability, with overwhelming concern for the stabilization of inflation—potentially at the expense of output. This course of action has historically been followed by the European Central Bank. On the other side, "inflation doves" suggest that monetary policy should place a greater emphasis on stabilizing output to decrease the severity of recessions, potentially at the expense of increased inflation. This more closely aligns with the approach of the Federal Reserve, which has a dual mandate to promote both maximum employment and stable prices. For policy makers, determining the proper emphasis to place on inflation versus output is a high-stakes decision that impacts everyone in the economy.

Existing studies of monetary policy predominantly find that stabilizing inflation is strongly preferred to stabilizing output.[1] However, these studies suffer from the risk-free rate puzzle (Weil 1989) and the equity premium puzzle (Mehra and Prescott 1985), and thus they ignore key characteristics of financial data. The present study addresses this issue by incorporating financial data while evaluating the welfare implications of simple monetary policy rules that are functions of inflation and output. Specifically, I construct a model that is consistent with the historical risk-free rate, the historical equity premium, and the presence of long-run risk in productivity. Each of these

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[1]See Canzoneri, Cumby, and Diba (2011) and Woodford (2010) for extensive overviews.

features is important in capturing key aspects of the macroeconomy. The equity premium captures the welfare costs of recessions; the risk-free rate dictates the extent to which households and firms are patient and forward looking; and long-run productivity risk is crucial because of its major impact on the pricing decisions of forward-looking firms. Taken together, these three characteristics lead to policy recommendations that place significantly greater weight on output and less weight on inflation than is the case in the existing literature.

To explain this result, I investigate the trade-offs among three sources of welfare losses in the New Keynesian model: inflation volatility, output volatility, and the average markup. Output volatility and the average markup have greater impact within my model relative to previous studies because households and firms are assumed to have recursive preferences. Unlike constant relative risk aversion (CRRA) preferences, recursive preferences break the inverse relationship between risk aversion and the intertemporal elasticity of substitution (IES). This allows my model to replicate both the high equity premium and low risk-free rate observed in financial data. High levels of risk aversion combined with a high IES causes households to dislike recessions strongly while being much more patient and forward looking.

The combination of greater patience with long-run productivity shocks dramatically alters the influence of monetary policy on firms' price setting and the average markup. The reduction in the average markup, a key determinant of welfare, provides substantial welfare benefits. To understand fully the mechanism that drives the importance of the markup, it is first necessary to recognize that in the context of my fully specified nonlinear model, risk-adjusted measures are what matter for pricing and consumer decisions. The likelihood of positive shocks is down-weighted, while negative shocks receive greater weight; this creates an asymmetry that is present in any standard macro model that does not linearize first-order conditions. This second-order-based asymmetry is crucial for risk characterization, the determination of patience, and ultimately the determination of optimal price setting.

This asymmetry also generates important implications for monetary policy when bad news for

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long-run growth is realized. Specifically, negative long-run news shocks to productivity lead patient (i.e., very forward-looking) firms to choose substantially higher prices, which pushes inflation persistently higher. Higher inflation in turn mechanically lowers relative prices set by firms in previous periods and erodes the real value of the average markup. The persistent reduction of the average markup works like a hedge when the household receives negative long-run news shocks. By allowing inflation to rise, monetary policy provides good long-run news thanks to the reduction in the average markup.

Across a wide range of values for the coefficient on inflation in the monetary policy rule, my model yields an interior solution of 3.0, where the benefits and costs to stabilizing inflation perfectly balance each other. With higher values on the coefficient of inflation in the monetary policy rule, inflation does not rise as much in response to a negative shock, which implies a smaller reduction in the markup. As a result of this smaller reduction, the steady-state markup rises with the inflation coefficient, placing a greater implicit tax on labor and capital as monetary policy increasingly stabilizes inflation. At values greater than 3.0 for the inflation coefficient, I find that the costs of the higher markup outweigh the benefits associated with lower inflation volatility.

This result stands in contrast to the conclusions of a number of previous studies, which suggest that the reduction of inflation volatility should be the primary focus of monetary policy. I replicate this finding in my model with CRRA utility, in which the optimal weight placed on fluctuations of inflation in the monetary policy rule is set to infinity. Results show that the markup channel is insignificant in the standard (second-order CRRA) setting because its movements are not as asymmetric and persistent as in the recursive preferences setting. In the CRRA utility setting, both the representative agent and firms are relatively impatient, and monetary policy is unable to influence persistently the price setting and average markup. Furthermore, not as much weight is placed on negative shocks in the stochastic discount factor, which reduces the asymmetry compared to the setting with recursive preferences.

Another justification for the low value of the inflation coefficient is the trade-off between real and nominal uncertainty. In my model, monetary policy can lower nominal uncertainty by placing

a greater weight on inflation fluctuations, but this comes at the expense of the greater volatility of real variables such as output. This makes intuitive sense, because greater stabilization of inflation is achieved only through greater changes in real interest rates. The higher IES by definition makes households more willing to substitute consumption intertemporally due to changes in the real interest rates, which implies that monetary policy is more effective in altering real quantities. This channel is also present in a standard model but is much smaller (due to the restricted, lower IES) and is dominated in terms of welfare by the price dispersion channel. Holding all else constant, higher output and consumption volatility reduce welfare. Thus, this channel also contributes to the finding of an interior solution of 3.0 for the coefficient on inflation.

In addition to the lower value for the coefficient on inflation, my proposed model also yields a high value on the coefficient for output. Unlike most previous studies, I focus on output growth rather than the typical output gap (the deviation between the actual level and the flexible-price output level). I include output growth because it is easier to observe in real time and does not require policy makers to make decisions based on the unobservable flexible-price level of output. As pointed out in Sims (2013), focusing on output growth allows monetary policy to respond to recessions while also anchoring inflation expectations. These expectations are better anchored because monetary policy is implicitly promising to raise rates as the economy recovers and growth rates rise. Anchoring inflation expectations is imperative because current inflation depends on expectations of future inflation, and in the proposed model, firms are very patient and forward looking.

Placing a higher weight on the output growth benefits welfare because it reduces fluctuations in consumption. Moreover, it also pushes up inflation during negative long-run productivity shocks, which effectively lowers the markup. Matching the high equity premium in the data implies that households strongly dislike the recessions associated with output fluctuations, so that the costs and benefits equal at a coefficient value of 1.5 for output growth in the interest rate rule. This weight is three times greater than the optimal weight on the output growth of Sims (2013), who does not include long-run productivity shocks and instead uses habits in a comparable framework. Results

from my model with CRRA utility show that zero weight should be placed on the output growth; this is because the welfare costs of recessions are significantly lower and the costs coming from inflation volatility dominate.

2.1.1 Related Literature

This paper contributes to the sizable literature on monetary policy as well as a growing body of work on production-based asset pricing. A benchmark result in the monetary policy literature is that attention should be completely focused on inflation stabilization (Goodfriend and King 1997; Rotemberg and Woodford 1997; Woodford 2001; King and Wolman 1999; Benigno and Woodford 2005; Khan, King, and Wolman 2003; Siu 2004a; Schmitt-Grohé and Uribe 2007; Kollmann 2008).[2] However, my asset pricing–driven approach suggests that strict inflation stabilization may be suboptimal. In contrast to Erceg, Henderson, and Levin (2000); Giannoni and Woodford (2004); and Schmitt-Grohé and Uribe (2005), my results do not hinge on wage stickiness.

To isolate the welfare effects of asset pricing data better, I do not include sticky wages or pure cost-push shocks. Rather, I simply use a second-order approximation around a distorted steady state and assume Epstein and Zin (1989) preferences for households. I resolve both the equity premium puzzle (Mehra and Prescott 1985) and the risk-free rate puzzle (Weil 1989) by introducing productivity long-run risk, in the spirit of Croce (2014a) and more broadly of Bansal and Yaron (2004). This setting has not been explored to date in the monetary policy literature.

Long-run risk is a key driver of my qualitative results. Croce (2014a), Beaudry and Portier (2004), Schmitt-Grohé and Uribe (2012), Kurmann and Otrok (2010), and Barsky and Sims (2011) have all found evidence of long-run news shocks to productivity, which explain a large fraction of business cycle fluctuations. Endogenous growth models have also been used to generate long-run consumption risk, as in Kung and Schmid (2011). The connection between endogenous growth, monetary policy and the term structure of interest rates has also been explored by Kung (2014).

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[2]For instance, the Ramsey solution for Schmitt-Grohé and Uribe (2007) yields an optimal inflation volatility of 0.01%. Moreover, in a similar study Kollmann (2008) finds the optimal value on the inflation coefficient in the interest rate rule is 8,660.

None of these studies has explored the welfare implications of long-run news for the trade-off between inflation and output stabilization.

To be clear, my study is not the first to incorporate recursive preferences when evaluating the welfare effects of monetary policy. Levin, David López-Salido, Nelson, and Yun (2008) use a very stylized, one-shock New Keynesian model with no capital in order to study the linearized Ramsey planner problem. They find that the planner is more risk averse and permits fewer fluctuations in output with more volatile inflation. In contrast to my study, there is no long-run risk and no quantification of optimal inflation volatility or the optimal coefficients on an interest rate rule.

An (2010) shows how to use perturbation methods to solve models with recursive preferences and simple monetary policy rules. Long-run risk is not incorporated, and his optimal policy coefficients and inflation volatility are low and almost identical to those in the setting of Schmitt-Grohé and Uribe (2007) with CRRA preferences.

Darracq Paries and Loublier (2010) come closest to my study by moving beyond a highly stylized setting to look at the effects of recursive preferences. Their study differs from mine in a number of ways: (1) habits are incorporated, (2) the IES is less than one, (3) wages are rigid, and (4) there is no growth and no long-run risk. They find that the optimal inflation volatility is less than 0.05 percent after including Epstein-Zin preferences. Finally, Benigno and Paciello (2014) incorporate doubts and ambiguity aversion and find that as doubts rise, monetary policy finds it optimal to further deviate from strict inflation targeting. However, while they target a high equity premium, they do not match the low risk-free rate. None of the studies that incorporate recursive preference when evaluating the effects of monetary policy includes long-run risk shocks or attempts to match both the equity premium and the risk-free rate.

Certain studies, such as Gavin, Keen, and Pakko (2009), do look at the effects of monetary policy with permanent changes in the growth rate of productivity. However, they use log utility and do not match financial data. In their model, the central bank's optimal policy is to fully stabilize the inflation rate at its steady state in order to completely eliminate the sticky price distortion.

The rest of the paper is organized as follows. Section 2.2 discusses the model and empirical

motivation. Section 2.3 shows the optimal interest rate rules and explains the welfare channels driving the results. Section 2.4 explores the underlying dynamics of the welfare channels and Section 2.5 concludes.

2.2 Model and Empirical Motivation

In the discussion below I focus on two key differences of my model with respect to existing monetary policy analysis: the preferences and the productivity process.[3] The economy consists of a continuum of identical households, a continuum of intermediate-goods firms, and a government that conducts monetary and fiscal policy. The structure of the model is a standard neoclassical growth model augmented with real and nominal frictions. The nominal friction is sticky prices. The real friction is monopolistic competition, which results in a markup of price over marginal costs. Monetary policy assumes full commitment to an interest rate rule that is a function of inflation, output growth, and the previous period's interest rate. Fiscal policy raises lump-sum taxes to pay for exogenous expenditures.

Preferences. The households have Epstein-Zin preferences defined over consumption goods, c_t, and leisure, $1 - h_t$. These preferences exhibit a CES aggregate of current and future utility certainty equivalent weighted by (1-β) and β, respectively.

$$v_t = \left\{ (1 - \beta)(c_t^{\iota}(1 - h_t)^{1-\iota})^{1 - \frac{1}{\psi}} + \beta(E_t[v_{t+1}^{1-\gamma}])^{\frac{1 - \frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1 - \frac{1}{\psi}}}$$

s.t.

$$b_t + c_t + i_t + \tau_t = R_{t-1}\frac{b_{t-1}}{\pi_t} + w_t h_t + u_t k_t + \check{\phi}_t$$

The real value of debt is b_t; c_t is consumption; i_t is investment; R_{t-1} is the risk-free rate; π_t is the inflation rate $\frac{P_t}{P_{t-1}}$; τ_t is the lump-sum tax; w_t is the real wage; h_t is labor hours; u_t is the rental rate of capital; k_t is capital; and $\check{\phi}_t$ is profits.

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[3]The full model is described in appendix A.1.

Unlike CRRA preferences, Epstein-Zin preferences allow for the disentanglement of γ, the coefficient of relative risk aversion, and ψ, the elasticity of intertemporal substitution. When $\frac{1}{\psi} = \gamma$, the utility collapses to CRRA preferences, with additively separable expected utility both in time and state. When $\gamma > \frac{1}{\psi}$, the agent prefers early resolution of uncertainty, so the agent dislikes shocks to long-run expected growth rates.

Stochastic Discount Factor. The stochastic discount factor (SDF) represents the intertemporal marginal rate of substitution for consumption. It is the major focal point in the forward-looking New Keynesian model, as it translates the value of future income/profits to the present. Given the fact that monetary policy relies on long-term expectations to influence the economy, the functional form is very relevant for all of the household's and firm's intertemporal maximization decisions:

$$M_{t,t+1} = \beta \left(\frac{c_{t+1}}{c_t} \right)^{\iota(1-\frac{1}{\psi})-1} \left(\frac{1-h_{t+1}}{1-h_t} \right)^{(1-\iota)(1-\frac{1}{\psi})} \frac{P_t}{P_{t+1}} \left[\frac{v_{t+1}}{E_t[v_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right]^{\frac{1}{\psi}-\gamma} \tag{2.1}$$

The last part of equation 2.1 is unique to recursive preferences. This factor captures news regarding the continuation value of the representative agent. Future utility, as represented by the continuation value, is very sensitive to long-run news and this allows for greater variation of the stochastic discount factor without the need for excessive levels of risk aversion. Compared to CRRA preferences, the last factor implies a significantly higher weight on negative outcomes as marginal utility rises. This results in endogenous asymmetric responses to shocks because agents are more concerned with negative long-run news.

Productivity. The law of motion of the productivity process captures both short-run and long-run productivity risks:

$$\log \frac{A_{t+1}}{A_t} \equiv \Delta a_{t+1} = \mu + x_t + \sigma_a \varepsilon_{a,t+1},$$

$$x_{t+1} = \rho x_t + \sigma_x \varepsilon_{x,t+1},$$

$$\begin{bmatrix} \varepsilon_{a,t+1} \\ \varepsilon_{x,t+1} \end{bmatrix} \sim i.i.d.N \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right), \quad t = 0, 1, 2, \cdots.$$

According to the above specification, short-run productivity shocks, $\varepsilon_{a,t+1}$, affect contemporaneous output directly, but they have no effect on future productivity growth. Shocks to long-run productivity, represented by $\varepsilon_{x,t+1}$, carry news about future productivity growth rates but do not affect current output.

2.2.1 Welfare Analysis: Three Major Channels

In this section I describe the three key sources of welfare losses in the New Keynesian model: inflation volatility, the average markup, and output volatility. In short, inflation volatility causes relative price dispersion and inefficient production; the average markup acts as an implicit tax on factors of production; and output volatility reduces concave utility. The average markup and output volatility will have a greater impact within my model relative to previous studies. The reasons for this will be discussed in the following section.

2.2.1.1 Inflation Volatility: Price Dispersion

From a welfare perspective, price dispersion is a crucial characteristic of the Calvo-based time-dependent sticky price models. Each period, a fraction $\alpha \in [0, 1]$ of randomly picked firms is not allowed to optimally set the nominal price of the good they produce. The remaining $1 - \alpha$ firms choose $P_{i,t}$ to maximize the expected present discounted value of profits.

Price dispersion arises when a subset of firms finds it optimal to choose a different price relative to the remaining firms who are unable to update. Differences in pricing across firms are important because it is assumed that monopolistically competitive firms choose a price and agree to supply the quantity demanded. The quantity demanded for each firm $(Y_{i,t})$ follows a downward-sloping demand schedule based on the firm's price $(P_{i,t})$ and the elasticity of substitution across goods, η:

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\eta} Y_t$$

Given that supply must equal demand at the firm level,

$$K_{i,t}^{\theta}(A_t N_{i,t})^{1-\theta} = \left(\frac{P_{i,t}}{P_t}\right)^{-\eta} Y_t$$

One can then aggregate across all firms to arrive at

$$K_t^\theta (A_t N_t)^{1-\theta} = \int_0^1 \left(\frac{P_{i,t}}{P_t} \right)^{-\eta} di \cdot Y_t.$$

Defining the resource cost of price dispersion as $s_t = \int_0^1 \left(\frac{P_{i,t}}{P_t} \right)^{-\eta} di$, one can see that its effect is similar to a negative aggregate productivity shock, as it increases the amount of labor and capital required to produce a given level of output.

$$\frac{1}{s_t} K_t^\theta (A_t N_t)^{1-\theta} = Y_t$$

This happens because firms with relatively low prices produce an inefficiently high quantity to meet relatively high demand, while the opposite occurs for the high-price firms. As shown by Schmitt-Grohé and Uribe (2007), $s_t \geq 1$, and s_t is equal to one when there is no price dispersion. Furthermore, price dispersion can be recursively decomposed into the following equation:

$$s_t = (1 - \alpha)(p_t^*)^{-\eta} + \alpha \pi_t^\eta s_{t-1} \tag{2.2}$$

where $p_t^* = \frac{P_t^*}{P_t}$ represents the relative price of the optimizing firm at time t. Price dispersion is an increasing function of α, the probability that firms are unable to update their prices; η, the elasticity of substitution across goods; and π, the steady-state rate of inflation.[4]

The main driver of price dispersion within the model is inflation volatility. Given the elasticity of substitution ($\eta \geq 1$), more volatile inflation will lead to higher price dispersion on average due to the Jensens Inequality (π_t^η) in equation 2.2. This effect is absent in a first-order approximation.

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[4]If prices were flexible ($\alpha = 0$), all firms would be able re-optimize every period, and there would be no price dispersion ($s = 1$). A higher elasticity of substitution across intermediate goods moves the economy closer to perfect competition (where $\eta = \infty$). This results in greater costs of price dispersion because households are more willing to switch from the high-price good to the low-price good, causing aggregate production to become more inefficient because the low-price firm must meet the higher demand. Lastly, price dispersion increases with steady-state inflation because firms that are resetting their prices optimally choose a higher price than the existing price level.

Price Dispersion and the Stochastic Discount Factor. The stochastic discount factor affects price dispersion through the relative price of the optimizing firm. The forward-looking firm chooses a price to maximize expected profits while knowing that its price may become stuck for multiple periods. The price is a markup over a ratio of the present discounted value of future marginal costs and the present discounted value of future marginal revenues:

$$p_t^* = \frac{\eta}{\eta - 1} \frac{E_t \sum_{j=0}^{\infty} \alpha^j M_{t,t+j} \pi_{t,t+j}^{\eta} y_{t+j} mc_{t+j}}{E_t \sum_{j=0}^{\infty} \alpha^j M_{t,t+j} \pi_{t,t+j}^{\eta-1} y_{t+j}} \tag{2.3}$$

where $\frac{\eta}{\eta-1}$ is the nonstochastic steady-state markup, α is the probability of not being able to update next quarter, $M_{t,t+j}$ is the nominal stochastic discount factor between t and $t+j$, and mc_{t+j} is the marginal costs.

The stochastic discount factor is an important component of equation 2.3, the pricing equilibrium condition. The use of financial data to discipline the dynamics of the pricing equilibrium condition can have a significant impact on the predictions of the model. Specifically, matching the low risk-free rate in the data makes the firms more patient and forward looking, placing more weight on future economic conditions as compared to the present. This is especially important in a world with highly persistent shocks, such as the long-run risk shocks to productivity. Although these shocks are quantitatively small, their persistence combined with the inability of firms to update each period tends to magnify firms' pricing decisions. Firms also use expected inflation rates to discount future marginal costs and marginal revenues, because inflation erodes the markup over time. Higher expected inflation places greater weight on future marginal costs, which again is important in a setting with small but highly persistent productivity shocks. The greater weight on future marginal costs (versus future marginal revenues) can be seen by the different exponents on expected inflation (η vs. $\eta - 1$) in the numerator and denominator.

2.2.1.2 The Markup: Implicit Tax

Monopolistic competition allows firms to charge a price that is higher than their marginal costs. The difference between the price and the marginal costs is known as the average markup. From

a welfare perspective, the average markup is very important because it acts as a wedge between factor prices and marginal products, which causes inefficiently low levels of labor, capital, and output. Hence, the average markup is akin to an implicit tax on capital and labor.

The implicit tax can be seen in the firm's demand for labor and capital:

$$MPL_t = \mu_t w_t \qquad\qquad\qquad MPK_t = \mu_t u_t$$

where μ_t is the markup. Higher markups imply lower real wages and rental rates of capital, and this affects both labor and capital supply. For example, combining the labor supply equation with labor demand yields

$$\frac{1 - \iota}{\iota} \frac{c_t}{1 - h_t} = w_t = \frac{MPL_t}{\mu_t}$$

where ι is the share of consumption in the consumption-leisure bundle. This shows that a higher markup reduces the amount of labor supplied. Moreover, given that the slope of the labor supply is both positive and increasing, increases in the markup result in greater and greater decreases in the quantity of labor supplied. This fact is important in explaining the reasons that the costs of higher markups dominate the benefits of reduced price dispersion as monetary policy increasingly stabilizes inflation.

Markup decomposition.   As outlined in King and Wolman (1996), the average markup of price over marginal cost can be decomposed into two components:

$$\mu_t = \left(\frac{P_t}{P_t^*} \right) \left(\frac{P_t^*}{MC_t} \right)$$

where $\left(\frac{P_t}{P_t^*} \right)$ is defined as the price adjustment gap and $\left(\frac{P_t^*}{MC_t} \right)$ is defined as the marginal markup. The price adjustment gap is just the inverse of the relative price of the optimizing firm at time t and the marginal markup is the ratio of price to marginal cost for firms allowed to adjust their price in period t.

If inflation increases, it must be that P_t^* is greater than P_t, and the price adjustment gap falls.

The price adjustment gap captures the notion that higher inflation automatically decreases relative prices set by firms in previous periods and decreases the real value of the average markup. King and Wolman (1996) find that if the average markup only consisted of the price adjustment gap, an increase in inflation from 5 to 10 percent would raise output permanently by 7 percent.

Marginal markup. The marginal markup captures the markup that re-optimizing firms are able to charge. This can be shown to depend positively on expected future inflation as firms choose a higher price when they are allowed to update their prices. Firms will choose a higher price because they are concerned that they will get "stuck" (i.e., be unable to re-optimize) and that inflation will erode their relative price. Erosion of a firm's relative price causes households to substitute toward their good as it becomes relatively less expensive, and this can be problematic as the firm is required to meet demand by securing more labor at higher costs. Inflation will also erode the real value of any markup established at time t, so that per-unit profits will decline for as long as the firm is stuck.

Ascari and Sbordone (2013) show that as trend inflation increases, the increase in the marginal markup dominates so that the overall average markup also rises. As the average markup rises, output declines along with welfare. This raises the question of which channel dominates in a setting with zero trend inflation or a zero inflation target. In a comparison across different policy rules, I find that the price adjustment gap channel dominates the marginal markup for negative productivity shocks, so that the average markup falls as inflation volatility increases. This is not surprising because under the benchmark calibration, most firms are unable to update their prices each period.[5]

The Markup and the Stochastic Discount Factor. The stochastic discount factor significantly impacts both the price adjustment gap and the marginal markup. Matching the low risk-free rate in the data makes the firms more patient and forward looking, raising concerns about the erosion

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[5]Under the benchmark calibration, 75% of the firms are unable to update in any given period, which is equivalent to firms getting stuck on average for 12 months. This duration is in the middle of empirical estimates and will be further discussed in the calibration section.

of future markups. This suggests that more patient firms will choose higher marginal markups in response to persistently higher expected inflation. At the same time, the price adjustment gap will also decline as firms choose prices further away from the existing price level. Results show that the price adjustment gap dominates in the benchmark model.[6]

2.2.1.3   The Output Gap: Consumption-Leisure Volatility

The output gap is defined as the deviation between the actual level of output and its natural level (the level of output in the absence of nominal rigidities). In the typical New Keynesian setup, a second-order approximation to household welfare gives rise to a loss function in the variances of the output gap and inflation. The loss function is then used to evaluate various monetary policy rules. However, the reason the output gap enters the loss function is due to the simplifying assumption that consumption is equal to output.

In my model, output of final goods and services goes toward not only consumption but also investment and government expenditures. In addition, agents care not about consumption but rather a consumption-leisure bundle. Therefore, I focus on the bundle rather than output when evaluating the effects of policy on welfare. With regard to the welfare costs of recessions, the magnitude is much greater in the asset pricing–oriented New Keynesian model, as indicated by the higher equity premium. The higher welfare costs suggest that greater weight should be placed on stabilizing output and the consumption-leisure bundle, in contrast to what is the case in existing studies that do not match the equity premium.[7]

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[6]Although it may appear that P_t^* cancels out between the two channels, note that the average markup can also be defined as $\mu_t = mc_t^{-1} \int_0^1 \frac{P_{i,t}}{P_t} di$. Letting $x_t = \int_0^1 \frac{P_{i,t}}{P_t} di$, this can be stated recursively as shown in Schmitt-Grohé and Uribe (2007)

$$x_t = (1 -)p_t^* + \frac{\alpha}{\pi}x_{t-1}$$

Therefore, P_t^* is still implicitly on the right-hand side of the equation that defines the average markup.

[7]The procedure for computing welfare is based on An (2010). Welfare costs in consumption equivalent units is defined as $\chi_c = 1 - (\frac{v_{ss}^i}{v_{ss}^j})^\iota$ where ι is the share of consumption in the consumption-leisure bundle and v_{ss}^k represents the lifetime welfare based on policy $k = i, j$.

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2.2.2 Empirical Motivation for Welfare Channels

The existing literature on optimal monetary policy finds that movement toward a hawk policy has no effect on the steady-state markup. However, I show below that the theoretical prediction of a nil effect is not supported by the data. In other words, CRRA preferences are not only inconsistent with asset pricing facts but also with the empirical evidence on the average markup when monetary policy increasingly stabilizes inflation. In addition, CRRA models do not predict a meaningful trade-off between reducing nominal uncertainty at the expense of higher real uncertainty. This lack of a trade-off is also inconsistent with empirical evidence discussed in more detail below.

Compared to empirical estimates of the Taylor rule, the optimal coefficients on inflation in the interest rate rule as determined by the existing literature are often orders of magnitude higher. This is because the CRRA models are not fully taking into account the explicit costs of the higher markup and greater consumption volatility implied by the data, so the benefits of reducing inflation volatility dominate all other channels. In contrast, my novel asset pricing-oriented New Keynesian model is consistent with the empirical evidence on the average markup and the real-nominal trade-off. As this model endogenously captures these channels as reflected in the data, the optimal policy coefficients are much closer to empirical estimates for the interest rate rule.

In the sections that follow, I provide a discussion along with empirical evidence on the markup and the trade-off involved in reducing nominal volatility at the expense of increased consumption volatility. I then estimate interest rate rules over the pre-Volcker and post-Volcker periods to connect the observed behavior of the Federal Reserve with the markup channel and real-nominal trade-off.

The Markup. The empirical evidence of the association of a higher markup with greater inflation stabilization was first found by Benabou (1992). Using US data on the retail trade sector, he finds that inflation has significantly negative effects on the markup. Other studies have focused on the inverse of the labor share, as this can be shown to be theoretically proportional to the markup if the production function is Cobb-Douglas. Nekarda and Ramey (2013) show that an upward trend of the markup began in the early 1980s. The rise in the markup coincides with the more aggressive
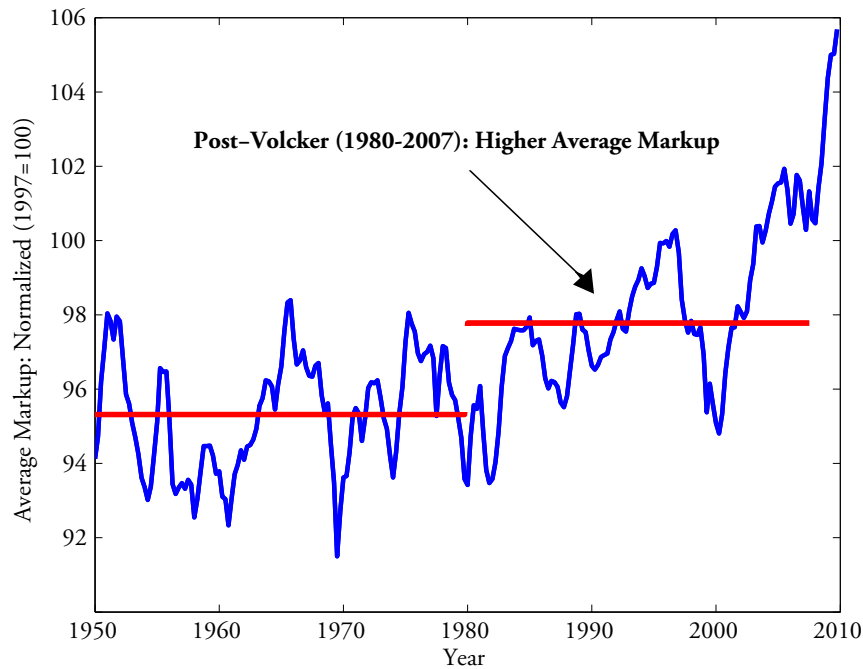
Figure 2.1: Historical Average Markup: Higher Markup Since 1980

The data depicted in this figure are based on the inverse of the labor share of income, as computed by the Bureau of Labor Statistics. The inverse of the labor share of income can be shown to be theoretically equal to the average markup when the production function is Cobb-Douglas. Splitting the time series into 1950–1980 and 1980–2007, the solid red line reflects the increase in the mean of the markup for the post-Volcker period (1980-2007), a period in which inflation was stabilized to a much greater extent. This figure provides empirical evidence for the theoretical result that increasingly stabilizing inflation is associated with a higher markup, which is relevant for my welfare analysis.

role of monetary policy in stabilizing inflation. This can be seen in figure 2.1, which plots data on the average markup according to the Bureau of Labor Statistics records dating back to 1950. During the post-Volcker period (1980–2007), the mean of the markup increased as inflation was stabilized to a greater extent. Other studies such as Alcala and Sancho (2000) and Raurich, Sala, and Sorolla (2012) have shown using various measures that the markup has risen since 1980.[8]

The rise in the markup due to greater inflation stabilization is consistent with the theoretical dynamics of my asset pricing-oriented New Keynesian model. Specifically, figure 2.1 shows that

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[8]The mechanism for the relationship between inflation and labor share is simple. As pointed out by Alcala and Sancho (2000), accelerated inflation is correlated with higher employment, higher employment leads to greater bargaining power, and greater bargaining power is correlated with lower markups. In my New Keynesian model inflation is largely due to output being pushed above the natural level, which reduces the real average markup because labor costs rise but most firms are unable to update their prices.

the mean of the markup rises between 2.5–3% when moving from pre-Volcker to post-Volcker. Similarly, my general equilibrium model predicts that the average markup will also rise 3%, from 12% to 15%, as monetary policy increasingly stabilizes inflation.[9] Therefore, the theoretical effect of monetary policy on the markup lines up with the empirical evidence. Moreover, the volatility of the markup is 3% under the optimal rule within my model, while in the data, the markup volatility is historically between 5% and 6%. This suggests that my model is conservative with respect to the observed volatility of the markup and that the relative importance of the markup channel for welfare is not driven by exaggerated or implausible dynamics.

Real-Nominal Trade-Off.   The real-nominal trade-off suggests that as monetary policy increasingly stabilizes inflation, nominal uncertainty falls while real uncertainty increases. This trade-off arises as an endogenous outcome of my general equilibrium model. The intuition is that as the central bank increasingly targets inflation, this induces greater changes in both nominal rates and real rates (due to sticky prices), which causes higher real consumption volatility. This channel is also present in the endogenous growth model of Kung (2014). Bansal and Shaliastovich (2013) provide empirical evidence that real uncertainty is higher relative to nominal uncertainty for the post-Volcker period.

Empirical Interest Rate Rules.   A number of studies suggest that simple interest rate rules can characterize the behavior of the Federal Reserve over various time periods. Taylor (1993) proposes a simple rule of the Federal Funds Rate as a function of inflation and the output gap around a trend. Weights of 1.5 and 0.5 are assumed on inflation and output, respectively, and seem to capture roughly the behavior of monetary policy. Other papers have since evaluated the empirical fit of simple interest rate rules, including Judd and Rudebusch (1998), Taylor (1999), Clarida, Gali, and Gertler (1998) and Orphanides (2003). In contrast to many of these studies, I choose to focus on output growth rather than the output gap because there is greater consensus in terms of its

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[9]The rise in the markup within the asset pricing-oriented New Keynesian model is further demonstrated in section 2.3, figure 2.2.

Table 2.1: Estimated Interest Rate Reaction Function

	α_r	α_π	$\alpha_{\Delta y}$
Parsimonious Regression			
1955:1–1982:4	0.90	1.60	0.79
	(0.41)	(0.55)	(0.25)
1983:1–2002:4	0.92	2.46	1.10
	(0.35)	(0.82)	(0.26)
Coibion & Gorodnichenko (2012)			
1983:1–2002:4	0.93	2.20	1.56
	(0.11)	(0.40)	(0.39)

This table shows results of regressions of the Federal Funds Rate on the lagged rate (α_r), inflation based on the GDP price deflator (α_π), and the growth of real GDP ($\alpha_{\Delta y}$). Results from Coibion and Gorodnichenko (2011) over a similar time period are shown for sake of comparison. Their method uses real-time measures of expected inflation and expected output growth based on Greenbook forecasts from the Federal Open Market Committee (FOMC). Standard errors are listed in parentheses.

measurement.[10]

I conduct my own estimation of the interest rate reaction function using data from 1983Q1 to 2002Q4. The starting and ending dates are chosen to match Coibion and Gorodnichenko (2011). I regress the Federal Funds Rate on its lagged term, the demeaned inflation rate according to the GDP price deflator, and the demeaned output growth rate of real GDP:

$$R_t = \alpha_r \cdot R_{t-1} + (1 - \alpha_r)\left(\alpha_\pi \cdot (\pi_t - \pi^*) + \alpha_{\Delta y} \cdot (\Delta y_t - \Delta y^*)\right) + \epsilon_t$$

where α_r captures partial adjustment or inertia, α_π is the weight on inflation, $\alpha_{\Delta y}$ is the weight on output growth, and the starred variables indicate means that act as proxies for the targets.

The results of my regression for post-1983 are in line with Coibion and Gorodnichenko (2011), as shown in table 2.1. Coibion and Gorodnichenko (2011) solely focus on characterizing Federal Reserve policy, which leads them to use a more richly parameterized empirical model. Here, I characterize this behavior in a more parsimonious and straightforward manner. The small difference

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[10]Other studies have estimated interest rate rules that include output growth, including Ireland (2004), Carlstrom and Fuerst (2012), and Coibion and Gorodnichenko (2011).

in results can be attributed to these modeling differences, along with Coibion and Gorodnichenko (2011)'s use of expected inflation and expected output growth based on the Greenbook forecasts from the Federal Open Market Committee (FOMC).

In both instances, it is clear that the Federal Reserve did not target inflation as much for the pre-Volcker period. With less weight placed on inflation, higher inflation volatility was associated with lower average markups, which is an important channel for my welfare analysis. Most importantly, the values on the inflation coefficient for the post-Volcker regressions are much lower than the optimal monetary policy literature frequently suggests. For example, the model of Schmitt-Grohé and Uribe (2007) in a similar setting with no long-run risk and CRRA preferences yields an optimal inflation coefficient of 332 with no weight on output. Likewise, Kollmann (2008) finds an optimal inflation coefficient of 8,660.

The optimal policy in my asset pricing-oriented New Keynesian model places a weight on inflation that is within the standard error of the point estimate based on my post-Volcker regression. Also, the optimal weight placed on output growth is higher than that estimated in both of my regressions. Thus, this model, with its high welfare costs of recessions, suggests that it would have been optimal for the Federal Reserve to respond more to output growth over the estimated time period.

Overall, CRRA preferences are inconsistent not only with asset pricing facts but also with the empirical evidence described in this section. Once Epstein-Zin preferences are introduced, the empirical evidence on the markup and consumption volatility is reproduced in a general equilibrium setting and the implications for monetary policy change dramatically.

2.2.3 Calibration

In the proposed model, I calibrate the time period to a quarterly frequency. I then annualize the moments and focus on matching the behavior of macroeconomic variables over the long sample of US data from 1929–2008. Data on consumption and investment are from the Bureau of Economic Analysis (BEA). Fiscal policy variables such as government spending and steady-state debt are taken from Schmitt-Grohé and Uribe (2007). The parameters described below are listed in table

Table 2.2: Model Features and Parameter Values

		Recursive		CRRA	
		High IES High RA	Low IES High RA	High IES Low RA	Low IES High RA
Preference parameters					
Discount factor	β	0.9955	0.999	0.998	0.999
Effective risk aversion	γ	10	10	1/2	10
Intertemporal elasticity of subs.	ψ	2.0	0.2	2.0	$1/\gamma$
Leisure weight	o	0.35	0.35	0.35	0.35
Technology parameters					
Capital share	θ	0.25	0.25	0.25	0.25
Quarterly depreciation rate	δ	1.725%	1.5%	1.725%	1.5%
Productivity parameters					
Risk exposure of new investment	ϕ_0	0	0	0	0
Average quarterly growth rate	μ	0.005	0.005	0.005	0.005
Volatility of short-run risk	σ_a	0.0055	0.0055	0.0065	0.003
Volatility of long-run risk	σ_x	$0.15 \cdot \sigma_a$	$0.15 \cdot \sigma_a$	$0.15 \cdot \sigma_a$	$0.15 \cdot \sigma_a$
AR(1) of expected growth	ρ	0.98	0.98	0.98	0.98
New Keynesian parameters					
Price elasticity of demand	η	7	7	7	7
Probability firm cannot change P	α	75%	75%	75%	75%
Policy parameters					
Steady-state debt to GDP	S_B	0.44	0.44	0.44	0.44
Steady-state $\frac{G}{Y}$	S_G	0.17	0.17	0.17	0.17
Monetary policy inflation coeff.	α_π	1.5	1.5	1.5	1.5
Output growth gap coeff.	$\alpha_{\Delta y}$	0.75	0.75	0.75	0.75
Inertia coeff.	α_r	0.8	0.8	0.8	0.8

The four models were calibrated to minimize the distance between the moments implied by the model and the moments taken from the data. The moments to match were the volatilities of consumption and investment growth, the level of the risk-free rate, and if possible the equity premium.

4.1.

For the New Keynesian parameters, the markup due to monopolistic competition is set to 15%, which is in line with previous studies (Bils and Klenow 2002). Firms are assumed to re-optimize their prices every 12 months, which is in the middle of empirical estimates that range from 6 to 18 months (see Altig, Christiano, Eichenbaum, and Linde (2011)). With regard to fiscal policy, steady-state government purchases make up 17% of GDP, and the steady-state debt-GDP ratio is set to the historical average of 44%, following Schmitt-Grohé and Uribe (2007). Taxes are collected by lump sum to pay for an exogenous expenditure stream. The persistence and standard

deviation of the government spending shocks follow Croce, Kung, Nguyen, and Schmid (2012), but given the assumed nondistortionary nature of taxes, they essentially have a nil effect on the results.

For monetary policy, the default interest rate rule used for calibration includes an inertia coefficient of 0.8 and an output growth coefficient of 0.75. The parameters chosen for these coefficients are set to match inflation dynamics and the interest rate serial correlation observed in the data. An inertia coefficient of 0.8 is consistent with empirical quarterly estimates, which set it as high as 0.9. Without including output growth, inflation in the model is positively correlated with permanent productivity shocks, which is counterfactual. The incorporation of the output growth causes inflation to fall with good productivity shocks and rise with bad productivity shocks. The inflation coefficient is set to 1.5 to match the original work of Taylor (1993).

Production and Preference Parameters. The parameters for effective risk aversion ($\gamma = 10$) and intertemporal elasticity of substitution ($\psi = 2$) are consistent with the estimates of Bansal, Gallant, and Tauchen (2007), Bansal, Kiku, and Yaron (2010), and Colacito and Croce (2011).[11] The capital share ($\alpha = 0.25$) and the quarterly depreciation rate of physical capital ($\delta = 0.01725\%$) are consistent with the labor share of income in the data and with the quarterly depreciation rate of 1.5 to 4% observed in the real business cycle (RBC) literature. I calibrate μ at 2% per year, consistent with the average annual real growth rate of the US economy. I set the persistence parameter on long run risk at $\rho = 0.98$, which is close to the point estimate of Croce (2014a).

The subjective discount factor is set to be consistent with the low risk-free rate observed in the data. Labor is endogenous and set to match the level of hours in the data, $\iota = 0.35$. I set σ_a to match the standard deviation of consumption. The smaller long-run shock is set to $0.15 \cdot \sigma_a$ as estimated by Croce (2014a).

Free Parameters and Moments Matched. The free parameters above are the subjective discount factor (β), the depreciation rate for capital (δ), the volatility of short-run risk (σ_a), and the

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[11]See Swanson (2012) for a discussion of risk aversion when leisure is present.

persistence parameter on long-run risk (ρ). These parameters are chosen within a grid of values accepted by the literature in order to maximize the model's ability to reproduce the moments of interest, which are the mean of the real risk-free rate, the levered excess return, and the volatilities of consumption and investment growth. I minimize the distance between the moments implied by the model and the moments taken from the data as shown in table 2.3. The distance is measured by

$$\min_a \zeta(a) = [\hat{F}_T - f(a)]'[\hat{F}_T - f(a)]$$

where $f(a)$ is the vector of moments generated by the model, and $\hat{F}_T$ is the moments in the data. The minimization is done by searching over a grid of values for a: $\beta = [0.995, 1]$, $\delta = [.015, .04]$, $\sigma_a = [0.005, 0.02]$, and $\rho = [0.92, 0.98]$. Note that in the data, excess returns are levered. Hence, I use the following excess return: $R_{ex,t}^{LEV} = \chi_{LEV}(R_t^K - R_{t-1}^f)$. The calibration of χ_{LEV} is set to 3 to match the debt-equity ratio in the data along with the degree of operating leverage as estimated in García-Feijóo and Jorgensen (2010).

Simulation. The policy rules are numerically computed using second-order approximations from Dynare++. The simulations consist of random draws of the two productivity shocks (short-run and long-run) and a fiscal shock (government spending). The number of periods is 200 (the first 100 are discarded) and the number of simulations is 100. The moments for the models are listed in table 2.3. The preferred High IES ($\psi = 2$), High RA ($\gamma = 10$) model comes closest to matching the low risk-free rate, the high equity premium, the smooth volatility of consumption growth, and volatile investment growth. Matching data on both macroeconomic aggregates and asset pricing facts imposes joint structural restrictions on both the quantity and price of risk in the data.

2.3   Optimal Interest Rate Rules

In the following section, I describe the characteristics of the interest rate rules that yield the highest welfare. I then restrict the model to a setting with only long-run shocks and a setting with only short-run shocks to provide a deeper understanding of the underlying dynamics. Following this, I examine the effect of the inflation coefficient and output growth coefficient on the three

Table 2.3: Main Moments

		Recursive		CRRA	
		High IES	Low IES	High IES	Low IES
	Data	High RA	High RA	Low RA	High RA
$E(I/Y)$	0.18	0.20	0.16	0.20	0.08
$\sigma(\Delta c)$	2.14	2.09	2.81	2.29	2.64
$\sigma(\Delta i)$	13.17	11.58	11.78	13.23	11.14
$\sigma(\Delta n)$	3.66	3.62	2.19	2.81	2.99
$\sigma(r^f)$	1.35	0.39	0.44	0.32	0.60
$E[r^f]$	0.89	2.10	4.78	2.42	15.79
$E[r^{L,ex}]$	4.71	4.56	3.06	0.02	−0.01
$ACF_1[R_t^f]$	0.89	0.83	0.92	0.90	0.88
$\rho(\Delta a, \pi)$	−0.30	−0.54	−0.31	−0.72	0.23

The four models are calibrated to minimize the distance between the moments implied by the model and the moments taken from the data. The minimization is done by searching over a grid of values: $\beta = [0.995, 1]$, $\delta = [.015, .04]$, $\sigma_a = [0.005, 0.02]$, and $\rho = [0.92, 0.98]$. The moments to match were the volatilities of consumption and investment growth, the level of the risk-free rate, and the equity premium, if possible. For recursive preferences, settings tested were High RA ($\gamma = 10$), High IES ($\psi = 2$), and Low IES ($\psi = 0.2$). For CRRA preferences, settings tested were High RA ($\gamma = 10$) and High IES ($\psi = 2$). All entries for the models are obtained from repetitions of small samples. Data refer to the US and include pre–World War II observations (1930–2012). Quarterly calibrations are reported in table 4.1. Excess returns are levered by a factor of three, consistent with García-Feijóo and Jorgensen (2010). Note that with CRRA preferences, a low risk free rate and high equity premium are not possible given the inverse link of RA and IES.

major channels of welfare.

To obtain the simple monetary policy rule that yields the highest welfare, I search across a grid for the inflation coefficient, α_π, the output growth coefficient, $\alpha_{\Delta y}$, and the inertia coefficient, α_r. Their respective grids are $(1, \infty)$, $(-\infty, \infty)$, and $(-\infty, \infty)$. I constrain $\alpha_\pi > 1$ in order to be consistent with the Taylor principle. With $\alpha_\pi > 1$, the real interest rate rises with inflation, and this ensures determinacy. The rule is formulated as follows:

$$\hat{R}_t = \alpha_r \cdot \hat{R}_{t-1} + (1 - \alpha_r)(\alpha_\pi \cdot \hat{\pi}_t + \alpha_{\Delta y} \cdot \Delta \hat{y}_t) \tag{2.4}$$

The variables denoted with a hat are log deviations from steady state. The first two panels of table 2.4 list the optimal inflation volatility and inflation coefficient for each model, and the third panel shows the optimal output growth coefficient. The bottom panel shows the relative welfare gain (in

the model that matches asset prices) for the optimal policy compared to the policy that completely stabilizes inflation. The columns are split into settings based on the sources of the shocks in order to capture the role of long-run risk.

Inflation Volatility. The setting with recursive preferences, high risk aversion ($\gamma = 10$), and a high IES ($\psi = 2$) yields the highest optimal inflation volatility of 0.42% with all shocks. Compared to results in extant studies with similar model features, this value is relatively high and represents close to 20% of the observed historical inflation volatility.[12] Most of the inflation volatility can be attributed to the long-run shocks. The higher optimal inflation volatility is due to the rise in the average markup as monetary policy increasingly stabilizes inflation. These dynamics are explained in greater detail in section 2.3.1.

Output Growth. Under recursive preferences, I find that the output growth coefficient is dramatically larger for the setting with long-run shocks compared to that with only short-run shocks. Increasing the weight on the output growth reduces the markup and lowers the volatility of the consumption-leisure bundle. For CRRA preferences, I find it optimal to eliminate price dispersion completely and place an infinite coefficient on inflation with no weight on output growth. The average markup and the volatility of the consumption-leisure bundle stay relatively constant as monetary policy increasingly stabilizes inflation, which is counterfactual to empirical evidence.

Welfare Gains. For the benchmark setting with a low risk free rate and high equity premium (table 2.4, last panel), I find the optimal policy provides a welfare gain of 0.07% compared to the policy that places an infinite weight on inflation. This translates into about 0.20 additional percentage of consumption units every quarter. While this may be small compared to the gains found in the policy literature that incorporates endogenous growth, a perpetuity that pays this amount each year from now on is worth over $3,000, assuming an interest rate of 2%. In other words, a greater response to output growth and less to inflation (relative to that advocated in the

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[12]Inflation is defined as the annualized percentage change in the quarterly GDP price deflator dating back to 1947.

Table 2.4: Optimal Coefficients, Volatility, and Welfare

			Optimal Inflation Volatility		
Preferences	RA	IES	All Shocks	LRR only	SRR only
Recursive	High	High	0.42%	0.39%	0.05%
Recursive	High	Low	0.16%	0.18%	0.06%
CRRA	High	Low	0	0	0
CRRA	Low	High	0	0	0
			Optimal Inflation Coefficient		
Preferences	RA	IES	All Shocks	LRR only	SRR only
Recursive	High	High	3	3	1.75
Recursive	High	Low	16	11	3.25
CRRA	High	Low	∞	∞	∞
CRRA	Low	High	∞	∞	∞
			Optimal Output Growth Coefficient		
Preferences	RA	IES	All Shocks	LRR only	SRR only
Recursive	High	High	1.5	1.625	0.25
Recursive	High	Low	3	3.25	0.25
CRRA	High	Low	0	0	0
CRRA	Low	High	0	0	0
Rec. Pref., High RA, High IES:			All Shocks	LRR only	SRR only
Relative Welfare Gain			0.07%	0.07%	0.00037%
Consumption Equivalent Units			0.19%	0.20%	0.001%
Perpetuity of Welfare Gain			$3,255	$3,427	$17.13

This table shows the optimal inflation volatility, optimal inflation coefficient, and optimal output growth coefficient across different shocks and different utility specifications. RA is risk aversion, IES is intertemporal elasticity of substitution, and CRRA is constant relative risk aversion. For recursive preferences, settings tested were High RA ($\gamma = 10$), High IES ($\psi = 2$), and Low IES ($\psi = 0.2$). For CRRA preferences, settings tested were High RA ($\gamma = 10$) and High IES ($\psi = 2$). Quarterly calibrations are reported in table 4.1. The bottom panel shows the relative welfare gain compared to the policy that places infinite weight on inflation. The consumption equivalent units are computed as in An (2010). The perpetuity of the welfare gain is computed by assuming an interest rate of 2% and real consumption expenditures per capita of $34,270 per year. The consumption equivalent unit percentage is multiplied by $34,270 and divided by the interest rate to arrive at the value of the perpetuity.

existing literature) would be worth a one-time payment of over $3,000 to each individual.[13] This is

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[13]Base year 2009 dollars.

in contrast to results from the setting with only short-run shocks, in which an equivalent calculation would yield a perpetuity worth only \$17. This small magnitude is in line with the existing literature (see Schmitt-Grohé and Uribe (2007)).

To explain the low inflation coefficient and high weight on the output growth for the asset pricing-oriented model, I focus on the setting in which there are only long-run shocks. Although the long-run shock is one-seventh the size of the short-run shock, its persistence (combined with the very forward-looking nature of agents) dominates the other shocks.

2.3.1 Long-Run Productivity Shocks Only

The small but persistent news shock to productivity growth has been empirically documented by Croce (2014a), Beaudry and Portier (2004), Schmitt-Grohé and Uribe (2007), Barsky and Sims (2011), and Kurmann and Otrok (2010). Specifically, Croce (2014a) finds that the conditional mean of productivity growth is extremely persistent and time-varying. In a setting with forward-looking monopolistically competitive firms, a low-frequency predictable fluctuation in productivity can have significant ramifications for the prices chosen by firms, which reverberates through the demand-driven New Keynesian model. Below, I examine the channels that drive the finding of a low optimal inflation coefficient and relatively high weight on output growth.[14]

Optimal Inflation Coefficient and Three Welfare Channels. In this section I examine the reasons the optimal inflation coefficient is low for the recursive preferences asset pricing-oriented model and high for the CRRA preferences model. In figures 2.2–2.3, I compare three different models: (1) recursive preferences with high risk aversion ($\gamma = 10$) and high IES ($\psi = 2$); (2) recursive preferences with high risk aversion ($\gamma = 10$) and low IES ($\psi = 0.2$); and (3) CRRA preferences with high risk aversion ($\gamma = 10$) and low IES ($\psi = 1/10$). Figure 2.2 depicts the effects of increasing the inflation coefficient and figure 2.3 shows the welfare. The increase in α_π can be thought of as moving from a dove regime to a hawk regime. The level of price dispersion decreases in all settings due to the lower inflation volatility (far right panel of figure 2.2). Monetary

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[14]Discussion of the optimal inertia coefficient, α_r, is reserved for appendix A.2.
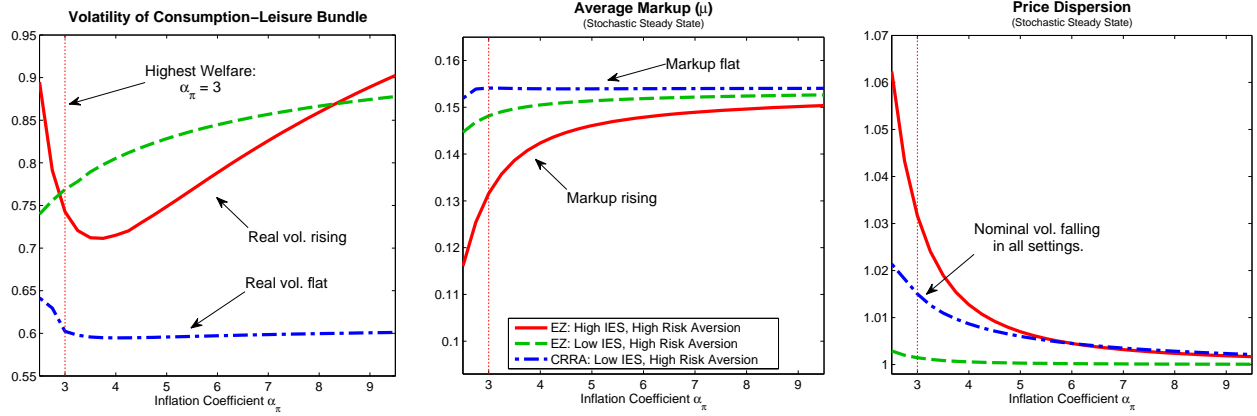
Figure 2.2: Effects of Increasing the Inflation Coefficient (α_π)

This figure shows the three key channels for welfare (volatility of consumption-leisure bundle, average markup, price dispersion) and the effects of greater inflation stabilization. The setting is a world with only long-run news shocks to productivity. The other coefficients are set to match the rule that yields the highest welfare for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case, as in equation 2.4 and table 4.1. Both of the recursive preference settings exhibit strong increases in the volatility of the consumption-leisure bundle compared to the CRRA preferences. The average markup rises the most for the high IES and high risk aversion setting. All of the settings see a reduction in price dispersion as the inflation coefficient rises.

policy, by increasingly stabilizing inflation, reduces nominal uncertainty.

Major differences across the three settings can be seen in the left two panels of figure 2.2. The far left panel shows the volatility of the consumption-leisure bundle. While volatility is increasing with the degree of inflation stabilization for all three settings, the increase is lowest for the CRRA preferences. This makes sense because of the inverse nature of CRRA preferences, in which the IES is lower due to the high risk aversion. With a lower IES, by definition agents will react less to monetary policy and so the volatility does not rise as much for a given change in policy. This is also true for the recursive preferences as one moves from a low IES to a high IES. The increase in volatility of the consumption-leisure bundle is greatest for the high IES case.

The average markup rises the most for the model with the high IES.[15] The markup falls more in response to negative productivity shocks, and the more that monetary policy stabilizes inflation, the less the markup will be allowed to decline, resulting in a higher average markup. Note that with less asymmetry, the low IES markup does not rise as much with the inflation coefficient. All three models converge to the average markup that would occur in the nonstochastic steady-state,

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[15]This is perfectly consistent with the asymmetric responses discussed in appendix A.3 and figure A1
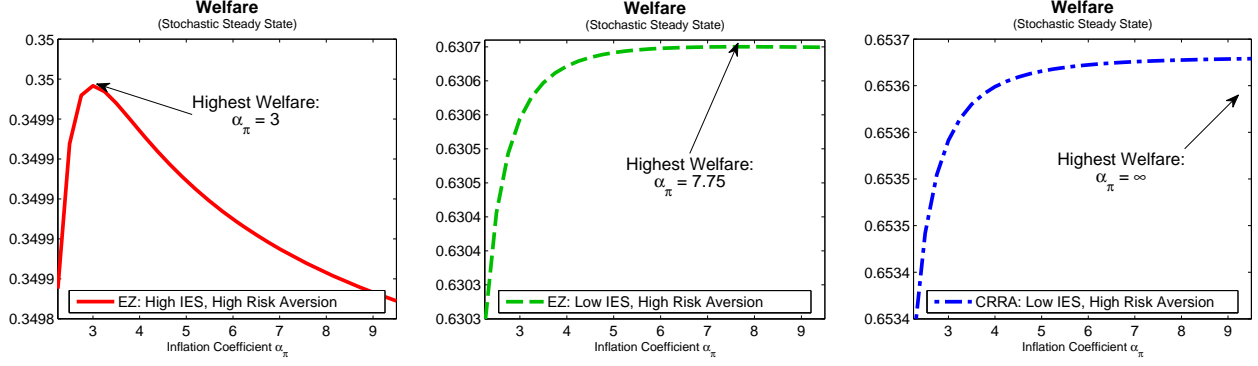
Figure 2.3: Effects of Increasing the Inflation Coefficient: Welfare (α_π)

This figure shows the effects on welfare of increasing the inflation coefficient in a world with only long-run productivity shocks. The other coefficients are set to match the rule that yields the highest welfare for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case as in equation 2.4 and table 4.1. The greatest fall in welfare comes with the High IES, High Risk Aversion on the far left due to the higher markup from stabilizing inflation and the increased volatility of the consumption-leisure bundle. This is in contrast to the CRRA preferences setting in which completely stabilizing inflation is optimal.

in which the variance of the markup is zero. In other words, they all converge to the level of the markup that would occur under a first-order approximation.

In terms of overall welfare, the optimal inflation coefficient is lowest for the model with high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$), as shown in figure 2.3. Beyond the value of 3 for the inflation coefficient, the benefits of reducing price dispersion are outweighed by the costs of the higher markup and greater volatility of the consumption-leisure bundle. For the low IES case, the optimal inflation coefficient is higher with lesser increases in the markup. Finally, the CRRA preferences setting has a value on the inflation coefficient of infinity as the reduction in price dispersion dominates the markup channel. Monetary policy has very little effect on the volatility of the consumption-leisure bundle and the markup, which means the costs of stabilizing inflation are essentially nil.

Output Growth Coefficient and Three Welfare Channels. In this section I examine the reasons the optimal output growth coefficient is high for the asset pricing-oriented model. As shown in figure 2.4, placing weight on the output growth reduces the variability of the consumption-leisure bundle and also provides a greater anchor for inflation expectations. This is because when output falls below potential, monetary policy lowers interest rates with the implicit assurance that interest
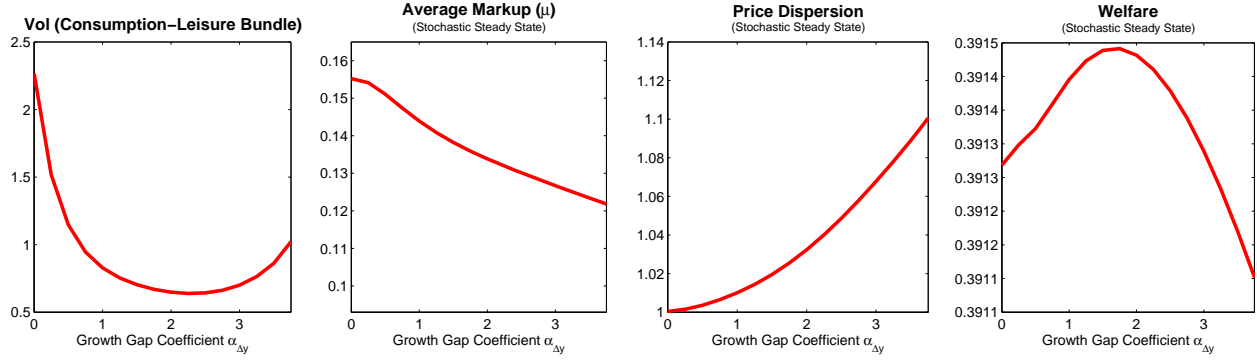
Figure 2.4: Effects of Increasing the Output Growth Coefficient ($\alpha_{\Delta y}$)

This figure shows the effect of placing higher weight on the output growth in a world with only long-run productivity shocks. The other coefficients are set to match the rule that yields the highest welfare for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case, as in equation 2.4 and table 4.1. The volatility of the consumption-leisure bundle and the average markup decline, while price dispersion is increasing due to higher inflation volatility, which causes a hump-shape for welfare.

rates will rise as output increases back to potential. Anchoring inflation expectations is imperative because current inflation depends on expectations of future inflation, and in the model firms are very patient and forward looking.[16]

In addition, the markup monotonically decreases with the output growth coefficient. Greater weight on the output growth means relatively less weight on inflation, so that inflation volatility and price dispersion increase. Thus, after the negative long-run productivity shock shown in Figure 2.5, the average markup is persistently lower in the medium to long term, while inflation is higher. Furthermore, the decline in the response of the consumption-leisure bundle is also beneficial to welfare. Eventually, the consumption-leisure bundle volatility increases due to monetary policy overcompensation. This, combined with the higher price dispersion, leads to the decline in welfare when moving beyond an output growth coefficient of 1.5.

2.3.2 CRRA Preferences

This section shows how agents and firms with CRRA preferences react to negative long-run productivity shocks. Figure 2.6 shows the real stochastic discount factor in the upper left panel. Note the rise for recursive preferences is eight times greater in magnitude due to the continuation

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[16]This is in contrast to reacting to simply the level of output, which destabilizes inflation expectations. I find that a zero weight on the level of output is optimal as the negative effects of price dispersion dominate.
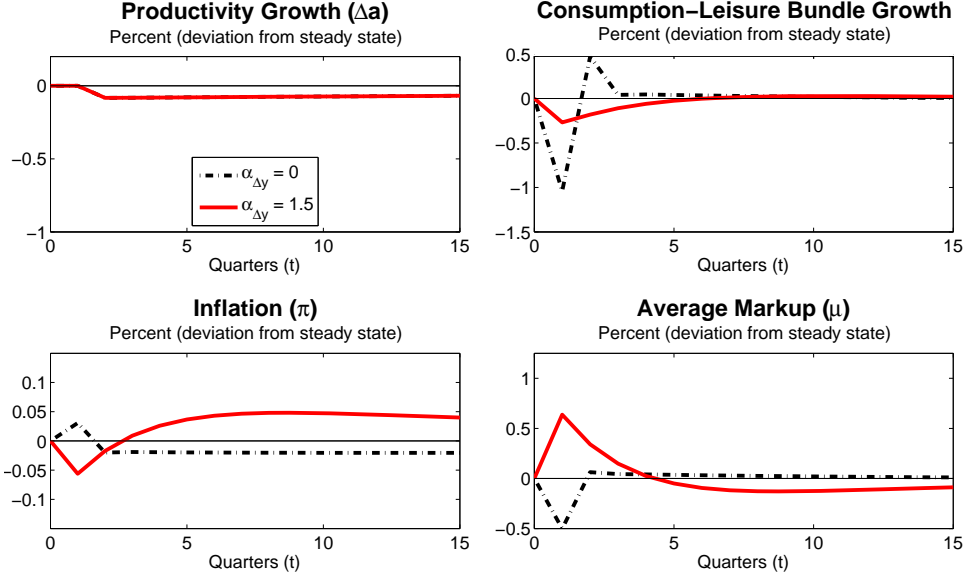
Figure 2.5: Higher Output Growth Response: Negative Long-Run Shock ($\alpha_{\Delta y}$)

This figure shows the response to a negative long-run productivity shock. The parameterization is based on the calibration in table 4.1 for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case and focuses on the policy that yields the highest welfare in equation 2.4. The volatility of the consumption-leisure bundle declines and the average markup falls more over the medium to long term due to the higher inflation.

value that captures news. The higher real SDF combined with the higher IES makes firms more forward looking, which causes them to raise prices to a greater extent because they are concerned with higher future marginal costs.

The higher inflation directly translates into a lower real markup, which acts as a hedge and provides good long-run news. The low IES with CRRA preferences reduces the effectiveness of monetary policy so that the consumption-leisure bundle and average markup quickly converge to the steady state. This analysis concurs with the evidence in figure 2.2, which shows that for CRRA preferences, monetary policy is less effective in reducing the average markup and the volatility of the consumption-leisure bundle.

2.3.3 Short-Run Shocks Only

In a setting with only short-run shocks, I find that the differences in welfare across policies are negligible, as shown in figure 2.7. Under CRRA preferences, the policy that yields the highest welfare places an infinite value on the inflation coefficient. Under recursive preferences, the following rule yields the highest welfare: $\hat{R}_t = 0.9 \cdot \hat{R}_{t-1} + 1.75 \cdot (1 - 0.9) \cdot \hat{\pi}_t + \frac{1}{4} \cdot (1 - 0.9) \cdot \Delta \hat{y}_t$.
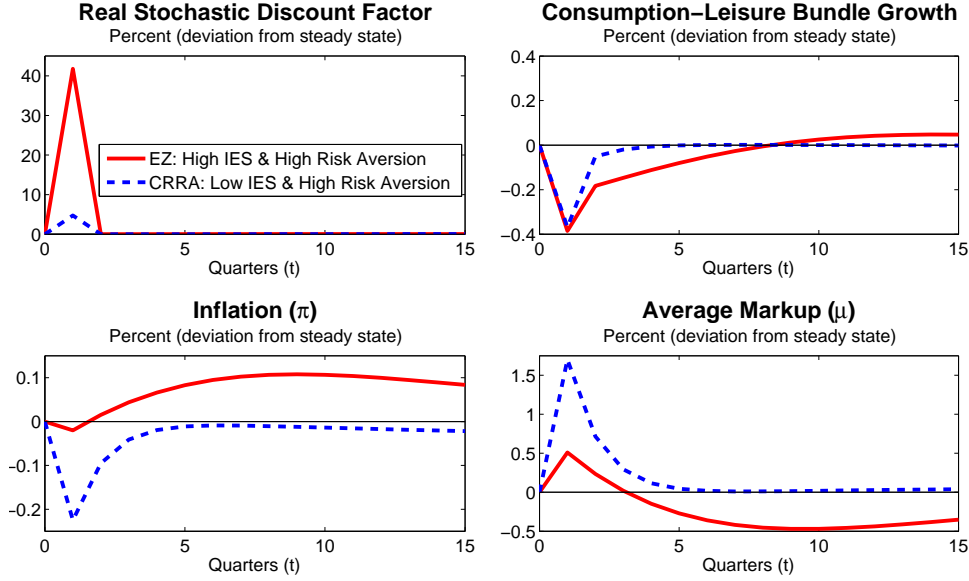
Figure 2.6: CRRA: Low IES, High Risk Aversion, Negative Long-Run Shock

This figure shows the response to a negative long-run productivity shock. The parameterization is based on the cali-
bration in table 4.1 for the low IES ($\psi = 1/10$) and high risk aversion ($\gamma = 10$) case and around the policy that yields
the highest welfare in equation 2.4. The real stochastic discount factor (SDF) in the top-left panel shows the impact
of the continuation utility and the higher IES for recursive preferences. The negative news leads to a greater rise in
the real SDF. This translates into a greater rise of inflation and much lower markup compared to the CRRA setting, as
firms place greater weight on the future. In addition, the low IES for CRRA preferences reduces the effectiveness of
monetary policy so that the consumption-leisure bundle and average markup quickly converge to steady state.

However, in contrast to the policy that places an infinite weight on inflation, the welfare benefit is
only 0.000367%. This is 200 times smaller than a similar comparison with a setting comprising
only long-run shocks, where the welfare benefit of the best policy is 0.07% compared to the one
that places an infinite weight on inflation.

The differences in welfare across policies are small due to the largely symmetric responses
of the average markup and inflation to short-run shocks. Moreover, these variables revert to the
steady state very quickly compared to those in the setting with long-run shocks. In summary, the
lack of persistence and asymmetry in response to short-run shocks combined with the near-zero
equity premium makes all three welfare channels insignificant. Note that the small differences in
welfare across policies in this setting are consistent with the findings of Schmitt-Grohé and Uribe
(2007), who also reach this conclusion in a setting without long-run risk.
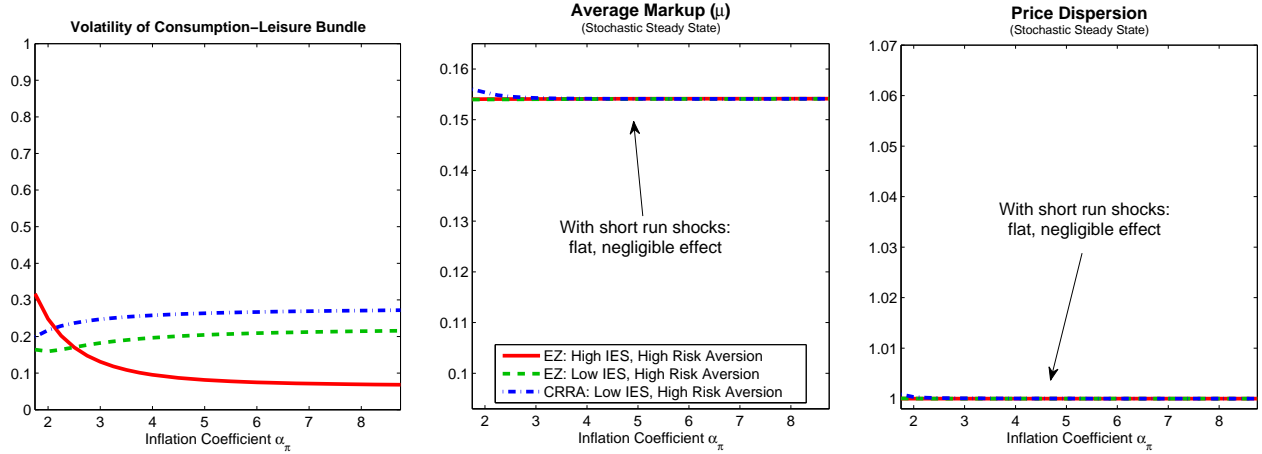
Figure 2.7: Effects of Increasing the Inflation Coefficient (α_π), Short-Run Shocks Only

This figure shows the three key channels for welfare (volatility of consumption-leisure bundle, average markup, price dispersion) and the effects of greater inflation stabilization. The setting is a world with only short-run shocks to productivity. The other coefficients are set to match the rule that yields the highest welfare for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case, as in table 4.1. The effect on the average markup and price dispersion is essentially flat for all three models. The effects on the volatility of the consumption-leisure bundle are muted compared to the setting with long-run shocks only. Overall, I find the welfare differences across policies are negligible.

2.4   Further Inspection of Dynamics

In this section I directly compare the low IES ($\psi = 0.2$) and high IES ($\psi = 2$) settings to further emphasize the importance of making firms and agents more patient. Following that, I show the reasons the average markup rises as monetary policy increasingly stabilizes inflation. Further sensitivity analysis with respect to changes in the risk aversion and intertemporal elasticity of substitution can be found in appendix A.4.[17]

High vs. Low IES.   The high IES model better captures the low risk-free rate in the data and makes forward-looking agents and firms more patient, as shown in the left panel of figure 2.8. With greater precautionary savings, the consumption-leisure bundle growth declines more, and this results in the doubling of the stochastic discount factor when moving from the low to high IES model. In this context, forward-looking firms place greater weight on future marginal costs, so that the decrease in inflation in the initial period is five times less in the high IES model than the low

---

[17]In appendix A.4, I also show why the markup channel is largely not present in other studies–namely, due to the absence of both a high IES and high risk aversion. When the IES is relatively low (which is typically the case for CRRA preferences), moving from a first-order to second-order approximation barely changes the dynamics.

IES model. The higher inflation pushes down the relative prices set by firms in previous periods and decreases the real value of the average markup. All of the above results suggest that the high IES model has a greater negative effect on the average markup.

High vs. Low IES ($\psi = 2$ vs. $\psi = 0.2$)

Low α_π vs. High α_π
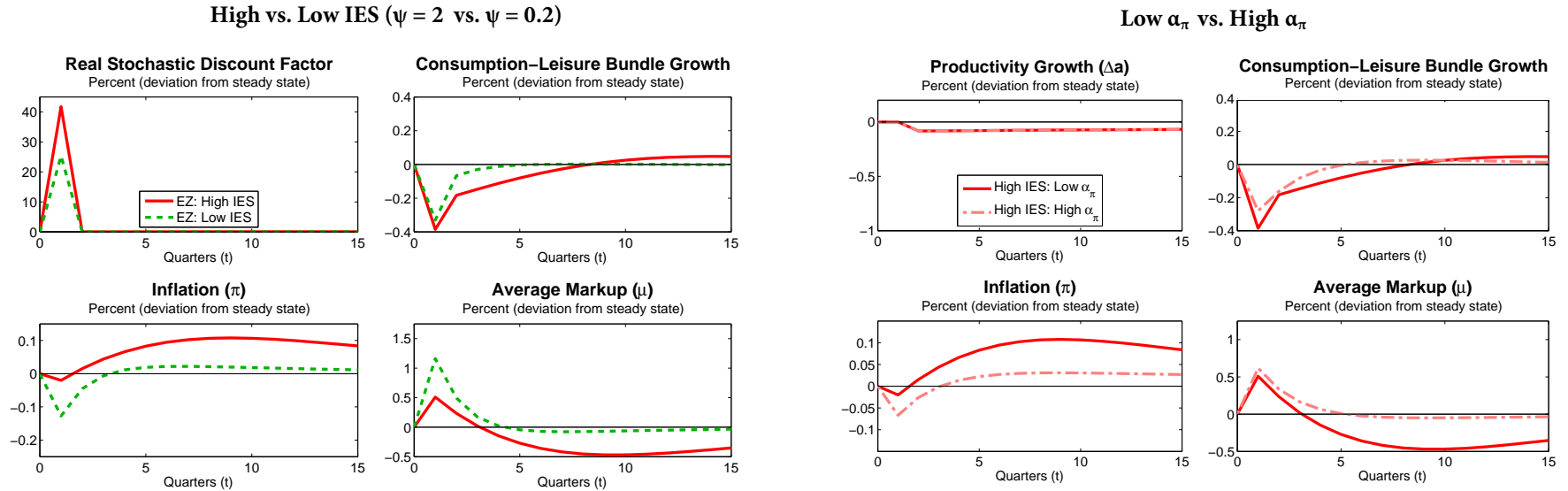
Figure 2.8: Negative Long-Run Shock

This figure shows the effects of a negative long-run productivity shock on the three key channels for welfare: inflation volatility, markup, and consumption-leisure volatility. The parameterization is based on the calibration in table 4.1 and focuses on the policy that yields the highest welfare in equation 2.4. The left panel shows that moving from a low IES to a high IES leads to significantly different implications for each channel. The right panel shows that moving from the low inflation coefficient of 2.25 to the high inflation coefficient of 5, there is a decrease in inflation volatility which means the markup does not fall by as much in recessions. This suggests the average markup will be higher as monetary policy increasingly stabilizes inflation.

High IES: Low vs. High α_π (Dove vs. Hawk). As shown in the right panel of figure 2.8, a higher inflation coefficient combined with a high coefficient on the lagged interest rate imply a higher real interest rate for many periods in response to inflation. Forward-looking firms take this into account when setting prices, knowing that monetary policy is actively attempting to stabilize inflation. Therefore, firms choose lower prices due to the lower expected inflation, and this causes the initial inflation to be lower.

However, the decrease of inflation volatility lowers the inefficient allocation coming from price dispersion. Therefore, a trade-off exists between increasing the average markup and decreasing price dispersion as monetary policy increasingly stabilizes inflation. Note that this markup channel is nonexistent for first-order approximations and is not as large for the low IES model. Since the decrease in inflation volatility means the markup does not decrease by as much in recessions, this implies the average markup will be higher as monetary policy increasingly stabilizes inflation.

2.5   Conclusion

Asset pricing is important for monetary policy analysis because it reveals how much agents dislike recessions and the extent to which they are forward-looking and patient. I have shown in this study that incorporating the combination of these two characteristics, along with the presence of long-run risk, leads to policy recommendations that are very different from those of prior studies. Specifically, in my asset pricing-oriented New Keynesian model, much greater weight is placed on output growth, and a much smaller weight is placed on inflation. Price dispersion is no longer the dominant channel in this setting. In addition, the effects of monetary policy on the volatility of the consumption-leisure bundle and the average markup become first-order concerns.

I find that the welfare gain of moving away from a policy that completely stabilizes inflation is two hundred times greater for settings with long-run shocks relative to those with short-run shocks. This translates into the equivalent of a one-time benefit of over \$3,000 for every individual. Moreover, the optimal inflation volatility is forty times greater in this setting than in similar settings without long-run risk. In my model, the weight on the output growth is over 14 times greater than the weight that is placed on the output level in the original study by Taylor (1993). All of these

findings would likely be magnified in a setting with endogenous rather than exogenous growth. In the current economic setting, monetary policy is unable to increase or decrease long term growth, and I leave this as a topic for future research.

CHAPTER 3

TAXES, SPENDING, AND MARKET RETURNS

3.1 Introduction

Recent papers by Romer and Romer (2010) and Blanchard and Perotti (2002), among others, have documented specific real effects of fiscal policy on the economy. On the one hand, increased taxes are associated with lower investment and lower GDP. A fall in both investment and GDP implies a decrease in current/future production and lower cash flows for the firm. On the other hand, lowering the deficit is associated with lower real interest rates (Gale and Orszag 2003). From an asset-pricing perspective, the change in fiscal policy leads to two countervailing effects: a negative effect on cash flows and a negative effect on discount rates. The question then becomes, which channel dominates? Do the lower future cash flows result in lower aggregate returns or do the lower discount rates dominate and imply higher aggregate returns? Based on a news decomposition, we find that the answer is heavily dependent upon the stance of monetary policy.

News decompositions[1] consist of splitting the variation in unexpected stock market returns into two fundamental components – news about future discount rates and news about future cash flows. Cash flows often represent dividends and are related to profits and production. Discount rates tend to reflect the actions of monetary policy along with risk aversion or investor sentiment. The news component of both channels reflect changes in investors expectations, which can be proxied using vector autoregressions (VARs) to capture revisions in forecasts of cash flows and discount rates.

Given that a VAR can always be transformed into an infinite moving average, discounted sums

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[1]See Campbell and Shiller (1988); Campbell (1991); Campbell and Ammer (1993); Vuolteenaho (2002); Chen and Zhao (2009) among many others focus on importance of discount rate news. Cash flow news is emphasized by Bansal and Yaron (2004); Bansal, Dittmar, and Lundblad (2005); Lettau and Ludvigson (2005); Santos and Veronesi (2010); Cohen, Polk, and Vuolteenaho (2009); Da (2009); Hansen, Heaton, and Li (2008).

can be computed for expected future excess returns, dividends, and real interest rates. The channels through which fiscal policy impacts the stock market can then be explained by incorporating unexpected fiscal spending or tax shocks into the VAR as an exogenous variable. For the government spending shocks, our study makes use of Ramey (2011), a narrative dataset that categorizes unexpected variations in government spending dating back to 1890. We also use the narrative dataset of Romer and Romer (2010) to evaluate the effects of exogenous tax shocks, dating back to 1947. While these datasets are subjective, they provide for more transparent analysis and empirical tests have confirmed their exogeneity.

Previous studies have used similar empirical methods to derive the effects of monetary policy on the stock market, but not fiscal policy. Patelis (1997); Bernanke and Kuttner (2005); and Maio (2013) have all found monetary policy imposing significant effects on the stock market using a news decomposition. For instance, Bernanke and Kuttner (2005) find that unexpected monetary policy shocks impact stock market returns predominantly through the future excess returns channel, whereas the effect on real interest rates and dividends are smaller and less significant. Studies that do focus on the effect of fiscal policy on the stock market (Darrat 1988; Jansen, Li, Wang, and Yang 2008; Arin, Mamun, and Purushothman 2009; Ardagna 2009; Afonso and Sousa 2009, 2012; Agnello and Sousa 2013; Chatziantoniou, Duffy, and Filis 2013) typically find that government spending has a negative effect on stock prices.

Santa-Clara and Valkanov (2003); Tavares and Valkanov (2001); and Belo, Gala, and Li (2013) also focus on the effects of government spending on the stock market. Our study differs from these papers in several respects. First, our analysis focuses on a wider set of fiscal policy shocks, including both changes to government spending and changes to tax policy. Furthermore, our analysis encompasses a broader set of asset classes across multiple financial markets. Third, our use of the Campbell-Shiller (1989) decomposition allows us to determine which channels (cash flows or discount rates) are specifically impacted by fiscal policy. Finally, our methodology explicitly controls for macroeconomic conditions via a VAR framework and avoids potential endogeneity issues by

identifying a set of plausibly exogenous fiscal policy shocks.[2]

Statistical tests suggest a structural break in our data in 1980. For this reason, we split the time series into Pre-1980 and Post-1980 eras. We find that over the 1980-2008 period, a one percent increase in tax revenues relative to GDP (roughly five percent of government spending) is associated with a 5.82 percent decrease in the present value of expected future cash flows. However, the net effect of a tax shock is an 8.24 percent increase in current excess equity returns. This positive relationship between taxes and equity returns is due to a significant decrease in real interest rate news of 9.96 percent.

In contrast, for the Pre-1980 era, we find that the effects on cash flows and discount rates flip signs so that higher taxes are associated with lower equity returns. This documented change in the relationship between taxes and equity returns can be fully rationalized within the context of a standard New Keynesian DSGE model by slightly altering just one parameter, the weight monetary policy places on output in the interest rate reaction function.

The importance of monetary policy stems from the degree to which it accommodates fiscal policy shocks. For this reason, any analysis of fiscal policy that excludes the endogenous responses of monetary policy will be incomplete. This is especially true when attempting to disentangle the effects on the discount rate and cash flow channels. We use a prototypical New Keynesian DSGE model to show the following: An increase in taxes is associated with lower output. Monetary policy, following a standard Taylor (1993) rule, responds by decreasing nominal rates to a greater extent, which lowers real interest rates due to sticky prices. Based on a completely standard calibration, we show that the effect on the discount rate (e.g. real interest rate) channel will be larger than the negative cash flow channel. Therefore, higher taxes are associated with higher equity returns due to the discount rate effect dominating.

Furthermore, our model predicts this positive relationship between taxes and equity returns will disappear if we change just one parameter, the weight placed on output in the interest rate reaction

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[2]Santa-Clara and Valkanov (2003) and Belo et al. (2013) use univariate regressions that include limited controls for macroeconomic conditions. Tavares and Valkanov (2001) use a structural VAR to identify their fiscal policy shocks, which may reflect endogenous policy responses to the economic environment.

function. We find that placing greater weight on output is equivalent to monetary policy providing a "put" or insurance against the higher tax shock. Households take this insurance into account so that consumption growth declines less in response to the negative tax shock, as monetary policy is able to dampen the negative wealth effect. The end result is that real interest rates do not decline as much (since consumption growth declines less) and the cash flow channel also becomes less negative. In fact, our model predicts that the tax shocks' effects on discount rates and cash flows may flip signs, after taking into account monetary policy's insurance or greater weight on output.

For the effect of taxes on equity returns, we are able to run similar decompositions within both our DSGE model and the data. The DSGE model's effect of taxes on equity returns matches the signs of our empirical exercise for each channel and for both time periods. More importantly, the magnitudes predicted by the model (with a typical calibration) are all within one standard error of their empirical counterparts.

In addition to the effects on equity returns, we find that the tax shocks have a significantly positive effect on future excess bond return news, which is associated with a 9.69% drop in inflation news for the Pre-1980 period. This empirical finding is also validated by the predictions of our DSGE model.

We also explore the effect of exogenous defense spending on the aggregate stock market and find positive significant effects on cash-flows. We then examine the industry specific effects of tax shocks and defense spending shocks and continue to find significance. Specifically, the Transportation sector of the Fama and French 17 Industry portfolios shows a positive significant effect (1.18 percent increase for a given one percent increase in defense spending relative to GDP) on cash flow news. Finally, we extend our analysis to the international setting and show that UK fiscal policy has similar significant negative effects on real interest news and cash flow news for the UK stock market.

The rest of the paper proceeds as follows: Section 2 describes our DSGE model and provides model predictions. Section 3 is the theoretical background on the news decomposition. Section 4 discusses our dataset in detail. Section 5 explains the main empirical results and Section 6 provides

additional tests. Section 7 concludes.

3.2 Theoretical News Decomposition background

In this section, we describe the basic framework of Campbell and Shiller (1988); Campbell (1991); and Campbell and Ammer (1993). Those studies show that according to a simple dynamic accounting identity, innovations in current equity excess returns can be decomposed into revisions of future expected cash flows, revisions of future expected excess returns, and revisions of future expected real interest rates.

$$
\begin{aligned}
r_{ex,t+1} - E_t(r_{ex,t+1}) =& (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} - (E_{t+1} - E_t) \sum_{j=1}^{\infty} \rho^j r_{ex,t+1+j} \\
& - (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j r_{real,t+1+j}
\end{aligned}
\tag{3.1}
$$

$$
r_{ex,t+1} - E_t(r_{ex,t+1}) \equiv N_{CF,t+1} - N_{ex,t+1} - N_{real,t+1}
\tag{3.2}
$$

where

$$
N_{CF,t+1} \equiv (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} = r_{ex,t+1} - E_t(r_{ex,t+1}) + N_{ex,t+1} + N_{real,t+1}
\tag{3.3}
$$

$$
N_{ex,t+1} \equiv (E_{t+1} - E_t) \sum_{j=1}^{\infty} \rho^j r_{ex,t+1+j}
\tag{3.4}
$$

$$
N_{real,t+1} \equiv (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j r^f_{real,t+1+j}
\tag{3.5}
$$

represents revisions about future cash-flows, revisions in future expected excess returns, and revisions in future real interest rates. The discount factor ρ is set to 0.9962, following the previous literature (Campbell and Ammer 1993; Bernanke and Kuttner 2005) and is used to match the steady state average annual dividend yield of 5%. As previously stated, the above relationships reflect dynamic accounting identities and have no economic or behavioral content. The explicit derivations for the above equations can be found in the Appendix.

While excess equity returns and real interest rates are to an extent observable, the expectations

appearing above require empirical proxies. The approach taken to capture these expectations follows Bernanke and Kuttner (2005) as we implement a vector autoregression (VAR) involving the variables that we are concerned with (real interest rate and excess returns) along with other state variables that are considered useful in forecasting them. Computing the discounted sum of the revisions in expectations involves writing the n-variable, p-lag VAR as a first-order system

$$Z_{t+1} = AZ_t + w_{t+1} \tag{3.6}$$

where Z_{t+1} is a stacked $np \times 1$ vector containing the real interest rate, the excess equity return, and other variables that are considered useful for forecasting that will be discussed in the following section.

3.2.1 Empirical Implementation with Cash-Flow Residual

With the VAR expressed as above, the discounted sum of revisions in expectations are estimated as follows by Campbell (1991); Campbell and Ammer (1993); and Bernanke and Kuttner (2005):

$$\begin{aligned} N_{ex,t+1} &\equiv (E_{t+1} - E_t) \sum_{j=1}^{\infty} \rho^j r_{ex,t+1+j} \\ &= \mathbf{e1}' \rho \mathbf{A} (\mathbf{I} - \rho \mathbf{A})^{-1} w_{t+1} \end{aligned} \tag{3.7}$$

$$\begin{aligned} N_{real,t+1} &\equiv (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j r_{real,t+1+j} \\ &= \mathbf{e2}' (\mathbf{I} - \rho \mathbf{A})^{-1} w_{t+1} \end{aligned} \tag{3.8}$$

$$\begin{aligned} N_{CF,t+1} &\equiv (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} \\ &= r_{ex,t+1} - E_t(r_{ex,t+1}) + N_{ex,t+1} + N_{real,t+1} \\ &= \left[\mathbf{e1}' + \mathbf{e1}' \rho \mathbf{A} (\mathbf{I} - \rho \mathbf{A})^{-1} + \mathbf{e2}' (\mathbf{I} - \rho \mathbf{A})^{-1} \right] w_{t+1} \end{aligned} \tag{3.9}$$

In the above equations, $\mathbf{e1}$ is a vector whose first element is equal to one and zero otherwise, which corresponds to the position in the VAR for the excess return of the CRSP value-weighted

excess equity return; **e2** is a vector whose second element is equal to one and zero otherwise, corresponding to the position in the VAR for the real interest rate. In the above equations, cash-flow news is the residual of the unexpected excess return that cannot be explained by future excess returns and future real interest rates. Calculating cash-flow news as the residual has the advantage of not having to directly model the dynamics of dividends, which often exhibit seasonality and are non-stationary (Maio 2013).

The state vector associated with the VAR above is given by

$$Z_t \equiv [r_{ex,t}, \; r_{real,t}, \; \Delta r_t, \; SPREAD_{t,} \, d_t - p_t, \; REL_t]' \tag{3.10}$$

where $r_{ex,t}$ is the CRSP value-weighted return in excess of the risk-free rate; $r_{real,t}$ is the real interest rate, defined as the 3-Month Treasury bill rate divided by quarterly CPI; Δr_t denotes the change in the nominal 3-Month Treasury bill rate; $SPREAD_t$ denotes the difference between the yields on the 10-year T-Bill and 3-month T-Bill; $d_t - p_t$ denotes the log dividend-price ratio for the S&P 500; and REL_t is the difference between the 3-Month T-Bill and its 12-month moving average.

Including variables beyond the excess equity return and real risk free rate are important for improving the forecast of future news about discount rates and cash-flows. For instance, both Δr_t and REL_t are known to be good predictors of the real interest rate. As pointed out in Campbell and Ammer (1993), the relative bill rate helps to capture the longer-run dynamics of changes in the interest rate without introducing long lags that drive up the number of parameters to be estimated. The $SPREAD_t$ variable has been popular in the predictability of returns literature as Campbell (1991) shows it tracks the business cycle relatively well. The aggregate dividend-price ratio is another popular predictor of aggregate stock returns (see Cochrane (2008)) and is appealing from a theoretical perspective based on the Campbell and Shiller (1988) decomposition (Maio 2013).

3.2.2 Empirical Implementation with Directly Modeled Cash-Flow

In contrast to the Campbell and Ammer (1993) approach of using the residual, Chen and Zhao (2009) directly model the cash-flow news. They argue that there is often large mis-specification error that shows up in the cash-flow residual because there is small predictive power for the discount rate news. Cash-flow news is directly modeled by incorporating the dividend growth rate. A separate VAR system is devoted to the dividend growth rate because the state variables that predict equity returns are not necessarily the same variables that predict dividend growth rate (Chen and Zhao 2009).

Following Chen and Zhao (2009), the state variables in the dividend growth VAR include dividend growth rate, market equity return, and dividend yield. Alternatively, this is equivalent to having a single VAR with dividend growth but with parameter restrictions. By directly modeling cash-flows in this way, the noise component of stock returns is not being lumped together with cash-flow news. We choose to not take a stand on which is our preferred method and instead include empirical results for both. With dividend growth directly included in the VAR, the excess return can be rewritten as

$$r_{ex,t+1} - E_t(r_{ex,t+1}) \equiv (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j \Delta d_{t+1+j} = N_{CF,t+1} - N_{ex,t+1} - N_{real,t+1} + \varepsilon \quad (3.11)$$

where

$$N_{CF,t+1} \equiv \mathbf{e7}'(\mathbf{I} - \rho\mathbf{A})^{-1}w_{t+1}, \quad (3.12)$$

e7 corresponds to the location in the state vector of the dividend growth rate, and ε is the residual.

3.2.3 Explaining the Responses to Fiscal Policy Actions

Following Bernanke and Kuttner (2005), the proxy for fiscal policy is included in the VAR as an exogenous variable,

$$Z_t = AZ_{t-1} + \phi FISCAL_t + u_t \quad (3.13)$$

where $FISCAL_t$ represents either the exogenous defense spending shocks of Ramey (2011) or the exogenous tax shocks of Romer and Romer (2010). The effects of the fiscal shock on current (unexpected) excess returns, future excess return news, real interest rate news, and cash flow news are given by

$$\xi_{ex,current} \equiv \mathbf{e1}'\phi \tag{3.14}$$

$$\xi_{ex,future} \equiv \mathbf{e1}'\rho\mathbf{A}(\mathbf{I} - \rho\mathbf{A})^{-1}\phi \tag{3.15}$$

$$\xi_{real} \equiv \mathbf{e2}'(\mathbf{I} - \rho\mathbf{A})^{-1}\phi \tag{3.16}$$

$$\xi_{CF} \equiv \mathbf{e1}'\phi + \mathbf{e1}'\rho\mathbf{A}(\mathbf{I} - \rho\mathbf{A})^{-1}\phi + \mathbf{e2}'(\mathbf{I} - \rho\mathbf{A})^{-1}\phi \tag{3.17}$$

The above effects are derived for the Campbell and Ammer (1993) method in which cash-flow news is the residual. Note that both the VAR dynamics and coefficient ϕ are relevant for characterizing the effects of fiscal policy. Alternatively, the effect of the fiscal policy shock on cash flow news when it is modeled directly as in Chen and Zhao (2009) is the following

$$\xi_{CF} \equiv \mathbf{e7}'\phi \tag{3.18}$$

3.2.4 Excess Bond Returns

We follow Campbell and Ammer (1993) by using a dynamic accounting identity to decompose the ten-year bond excess return into future excess return news, inflation news, and real interest rate news:

$$
\begin{aligned}
r_{n,t+1}^{b,ex} - E_t r_{n,t+1}^{b,ex} =& (E_{t+1} - E_t) \left[-\sum_{j=1}^{n-1} r_{n-i,t+1+i}^{b,ex} - \sum_{j=1}^{n-1} \pi_{t+1+i} - \sum_{j=1}^{n-1} r_{real,t+1} \right] \\
=& -N_{t+1}^{b,ex} - N_{\pi,t+1} - N_{real,t+1}
\end{aligned}
\tag{3.19}
$$

The derivation for this decomposition can be found in the Appendix. The effects of fiscal policy on current (unexpected) excess bond returns, future excess bond return news, real interest

rate news, and inflation news are given by

$$\xi_{ex,current} \equiv \mathbf{e1}'\phi^B \tag{3.20}$$

$$\xi_{ex,future} \equiv -\mathbf{e1}'\phi^B - (\mathbf{e2} + \mathbf{e3})'(\mathbf{A} - \mathbf{A}^N)(\mathbf{I} - \mathbf{A})^{-1}\phi^B \tag{3.21}$$

$$\xi_{real} \equiv \mathbf{e2}'(\mathbf{A} - \mathbf{A}^N)(\mathbf{I} - \mathbf{A})^{-1}\phi^B \tag{3.22}$$

$$\xi_\pi \equiv \mathbf{e3}'(\mathbf{A} - \mathbf{A}^N)(\mathbf{I} - \mathbf{A})^{-1}\phi^B \tag{3.23}$$

We use direct forecasting to obtain inflation and real interest rate news, which forces the revision in expected excess returns to be the residual. Modeling noise may enter the residual as we cannot directly measure the excess returns on the bond as its maturity decreases over the remaining periods.[3] This approach mirrors that of Campbell and Ammer (1993). Moreover, Chen and Zhao (2009) suggest that this modeling noise is unlikely to be a main driver of the results.

3.3 Data and Sample Period

3.3.1 Data

In our main analysis, we estimate the VAR given in equation 6 for excess US equity returns and excess US bond returns. Data are as in Goyal and Welch (2008).[4] Specifically, our state variables for each excess return series are as follows.

As discussed above, we estimate a constrained VAR for excess equity returns. The state vector is given by

$$Z_t \equiv [r_{ex,t},\ r_{real,t},\ \Delta r_t,\ SPREAD_t, d_t - p_t,\ REL_t,\ \Delta D_t]' \tag{3.24}$$

where $r_{ex,t}$ is the CRSP value-weighted return in excess of the risk-free rate; $r_{real,t}$ is the real interest rate, defined as the 3-Month Treasury bill rate divided by quarterly CPI; Δr_t denotes the change in the nominal 3-Month Treasury bill rate; $SPREAD_t$ denotes the difference between

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[3]Instead of observing returns on individual bonds, our data provide returns on a constant maturity portfolio of bonds.

[4]We thank Amit Goyal for providing these data.

the yields on the 10-year T-Bill and 3-month T-Bill; $d_t - p_t$ denotes the log dividend-price ratio for the S&P 500; REL_t is the difference between the 3-Month T-Bill and its 12-month moving average; and ΔD_t is the dividend growth of the S&P 500 smoothed over 12 months. We impose two restrictions on this system. First, ΔD_t cannot feedback on the first six state variables. Second, ΔD_t is a function of the following variables: ΔD_{t-1}, $d_{t-1} - p_{t-1}$, and $r_{ex,t-1}$.

The state vector for excess bond returns is given by

$$Z_t \equiv [r_{Bond\ ex,t},\ r_{real,t},\ \pi_t,\ SPREAD_t, CREDIT_t]' \tag{3.25}$$

where $r_{Bond\ ex,t}$ is the return on the intermediate-term Treasury in excess of the risk-free rate; $r_{real,t}$ is the real interest rate, defined as the 3-Month Treasury bill rate divided by quarterly CPI; π_t denotes the change in the 12-month inflation rate; $SPREAD_t$ denotes the difference between the yields on the 10-year T-Bill and 3-month T-Bill; and $CREDIT_t$ denotes the spread between Baa and Aaa bond yields.

3.3.2 Identification of Fiscal Policy Shocks

3.3.2.1 Exogenous Tax Changes for United States

In defining our exogenous tax shocks for the United States, we follow Romer and Romer (2010). They conduct a narrative analysis that focuses on identifying all significant federal tax actions from 1947 to 2007. The sources used to identify the shocks are public government documents coming from both the executive branch (e.g. *Economic Report of the President*) and the legislative branch (e.g. *Congressional Record*). Fifty significant exogenous federal tax actions are identified and analysis is limited to tax actions that actually change tax liabilities. The size of tax changes are measured at the time of implementation and are normalized by the previous period's nominal GDP.

Common measures of tax shocks typically focus on changes in overall revenues and changes in cyclically adjusted revenues (see Blanchard and Perotti (2002)). A concern with using these measures for tax shocks is that they could reflect endogenous policy responses to the economic

environment. The goal in using the narrative analysis is to avoid the potential correlation of tax shocks with influences on aggregate outcomes. To accomplish this, federal tax actions are classified into four categories: spending-driven, countercyclical, deficit-driven, and for long-run growth. The spending-driven and countercyclical tax actions are considered endogenous tax changes because they are correlated with other forces affecting output in the short run. These tax changes are typically taken in response to current or future economic conditions, so we exclude them from our analysis.

The two tax actions we focus on are the deficit-driven tax change and the long-run tax change aimed at raising growth in the long run. Both tax changes are not motivated by current or future short-run economic conditions. We find that these tax changes have low correlations with all of our state variables, which is consistent with our goal of using exogenous shocks in our analysis. By focusing on unexpected policy actions, we can more clearly discern the stock market reaction to tax changes.

It is important to note that the timing of implementation for tax changes matters from a theoretical perspective. Yang (2005) and Leeper, Walker, and Yang (2009) point out the differences between anticipated and unanticipated tax changes. Romer and Romer (2010) take this into account and find only slight evidence of expectational effects. They find that the relationship between exogenous tax increases (when liabilities actually change) and output is robust while including a proxy for fiscal news. If anything, not correctly timing the implementation should bias our results toward showing no effects.

3.3.2.2 Exogenous Government Spending Changes for United States

For the government spending shocks, we follow Ramey (2011). Similar to Romer and Romer (2010), a narrative analysis is conducted to identify exogenous defense spending shocks from 1947 to 2012. The sources used to identify the shocks are from *Business Week* as well as several other newspaper sources because government officials have often underestimated the cost of military actions. These shocks are deemed exogenous because they are unrelated to the state of the economy or future short-run economic conditions.

In contrast to the exogenous tax shocks, Ramey (2011) points out that changes in government spending are often anticipated long before changes in government spending actually occur (e.g. years in advance), which suggests standard VARS do not properly capture the timing of spending shocks. This is addressed by calculating the present discounted value of unexpected news about current and future defense spending. These shocks are then normalized by the previous period's nominal GDP. Although the narrative analysis is admittedly subjective, we find that the defense spending shocks have low correlations with all of our state variables, which is consistent with our goal of clearly discerning the stock market reaction to government spending.

It also should be noted that unlike Romer and Romer (2010), Ramey (2011) does not try to exclude events in which both government spending and distortionary taxes rise in the same period. Our tax shocks exclude spending-driven tax changes, whereas the defense spending shocks are typically accompanied by increases in distortionary taxes during a military build-up.

3.3.2.3 Exogenous Government Spending Changes By Sector for United States

We define the industry-specific government spending shocks as in Nekarda and Ramey (2011). The data is only available on an annual basis from 1965 to 2005. The spending shocks are computed in multiple steps. First, with annual industry-specific government spending for over 275 industries, we link each of the industries by SIC code to each of the Fama and French 17 Industry Portfolios. We compute a value weighted average of the government spending based on the SICs within each Fama and French portfolio. Next, upon calculating the industry specific government spending for each Fama and French portfolio, we orthogonalize these variables with respect to the VAR state variables to obtain our exogenous spending shocks. We then estimate the effects of our orthogonalized spending shocks on the excess equity returns for each portfolio.

3.3.2.4 Exogenous Tax Changes for United Kingdom

We define the United Kingdom exogenous tax changes as in Cloyne (2013). Shocks are identified using a narrative analysis from 1945 to 2009. Detailed revenue forecasts and highly centralized tax policy allow for the categorizing of 2,500 discretionary policy changes. This translates into 60 percent of the quarters having non-zero entries for the exogenous shocks.

Similar to Romer and Romer (2010), tax policy changes that are related to the funding of spending decisions, managing demand, stimulating production, or offseting a debt crisis are considered endogenous. Shocks that are considered exogenous are those taken to improve long-run economic performance, fiscal measures based on long-run considerations, and ideological changes related to political party causes.

Cloyne (2013) tests the Granger causality of the exogenous tax shocks and finds that output, government spending, inflation, and the policy interest rate have zero coefficients. In contrast, the tax changes that are categorized as countercyclical or endogenous are found to be predictable. Furthermore, an analysis of anticipated versus unexpected shocks also shows that the decision to change taxes is not forecastable based on past information. An ordered probit model estimated by maximum likelihood shows a failure to reject the hypothesis that past information in the regression contain no information for forecasting the exogenous tax shocks.

3.3.3 Sample Period

Our analysis focuses on the post-World War II period for which we can construct a series of fiscal policy shocks, either tax policy shocks or defense spending shocks. We are therefore constrained to the period in which quarterly national income and product accounts (NIPA) are available: 1947q1 to 2012q4. Since identifying the exact announcement date for our fiscal policy shocks is difficult we restrict our analysis to estimating equations 14-17 using quarterly data.

The results presented below focus on four periods, the full sample period and three subsamples. We define the following subsamples: 1947q1-1980q2, 1980q3-2012q4 and 1980q3-2008q2. Our cutoff between 1980q2 and 1980q3 captures the Pre- and Post-Volcker period in our data.[5] We also consider ending our sample before the financial crisis to avoid structural breaks at the end of our sample where breaks are difficult to detect.

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[5]Distinguishing between these two periods is important economically as inflation targeting reduced the yields (and variation in yields) of treasuries used in our VAR specification.We confirm that the distinction between these two periods is also important statistically. Specifically, we test for multiple unknown structural breaks using the $SupW$ test of Andrews (1993). We allow for heteroskedasticity within regimes and implement the fixed regressor bootstrap of Hansen (2000) to calculate the critical values for our conditional model.

3.3.4 Bootstrap Algorithm

To calculate standard errors for our news decomposition, we follow the algorithm proposed by Maio (2013). Specifically, we estimate the VAR given in equation 6 to obtain $\widehat{A}$ and a vector of residuals, $\widehat{w}_{t+1}$. For each bootstrap replication $b = 1, ..., 1000$, we then draw with replacement a series of residuals

$$\{\widehat{w}_{t+1}^b\}, \ t = s_1^b, s_2^b, ..., s_T^b, \tag{3.26}$$

where the residuals in the VAR have the same time sequence to preserve any contemporaneous cross-correlation. We then separately draw with replacement a series of fiscal policy shocks

$$\{FISCAL_{t+1}^b\}, \ t = r_1^b, r_2^b, ..., r_T^b. \tag{3.27}$$

After estimating the effects of the fiscal shock given by equations 14-17 for each bootstrapped sample, we can construct the empirical standard error in the usual way.[6]

3.4 Results

Throughout the paper we report results that are quarterly for the full sample period 1947q1-2012q4, as well as for subsamples 1947q1-1980q2, 1980q3-2008q2, and 1980q3-2012q4. The initial period for the full sample is constrained by the availability of our data, specifically the quarterly tax shocks of Romer and Romer (2010). The breaking point of 1980q2 is consistent with the notion of a major shift in monetary policy, which we refer to as Pre-Volcker and Post-Volcker. A test for a structural break confirms this date as an acceptable point at which to split the data. We also focus on two different windows for the Post-Volcker era, with the difference being the exclusion of the financial crisis of 2008.

Table 3.1 reports basic summary statistics about the state variables included in our benchmark

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[6]Since both the residual draws for the VAR and the fiscal policy shock draws are independent, we term this bootstrap algorithm an independent-independent algorithm. We consider two additional algorithms: a block-independent algorithm and a block-block algorithm. In these cases, the block draw is a stationary bootstrap, or a moving block bootstrap where block size is varied randomly. See Politis and Romano (1994) for additional details. Results are quantitatively similar using either of these alternative algorithms.

VAR. The standard deviations are reported in the first column and the remaining entries represent correlations. A few points are worth mentioning. First, as one might expect, the excess equity return has the highest volatility amongst the state variables. Furthermore, the excess equity return and excess bond return have a very low correlation. Both of these features are consistent with the smaller sample periods (not shown) and the data used in Campbell and Ammer (1993).

The major takeaway coming from Table 3.1 is that our exogenous tax shocks as defined by Romer and Romer (2010) along with our defense spending shocks as defined by Ramey (2011) have very low correlations with the rest of the variables in the VAR. This suggests that even though the shocks are coming from narratives, their lack of correlation with the other state variables appears to be consistent with our assumption of their exogeneity. Although small, the correlation of both exogenous shocks with respect to the excess equity return is positive.

The potential channels through which this positive correlation could be operating include the negative correlation between the change in the T-Bill and the tax shocks, reflecting the possibility of lower crowding out as taxes rise, holding all else constant. Lower crowding out would entail lower discount rates and higher current equity excess returns. In addition, the observed negative correlation between the dividend yield and the tax shocks is consistent with higher taxes being associated with lower cash-flow news. These correlations are broadly concurrent with our more formal analysis of the effects of fiscal policy on discount rate news and cash-flow news below.

3.4.1 The Effects of Exogenous Tax Shocks on Excess Returns

This section focuses on the effects of tax shocks as identified by Romer and Romer (2010). We proceed by first discussing the effects on the aggregate stock market, followed by a discussion of the effects on the excess returns of 10 year T-Notes.

3.4.1.1 The Effects of Exogenous Tax Shocks on Equity

Table 3.2 shows the effect of exogenous tax shocks on the current unexpected excess return, future excess return news, real interest rate news, and cash-flow news. Significance is found for both Post-Volcker periods for the current excess return, real interest rate news, and the residual

cash-flow news coming from the Campbell and Ammer (1993) method. In words, a one percent increase in tax revenues as a percentage of GDP results in a 7.7615% increase in the unexpected excess equity return. This increase in the unexpected return is coming from the 9.47% decrease in real interest rate news. As real interest rate news declines, the return rises because the cash-flows are being discounted at a lower rate.[7]

The cash-flow news based on the Chen and Zhao (2009) direct modeling of dividends yields an insignificant coefficient, regardless of the time period. In contrast, the Campbell and Ammer (1993) residual cash-flow method yields a negative effect of taxes on future cash-flow news. Cash-flow news reflects future expected dividends that are the result of production and profits.

3.4.1.2 The Effects of Exogenous Tax Shocks on Bonds

Table 3.3 shows the effect of tax shocks on the current unexpected excess return on the 10 year T-Note, future bond excess return news, real interest rate news, and inflation news. None of the time periods result in a significant effect on the current unexpected excess return. However, both the future bond excess return news, real interest rate news, and inflation news channels are significant for the Pre-Volcker period. Exogenous increases in taxes are associated with a -9.69% drop in inflation news.

The fall in inflation news is consistent with higher future expected excess bond returns. The combination with the positive effects on real interest rates appears to cancel out the overall effect on the current excess bond return. One should notice that in the previous analysis the effect of taxes on real interest rate news was negative. However, this change in sign is perfectly consistent with the above equity analysis as the time period is now the Pre-Volcker period as opposed to the Post-Volcker period. The relationship between inflation and real interest rates flips going from

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[7]The concurrent effects of monetary policy are frequently suggested as a possible issue with our estimation. We address this concern in two ways. First, we incorporate the federal funds rate as an additional state variable and find quantitatively similar results. Second, we perform a Hall (1988) and Evans (1992) test by regressing our tax shocks on the monetary policy shocks used in Bernanke and Kuttner (2005). Specifically, we regress our tax shocks on four lags of our tax shocks, contemporaneous monetary policy shocks and four lags of monetary policy shocks. We fail to reject the hypothesis of exogeneity (p-value = 0.4649) over the period where both of these shocks are available, 1989Q2 to 2008Q2.

Pre-Volcker to Post-Volcker, as discussed in Section B.3.2.

3.4.2 The Effects of Exogenous Shocks to Defense Spending on Excess Returns

This section focuses on the effects of defense spending shocks as identified by Ramey (2011). We proceed by first discussing the effects on the aggregate stock market, followed by a discussion of the effects on the excess returns of 10 year T-Notes.

3.4.2.1 The Effects of Exogenous Shocks to Defense Spending on Equity

Table 3.4 lists the effects of defense spending shocks. Given the limited scope of the shocks, as they pertain strictly to the defense industry, we find no significance for the current unexpected excess return or any of the channels based on the Campbell and Ammer (1993) residual method. While we do find a positive significant effect on the cash-flow channel based on the Chen and Zhao (2009) method of directly modeling dividends, we also find an equally signficant negative effect on the residual, which in effect cancels out the positive effect on the cash-flow news channel. The limited scope of the defense spending shocks on the entire stock market would suggest a focus on a smaller subset of stocks that are directly affected by defense spending would be more appropriate. We explore this idea in Section 3.5.1.2.

3.4.2.2 The Effects of Exogenous Shocks to Defense Spending on Bonds

Table 3.5 shows no significance on any of the channels with the exception of the effect on inflation news for the entire sample. In words, a one percent increase in government spending as a ratio of nominal GDP raises future inflation news 0.39%. The increase in aggregate demand due to higher government spending is consistent with textbook theory that would suggest higher inflation. In addition, although the effect on real interest rate news is insignificant, the positive effect for the Post-Volcker time period is fully consistent with a standard New Keynesian DSGE model.

While these tests provide little evidence of the impact of government spending shocks on market returns, there are several reasons why this finding may be the case. First over our sample period, there have been relatively few shocks to defense spending. This resulting lack of power is consistent with many of the signs of our results being in the hypothesized direction but the

absence of statistical significance. Second, these shocks to defense spending may be funded by distortionary taxes. If these two shocks to fiscal policy work in opposite directions as hypothesized, changes to tax policy concurrent with defense spending shocks would bias against finding results. Third, defense spending may be concentrated in a few firms with relatively few spillovers to other industries due to input-output linkages. When aggregate to the market as a whole, this concentrated loading on defense spending may be muted, consistent with out lack of findings. We explore industry-specific sensitivities to government spending in the next section.

3.5   Additional Tests

In this section, we discuss results from cross-sectional variation in the exposure to our exogenous shocks to fiscal policy and the effects of exogenous tax shocks on excess returns in the UK.

3.5.1   Cross-sectional Results

To begin, we explore cross-sectional variation in the impact of exogenous fiscal policy shocks on excess stock returns and the specific news channels through which these shocks operate. Our approach follows that of Maio (2013) in that we sort stocks into portfolios based on specific stock characteristics which should proxy for differential exposures to the fiscal policy shocks. We then calculate value-weighted returns for each of these portfolios and consider the impact of fiscal policy surprises on the news components of current unexpected excess returns.[8] For these portfolios, the state vector for the VAR associated with portfolio p is given by

$$Z_t^p \equiv [r_{ex,t}^p,\ r_{real,t},\ \Delta r_t,\ SPREAD_t,\ d_t - p_t,\ REL_t]' \tag{3.28}$$

where $r_{ex,t}^p$ is the excess return of portfolio p in quarter t and the other state variables are as defined above. In this specification, we proxy portfolio-specific dividend growth with aggregate dividend

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[8]Results are quantitatively similar if portfolio returns are equally-weighted. These results are available from the authors upon request.

growth.[9]

3.5.1.1 The Effects of Exogenous Tax Shocks on Specific Industries

Changes to tax policy could have a differential impact on firms with different marginal tax rates. For example, low marginal tax rate firms may receive preferential treatment from progressive changes to tax policy relative to high marginal tax rate firms. This preferential treatment would manifest itself in higher current excess returns. The increase in returns may be attributable to news about discount rates. Consider a simple tradeoff model where tax policy increases and the shift is more progressive. The present value of the tax shield increases so firms take on more debt with the increase in leverage disproportionately coming from high MTR firms. Since cost of equity is increasing in leverage, high marginal tax rate firms have higher future excess returns. Alternatively, the increase in returns may be attributable to news about cash flows. This evidence would be consistent with a new tax policy where net transfers to firms are more progressive after the policy.

To proxy for differences in firm exposure to changes in tax policy, we consider a firm's marginal tax rate as calculated in Graham and Mills (2008).[10] Changes to either tax rates or transfers within these groups would generate differences in these marginal tax rate portfolios' current excess stock

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[9] We also consider an alternative VAR specification given by

$$Z_t^p \equiv [r_{ex,t}^p,\ r_{real,t},\ \Delta r_t,\ SPREAD_t,\ d_t^p - p_t^p,\ REL_t]' \tag{3.29}$$

where $d_t^p - p_t^p$ is the log dividend price ratio for portfolio p in quarter t. In this specification, portfolio-specific dividend growth is proxied by the value-weighted dividend growth. The dividend-price ratio of portfolio p is given by

$$\frac{D_{p,t+1}}{P_{p,t+1}} = R_{p,t+1} R_{p,t+1}^* - 1, \tag{3.30}$$

and the dividend growth of portfolio p is given by

$$\frac{D_{p,t+1}}{D_{p,t}} = R_{p,t+1} - R_{p,t+1}^* R_{p,t} R_{p,t}^* R_{p,t}^*. \tag{3.31}$$

$D_{p,t+1}$ denotes the dividend level for portfolio p in quarter $t+1$. $P_{p,t+1}$ denotes the price level for portfolio p in quarter $t+1$. $R_{p,t+1}$ denotes the gross return for portfolio p in quarter $t+1$. $R_{p,t+1}^*$ denotes the gross return excluding dividends for portfolio p in quarter $t+1$. Results using this alternative specification are qualitatively similar to the reported results and are available upon request.

[10] We thank John Graham for making these data available. For additional details regarding the simulation of firms' marginal tax rates, see Graham (1996a) and Graham (1996b).

returns or the news components of these returns.

Following Fama and French, we form tercile portfolios in June of year t using simulated marginal tax rates at year end for fiscal year $t-1$. After calculating the smoothed dividend growth and dividend-price ratio for these portfolios, we can estimate portfolio responses from 1982q4 to 2012q4.

Table 3.6 reports these results. Overall results are qualitatively similar to the aggregate market results reported in Table 3.2. Specifically, current excess returns rise in response to shocks to tax policy with these returns primarily being generated by a decrease in real interest rate news. For both sample periods, current excess returns decrease monotonically with marginal tax rates consistent with either a more progressive tax policy or more progressive transfers stemming from the fiscal policy shock. However, the differences across these extreme portfolios are not significant. The estimated difference in current excess returns does not appear to be due to a differential impact of news about real interest rates across the portfolios. Rather, the majority of the difference is attributable to unmodeled noise.

3.5.1.2 The Effects of Exogenous Shocks to Defense Spending on Specific Industries

We isolate the effects of government defense spending on portfolios likely to be the beneficiaries of such spending. Specifically, we focus on Sectors 10 and 13 of the Fama and French 17 Industry Portfolios[11], which fall under the category of Fabricated Products and Transportation, respectively. The Fabricated Products Sector seems appropriate to further isolate the effects of the exogenous shocks to defense spending as it includes industries such as Sheet Metal Work and Ordnance & Accessories. Similarly, the Transportation Sector includes industries such as Aircraft, Aircraft Engines and Parts, Ship Building and Repair, Guided Missiles and Space Vehicles, and Tanks & Tank Components.[12]

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[11]We would like to thank Kenneth French for providing both the industry definitions and return series for each industry.

[12]The decision to include these industries is two-fold. First, these sectors contain industries with the largest share of shipments to the government as reported in Table 1 of Nekarda and Ramey (2011). Second, these sectors contain SIC codes found in the Aircraft, Shipbuilding/Railroad Equipment, and Defense industries in the Fama and French 48

As shown in Table 3.8, a one percent increase in the ratio of government spending to nominal GDP is found to have a significant 0.97% to 1.18% effect on cash-flow news, depending on industry and time period. The cash-flow channel appears to dominate bad news from unmodelled noise, as the overall effect on the current excess returns is positive, albeit insignificant.

3.5.1.3 The Effects of Industry-specific Government Spending Shocks

The goal of this section is to move beyond the defense industry and analyze the effects of government spending on other sectors. To accomplish this, we turn our attention to industry-specific government spending, as defined in Nekarda and Ramey (2011). They focus on the industry-specific effects of government spending on output and hours, whereas we restrict attention to the effects on excess equity returns. As shown in Table 3.7, we find a significant positive effect on cash flows for the Food Sector (1) and the Clothing and Textiles Sector (4). In addition, over 3/4 of the Fama and French portfolios show evidence of a positive effect on future cash flows, although not all are significant. The positive effects on cash flows translates into significant positive excess returns for the Construction Sector (9) and the Machinery Sector (11).

As before, our lack of findings relating government spending shocks to market returns is consistent with the notion that these spending shocks are funded through changes to tax policy. These changes to distortionary taxes concurrent with our government spending shocks may bias us against finding a result.

3.5.2 The Effects of Exogenous Tax Shocks on UK Returns

We extend our analysis beyond the United States to the UK stock market and focus on the effects of exogenous tax shocks in the UK. Although financial markets in these two countries are similar, differences in corporate marginal tax rates and differences in the reliance on deficit

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industry classification. It should be noted that Fama and French provide other industry definitions that split the stock market into 5 industries and all the way up to 49 industry portfolios. We found that more refined specifications of industry portfolios resulted in some portfolios with as little as 5 firms throughout the time period, making it difficult to detect any significance due to the higher level of noise. The choice of focusing on the 17 Industry Portfolios allowed us to greater isolate the potential effects of defense spending while not yielding a substantial increase in idiosyncratic volatility as the number of firms in each portfolio is often greater than 100.

spending may drive differences in the impact of tax shocks on excess equity and bond returns across the two countries.

We obtain data for the UK analogues of our US state variables from Global Financial Data from 1966 to the present. Exogenous tax shocks are defined in a similar manner to Romer and Romer (2010) and are obtained from Cloyne (2013) for the years 1947 to 2009. We split the data into a subsample starting in the second quarter of 1975 in order to avoid the 75% aggregate stock market return that occurred in the first quarter of 1975. For the subsample starting in 1975, we find that a one percent increase in taxes relative to GDP results in a significant 7.16% drop in real interest rate news. This result is quantitatively consistent with the Post-Volcker era for the US stock market in which there was a 9.47% drop in real interest rate news.

In contrast to the effects of tax shocks on the US stock market, we find that UK tax shocks have a significant positive effect on inflation news. However, this channel is dominated by the fall in interest rate news as the overall effect on the current excess bond return is positive. This positive but insignificant effect of taxes on the current excess bond return is consistent with what we observe for the US in Table 3.3.

3.6 DSGE Simulation

This sections provides model predictions for the effects of fiscal policy on equity returns based on the dynamic stochastic general equilibrium model of Schmitt-Grohé and Uribe (2007). Following a typical parameter specification and calibration, we show that higher taxes result in lower real interest rate news and lower cash flow news using simulated data coming from the general equilibrium model. We also show that if monetary policy places a greater weight on output, the effect of higher taxes on the discount rate and cash flow channels may flip signs.

3.6.1 Households

The economy is populated by a continuum of identical infinitely lived households. Each household has preferences defined for consumption, c_t, and labor hours, h_t. Preferences are based on the standard CRRA utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{(c_t^{\iota}(1 - h_t)^{1-\iota})^{1-\sigma} - 1}{1 - \sigma} \qquad (3.32)$$

where E_t denotes the expectations operator conditional on information available at time t, $\beta \in (0, 1)$ is the subjective discount factor, c_t is the consumption, and h_t is labor. The consumption good is assumed to be a composite good produced with a continuum of differentiated goods, c_{it}, $i \in [0, 1]$, via the aggregator function

$$c_t = \left[\int_0^1 c_{it}^{1-1/\eta} di \right]^{1/(1-1/\eta)} \qquad (3.33)$$

where the parameter $\eta > 1$ denotes the intratemporal elasticity of substitution across different varieties of consumption goods. For any given level of consumption of the composite good, purchases of each variety i in period t must solve the dual problem of minimizing total expenditure, $\int_0^1 P_{it} c_{it} di$ subject to the aggregation constraint above, where P_{it} denotes the nominal price of a good of variety i at time t. Upon solving this problem, the optimal level of c_{it} is given by $c_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} c_t$ and P_t is a nominal price index given by $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di \right]^{1/(1-\eta)}$. This price index has the property that the minimum cost of a bundle of intermediate goods yielding c_t units of the composite good is given by $P_t c_t$.

Households are assumed to have access to a complete set of nominal contingent claims. The household's budget constraint is given by

$$E_t d_{t,s} \frac{x_{t+1}}{P_t} + c_t + i_t = \frac{x_t}{P_t} + (1 - \tau_t^D) \cdot (w_t h_t + u_t k_t) + \delta q_t \tau_t^D k_t + \phi_t \qquad (3.34)$$

where $d_{t,s}$ is the stochastic discount factor, defined such that $E_t d_{t,s} x_s$ is the nominal value in period t of a random nominal payment x_s in period $s \geq t$. The variable i_t denotes investment, τ_t^D is the distortionary income tax rate, w_t is the real wage, u_t is the rental rate of capital, k_t denotes capital, and q_t denotes the market price of one unit of installed capital. The term $\delta \tau_t^D q_t k_t$ denotes deprecation allowance for tax purposes and ϕ_t denotes profits received from ownership of firms

net of income taxes.

The evolution of capital is given by

$$k_{t+1} = (1-\delta)k_t + i_t \Psi_t \left(\frac{i_t}{i_{t-1}} \right) \tag{3.35}$$

where the function Ψ represents investment adjustment costs that take the form $\Psi(x) = 1 - \frac{\psi}{2}(x - 1)^2$ and ψ is a positive constant set equal to 2.48 in line with Christiano, Eichenbaum, and Evans (2005a). Without adjustment costs on investment, the price of capital (or aggregate stock market price) would never change because the supply would be perfectly elastic and always equal to one. Households are assumed to be subject to a borrowing limit that prevents them from engaging in Ponzi schemes.

3.6.2 The Government

The government issues one-period nominal risk-free bonds, B_t, collects tax revenues $P_t \tau_t$, and spends an exogenous amount each period, g_t. In real terms, the government's budget constraint is

$$b_t = \frac{R_{t-1}}{\pi_t} b_{t-1} + g_t - \tau_t \tag{3.36}$$

where lower case letters denote real values, $\pi_t \equiv P_t/P_{t-1}$ denotes gross consumer price inflation, R_t denotes the gross one-period risk free nominal interest rate in period t.

Total tax revenues are $\tau_t = \tau_t^D y_t$. The fiscal rule is defined so that tax revenues must rise with debt

$$\tau_t = \tau^* + \gamma_1 (R_{t-1} b_{t-1} - R^* b^*) \tag{3.37}$$

where γ_1 denotes how fast taxes are paid back, τ^* and B^* denote the deterministic steady state values of τ_t and B_t respectively.

To analyze the effect of tax shocks, a normal, mean zero shock is appended to the tax revenue equation such that

$$\frac{\tau_t}{y_t} = \tau_t^D + \epsilon_t^{tax}. \tag{3.38}$$

The standard deviation is set to match the standard deviation of the tax shocks coming from Romer and Romer (2010).

The monetary authority sets the short-term nominal interest rate according to a simple feedback rule.

$$\ln(R_t/R^*) = \alpha_r \ln(R_{t-1}/R^*) + (1 - \alpha_r)\left[\alpha_\pi \ln(\pi_t/\pi^*) + \alpha_y \ln(y_t/y^*)\right] \qquad (3.39)$$

where y^* denotes the deterministic steady state of output.

3.6.3 Firms

Each variety $i \in [0, 1]$ is produced by a single firm in a monopolistically competitive environment. The production technology is given by $z_t k_{it}^\theta h_{it}^{1-\theta} - \chi$ where χ denotes fixed costs and z_t denotes an exogenous, aggregate productivity shock.

Aggregate demand for good i is denoted by $a_{it} = c_{it} + i_{it} + g_{it} = (P_{it}/P_t)^{-\eta}a_t$ given the aggregation constraint. It is assumed that the firm must satisfy demand at the posted price so that firms maximize expected profits subject to the following constraint

$$z_t k_{it}^\theta h_{it}^{1-\theta} - \chi \geq \left(\frac{P_{it}}{P_t}\right)^{-\eta} a_t \qquad (3.40)$$

Prices are assumed to be sticky as in Calvo (1983). Each period a fraction $\alpha \in [0, 1)$ of randomly picked firms are unable to change the nominal price of the good it produces. The remaining (1-α) firms choose prices optimally.

3.6.4 Calibration

The deep structural parameters have been set to the values in Schmitt-Grohé and Uribe (2007). Since the goal of Schmitt-Grohé and Uribe (2007) was to determine optimal policy and not necessarily to match empirical moments when specifying fiscal and monetary policy, we turn to prior literature to set the remaining parameters in our model. The four parameters that we are unable to obtain directly from Schmitt-Grohé and Uribe (2007) are γ_1, the speed of tax repayment, α_π, the

Parameter	Value	Description
σ	2	Relative Risk Aversion
θ	0.3	Cost share of capital
β	0.99	Quarterly subjective discount rate
η	5	Price Elasticity of Demand
δ	0.025	Quarterly Depreciation Rate
α	0.8	Share of firms that can change price each period
ι	3.6133	Set to match Labor = 0.2
Ψ	2.48	Investment Adjustment Cost Parameter (CEE 2005)
χ	0.0968	Fixed cost parameter
ρ_G	0.87	Serial correlation of government spending
σ^{ϵ_G}	0.016	Standard deviation of innovation to government purchases
ρ_z	0.8556	Serial correlation of productivity shock
σ^{ϵ_z}	0.0064	Standard deviation of innovation to productivity shock
ρ_τ	0.997	Serial correlation of tax shock
σ^{ϵ_τ}	0.0022	Standard deviation of innovation to tax rate Romer and Romer (2007)

inflation coefficient, α_y, the output coefficient, and α_R, the inertia coefficient in the monetary policy rule. For fiscal policy, our choice for the speed of tax repayment comes from recent estimates by Drautzburg and Uhlig (2011), which we set to 0.03.

For monetary policy, the inertia coefficient is set to 0.9 which is consistent with recent estimates by Christiano, Rostagno, and Motto (2010). We set the inflation coefficient for the post-Volcker era to 1.5 and the output gap coefficient to 0.5/4, which is consistent with Taylor (1993) and Smets and Wouters (2007). For our pre-Volcker era simulation, we modify only one parameter and that is the weight on the output gap. There is a consensus that greater weight was placed on output during this time period, and our weight of 0.85/4 is consistent with the estimation of Smets and Wouters (2007).

3.6.5 DSGE Results

Our DSGE model results present the exact mapping from the initial fiscal policy shock to the endogenous responses of returns and cash flows implied by the solution to the model. We solve the model by taking a second order approximation of the nonlinear equilibrium conditions. Since we observe the responses to returns and cash flows directly in our model economy, it is unnecessary to use a vector autoregression to estimate the effects of tax and government spending shocks on

news about future excess returns, interest rates, and cash-flows.[13] The effect that our shocks have on news is computed by finding the discounted ($\rho = 0.9962^3$) sum of the responses following the shock to fiscal policy.[14]

We start with a discussion of the impact of an exogenous tax shock on the economy as depicted in Figure 3.1. Then, we consider the impact of the tax shock on stock returns through the channels of discount rate news and cash flow news.

Figure 3.1 presents the impulse response functions for an exogenous tax shock. Our discussion starts with the dynamics for the Post-Volcker era calibration. At the onset of the tax shock, permanent income declines causing consumption growth to fall. The fall in consumption growth is consistent with a lower real risk free rate, as agents engage in precautionary savings to smooth the associated fall in future consumption. This explains the negative effect on real interest rate news. The fall in consumption growth also raises marginal utility so the stochastic discount factor also rises. Monetary policy amplifies the negative effect on the discount rate by further reducing nominal rates in response to the negative demand shock. The discount effect dominates the negative cash-flow effect (coming from lower output) so that the price of equity rises initially. The rise in the price of equity helps explain the positive current excess return.

To understand the dynamics for the Pre-Volcker era, note that monetary policy responds more forcefully to deviations of output in this calibration. Upon the higher tax shock, monetary policy's greater emphasis on output is taken into account by households and acts like a "put" or insurance. The positive effects of monetary policy's reaction dominates the negative fiscal policy shock, which leads to an increase of consumption growth and a corresponding rise in the real interest rate. The relatively higher output for the Pre-Volcker policy leads to a positive effect on future cash flows, but this effect is dominated by the positive real interest rate and future excess return news. The current excess return declines due to the fall in the price of equity in the initial period of the shock,

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[13]Alternately, we can estimate our empirical VAR specification using simulated data from our DSGE model. Results are quantitatively similar and available from the authors upon request.

[14]In keeping with this goal of consistency with our empirical results, we also compute cash-flows news for excess equity returns and future excess bond returns as residuals within our DSGE framework.

which is due to the higher discount channel dominating.

Table 3.10 reports the discounted sum of these effects on equity returns, which can be compared to the empirical evidence in Table 2. Note that the signs match up between Table 2 and Table 10 for the effect on each channel and for both time periods. More importantly, the magnitudes predicted by the model are all within one standard error of their empirical counterparts.

In addition to the above analysis, changes to tax policy could have a differential impact on firms with different marginal tax rates. To provide a rough benchmark for our cross-sectional results regarding high vs. low marginal tax rate firms, we consider an additional calibration of our model when firms are subject to higher taxes. In this high marginal tax rate calibration, we set the marginal tax rate to 35% versus 17% for the baseline Post-Volcker setup. Upon a one percent tax increase, we find that the high MTR results in a greater negative cash flow effect which contributes to a lower current excess return.

Table 3.11 reports the discounted sum of these effects on bond returns. For the Pre-Volcker era, our DSGE model predicts that both current excess bond returns and real interest rate news will be positive while inflation news will be negative. The negative inflation news component dominates in the simulated data. In our theoretical framework, inflation responds negatively because firms find it optimal to lower prices as future expected marginal costs are relatively lower compared to future expected marginal revenues. The higher expected marginal revenues is a result of monetary policy placing upward pressure on output after the positive tax shock.

We now focus on the impact of an exogenous shock to government spending implied by our model. Government spending shocks are frequently more short-lived than tax shocks. It is for this reason, the effects of government spending are much smaller in magnitude on forward-looking asset prices compared to the permanent tax shocks. Furthermore, given that our model is general equilibrium, increases in government spending are associated with higher future tax rates that are necessary to balance the budget. Our model predicts that high government spending is associated with higher inflation, higher real interest rate news, and lower current excess bond returns, which can be seen in Table 3.11. It also predicts that the price of equity will be largely unaffected for the

Post-Volcker period. The Pre-Volcker period leads to a sizable decline in the price of equity due to the higher discount rates coming from higher consumption growth. The higher consumption growth is due to the positive effects of monetary policy in response to the higher government spending shock and associated higher future taxes.

Overall, a major takeaway from this theoretical exercise is that the effects of fiscal policy are highly dependent upon the reaction of monetary policy. Monetary policy can amplify/diminish the discount rate channel depending on the relative weight on output, which also can affect the cash flow channel, as shown above. To recap, direct comparisons of the effects on the cash flow and discount rate channels are shown in Table 2 and Table 10. Table 2 provides the empirical evidence while Table 10 is the theoretical counterpart in the context of our New Keynesian DSGE model. The theoretical model is able to match the signs for the Pre-vs-Post Volcker periods, which is rationalized with the change of just one parameter, the weight on output.

3.7   Conclusion

Our study provides a positive answer on how fiscal policy affects the stock market by using a news decomposition. The news decomposition allows us to split the variation in unexpected stock market returns into three fundamental components: news about future excess returns, news about future interest rates, and news about future cash flows or dividends. Explaining the relative influence of each channel is important because it provides the empirical foundation for modeling the theoretical relationship between asset prices and fiscal policy.

We examine the effects of both tax shocks and spending shocks. Out of the two types of fiscal policy, we find that taxes have the most significant and robust effects on the stock market. For the Post-1980 era, increased taxes have a significantly positive effect on the unexpected excess return despite the significant fall in future cash flows based on the Campbell and Ammer (1993) method. This is because the decrease in real-interest-rate news dominates the fall in future cash flows. With cash flows being discounted at a lower rate, the excess return rises in response to higher taxes. This finding is consistent with our standard New Keynesian DSGE model, as the fall in consumption growth due to higher taxes is associated with lower real interest rates. For the Pre-1980 era, the

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effects on the cash flow and discount rate channel flip signs as monetary policy provides insurance against the higher tax shock. This theoretical prediction is confirmed by our empirical evidence, as we no longer find significance for this time period and the effects on the channels become positive.

Government spending is an equally important component of fiscal policy, although we find less significance when compared to the effects of tax shocks. With regards to defense spending shocks, we find a positive significant effect on directly modeled cash flow news. Our findings may be less significant than the case with taxes due to statistical lack of power, changes to distortionary tax policy concurrent with government spending shocks, or the benefactors of government spending contracts being a relatively small subset of the market as a whole. Furthermore, the government spending shocks are more temporary in nature than our observed tax shocks, which also implies a smaller quantitative effect on forward-looking asset prices.

To better isolate the effects of fiscal policy, we further examine the industry specific effects of tax shocks and defense spending shocks and continue to find significance. Finally, we extend our analysis to the international setting and show that UK fiscal policy has similar significant effects on the UK stock market.

Overall, our study documents the channels through which fiscal policy has significant effects on asset prices using a news decomposition. We have shown that many of the predictions of a standard New Keynesian model are fully consistent with our empirical findings. Specifically, the stance of monetary policy is very important in determining the effects of fiscal policy on financial markets. Future research should focus on whether or not the effects we find are state-dependent, to see if the impact depends on whether or not the economy is in a recession or expansion.

Figure 3.1: DSGE Impulse Response Functions for Exogenous Tax Shock

This figure presents quarterly percent deviations from the steady state for a positive shock to the tax rate. All parameters are calibrated to the values reported in Section 3.6.
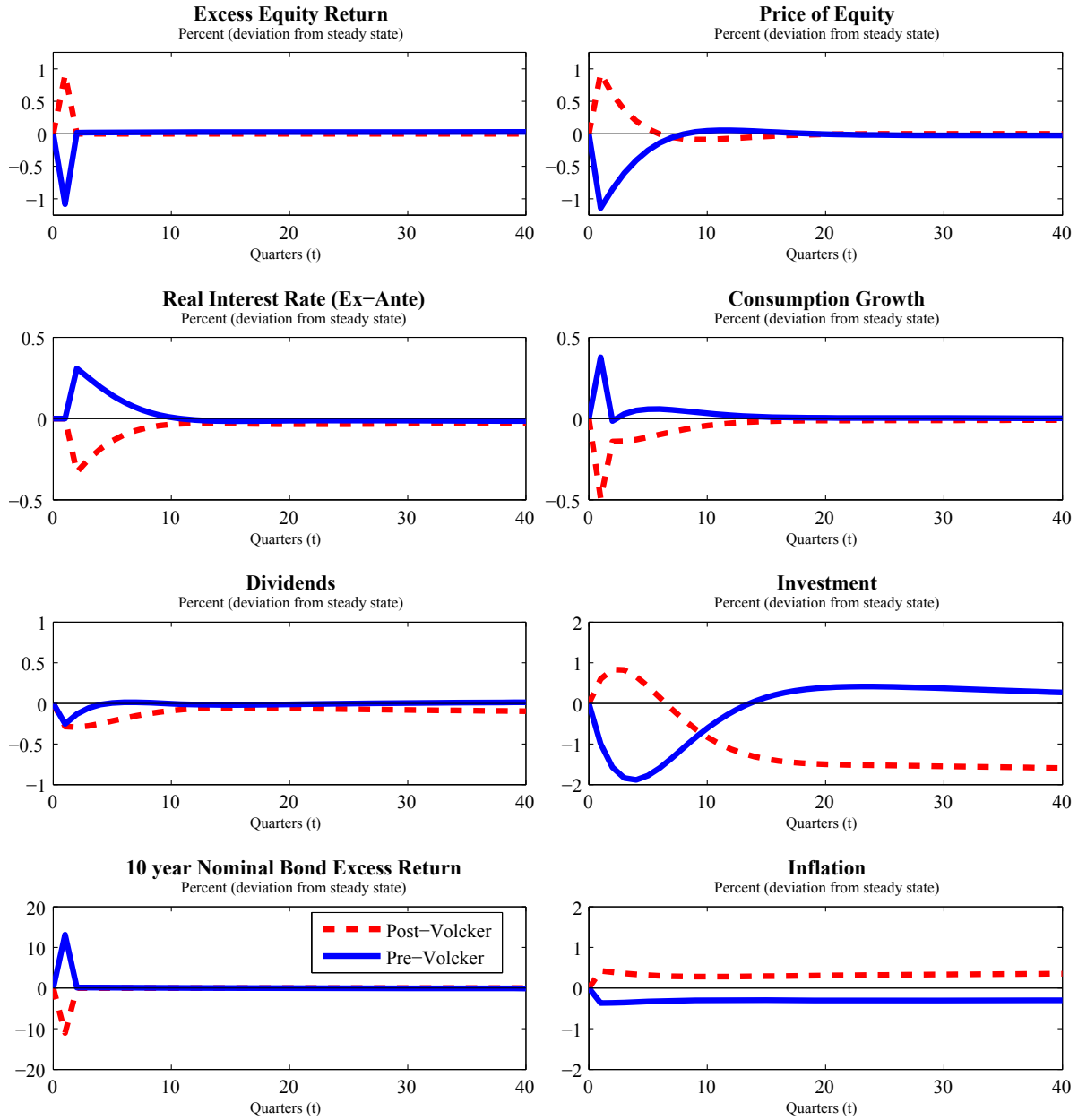
Figure 3.2: DSGE Impulse Response Functions for Exogenous Govt. Spending Shock

This figure presents quarterly percent deviations from the steady state for a positive shock to government spending. All parameters are calibrated to the values reported in Section 3.6.
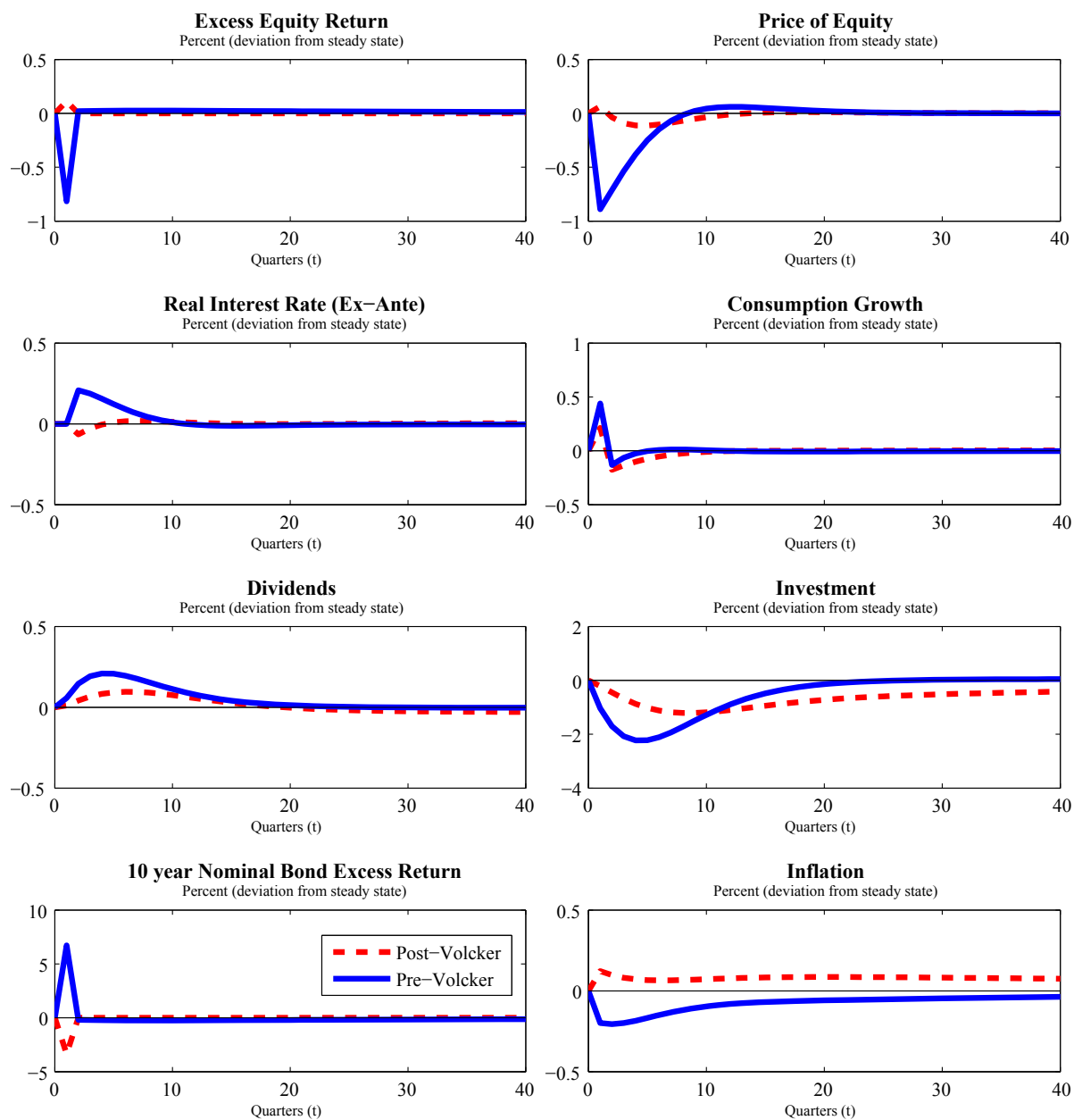
Table 3.1: Correlation Matrix for VAR State Variables and Fiscal Policy Shocks

This table reports the standard deviations and correlations for the VAR state variables, the exogenous tax shocks, and the exogenous shocks to defense spending for the full sample of 1947q1 to 2012q4. The exogenous shocks are normalized by the nominal GDP from the previous period. The VAR state variables are defined in the text. Exogenous tax shocks are defined as in Romer and Romer (2010). Exogenous shocks to defense spending are defined as in Ramey (2011).

	Std. Dev.	$r_{ex,t}$	$r_{Bond\ ex,t}$	$r_{real,t}$	Δr_t	$SPREAD_t$	$d_t - p_t$	REL_t	Romer Tax Shocks/GDP$_{t-1}$
$r_{ex,t}$	7.827								
$r_{Bond\ ex,t}$	5.090	0.044							
$r_{real,t}$	3.806	0.018	0.230						
Δr_t	0.953	-0.082	-0.522	-0.070					
$SPREAD_t$	1.379	0.115	0.214	-0.048	-0.327				
$d_t - p_t$	0.437	-0.032	-0.076	-0.076	0.008	-0.241			
REL_t	1.017	-0.139	-0.434	-0.111	0.746	-0.541	0.046		
Romer Tax Shocks/GDP$_{t-1}$	0.222	0.028	0.050	0.001	-0.116	0.038	-0.060	0.027	
Ramey Defense Shocks/GDP$_{t-1}$	4.631	0.092	-0.050	-0.228	0.019	-0.070	0.148	0.036	0.002

Table 3.2: The impact of exogenous tax shocks on dividends, interest rates, and future excess equity returns

This table reports the impact of exogenous tax shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future dividends (cash flows). Both the Chen and Zhao (2009) and Campbell and Ammer (1993) methods of computing cash flow news are provided. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. Exogenous tax shocks are defined as in Romer and Romer (2010). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Current Excess Return	1.771	−3.772	7.762**	8.236**
Future Excess Return	−1.469	5.413	−3.651	−4.099
Real Interest Rate News	1.287	1.096	−9.472***	−9.958***
Cash Flow News	2.769	4.272	18.486	5.195
Residual	−1.180	−1.534	−23.846**	−11.015**
CA (1993) Cash Flow Residual	1.588	2.738	−5.361**	−5.820***

Table 3.3: The impact of exogenous tax shocks on bond returns, interest rates, and inflation

This table reports the impact of exogenous tax shocks on the current excess bond return, and the discounted sums of future excess bond returns, current and future real interest rates, and current and future inflation. The five-variable VAR(1) used to construct excess bond return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. Exogenous tax shocks are defined as in Romer and Romer (2010). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Current Excess Bond Return	1.130	0.248	0.309	0.842
Future Excess Bond Returns	4.669**	4.934**	4.209	3.244
Real Interest Rate News	0.552	4.514**	-2.369	-2.084
Inflation News	-6.352**	-9.695**	-2.149	-2.002

Table 3.4: The impact of exogenous defense spending shocks on dividends, interest rates, and future excess equity returns

This table reports the impact of exogenous shocks to defense spending on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future dividends (cash flows). Both the Chen and Zhao (2009) and Campbell and Ammer (1993) methods of computing cash flow news are provided. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. Exogenous shocks to defense spending are defined as in Ramey (2011). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Current Excess Return	0.118	0.109	−0.362	−0.918
Future Excess Return	0.095	0.138	0.277	0.586
Real Interest Rate News	−0.236	−0.238	−0.598	0.314
Cash Flow News	1.189**	1.007*	−1.144	−0.613
Residual	−1.212**	−0.998*	0.462	0.594
CA (1993) Cash Flow Residual	−0.023	0.009	−0.683	−0.018

Table 3.5: The impact of exogenous defense spending shocks on bond returns, interest rates, and inflation

This table reports the impact of exogenous shocks to defense spending on the current excess bond return, and the discounted sums of future excess bond returns, current and future real interest rates, and current and future inflation. The five-variable VAR(1) used to construct excess bond return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. Exogenous shocks to defense spending are defined as in Ramey (2011). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Current Excess Bond Return	−0.035	−0.023	−0.649	−0.131
Future Excess Bond Returns	−0.268	−0.190	−0.085	−0.254
Real Interest Rate News	−0.095	−0.208	0.235	0.078
Inflation News	0.397*	0.421	0.498	0.307

Table 3.6: The impact of exogenous tax shocks on portfolios formed on marginal tax rates

This table reports the impact of exogenous tax shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future dividends (cash flows) for portfolios formed on marginal tax rates. Both the Chen and Zhao (2009) and Campbell and Ammer (1993) methods of computing cash flow news are provided. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. Following Fama and French, we form three value-weighted portfolios at the end of June of each year t based on simulated marginal tax rates from Graham and Mills (2008). $Low\ MTR$ is the portfolio with the lowest tercile marginal tax rates. $High\ MTR$ is the portfolio with the lowest tercile marginal tax rates. $Diff$ is the difference in the responses between these two portfolios. The VAR state variables are defined in the text. Exogenous tax shocks are defined as in Romer and Romer (2010). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

	Low MTR	High MTR	Diff
Panel A: 1982q4-2008q2			
Current Excess Return	11.476*	7.516*	−3.960
Future Excess Return	−4.200	−4.555	−0.355
Real Interest Rate News	−5.592**	−5.511**	0.081
Cash Flow News	6.797	6.468	−0.329
Residual	−5.113	−9.018	−3.905
CA (1993) Cash Flow Residual	1.684	−2.550	−4.233
Panel B: 1982q4-2012q4			
Current Excess Return	10.983*	6.967	−4.016
Future Excess Return	−3.836	−3.923	−0.086
Real Interest Rate News	−5.204	−5.206	−0.002
Cash Flow News	18.137	17.502	−0.636
Residual	−16.195	−19.663	−3.468
CA (1993) Cash Flow Residual	1.942	−2.162	−4.104

Table 3.7: The impact of government spending shocks on sector returns

This table reports the impact of government spending shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future dividends (cash flows) for Fama and French 17 Industry Portfolios. To be included, an industry must have more than one SIC code involved in manufacturing, as defined by inclusion in the BEA Input-Output Accounts. Both the Chen and Zhao (2009) and Campbell and Ammer (1993) methods of computing cash flow news are provided. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. Sector returns are value-weighted. We use the alternative VAR specification defined in Footnote 9 of the text. Government spending shocks are defined in two steps. First, we calculate the the annual government spending in a particular industry by multiplying the ratio of government spending to lag GDP and the value-weighted fraction of an industry's total shipments that are sent to the government. Second, we orthogonalize this variable relative to the state variables included in our VAR. Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

	Food	Clths	Durbl	Chems	Cnsum	Cnstr	Steel	FabPr	Machn	Cars	Trans	Other
Percentage of SIC Codes in IO Tables	6.19%	8.90%	20.95%	12.86%	4.42%	7.95%	23.64%	37.78%	34.81%	7.32%	2.56%	3.20%
Panel A: 1965-2005												
Current Excess Return	−5.864**	2.008	1.786	−2.465	−4.292*	3.378	2.736	−0.221	6.277*	0.113	−2.146	1.993
Future Excess Return	5.686**	4.342	−0.629	1.929	1.740	−0.882	−4.663	−1.612	−2.873	−1.547	0.165	−3.584
Real Interest Rate News	1.142**	1.723**	−0.474	0.832	−0.028	0.340	1.063	1.370	−0.627	−0.010	1.209	−0.634
Cash Flow News	−0.436	0.470	0.041	0.020	−0.031	0.156	0.009	−0.024	0.060	0.074	0.918	−0.058
Residual	1.400	7.604**	0.643	0.277	−2.550	2.680	−0.873	−0.438	2.717	−1.518	−1.689	−2.166
CA (1993) Cash Flow Residual	0.964	8.074**	0.684	0.296	−2.581*	2.836	−0.864	−0.462	2.777	−1.444	−0.772	−2.224
Panel B: 1981-2005												
Current Excess Return	−5.877**	1.137	2.681	−1.141	−5.920**	5.265**	2.243	−1.090	6.343	0.459	−2.577	−1.076
Future Excess Return	8.315***	4.723	−1.346	3.594	3.944	−0.853	−5.578	−2.855	0.051	4.688	2.725	−2.246
Real Interest Rate News	1.430**	4.362	−0.422	3.292	1.937	0.004	2.488	2.452	−1.543	2.936	1.664	−0.785
Cash Flow News	−1.019	0.701*	0.019	0.447	−0.114	0.413	0.321	0.157	0.173	0.192	0.194	−0.342
Residual	4.887	9.522**	0.895	5.298	0.075	4.003	−1.168	−1.650	4.678	7.891	1.618	−3.764
CA (1993) Cash Flow Residual	3.869**	10.222**	0.914	5.745	−0.039	4.416	−0.847	−1.493	4.851	8.083	1.812	−4.106

Table 3.8: The impact of exogenous defense spending shocks on sector returns

This table reports the impact of exogenous shocks to defense spending on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future dividends (cash flows) for specific Fama and French 17 Industry Portfolios. Both the Chen and Zhao (2009) and Campbell and Ammer (1993) methods of computing cash flow news are provided. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. Sector returns are value-weighted. The VAR state variables are defined in the text. Exogenous shocks to defense spending are defined as in Ramey (2011). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 1980q2	1947q1 - 2008q2	1947q1 - 2012q4
Panel A: Fabricated Products			
Current Excess Return	0.011	0.016	0.026
Future Excess Return	0.114	0.068	0.059
Real Interest Rate News	−0.243	−0.254	−0.243*
Cash Flow News	0.992	1.035***	1.177**
Residual	−1.111*	−1.205***	−1.335***
CA (1993) Cash Flow Residual	−0.118	−0.170	−0.157
Panel B: Transportation			
Current Excess Return	0.265	0.275	0.273
Future Excess Return	0.178	0.117	0.112
Real Interest Rate News	−0.267	−0.264	−0.249
Cash Flow News	0.996*	1.043***	1.182**
Residual	−0.820	−0.914**	−1.046**
CA (1993) Cash Flow Residual	0.176	0.128	0.137

Table 3.9: The impact of exogenous tax shocks on UK equity and bond returns

Panel A reports the impact of exogenous tax shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future cash flows. Panel B reports the impact of exogenous tax shocks on the current excess bond return, and the discounted sums of future excess bond returns, current and future real interest rates, and current and future inflation. The VAR used to construct excess equity and bond return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. Exogenous tax shocks in the UK are defined as in Cloyne (2013). Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1966q2 - 2009q4	1975q2 - 2009q4
Panel A: Equity Returns		
Current Excess Return	0.194	-0.793
Future Excess Return	0.917	2.752
Real Interest Rate News	-0.772	-7.160^{**}
Cash Flow News	2.120	-8.488
Residual	-1.781	3.288
CA (1993) Cash Flow Residual	0.339	-5.200^{*}
Panel B: Bond Returns		
Current Excess Bond Return	3.779	3.166
Future Excess Bond Returns	-8.338^{*}	-11.127^{**}
Real Interest Rate News	-5.669	-8.235^{***}
Inflation News	10.228	16.196^{**}

Table 3.10: The impact of exogenous fiscal policy shocks on simulated equity returns

Panel A reports the impact of exogenous tax shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future cash flows. Panel B reports the impact of exogenous government spending shocks on the current excess equity return, and the discounted sums of future excess equity returns, current and future real interest rates, and current and future cash flows. Data are the solutions to the DSGE model described in Section 3.6.

Time Periods:	Pre-Volcker	Post-Volcker	High MTR
Panel A: Tax Shock			
Current Excess Return	-4.327	3.624	2.919
Future Excess Return	9.021	-0.133	0.135
Real Interest Rate News	0.203	-9.099	-9.212
CA (1993) Cash Flow Residual	4.898	-5.608	-6.158
Panel B: Government Spending Shock			
Current Excess Return	-3.263	0.446	–
Future Excess Return	3.372	-0.024	–
Real Interest Rate News	2.713	0.895	–
CA (1993) Cash Flow Residual	2.821	1.317	–

Table 3.11: The impact of exogenous fiscal policy shocks on simulated bond returns

Panel A reports the impact of exogenous tax shocks on the current excess bond return, and the discounted sums of future excess bond returns, current and future real interest rates, and current and future inflation. Panel B reports the impact of exogenous government spending shocks on the current excess bond return, and the discounted sums of future excess bond returns, current and future real interest rates, and current and future inflation. Data are the solutions to the DSGE model described in Section 3.6.

Time Periods:	Pre-Volcker	Post-Volcker
Panel A: Tax Shock		
Current Excess Bond Return	52.517	-44.262
Future Excess Bond Returns	-16.210	11.272
Real Interest Rate News	3.204	-7.649
Inflation News	-39.509	40.639
Panel B: Government Spending Shock		
Current Excess Bond Return	26.861	-13.401
Future Excess Bond Returns	-18.888	3.069
Real Interest Rate News	2.973	0.105
Inflation News	-10.946	10.228

CHAPTER 4

INFLATING AWAY DEBT: TRADING OFF INFLATION RISK AND TAXATION RISK

4.1 Introduction

With the recent doubling of federal debt due to the financial crisis, several economists (Rogoff (2008, 2013); Mankiw (2009); Olivier Blanchard and Mauro (2010); Krugman (2013)) recently advocated for increases in inflation as a device to reduce fiscal stress.[1] I address these policy recommendations by studying the welfare implications of "inflating away debt" policies in the context of a production-based asset pricing model designed to price both inflation and tax risk. My general equilibrium analysis suggests that we should be cautious in urging the central bank to respond to public debt levels. Specifically, I find that altering the inflation target to respond to the debt-GDP ratio can provide benefits, but only at high debt levels where taxation risk becomes a first order concern and dominates inflation inefficiencies.

Taxation risk increases as the level of debt rises because higher interest payments are required to service debt and tax rates must adjust more to balance the budget. By allowing the inflation target to increase endogenously with the debt-GDP ratio, monetary policy substantially lowers tax rate uncertainty, which decreases the equity premium on the after-tax return of capital and boosts capital accumulation.

The study of the welfare trade-off between inflation and distortionary taxes with regards to financing the government dates back to Phelps (1973). In a Sidrauski (1967) flexible price model with money in the utility function, Phelps (1973) finds that a positive inflation tax is optimal to reduce the welfare costs of distortionary taxes. The intuition follows Ramsey (1927) which suggests

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[1]For example, Rogoff (2008) states that a "Sudden burst of moderate inflation would be extremely helpful in unwinding today's epic debt morass."

it is optimal to minimize the marginal distortions of all available taxes.

In contrast to Phelps (1973), Lucas and Stokey (1982) find that the Friedman Rule (zero nominal interest rate with deflation) is optimal for the cash-in-advance setting. In their model, inflation acts as a tax on an intermediate good (money is a means to consume) and this results in double taxation of consumption, which is sub-optimal.

Shifting focus from the first to the second moment of inflation, Chari, Christiano, and Kehoe (1991, 1994) and Calvo and Guidotti (1993) find that unexpected inflation fluctuations can be used to turn nominal non-state-contingent debt into real state-contingent debt. This allows the government to smooths taxes and consumption which provides welfare benefits due to concave utility. Unexpected inflation acts as a shock absorber and the optimal inflation volatility is greater than 20%. A high inflation volatility is optimal because unexpected inflation is non-distortionary as there are no substitution effects with flexible prices.

Unexpected inflation is no longer costless when moving to a model with sticky prices, and this dramatically changes the optimal volatility of inflation. In the Calvo (1983) setting, volatile inflation causes relative price dispersion as some firms are unable to update their price and an inefficient quantity is produced. Goodfriend and King (1998, 2001) , King and Wolman (1999), and Rotemberg and Woodford (1999) find it optimal to completely eliminate price dispersion so that the optimal inflation volatility is zero. However, these studies assume lump sum taxes so that the inflation-taxation trade-off is non-existent.

Benigno and Woodford (2004), Schmitt-Grohe and Uribe (2006, 2005), and Siu (2004b) all assume distortionary taxes and find that the optimal inflation volatility is still zero or very close to zero. The intuition for zero inflation volatility is that surprise inflation in these models only smooth the distortionary tax, and the benefits of smooth taxes are dominated by the welfare costs of price dispersion.

All of the papers above use either log linear approximations (which makes the agent risk-neutral across states of nature), log preferences, power utility, or no capital accumulation.[2] It is

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[2]An exception to this may be Schmitt-Grohe and Uribe (2005), which use habits. This class of preferences exhibits

well known that each of these setups is not capable of pricing risk consistent with the data. The production-based asset pricing literature that shows this includes Rouwenhorst (1991), Jermann (1998), Lettau and Uhlig (2000), Christiano, Boldrin, and Fisher (2001), Tallarini (2000), Guvenen (2009), Kaltenbrunner and Lochstoer (2010), Dew-Becker (2012), and Croce (2012). Therefore, analyzing a tradeoff between tax risk and inflation volatility will ultimately favor concerns for inflation when the price of risk is very low compared to the data. With a low price of risk, increased taxation risk will have very little effect on the risk premium of capital, so that capital accumulation is largely unaffected.

To address properly the questions of optimal inflation dynamics and the inflation-taxation trade-off, I use a model that matches business cycle statistics such as the volatility of consumption growth and investment growth. To price risk consistent with the data, I borrow features from my companion paper Ai, Croce, Diercks, and Li (2013). Specifically, I incorporate recursive preferences and long run risk in the spirit of Bansal and Yaron (2004). Standard capital adjustment costs make investment volatility counterfactually low, so I include heterogeneous vintages of capital which yields a high investment volatility as in the data.

I incorporate sticky prices and distortionary taxes in the spirit of Schmitt-Grohe and Uribe (2006). To ensure that nominal risk is correctly priced with the data, I match the sizable 5-year term spread for the term structure of nominal bonds. While consumption-based models such as Gallmeyer, Hollifield, Palomino, and Zin (2007) and Bansal and Shaliastovich (2013) find success in replicating nominal term structure dynamics, the production-based general equilibrium framework has had greater difficulty as documented by Rudebusch and Swanson (2008), Li and Palomino (2012), van Binsbergen, Fernndez-Villaverde, Koijen, and Rubio-Ramrez (2010), and Rudebusch and Swanson (2012). Kung (2013) finds success in matching the term spread in a model with endogenous growth, which is in contrast to my model's specification of exogenous growth. In addition, Hsu (2013) finds success by incorporating rule of thumb consumers, which I

the following issues: (1) highly volatile risk free rate, (2) high levels of risk aversion, (3) negative serial correlation of consumption growth, and (4) backwards looking asset prices.

also abstract from.

From there I endow the government with simple fiscal and monetary policy rules as in Schmitt-Grohe and Uribe (2006) and I find optimal policy characteristics. The fiscal rule ensures that tax revenues rise as debt rises. The monetary policy rule is a simple Taylor (1993) rule defined so that the nominal interest rate responds to the previous period's interest rate, deviations of inflation from its target, and an output growth gap. In addition, I incorporate an inflation target that responds to the debt-GDP ratio and determine its effects on welfare.

For a model that abstracts from risk considerations, I find it is never optimal to alter the inflation target to respond to the debt-GDP ratio. The potential welfare benefits of decreased tax risk are muted as the risk premium in these models is essentially zero. This suggests previous studies that determine optimal policy using first-order approximations are missing a key tax risk channel.

Even after pricing risk consistent with the data, I find it is not optimal for monetary policy to react directly to the debt-GDP ratio at current levels. This is because at lower levels of debt such as the current debt-GDP ratio (75%), tax rate volatility is relatively low. Therefore, reducing it further has little to no benefit for welfare but sizable losses coming from higher inflation volatility. Only at high levels of debt (200%) can monetary policy sufficiently reduce tax risk in order to obtain welfare gains.

Hence, my contribution to the literature is three-fold. First, I assess optimal inflation dynamics while departing from the existing literature in just one dimension -- risk considerations. Risk considerations include the equity premium and the nominal term structure found in the data, and this is achieved by introducing recursive preferences, long run risk, and heterogeneous vintages of capital.

I find that as monetary policy increasingly targets inflation (as indicated by increasing the co-efficient on inflation deviations in the Taylor rule), a tradeoff exists between lowering the inflation risk premium and raising the equity risk premium. In the risk-sensitive model, taxation risk is more costly, so optimal inflation volatility is higher (29 basis points versus zero basis points in Schmitt-Grohe and Uribe (2006)). This difference is economically significant, as it represents about 15%

of the observed inflation volatility in the data. Taxation risk becomes even more costly at higher debt levels, where interest payments are higher and tax rates must adjust more. From a policy perspective, my results suggest complete minimization of inflation volatility is sub-optimal due to the resulting increase in tax risk. This finding conflicts with previous studies that do not price risk consistent with the data.

My second contribution is to study the effects of monetary policy on the intertemporal distribution of both nominal and equity risk. The properties of the intertemporal distribution of equity risk have been previously studied by Lettau and Wachter (2011), van Binsbergen et al. (2010); van Binsbergen, Brandt, and Koijen (2012), Boguth, Carlson, Fisher, and Simutin (2012), Belo, Collin-Dufresne, and Goldstein (2012), and Ai et al. (2013). None of these studies has looked at the effects of policy on the term structure of equity. I find that as monetary policy increasingly stabilizes inflation, short-term equity risk decreases while long-term equity risk rises. The slope of the term structure increases due to excessive long-term tax risk, which depresses capital accumulation.

My third contribution involves studying the effects of monetary policy reacting directly to changes in the debt-GDP ratio through the inflation target. Kumhof, Nunes, and Yakadina (2008) incorporates debt directly into the Taylor rule (alongside inflation deviations and the previous period's interest rate) but they focus on scenarios related to the fiscal theory of the price level. Benigno and Woodford (2007) compute a Ramsey optimal monetary policy that responds to fiscal variables, but this policy is not implementable in the spirit of Schmitt-Grohe and Uribe (2006), as the policy depends on variables that are unobservable. In addition, power utility is used with a log-linear approximation so that risk considerations are muted. While my study allows the inflation target to react to the debt-GDP ratio, the rest of the literature keeps the inflation target fixed and typically focuses on the volatility around that target. An alternative analysis typically consists of exogenously changing the steady state target but not allowing it to dynamically adjust to fiscal variables such as the debt-GDP ratio.

The major policy prescription coming from this study is the following: it is not optimal for monetary policy to alter the inflation target to respond to the debt-GDP ratio at current debt levels

(75%). It is only at higher ratios (200%) of debt-GDP that the costs of inflation (misallocation of resources) are dominated by the benefits (lower tax risk). According to the CBO, such high debt levels are decades away for even the worst-case fiscal projections.

I acknowledge that government has multiple dimensions that I abstract from. For example, my analysis excludes utility-providing expenditures (Ferriere and Karantounias 2012) and any uncertainty about the monetary policy's actions or inflation target (Krause and Moyen 2013). In addition, debt is only made up of one period nominal bonds. Likewise, policy effects on endogenous growth as in Croce, Nguyen, and Schmid (2012), Croce et al. (2012) and the effects of asset prices on long-run growth as in Schmid and Kung (2011) are not included. Furthermore, more complex fiscal financing and their interactions with monetary policy as in Leeper, Plante, and Traum (2010), Yang and Traum (2010), and Traum (2008) are excluded. Lastly, monetary policy's effects on risk premia through bank balance sheets as in Drechsler, Savov, and Schnabl (2013) are also excluded. These issues are abstracted from for reasons of parsimony and are viewed as potential avenues of future research.

The remainder of the paper is organized as follows. In section 2, the model is introduced and I briefly discuss recursive preferences and heterogenous vintages of capital. In Section 3, I briefly detail the calibration approach. In section 4, the effects of inflation and taxation risk along with the policy tradeoff are discussed. The main results are presented in section 5. Section 6 concludes.

4.2   Model

The economy consists of a continuum of identical households, a continuum of intermediate-goods firms, and a government that conducts monetary and fiscal policy. The structure of the model is the standard neoclassical growth model augmented with real and nominal frictions. The nominal friction is sticky prices. The real frictions consist of monopolistic competition in product markets and distortionary taxation. These inefficiencies motivate the implementation of monetary and fiscal stabilization policy.

Preferences.   The households have Epstein-Zin preferences defined over consumption goods, c_t, and leisure, $1-h_t$. These preferences exhibit a CES aggregate of current and future utility certainty

equivalent weighted by $(1-\beta)$ and β, respectively.

$$v_t = \max_{\{c_j,h_j,i_j,b_j,k_{j+1}\}_{j=t}^{\infty}} \left\{ (1-\beta)(c_t^{\iota}(1-h_t)^{1-\iota})^{1-\frac{1}{\psi}} + \beta(E_t[v_{t+1}^{1-\gamma}])^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}$$

s.t.

$$b_t + c_t + i_t = R_{t-1}\frac{b_{t-1}}{\pi_t} + (1-\tau_t^D)(w_t h_t + u_t k_t) + \delta\check{q}\tau_t^D k_t + \check{\phi}_t$$

The real value of debt is b_t, c_t is consumption, i_t is investment, R_{t-1} is the risk free rate, π_t is the inflation rate $\frac{P_t}{P_{t-1}}$, τ_t^D is the tax rate, w_t is the wage, h_t is labor hours, u_t is the rental rate of capital, k_t is capital, $\delta\check{q}\tau_t^D k_t$ is a tax allowance for depreciation, and $\check{\phi}_t$ is profits.

Unlike standard preferences, Epstein-Zin preferences allow for the disentanglement of γ, the coefficient of relative risk aversion, and ψ, the elasticity of intertemporal substitution. When $\frac{1}{\psi} = \gamma$, the utility collapses to standard preferences with additively separable expected utility both in time and state. When $\gamma > \frac{1}{\psi}$, the agent prefers early resolution of uncertainty, so the agent dislikes shocks to long-run expected growth rates. This assumption allows asset prices to be influenced by the intertemporal distribution of tax rates (Croce, 2012).

Intermediate good bundling. The consumption good is assumed to be a composite made of a continuum of differentiated goods c_{it} indexed by $i \in [0,1]$ via the aggregator:

$$c_t = \left[\int_0^1 c_{it}^{1-\frac{1}{n}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}$$

The elasticity of substitution across different varieties of consumption goods is $\eta > 1$ (also the price elasticity of demand for good j) . As $\eta \to \infty$, the goods become closer and closer substitutes, so that individual firms have less market power.

The household minimizes total expenditures subject to an aggregation constraint, where P_{jt} is price of intermediate good j:

$$\min_{c_{jt}} \int_0^1 P_{jt}c_{jt}dj$$

s.t.

$$\left[\int_0^1 c_{it}^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}} \geq c_t$$

The optimal demand for the level of intermediate consumption good c_{jt} is given by

$$c_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\eta} c_t$$

where P_t is the nominal price index

$$P_t \equiv \left[\int_0^1 P_{jt}^{1-\eta} dj \right]^{\frac{1}{\eta-1}}$$

Productivity. The law of motion of the productivity process captures both short-run and long-run productivity risks:

$$\log \frac{A_{t+1}^0}{A_t^0} \equiv \Delta a_{t+1} = \mu + x_t + \sigma_a \varepsilon_{a,t+1}, \tag{4.1}$$

$$x_{t+1} = \rho x_t + \sigma_x \varepsilon_{x,t+1}, \tag{4.2}$$

$$\begin{bmatrix} \varepsilon_{a,t+1} \\ \varepsilon_{x,t+1} \end{bmatrix} \sim i.i.d.N \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right), \quad t = 0, 1, 2, \cdots. \tag{4.3}$$

According to the above specification, short-run productivity shocks, $\varepsilon_{a,t+1}$, affect contemporaneous output directly, but have no effect on future productivity growth. Shocks to long-run productivity, represented by $\varepsilon_{x,t+1}$, carry news about future productivity growth rates, but do not affect current output.

Capital Accumulation Technology. Assume that investments in different vintages of capital have heterogeneous exposure to aggregate productivity shocks.[3] In other words, there will be vintage specific productivity growth that is going to depend on the age $j = 0, 1, ..., t-1$ of the

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[3] Multiple frictions for capital accumulation have been tested, and this friction was chosen because standard capital adjustment costs result in counterfactually low investment growth volatility. The friction in this paper does not suffer from this issue.

vintage of capital

$$\frac{A_{t+1}^{t-j}}{A_t^{t-j}} = e^{\mu + \phi_j(\Delta a_{t+1} - \mu)}$$

Under the above specification, production units of all generations have the same unconditional expected growth rate. Also, $A_t^{t-0} = A_t^0$ is set to ensure that new production units are on average as productive as older ones. The log growth rate of the productivity process for the initial generation of production units, Δa_{t+1}, is given by equation (A.1). Heterogeneity is driven solely by differences in aggregate productivity risk exposure, ϕ_j.

The empirical findings in Ai, Croce, and Li (2012) suggests that older production units are more exposed to aggregate productivity shocks than younger ones, i.e. the exposure ϕ_j is increasing in j. To capture this fact, a parsimonious specification for ϕ_j is adopted:

$$\phi_j = \begin{cases} 0 & j = 0 \\ 1 & j = 1, ... \end{cases}.$$

$$\overbrace{\frac{A_{t+1}^{t-0}}{A_t^{t-0}} = e^{\mu}}^{\text{new vintage of capital, j=0}} \qquad \overbrace{\frac{A_{t+1}^{t-j}}{A_t^{t-j}} = e^{\mu + x_t + \sigma_a \epsilon_{a,t+1}}}^{\text{all other older vintages of capital, j=1,2..}} \qquad (4.4)$$

New production units have zero exposure to aggregate productivity shocks in the first period of life. Every period thereafter, they have 100% exposure to aggregate productivity shocks as do all other existing vintages.

Let K_t denote the productivity adjusted physical capital stock. Despite the heterogeneity in productivity, aggregate production can be represented as a function of K_t and N_t. The law of motion of the productivity-adjusted physical capital stock K_t, takes the following form:

$$K_1 = I_0, \quad K_{t+1} = (1-\delta)K_t + \omega_{t+1}I_t$$

$$\omega_{t+1} = \left(\frac{A_{t+1}^{t-0}}{A_{t+1}^0}\right)^{\frac{1-\alpha}{\alpha}} = e^{-\frac{1-\alpha}{\alpha}(x_t + \sigma_a \epsilon_{a,t+1})(1-\phi_0)}$$

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where I_t is the total mass of new vintage capital produced at time t, and ω_{t+1} is an endogenous process that accounts for the productivity gap between the newest vintage of capital and all older vintages. Note that when $\phi_0 = 1$, the new capital vintage has the same exposure to aggregate productivity shocks as older ones. In this case, $\omega_{t+1} = 1$ for all t and capital of all generations are identical.

The government. The government issues one-period nominal risk-free bonds, b_t, collects taxes in the amount of τ_t, and faces an exogenous expenditure and transfers stream, g_t and tr_t. It's period by period budget constraint is given by

$$b_t = \frac{R_{t-1}}{\pi_t} b_{t-1} + g_t - \tau_t + tr_t$$

The exogenous expenditure and transfer streams are formulated as in Schmitt-Grohe and Uribe (2006)

$$\frac{G}{Y} = \frac{1}{1 + e^{-\bar{gy}}}$$

$$\frac{tr}{Y} = \frac{1}{1 + e^{-\bar{try}}}$$

$$gy_t = (1 - \rho_g)\bar{gy} + \rho_g gy_{t-1} + \epsilon_{G,t}, \quad \epsilon_{G,t} \sim N(0, \sigma_{gy}^2)$$

$$try_t = (1 - \rho_g)\bar{try} + \rho_{tr} try_{t-1} + \epsilon_{tr,t}, \quad \epsilon_{tr,t} \sim N(0, \sigma_{try}^2)$$

Total tax revenues, τ_t, consist of revenue from income taxation, $\tau_t^D y_t$, where y_t denotes aggregate demand

$$\tau_t = \tau_t^D y_t$$

Tax smoothing by the government consists of tax revenues rising whenever the previous period's debt rises

$$\tau_t - \tau* = \gamma_1 (b_{t-1} - b*)$$

where $\gamma_1 > 0$ ensures that the debt-GDP ratio is bounded and there is a unique solution.

The monetary authority sets short-term nominal interest rate according to a simple Taylor rule

$$ln(R_t/R*) = \alpha_r ln(R_{t-1}/R*) + \alpha_\pi ln(\pi_t/\pi_t*) + \alpha_{\Delta y} ln(\Delta y_t/\Delta y*)$$

$$\pi_t^* = \pi^* + \frac{\alpha_G}{\alpha_\pi} ln(SB_t/SB^*)$$

where α_r is the inertia coefficient, α_π is the inflation coefficient, $\alpha_{\Delta y}$ is the output growth gap coefficient, α_G is the inflation target response to the debt-GDP ratio, SB_t.

Firms. Each variety $i \in [0,1]$ is produced by a single firm in a monopolistically competitive environment. Each firm i produces output using as factor inputs capital services, k_{it}, and labor services, h_{it}. It is assumed that the firm must satisfy demand at the posted price. Formally,

$$k_{it}^\theta (A_t h_{it})^{1-\theta} \geq \left(\frac{P_{it}}{P_t} \right)^{-\eta} y_t$$

The objective of the firm is to choose P_{it}, h_{it}, k_{it} to maximize the present discounted value of profits, given by

$$E_t \sum_{s=t}^\infty m_{t,s} P_s \phi_{is}$$

where real profits of firm i are

$$\phi_{it} \equiv \frac{P_{it}}{P_t} y_{it} - u_t k_{it} - w_t h_{it}$$

Prices are assumed to be sticky as in Calvo (1983). Each period, a fraction $\alpha \in [0,1)$ of randomly picked firms is not allowed to optimally set the nominal price of the good they produce. Instead, these firms index their prices to past inflation according to the equation

$$P_{it} = P_{it-1} \pi_{t-1}^\chi$$

The remaining $1 - \alpha$ firms choose $\check{P}_t$ to maximize the expected present discounted value of profits:

$$E_t \sum_{s=0}^{\infty} d_{t,t+s} P_{t+s} \alpha^s \left\{ \left(\frac{\check{P}_t}{P_t} \right)^{1-\eta} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}^{\chi}}{\pi_{t+k}} \right)^{1-\eta} y_{t+s} - u_{t+s} k_{it+s} - w_{t+s} h_{it+s} \right.$$

$$\left. + mc_{it+s} \left(k_{it+s}^{\theta} (A_t h_{it+s})^{1-\theta} - \left(\frac{\check{P}_t}{P_t} \right)^{-\eta} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}^{\chi}}{\pi_{t+k}} \right)^{-\eta} y_{t+s} \right) \right\}$$

The firm's first order conditions for labor, capital, and optimal price are

$$mc_t (1-\theta) \left(\frac{\tilde{k}_t}{h_t} \right)^{\theta} = \tilde{w}_t \tag{4.5}$$

$$mc_t \theta \left(\frac{\tilde{k}_t}{h_t} \right)^{\theta-1} = u_t \tag{4.6}$$

The firm's optimal price is set such that marginal revenues are equal to some markup over marginal costs

$$\frac{\eta}{\eta - 1} x_t^1 = x_t^2 \tag{4.7}$$

where

$$\tilde{x}_t^1 = p_t^{*-1-\eta} \tilde{y}_t mc_t + \alpha E_t D_{t,t+1} \pi_{t+1}^{\eta+1} \pi_t^{\chi(-\eta)} \left(\frac{p_t^*}{p_{t+1}^*} \right)^{-1-\eta} \tilde{x}_{t+1}^1 e^{\Delta a_{t+1}} \tag{4.8}$$

$$\tilde{x}_t^2 = p_t^{*-\eta} \tilde{y}_t + \alpha E_t D_{t,t+1} \pi_{t+1}^{\eta} \pi_t^{\chi(1-\eta)} \left(\frac{p_t^*}{p_{t+1}^*} \right)^{-\eta} \tilde{x}_{t+1}^2 e^{\Delta a_{t+1}} \tag{4.9}$$

Aggregation and equilibrium. This period's price level is a weighted average of the firm's optimal price and the previous period's price level:

$$1 = \alpha \pi_t^{-1+\eta} \pi_{t-1}^{\chi(1-\eta)} + (1-\alpha) p^{*(1-\eta)} \tag{4.10}$$

It can be shown that the resource costs of inefficient price dispersion are characterized as follows

$$s_t = (1-\alpha) p_t^{*-\eta} + \alpha \left(\frac{\pi_t}{\pi_{t-1}^{\chi}} \right)^{\eta} s_{t-1} \tag{4.11}$$

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Given the price dispersion, output is described by

$$\tilde{y}_t = \frac{1}{s_t}[\tilde{k}_t^\theta (A_t h_t)^{1-\theta}] \tag{4.12}$$

and aggregate demand is the following sum

$$\tilde{y}_t = \tilde{c}_t + \tilde{i}_t + \tilde{g}_t \tag{4.13}$$

4.3   Calibration

I calibrate the model at an annual frequency and evaluate its ability to replicate key moments of both macroeconomic quantities and asset returns. I focus on a long sample of US annual data, including pre-World War II data. All macroeconomic variables are real and per capita. Consumption and investment are from the Bureau of Economic Analysis (BEA). Fiscal policy variables such as government spending and steady state debt are taken from Schmitt-Grohe and Uribe (2006). The parameters described below are listed in Table 4.1.

Production and preference parameters.   The parameters for effective[4] risk aversion $\gamma = 10$, and intertemporal elasticity of substitution, $\psi = 2$, are set following the long run risk literature. The capital share $\alpha = 0.25$ and the annual depreciation rate of physical capital $\delta = 15\%$ are consistent with the labor share of income in the data and the quarterly depreciation rate of 2 to 4% observed in the RBC literature. I calibrate $\mu = 2\%$ per year, consistent with the average annual real growth rate of the US economy. I set the persistence parameter on long run risk, $\rho = 0.925$, which is close to the point estimate of Croce (2014b).

The subjective discount factor is set to be consistent with the low risk free rate observed in the data. Labor is endogenous and set to match the level of hours in the data, $\iota = 0.35$. I set σ_a and σ_x to match the standard deviation of consumption and output.[5]

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[4]See Swanson (2012) for a discussion of risk aversion when leisure is present.

[5]In models where $\sigma_x = 0$, σ_a is adjusted to match the standard deviation of consumption.

Sticky prices parameters.   The markup due to monopolistic competition is set to 15%, which is consistent with previous studies (Bils and Klenow (2004)). Firms are assumed to re-optimize their prices every 13 months, which is in the middle of empirical estimates that range from 6 months to 18 months (see Altig, Christiano, Eichenbaum, and Linde (2005)). The indexation parameter, χ, is set to one following Christiano, Eichenbaum, and Evans (2005b) and the empirical estimates of Giannoni and Woodford (2003). At first, the inflation target will be assumed to be constant and set to its average value of 3.5% which is consistent with the annual average observed from 1945-2012. Later exercises will consist of endogenizing the inflation target to take into account Debt-GDP ratio fluctuations.

Fiscal policy parameters.   Steady state government purchases make up 17% of GDP and transfers make up 5% of GDP. The steady state Debt-GDP ratio is set to the historical average of 44% following Schmitt-Grohe and Uribe (2006). The speed of the tax rule for repayment of debt controls both the persistence of the debt-GDP ratio and the volatility of the tax rate. This parameter is set conservatively so that tax risk (which increases with the speed of repayment) is not amplified (tax rate volatility for the benchmark model is relatively low at 1.3%). The autoregressive coefficient of the debt-GDP ratio in the model is 90%, which is close to its persistence in the data of 94%. The average income tax rate is 21%, which is pinned down by the model's Debt-GDP ratio and government expenditures and transfers.

Monetary policy parameters.   The default Taylor Rule includes an inertia coefficient of 0.6 and an output growth gap coefficient of 0.5. The parameters chosen for the inertia coefficient and the output growth gap are set to match inflation dynamics and the interest rate serial correlation observed in the data. An inertia coefficient of 0.6 is consistent with empirical quarterly estimates that set it as high as 0.9.

Without the output growth gap, inflation in the model is positively correlated with permanent productivity shocks, which is counterfactual. Incorporating the output growth gap results in inflation falling with good productivity shocks and rising with bad productivity shocks. The inflation coefficient is set to 0.6 so that the long run inflation coefficient, $\frac{\alpha_\pi}{1-\alpha_r}$ is consistent with the original

work of Taylor (1993). For later exercises, the inflation coefficient will be scaled to determine optimal inflation volatility.

Simulation. The policy rules are numerically computed using second order approximations from Dynare++. The simulations consist of random draws of the two productivity shocks (short run and long run) and two fiscal shocks (government spending and transfers). The number of periods is 200 (the first 100 are thrown out) and the number of simulations is 100.

Model Moments. The moments for the data are listed in Table 4.2. The Main Model is capable of matching the low risk free rate, the high equity premium, the smooth volatility of consumption growth, and volatile investment growth. Matching data on both macroeconomic aggregates and asset pricing facts imposes joint structural restrictions on both the quantity and price of risk in the data. In addition, to properly account for nominal risks, the first two moments of inflation were also matched to the data.

4.4 Policy and the Role of Expectations

Expectations are crucial for the transmission of monetary policy in the forward-looking New Keynesian model. Iterating forward the intertemporal Euler equation, it can be shown that consumption and aggregate demand depend upon all expected future short real rates, and not simply upon the current real interest rate. This implies that the long-term real rate of interest determines aggregate demand in the model, not the short real rate. In other words, monetary policy needs to be very careful about managing expectations of future policy, as the central bank's primary impact on the economy comes through the way it affects private-sector expectations about the probable future path of interest rates.

It should be noted that a key variable that determines the effectiveness of monetary policy is the intertemporal elasticity of substitution (IES). Based on a simple log-linearization of the intertemporal Euler equation, it can be shown that the sum of the future real rates are multiplied by the IES. This implies that the magnitude of the IES will play a role in determining how much aggregate demand responds to expectations of future real rates. With standard preferences and a

coefficient of relative risk aversion greater than one, the IES will be small, indicating that monetary policy will be less effective than in the case with recursive preferences. With recursive preferences, the IES and risk aversion coefficient are decoupled, and the IES is set to 2 in order to match the real risk free rate in the data. The lower risk free rate implies an agent that is more patient, placing greater weight on future expectations of real rates.

Given the importance of expectations, in the model it is assumed that monetary and fiscal policy follow simple rules, for which the agents have full information. The government is assumed to be perfectly credible and has the exact same information as the actors in the model. Monetary policy searches across the parameter space of inflation coefficients, output growth gap coefficients, and inertia coefficients to find the optimal policy, taking fiscal policy as given. The speed with which fiscal policy repays taxes is set conservatively to ensure that the debt-GDP ratio has a high autocorrelation (as in the data) and not to overstate the tax rate volatility. In terms of inflation expectations, there are two alternatives to pinning down inflation dynamics. The first method consists of combining the Taylor Rule and the intertemporal Euler equation:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\alpha_r} \left(\frac{\pi_t}{\pi_t^*}\right)^{\alpha_\pi} \left(\frac{\Delta y_t}{\Delta y_{ss}}\right)^{\alpha_y}$$

$$\frac{1}{R_t} = E_t \left(\frac{M_{t+1}}{\pi_{t+1}}\right)$$

and the inflation target is defined as $\pi_t^* = \pi^* + \alpha_G ln \frac{BY_t}{BY*}$, where BY_t is the debt to GDP ratio, and M_{t+1} is the real stochastic discount factor. The inflation rate can then be solved to form a stochastic difference equation that governs the evolution of inflation.

$$\pi_t = \left(\pi^* + \alpha_G \cdot ln\left(\frac{BY_t}{BY*}\right)\right) \left[\frac{\left(E_t\left[\frac{M_{t+1}}{\pi_{t+1}}\right]\right)^{-1}}{R_{t-1}^{\alpha_r} R^{*1-\alpha_r} \left(\frac{\Delta y_t}{\Delta y_s s}\right)^{\alpha_y}}\right]^{\frac{1}{\alpha_\pi}}$$

From this equation, a great deal of economic content can be gleaned. First, it is clear that the stochastic discount factor plays an important role in transmitting the effect of expected inflation to current inflation. Given the forward looking nature of inflation, it can be seen that expected future

inflation results in higher inflation today, as forward looking firms set their prices with the expectation they may not be able to update their price for multiple periods. Second, a greater response of monetary policy to inflation, higher α_π, brings expected inflation closer to zero and thus stabilizes current inflation. Third, this equation shows the importance of including the output growth gap if the goal is to generate a positive inflation risk premium. A positive inflation risk premium requires that the covariance between the stochastic discount factor and inflation be positive. Including the output growth gap breaks the inverse link between the SDF and current inflation. Lastly, a positive α_G results in higher inflation today if the debt to GDP ratio is above steady state. Given the persistent nature of debt to GDP, the inflation target will be persistently higher for many periods, resulting in even greater changes in the current inflation rate.

The alternative way of deriving the New Keynesian Philips Curve involves the definition of the aggregate price index and the optimal price chosen by the firm:

$$P_t = \left[(1-\alpha)p_t^{*(1-\eta)} + \alpha P_{t-1}^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

Which can be rewritten as

$$\pi_t = \left[\frac{1 - (1-\alpha)p_t^{*(1-\eta)}}{\alpha} \right]^{\frac{1}{\eta-1}}$$

This shows that inflation today is a positive function of the firm's optimal price chosen at time t. The firm's optimal price is chosen to be a markup over a weighted present discounted value of future marginal costs

$$p_t^* = \frac{\eta}{\eta-1} \frac{(E_t \sum_{s=t}^{\infty} M_{t,s} \alpha^{s-t} y_s mc_s)}{(E_t \sum_{s=t}^{\infty} M_{t,s} \alpha^{s-t} y_s)}$$

The optimal price chosen by the firm combined with the previous equation shows that inflation is a function of expected future marginal costs, for which the stochastic discount factor is crucial. The stochastic discount factor for recursive preferences incorporates the continuation value of utility, which is important for long run news shocks. For instance, a negative long run news shock would drastically increase the marginal utility and stochastic discount factor with recursive preferences,

and this would result in much greater weight placed on future marginal costs as the firm chooses its optimal price.

4.4.0.1 Credibility of Policy

The key element of the New Keynesian model is the forward-looking behavior of individuals and firms. Agents are assumed to anticipate the policymaker's actions. Therefore, knowledge of the policymaker's incentives and the frequency at which the policymaker re-optimizes will heavily influence the agent's decisions. A monetary policy that is able to commit to future promises can better influence expectations than one that is given discretion to break its promises in any given period. These expectations feed back into current inflation and output. This feedback occurs because households experience wealth effects from higher expected future output while firms change their prices to stay in sync with higher expected future prices.

I assume that the government has the ability to commit fully to the enactment of announced monetary and fiscal policies. These policies take the form of simple, implementable rules for which agents have full information. My focus on maximizing welfare by numerically searching across simple policies (policies that depend on easily observable macro indicators) that are implementable (deliver uniqueness of rational expectations equilibrium) is in contrast to the analytical Ramsey and quadratic loss function analysis that is also popular within the literature. The analytically derived optimal rules require policymakers to know the true values of all exogenous shocks and all endogenous predetermined variables, including unobservable ones such as the output gap or natural rate of interest. In comparison, the simple rule requires observation of only the rate of inflation, the output growth, and the previous period's interest rate. Furthermore, even if it were possible for policymakers to obtain the true values of all the variables within the economy, there is no guarantee that a unique equilibrium would exist.

Before moving forward, it is important to note that the government, in reality, is unlikely to be capable of 100% commitment to specific rules for all future periods. Full commitment requires that future policymakers (ones not even born yet) will continue to honor the promises set forth by current rules. While clearly imperfect, the commitment assumption in my model is a parsimonious

way of providing the government with credibility so that policy can meaningfully affect agents' expectations. This credibility has become well established in the post-Volcker era dating back to the early 1980s.

Credibility allows for the manipulation of private-sector expectations, which lets monetary policy improve the short-run tradeoffs when inflation and output move in opposite directions. On the opposite spectrum of full commitment is discretionary policy. In contrast to commitment, optimal discretionary policy involves re-optimization every period by the policymaker. Kydland and Prescott (1977), Barro and Gordon (1983), and Rogoff (1985) were the first to focus on the gains of moving away from discretionary policy towards commitment and credibility.

Commitment permits monetary policy to follow a time-inconsistent path. A time-inconsistent path is one in which the policymaker would find it optimal to break its promises at a future date if given the opportunity. This situation would arise following a cost push shock (inflation and the output gap move in opposite directions). Optimal commitment policy partially reduces current inflation (which is forward looking) by promising higher real rates, lower inflation, and lower output gaps in the future. By committing to such a response, the policymaker can improve the inflation/output gap tradeoff during the period of the shock. The implied benefits in the short term dominate the relatively small losses generated by lower output gaps in future periods.

Once the cost-push shock subsides, the tradeoff is no longer present, and in contrast to the policymaker under commitment, the discretionary policymaker chooses to stabilize inflation and the output gap completely every period thereafter. The discretionary policymaker stabilizes the output gap (in the medium term) to a greater extent than the policymaker under commitment because it is unable to affect current inflation through expectations. This is known as the stabilization bias. The discretionary policymaker is unable to influence expectations because the agents know that the policymaker will re-optimize each period and will not keep promises about future policy.

In my model, purely exogenous cost-push shocks are not incorporated. The only shocks are short run shocks to productivity growth, smaller but more persistent (long run) shocks to productivity growth, and government expenditure shocks. Each of these shocks result in the output

gap (between the flexible and sticky price level of output) and inflation moving together in the same direction. Therefore, in a setting where the steady state is not distorted and there are no real imperfections, stabilizing inflation amounts to stabilizing the output gap, which as known as the divine coincidence. In the undistorted setup, the optimal inflation coefficient in the interest rate reaction function would be infinite. This would eliminate the distortions associated with sticky prices, namely price dispersion and time-varying markups, and the efficient flexible price allocations would be attained.

However, my analysis is conducted around a distorted steady state so that the flexible price allocation is not efficient. I do not assume that an employment subsidy is put in place by the government to offset the monopolistic distortion. In addition, distortionary taxes are used to fund the government rather than lump sum taxes. Each of these distortions generates an inefficient steady state in which the natural (flexible price) level of output is permanently different from the efficient level of output. Specifically, the ratio of marginal rate of substitution between consumption and leisure and the marginal product of labor would be 1 if the economy were efficient. Instead, the ratio is approximately 0.85 with monopolistic competition (due to the markup), and 0.7 when distortionary taxes are included. If it is assumed that these distortions cannot be simply abstracted away, then there exists a tradeoff between inflation and output. Variations in the gap between the efficient and natural levels of output makes it impossible to attain both zero inflation and the efficient level of output.

With discretionary policy around a distorted steady state, it is no longer optimal for the policymaker to replicate the flexible price allocation. On the other hand, any deviation of output from the flexible price level generates variations in inflation. Agents form expectations that take into account the desire for the policymaker to correct for the inefficiently low average level of activity. The only way for the policymaker to achieve a higher level of activity is to push output past the natural level and increase inflation. Agents expect this and the net result is higher inflation, with no impact on output. This is known as the inflation bias.

The discretionary policymaker chooses a positive level of inflation because this is where the

marginal costs of inflation are equal to the marginal benefits in terms of output. At a rate of zero inflation and with wages set, the marginal benefit of incremental inflation on output is positive, and the marginal cost of zero inflation is zero, so the benefits outweigh the costs. The policymaker systematically raises inflation until the marginal benefits equal the marginal costs, which results in the inflation bias. Rogoff (1985) showed that one way to address this is to appoint an independent and conservative central banker who places less weight on the output gap compared to the social welfare loss function. This would be equivalent to finding that the optimal inflation coefficient is very high relative to the coefficient on output in a simple monetary policy rule. There are many studies such as Schmitt-Grohe and Uribe (2004, 2006a, b) that find this to be the case.

The policymaker under commitment is able to raise output initially above its natural level, but then promises to return output gradually to its natural level. By promising to return output to its natural level, there are more subdued effects on inflation which improves the short run tradeoff. Under commitment, the policymaker can commit to avoiding a positive inflation bias asymptotically.

4.4.0.2 Inertia Coefficient

In the New Keynesian model, forward-looking expectations are a crucial component through which monetary policy can influence the economy. This is because consumption and investment (i.e. aggregate demand) is dependent upon not just the current real interest rate, but also all future expected real interest rates. Given that the policymaker in my model is committing to a rule in which it has full credibility, monetary policy is capable of altering the expectations of the households and firms. This is important from a welfare perspective because it allows the policymaker to improve the short-run tradeoff when inflation and the welfare-relevant output gap move in opposite directions.

Since firms are forward-looking when resetting their prices, inflation (which is a function of the firms' optimal prices) will not rise by as much during a cost-push shock if the firms are promised by monetary policy that future output gaps and marginal costs will be lower. This improves the short-run tradeoff between inflation and output and is the basis for why policies under commitment

welfare-dominate discretionary policies. It is in this spirit that a positive inertia coefficient could potentially improve welfare. With a positive inertia coefficient, dependence on a lagged term permits the policymaker to manipulate long term interest rates with more modest movements in the short term rate than would otherwise be necessary. As pointed out in Rotemberg and Woodford (1997), the central bank can achieve its stabilization goals only insofar as its actions affect longer-term rates as output and prices do not respond to daily fluctuations in the federal funds rate. A straightforward way to influence the future path of short term rates is to maintain a higher level of interest rates for a period of time after they have been raised. Hence, given the agents forward-looking expectations, monetary policy can impose significant effects on aggregate demand without using extremely volatile movements in the short-term interest rate.

4.5   Tax Risk and Inflation Risk

The sources of taxation and inflation risk are discussed in the following paragraphs. Both types of risk have consequences for forward looking optimizing firms and households along with welfare, especially in the context of a risk-sensitive model. Prior to exploring these specific risks further, it is necessary to discuss a broader view of risk.

Risk is exposure to a stochastic environment in which there are known probabilities to all potential events. This definition is not to be confused with Knightian uncertainty, in which the probabilistic distribution of outcomes is unknown. From this point forward, any mention of uncertainty will be in the context of a well-defined probability distribution for which the parameters are assumed to be known by all actors in the economy.

In my general equilibrium model, the primitive sources of risk are three well-defined exogenous i.i.d., Gaussian symmetric shocks. These shocks consist of a mean-reverting demand shock to the government expenditures share of output and both a short-run and long-run productivity growth shock. The long-run productivity growth shock is represented by a persistent AR(1) and has a smaller volatility compared to the short-run shock. It captures variation in expected productivity growth, as empirically documented by Croce (2013). My production-based asset pricing model endogenously creates links between the primitive well-defined sources of risk, cash flows, and

inflation.

In a setting where agents have concave utility, additional compensation is systematically required by the agent to hold an asset with stochastic payoffs. This compensation for risk is quantified by agents and is referred to as the risk premium. Mathematically, the risk premium is equivalent to the covariance of the stochastic discount factor (SDF) with the return of the asset. The covariance can be decomposed into three components: (1) the volatility of the SDF, (2) the volatility of the return and (3) the correlation between the SDF and the return.

4.5.1 Taxation Risk

Tax risk is a reflection of fluctuations and comovement of the tax rate with marginal utility of the agent. It is important because the agent cares about after-tax income (labor wages and capital return). In my general equilibrium model, there is no primitive tax risk and no policy uncertainty. Stochastic tax fluctuations are a result of shocks to productivity and government expenditures.

Capital accumulation. A distortionary tax on labor and capital income will be used to fund the government. The agent will be exposed to tax risk because the environment is stochastic and the tax rate on capital and labor income is time varying. In addition, the agent is forward looking and will care about the risk profile of the entire stream of taxation over the infinite horizon. The tax immediately enters the household's intertemporal Euler equation as follows

$$q_t = E_t \left[\underbrace{m_{t,t+1}}_{\text{Discount channel}} \left(\underbrace{(1 - \tau_{t+1}^D)u_{t+1}}_{\text{Cash flow channel}} + (1 - \delta)q_{t+1} \right) \right]$$

where the nominal stochastic discount factor used to price equity in this setting is

$$M_{t,t+1} = \beta \left(\frac{c_{t+1}}{c_t} \right)^{\iota(1 - \frac{1}{\psi}) - 1} \left(\frac{1 - h_{t+1}}{1 - h_t} \right)^{(1-\iota)(1 - \frac{1}{\psi})} \underbrace{\left[\frac{v_{t+1}}{E_t[v_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right]^{\frac{1}{\psi} - \gamma}}_{\text{Recursive Prefs.}} \frac{P_t}{P_{t+1}}$$

and the real stochastic discount factor is therefore

$$m_{t,t+1} = M_{t,t+1} \cdot \pi_{t+1}$$

The ex-dividend price of one unit of productivity-adjusted aggregate capital is represented by q_t. This quantity is affected by tax risk through two channels: the discount channel and the cash flow channel. The distortionary tax rate directly enters the cash flow channel and alters the after-tax rental rate of capital. Persistent changes in tax rates can affect this channel for many periods depending on the degree of tax smoothing by the government.

The discount channel is affected by the tax rate due to its general equilibrium effect on the properties of consumption. An increased tax rate results in lower output, altering the stochastic discount factor through changes in consumption. Note the stochastic discount factor under recursive preferences is able to take into account not just realized consumption/leisure growth but also expected consumption/leisure growth. In other words, the effects of changes in tax rates that are persistent beyond period t+1 are missing from the discount channel under power utility preferences. This suggests the price of tax risk will be substantially higher with risk-sensitive preferences.

Holding all else constant, tax risk leads to higher return uncertainty on capital through the cash-flow channel. This combined with its effects on the stochastic discount factor result in a higher equity premium while depressing capital accumulation. This leads to a loss in welfare as income and consumption fall.

Labor allocation. The tax on labor directly enters the intratemporal optimality equation of the household as follows

$$\frac{1-\iota}{\iota} \frac{c_t}{1-h_t} = w_t(1 - \tau_t^D)$$

A positive tax rate increases the cost of smoothing consumption, which increases the volatility of leisure and consumption. Furthermore, the tax has a propagation effect on the volatility of labor based on the following logic: A fall in the tax rate increases equilibrium labor by the substitution effect, which increases labor income and thus the size of the tax base. As the size of the tax base

rises, the tax rate needed to balance the budget falls, which then repeats the process just described.

A higher volatility of labor implies a higher volatility of leisure, which enters the stochastic discount factor used to discount future cash flows. Holding all else constant, a more volatile stochastic discount factor increases the equity premium ($\approx \rho_{m,r^K} \cdot \sigma(m) \cdot \sigma(r^K)$). In addition, increased volatility of leisure and consumption lowers welfare because of the assumed concavity of utility.

4.5.2 Inflation Risk

A measure of risk related to inflation is the inflation risk premium, which is captured by the covariance of inflation and the SDF of the agent. There are no pure inflation shocks in the model, as inflation is an endogenous reflection of fiscal and productivity shocks. Views about the size and sign of inflation risk premia vary considerably across the literature. Hordahl et al. (2007), Ravenna and Seppala (2007a, 2007b), and Veronesi and Yared (2000) estimate that inflation risk premia are very close to zero. This is likely due to the assumption of habits in the latter studies, which generates large real term premia (real interest rate risk), leaving little room for inflation risk to explain the upward sloping nominal yield curve observed in the data.

A number of empirical studies come to the opposite conclusion that inflation risk is positive and non-negligible. Buraschi and Jiltsov (2005), Ang, Bekaert, and Wei (2006), Kim and Wright (2005) estimate the inflation risk premium to be between 70 and 200 basis points depending on the horizon. In terms of inflation risk and optimal monetary policy, Gavin et al (2009) determine that putting weight on the price path for the monetary policy rule reduces long-run inflation variability. Their analysis is conducted with log utility and focuses on inflation volatility, which makes up only one component of the inflation risk premium (volatility of SDF and correlation of SDF with inflation being the other two).

Stochastic inflation affects the choices of the firm, household, and government. The following sections describe the sources and ramifications of inflation risk for each agent.

The firm. For the $(1 - \alpha)$ % of firms that do get to choose their price optimally, the equilibrium pricing condition consists of setting the present discounted value of future marginal revenues equal

to some markup over the present discounted value of future marginal costs. This is equivalent to $x_t^2 = \frac{\eta}{\eta-1}x_t^1$ where

$$
\underbrace{x_t^2}_{\text{Marginal Revenues}} = p_t^{*-\eta}y_t + \alpha E_t\left[M_{t,t+1}\pi_{t+1}^{\eta}\pi_t^{\chi(1-\eta)}\left(\frac{p_t^*}{p_{t+1}^*}\right)^{-\eta}x_{t+1}^2\right]
$$

$$
\underbrace{x_t^1}_{\text{Marginal Costs}} = \underbrace{p_t^{*-1-\eta}y_t mc_t}_{\text{Cash flow}} + \alpha E_t\left[\underbrace{M_{t,t+1}\pi_{t+1}^{\eta+1}\pi_t^{\chi(-\eta)}}_{\text{Discount channel}}\left(\frac{p_t^*}{p_{t+1}^*}\right)^{-1-\eta}x_{t+1}^1\right]
$$

The firm is affected by inflation risk through two channels: the cash-flow channel and the discount channel. As can be seen above, the cash flow channel is a function of the production of the firm. Inflation directly affects the efficiency of production as price dispersion results in misallocation of resources

$$
y_t = \frac{1}{s_t}\left[k_t^{\theta}(A_t h_t)^{1-\theta}\right] \tag{4.14}
$$

where s_t, the measure of price dispersion, is a function of inflation

$$
s_t = (1-\alpha)p_t^{*-\eta} + \alpha\left(\frac{\pi_t}{\pi_{t-1}^{\chi}}\right)^{\eta}s_{t-1}
$$

In the current setup, bad states of the world (e.g. negative productivity shocks) are associated with higher inflation. This makes the firm's cash flows riskier because they fall even more in bad states of the world (due to larger misallocation of resources as a result of higher inflation). Note this cash-flow channel and the costs of price dispersion are present in previous studies. However, the major difference between this model and previous efforts will revolve around the discount channel and its sensitivity to different risks.

With respect to the discount channel, inflation directly enters the equilibrium pricing condition. Firms are concerned with the possibility of not being able to adjust their prices optimally in the following periods. Therefore, if future expected inflation rises, firms place greater weight on these future marginal costs and benefits and discount them less when choosing the optimal price.

The firm is discounting cash flows based on the marginal utility of the household because this

is a general equilibrium model and the households own the firms. Inflation results in misallocation of resources, which impacts GDP and the equilibrium properties of consumption. The changes in consumption due to non-neutral inflation alters the household/firm's stochastic discount factor.

The government.   The government is impacted by inflation risk through two channels: the interest payments it must make on the previous period's debt and the changes in the size of the tax base. The tax base is equivalent to income and is going to be altered by inflation risk through the firm's production decisions, as described above. With regards to interest payments, agents are going to require compensation in the form of an inflation risk premium to hold nominal debt as follows

$$R_t - (r_t + E_t[\pi_{t+1}]) = cov_t(m_{t,t+1}, \pi_{t+1}) \tag{4.15}$$

where R_t is the nominal risk free rate, r_t is the real risk free rate, $E_t[\pi_{t+1}]$ is the expected inflation rate, and $m_{t,t+1}$ is the real stochastic discount factor.

Given that inflation is stochastic, the inflation risk premium is positive if inflation is associated with high marginal utility states (e.g. bad technology shocks). The intuition is the following: the agent's real return from holding the nominal bond is lower with higher realized inflation, and the agent dislikes lower real returns in high marginal utility states. Thus, the agent requires compensation above expected inflation in the form of an inflation risk premium for holding the nominal bond. Holding all else constant, the higher interest payment costs of debt put more pressure on tax rates when balancing the budget.

Observable measures of risk in the data.   Ideally, the observable measure of inflation risk would be the covariance between the stochastic discount factor and the inflation rate. However, the stochastic discount factor is not directly observable in the data. Due to this, I will focus on the volatility of the inflation rate. An additional measure of the inflation risk premium would be the difference between a nominal bond and treasury inflation protected security plus expected inflation. However, even this measure abstracts from liquidity premia that make it difficult to determine the true inflation risk premium.

Likewise, the observable measure of tax risk would ideally be the covariance between the SDF and the tax rate. However, as stated above, the stochastic discount factor is not directly observable in the data. Also, the correlation changes sign depending on the source of uncertainty. Short run shocks generate a positive correlation, so that tax rates rise in bad times. In contrast, long run shocks generate a negative correlation, as tax rates rise upon the realization of good news due to the wealth effect dominating (consumption/leisure rise). In the setting with all three shocks, the covariance becomes less negative as the inflation coefficient rises, indicating higher tax risk as monetary policy stabilizes inflation.

Excluded dimensions of risk. In my model, inflation has no effect on the firm's financing structure and leverage. That is because I assume the capital structure of the firm is not endogenous. I assume the firm is made up of 50% equity and 50% debt, which is what we observe in the data. Financial leverage is assumed to be fixed and there is no tax shield on debt, so the capital structure is independent of the value of the firm and Modigliani and Miller (1958) holds. Rather than focusing on corporate debt, the focus of my study is on public debt. Assuming endogenous leverage and public debt would lead to an analysis of crowding out between private and public debt, but I abstract from this situation.

In contrast, Gomes, Jermann, Schmid (2013) take into account the structure of the firm and model real corporate debt but do not include public debt. In their model, debt is written in nominal terms so that unanticipated changes in inflation affect firm balance sheets. The intuition is that the real value of debt rises with lower than expected inflation, which worsens firms' balance sheets and they become more likely to default. Given debt overhang or multi-period debt, surviving firms begin to cut future investment and production plans so that the increased real debt lowers the expected rewards to equity owners.

Their results show a channel through which inflation could improve welfare as it would avoid the negative welfare consequences of debt deflation. By modeling private debt, the policy recommendations are for allowing greater inflation in bad times in order to improve firms' balance sheets as it lowers the real value of their debt. To arrive at this result, the authors compare a setting with

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exogenous inflation to a monetary-policy rule that incorporates inflation and output. The goal of their study is not to find the optimal policy, but to show that inflation can have real effects without imposing sticky prices. My study focuses on finding the optimal policy with a focus on inflation's effect on public rather than private debt. Higher unexpected inflation in bad times can improve the balance sheet of the government because the level of real debt declines and tax rates are not forced to rise by as much.

Another issue is related to the symmetry of the shocks within the model. Shocks in the model are assumed to be iid, Gaussian, with no jumps, no skewness and no kurtosis. Assuming some form of skewness would very likely increase the compensation for risk as shown in Colacito et al (2014).

4.5.3 Tradeoff of Inflation and Taxation Risks: Motivation

The monetary authority controls the dynamics of inflation through the simple Taylor rule

$$ln\left(\frac{R_t}{R*}\right) = \alpha_r ln\left(\frac{R_{t-1}}{R*}\right) + \overset{\uparrow}{\overbrace{\alpha_\pi}} ln\underbrace{\left(\frac{\pi_t}{\pi*}\right)}_{\downarrow\,\sigma(\pi)} + \alpha_{\Delta y} ln\left(\frac{\Delta y_t}{\Delta y*}\right)$$

The central bank can decrease inflation risk and its associated costs by engaging in a Hawk policy (high α_π inflation coefficient). To understand better how this relates to taxation risk, assume monetary policy is able to stabilize inflation completely so that its volatility is zero. Then the real government budget constraint

$$b_t = \underbrace{\frac{R_{t-1}}{\pi_t}}_{\text{As }\sigma(\pi)\,\downarrow} b_{t-1} + g_t - \overset{\uparrow\,\sigma(\tau^D)}{\overbrace{\tau_t^D}} y_t.$$

can only be balanced through greater fluctuations in the distortionary tax rate, τ_t^D. Hence, monetary policy faces a tradeoff in which decreasing inflation risk will simultaneously increase tax risk.

Previous studies in the optimal fiscal and monetary policy literature suggest the benefits of

reducing misallocation of resources completely dominate the costs of increased tax volatility.[6] Re-call, the costs of increased tax risk include higher equity risk (increased after-tax return uncertainty) and higher labor income risk.[7] The increased costs of tax risk are quantitatively insignificant in previous studies because the price of risk (sensitivity of the stochastic discount factor to uncertainty) is counterfactually low. The goal of the next section is to show that when risk is priced consistent with the data, the welfare costs of increased tax risk will rise so that optimal inflation volatility will be substantially higher.

4.6   Results

4.6.1   Equity Premium, Inflation Risk Premium and Optimal Inflation Volatility

The optimal inflation volatility is determined by finding the inflation coefficient α_π in the interest rate rule that corresponds to the household's greatest lifetime utility. No other economic actor receives utility in the model except the household. This definition of optimality is specific to a class of rules that are not considered globally optimal. While there is value in determining what the economy would look like under the globally optimal policy, implementation of the Ramsey policy would require an unrealistic demand in terms of information or computing capacity for the decision maker. This is because the optimal policy would require perfect observation of all the shocks hitting the economy along with the laws of motion that govern the dynamics within the economy. These solutions are well-known for being extremely complicated and very model-specific while tending to be less robust to model uncertainty. For these reasons, I focus on a small subset of implementable simple rules that are functions of observable variables. Furthermore, multiple papers such as Schmitt-Grohe and Uribe (2007) have shown the best simple rules often come quite close to matching the welfare of the globally optimal Ramsey rule.

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[6]This is a result that I confirm with power utility in Section 4.6.1.

[7]Higher labor income risk is due to the stabilization of markups. The wedge/markup between the marginal product of labor and the real wage decreases in good times as monetary policy stabilizes inflation. This results in a higher labor response by the substitution effect as the lower markup entails a higher real wage (MPL = markup * w). Therefore, labor income is higher in good times and this higher labor volatility implies higher consumption/leisure volatility, which is suboptimal from a welfare perspective.

The following Taylor Rule will be used to conduct the analysis:

$$ln\left(\frac{R_t}{R*}\right) = 0.6 \cdot ln\left(\frac{R_{t-1}}{R*}\right) + 0.5 \cdot ln\left(\frac{\Delta y_t}{\Delta y*}\right) + \alpha_\pi ln\left(\frac{\pi_t}{\pi*}\right)$$

The parameters chosen for the inertia coefficient and the output growth gap are set to match inflation dynamics and interest rate serial correlation observed in the data. Specifically, without the output growth gap, inflation is theoretically positively correlated with permanent productivity shocks, which is counterfactual with respect to the empirical evidence and economic intuition. Incorporating the output growth gap results in inflation falling with good productivity shocks and rising with bad productivity shocks. At first, the inflation target will be assumed to be constant and set to its average value of 3.5% which is consistent with the annual average observed from 1945-2012.[8] Later exercises will consist of endogenizing the inflation target to take into account fluctuations in the debt-GDP ratio.

Loss function comparison. The linear-quadratic methodology involves deriving a linear policy rule that minimizes a quadratic approximation to the true welfare objective subject to linear constraints that are first-order approximations to the true structural equations (Benigno and Woodford 2007). The central bank loss function is a reduced-form second-order approximation of the household's utility, which is a quadratic function of inflation and the output gap. According to Gali (2008), the use of first-order approximations to the structural equations ignores welfare losses associated with the steady-state effects of different degrees of volatility.

Benigno and Woodford (2004) derive a different approach that computes the second-order approximation to the model's structural equations. They use a linear combination of those equations to eliminate the linear terms in the second-order approximation to the welfare measure to obtain a purely quadratic expression. According to Benigno and Woodford (2004), "Because the loss function is purely quadratic (lacking linear terms), it is possible to evaluate it to second order using only a first-order approximation to the equilibrium evolution of inflation and output under a given

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[8]Setting the inflation target to 2% yields little to no difference in results.

policy. Hence, log-linear approximations to the structural relations of their model suffice, yielding a standard linear-quadratic policy problem."

While this method computes the correct steady-state capital after accounting for volatility, the preferences that are used in this setting still abstract from asset-pricing considerations. In other words, these settings are not truly capturing the effect of uncertainty that is characterized by asset prices in the data. Furthermore, capital is typically abstracted from, so that labor is the only input for production. Capital is important to include because (1) it is an important determinant of wealth, (2) it acts as a propagation mechanism through which shocks affect the economy for many periods, and (3) changes in capital through investment are a driving factor in fluctuations of aggregate demand and the business cycle.

The following Figure 4.1 summarizes one method of "inflating away debt" through control of the inflation coefficient and the second moment. The Dove policy (low α_π) allows for a higher response of inflation to a negative productivity shock. This decreases the real debt-GDP ratio and relieves pressure on the fiscal side so tax rates don't have to rise as much. However, this decreased tax risk comes at the expense of inefficient price dispersion. The price dispersion costs completely dominate in previous studies and in the Power Utility model studied in this paper. Upon incorporating model features consistent with the asset pricing literature, optimal inflation volatility rises substantially, which suggests that tax risk becomes a first-order concern for monetary-policy considerations.

Optimal α_π for Power Utility   I find that the optimal inflation coefficient[9] for the Power Utility model is ∞. This corresponds to a zero volatility of inflation. Optimal monetary policy consists of completely eliminating inflation volatility at the expense of increased tax volatility. This is the general result in a simple model of productivity shocks, sticky prices and flexible wages.[10]

By preventing changes in the rate of inflation, monetary policy is minimizing dead-weight

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[9]I use grid values for the inflation coefficient and find the highest welfare when $\alpha_\pi = 1e^{16}$.

[10]See Schmitt-Grohe and Uribe (2006); Woodford (2004); Goodfriend and King (1998)
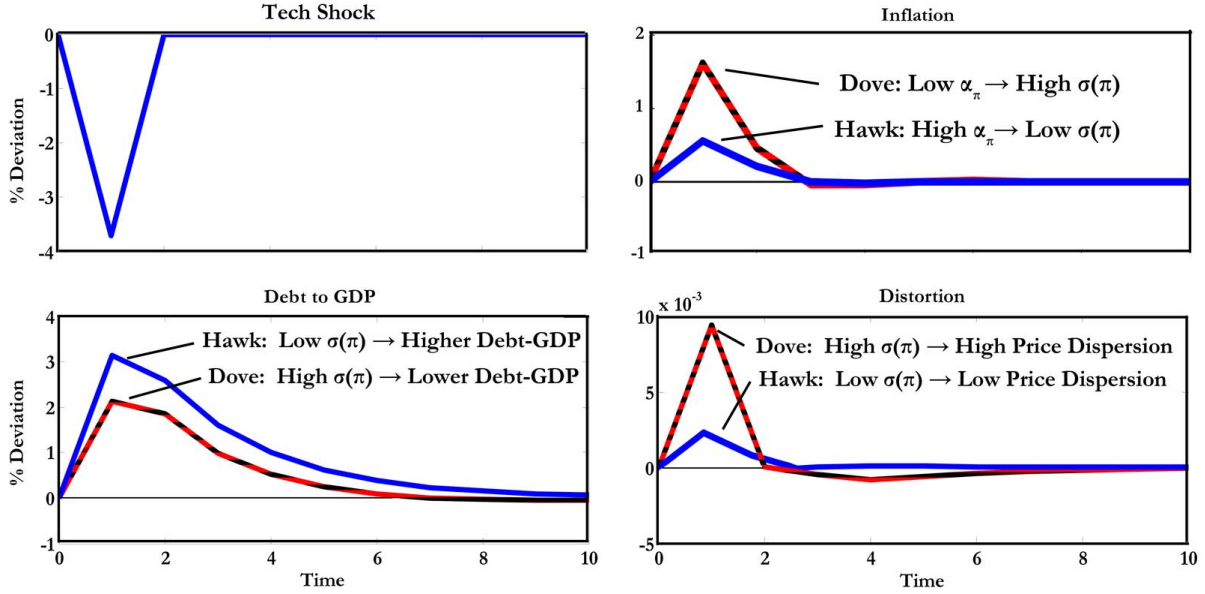
Figure 4.1: "Inflating Away Debt" with Inflation Coefficient (α_π)
This panel shows how the inflation coefficient (α_π) can be an important tool for allowing inflation to help stabilize the debt-GDP ratio. These results are based on the Main Model, and its calibration can be found in Table 4.1. The Dove policy corresponds to $\alpha_\pi = 0.6$ while the Hawk policy is for $\alpha_\pi = 1.6$.

losses due to price dispersion. This decreases misallocation of labor and misallocation of intermediate goods in the agent's utility function, which results in higher welfare. The benefits of lower price dispersion dominate the costs of increased tax volatility because this model understates the price of risk.

Optimal α_π for Main Model I find that the optimal inflation coefficient for the Main Model[11] is 5.65, as opposed to ∞ for the Power Utility model. This corresponds to an optimal inflation volatility of 21 basis points versus 0 basis points for the Power Utility model. Welfare gains turn into welfare losses upon reducing inflation volatility below 21 basis points in the Main Model. This substantial difference in optimal inflation volatility can be better understood by analyzing the tradeoff between inflation risk and tax risk.

Trading off inflation risk and tax risk. A comparison of the two models shows the equity premium in the left panel of Figure 4.2. The equity premium reacts significantly more for the

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[11]The model with vintages of capital, long-run risk, and recursive preferences.
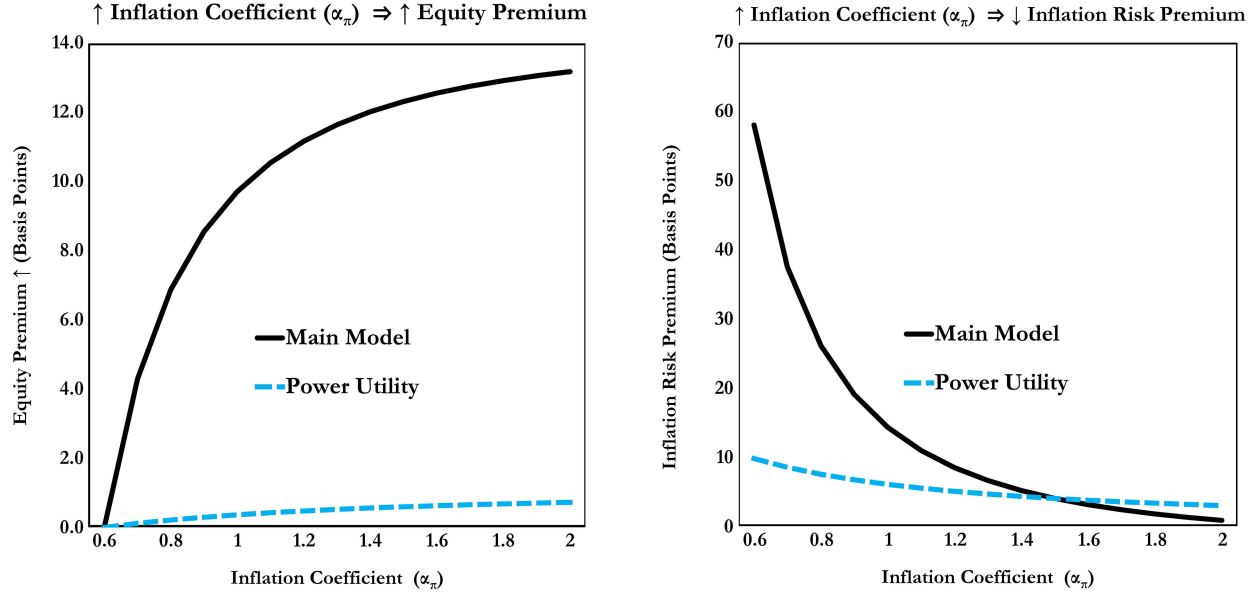
Figure 4.2: Trading off Equity Risk and Inflation Risk

The left panel shows the increase in the equity premium as monetary policy increasingly stabilizes inflation with a higher inflation coefficient (α_π). The right panel shows the level of the inflation risk premium as monetary policy increasingly stabilizes inflation with a higher inflation coefficient (α_π). The annual calibrations are reported in Table 4.1. Excess returns are levered by a factor of three, consistent with Garcia-Feijo and Jorgensen (2010).

Main Model compared to the Power Utility model. With monetary policy increasing tax risk, the resulting increased return uncertainty and labor risk combine to yield a 13 basis point increase in the equity premium for the Main Model. In contrast, the Power Utility model's equity premium goes up by less than a basis point. The higher equity premium lowers capital accumulation and welfare. Likewise, the inflation risk premium falls substantially as monetary policy increasingly targets inflation. This fall is more drastic in the Main Model because of its greater sensitivity to risk.

Composition of intertemporal nominal risk. The effect monetary policy has on the intertemporal composition of nominal risk can be seen in Figure 4.3. On the horizontal axis is the annual maturity and on the vertical axis is the real excess return of a nominal bond over the one-period-ahead risk-free rate. This curve captures compensation for both real interest rate risk and the inflation risk premium at multiple horizons. Note that the slope is positive and reaches over 100 basis points, which is broadly consistent with empirical evidence of the nominal term structure.

Term Structure of Nominal Bond
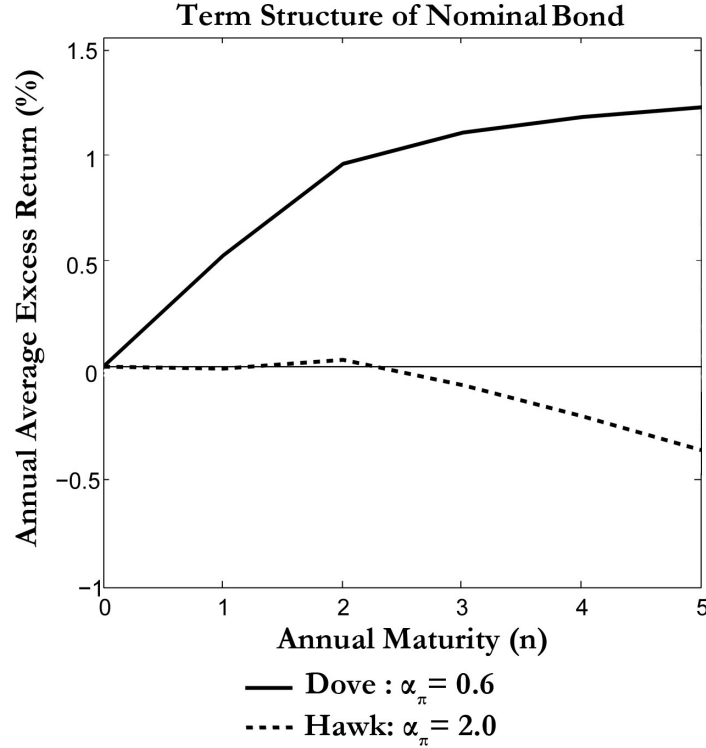
Figure 4.3: Intertemporal Composition of Nominal Risk as Inflation Coeff. $(\alpha_\pi) \uparrow$

This panel shows the nominal term structures for Dove ($\alpha_\pi = 0.6$) and Hawk ($\alpha_\pi = 2$) policies. The Dove policy corresponds to an inflation volatility of 2.2%, which is consistent with the historical average. These results are based on the Main Model, and its calibration can be found in Table 4.1.

As monetary policy stabilizes inflation, the term structure starts to fall and become downward sloping, which is due to the fact that the term structure of real bonds is downward sloping in this model.[12] As monetary policy increases the inflation coefficient, the inflation risk premium is decreasing and the nominal term structure starts to resemble the term structure of real bonds, which only captures real interest rate risk.

Composition of intertemporal equity risk. The effect monetary policy has on the intertemporal composition of the equity premium can be seen in Figure 4.4. The aggregate equity premium of

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[12]Note, the term structure of real bonds is downward sloping because real bonds provide insurance when consumption growth is positively autocorrelated. The reason is the following: good news today is associated with good news in the future (due to positive correlation), and good news is associated with higher real interest rates. Hence, good news today is associated with lower prices of real bonds, and the later maturity real bonds are most sensitive. Therefore, the longer term real bonds provide the most insurance as their prices rise the most in recessions or bad states, so their holding return is highest in bad states. This intuition is consistent with the most recent financial crisis, in which holding returns for real bonds increased as their prices increased.

the stock market can be thought of as a value-weighted average of zero coupon equity claims to the aggregate dividend ($D_t = Y_t - w_t L_t - I_t$) at different horizons. In other words, the price of equity can be decomposed into the sum of future discounted dividend strips

$$P_t^{equity} = \underbrace{E_t[m_{t+1|t} \cdot D_{t+1}]}_{P_t^1} + \cdots + \underbrace{E_t[m_{t+n|t} \cdot D_{t+n}]}_{P_t^n} + \cdots$$

The term structure of equity is made up of one-period excess returns of zero-coupon claims to dividends with maturity n defined as

$$E_t[R_{n,t+1}^{ex}] = E_t \left[\frac{P_{n-1,t+1}}{P_{n,t}} - R_t^f \right]$$

Figure 4.2 shows that as monetary policy attempts to stabilize inflation, tax risk rises and this increases return uncertainty and labor income risk, resulting in a higher aggregate equity premium. Figure 4.4 shows that with regards to the temporal distribution, Hawk monetary policy is actually decreasing equity risk in the short run but at the expense of higher equity risk in the long run.

Explanation of decreased short-term equity risk. The decreased equity risk in the short run of the Hawk monetary policy can be explained by the following logic: In good times, Hawk monetary policy stabilizes inflation which compresses the markup of marginal product of labor over the real wage in the firm's demand for labor. The smaller markup entails higher equilibrium labor, which increases labor income for the household. Given that labor income is higher, the total payout to the household becomes lower ($D_t = Y_t - w_t L_t - I_t$) in good times, which decreases the riskiness of dividends in the short run. In fact, the fall in equity risk is over 200 basis points for the Main Model. In contrast, the fall in equity risk for Power Utility is ten times smaller, as shown in Figure 4.5.

Explanation of increased long-term equity risk. The increased equity risk in the long run of the Hawk monetary policy is due to the increased tax risk, as fiscal policy can no longer depend on fluctuations of inflation to help balance its budget. The difference in expected excess returns
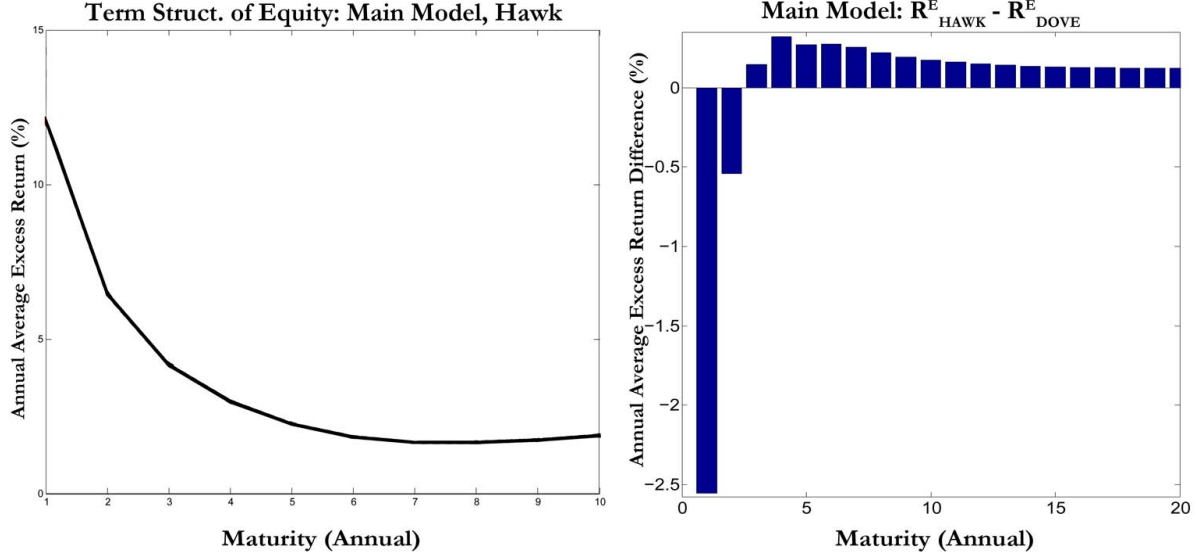
Figure 4.4: Intertemporal Composition of Equity Risk

The left panel shows the equity term structure for the Main Model with Hawk policy ($\alpha_\pi = 2$). The term structure of equity shows the one-period excess (holding) return of a zero coupon claim to the aggregate dividend ($D_t = Y_t - w_t L_t - I_t$) with maturity n:

$$R_{n,t} = E_t[P_{n-1,t+1}/P_{n,t}] - r_t^f$$

where $P_{n,t}$ (the time-t value of the dividend realized at time t+n) follows a recursion such that $P_{0,t} = D_t$, $P_{n,t} = E_t[m_{t+1}P_{n-1,t+1}]$. The right panel shows the difference in term structures for the Hawk policy ($\alpha_\pi = 2$) and the Dove Policy ($\alpha_\pi = 0.6$). The Hawk policy decreases equity risk in the short run but increases equity risk in the long run. The calibration for the Main Model can be found in Table 4.1.

after ten years is approximately 13 basis points, which closely resembles the overall increase in the

aggregate equity premium shown in Figure 4.2. This suggests that the aggregate equity premium,

which is essentially a value weighted average over an infinite stream of future cash flows, places

greater weight on long-term risk considerations. Ultimately, the agent's optimal investment deci-

sions will be more of a function of long-term uncertainty rather than short-term uncertainty. This

effect is muted in the Power Utility model, as shown in Figure 4.5.[13]

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[13]Note that the above results are suggesting that the value premium should be lower under Hawk vs Dove monetary policy. Whether this is consistent with empirical evidence is left for future research.
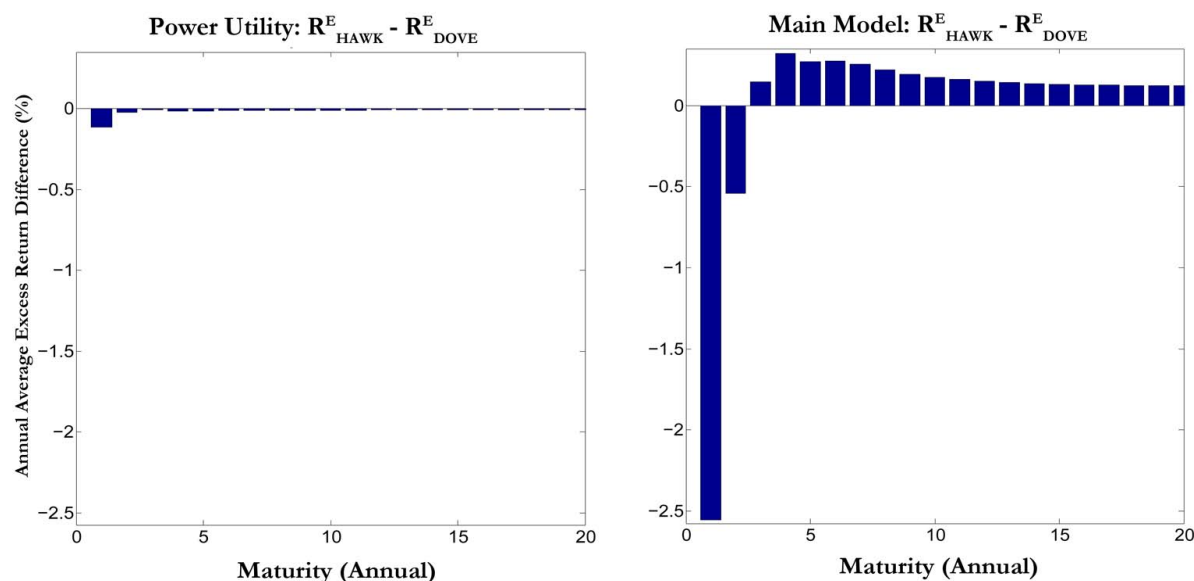
Figure 4.5: Hawk Minus Dove: Difference in Intertemporal Composition of Equity Risk

The left panel shows the difference in the equity term structures for the Hawk policy ($\alpha_\pi = 2$) and Dove policy ($\alpha_\pi = 0.6$) for Power Utility. The right panel shows the difference in term structures for the Hawk policy ($\alpha_\pi = 2$) and the Dove policy ($\alpha_\pi = 0.6$) for Main Model, which is identical to the right panel in Figure 4.4 and is included for comparison. The Hawk policy decreases equity risk in the short run but increases equity risk in the long run for the Main Model. The long run effect is muted in the Power Utility model. The calibrations for these models are in Table 4.1.

4.6.2 Increased Debt Levels and Tax Risk

According to the *2013 CBO Long-Term Budget Outlook*, "Under one set of alternative policies, referred to as the extended alternative fiscal scenario... federal debt held by the public would reach about **190 percent of GDP by 2038**, CBO projects." The extended alternative fiscal scenario is a projection based on items that are not currently law but may potentially happen. For example, the alternative scenario assumes lawmakers will prevent Medicare's payment rates for physicians from declining, as they have done every year previously.[14] The baseline scenario assumes current law will continue regardless of the feasibility.

The CBO outlines what the increased debt-GDP ratio could mean for tax risk, "Federal spending on **interest payments would rise**, thus requiring **larger changes in tax policies** ... to achieve

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[14]There are other examples. The alternative assumes that about 75 expiring tax provisions (including a provision allowing businesses to immediately deduct 50 percent of new investments in equipment) will be extended through 2023, whereas the baseline assumes no extension.

Federal Public Debt Under **Alternative** Extended Baseline Through 2049	Government Spending Under **Alternative** Extended Baseline Through 2048
(Percentage of Gross Domestic Product)	(Percentage of Gross Domestic Product)
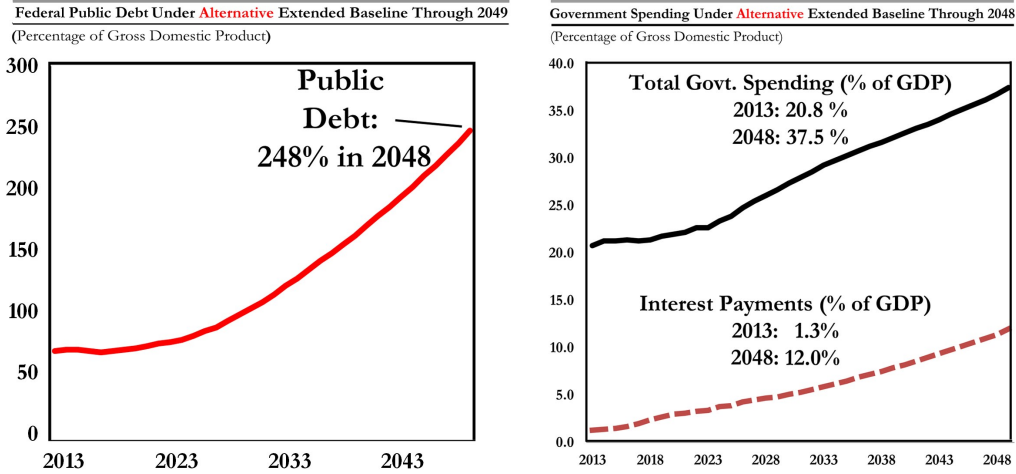
Figure 4.6: Higher Public Debt $\implies$ Higher Interest Payments $\implies$ Higher Tax Risk

The data for these two panels are taken from 2013 CBO Long-Term Budget Outlook Supplementary Data Excel file. Note under the alternative scenario, public debt levels cease to be estimated once they pass the 250% threshold of Debt-GDP.

any chosen targets for budget deficits and debt." This notion that tax risk will increase is clear from the government's budget constraint

$$b_t = \underbrace{\frac{R^f_{t-1}}{\pi_t} b_{t-1}}_{\text{As } \frac{b}{y} \uparrow} + g_t - \overbrace{\tau^D_t}^{\uparrow \sigma(\tau^D)} y_t$$

A higher steady state debt entails higher interest payments on debt, which leads to more volatile tax rates so that the budget constraint holds. At 190% debt-GDP ratio, tax volatility jumps 30 basis points as the inflation coefficient rises, compared to 7 basis points under the lower historical steady state debt. These higher costs of tax risk are reflected by the higher optimal inflation volatility as the models become more risk-sensitive, as shown in Figure 4.7.

Moving to the higher debt-GDP ratio in Figure 4.7, the optimal inflation volatility doubles under the Main Model and is now positive in all models except the Power Utility model. In fact, in results available upon request, the optimal inflation volatility was zero for debt levels as high as 500% of GDP. This suggests that in a model that does not price risk consistent with the data (Power Utility), an important cost of inflation stabilization (increased tax risk) is muted even at extreme

Optimal Inflation Volatility
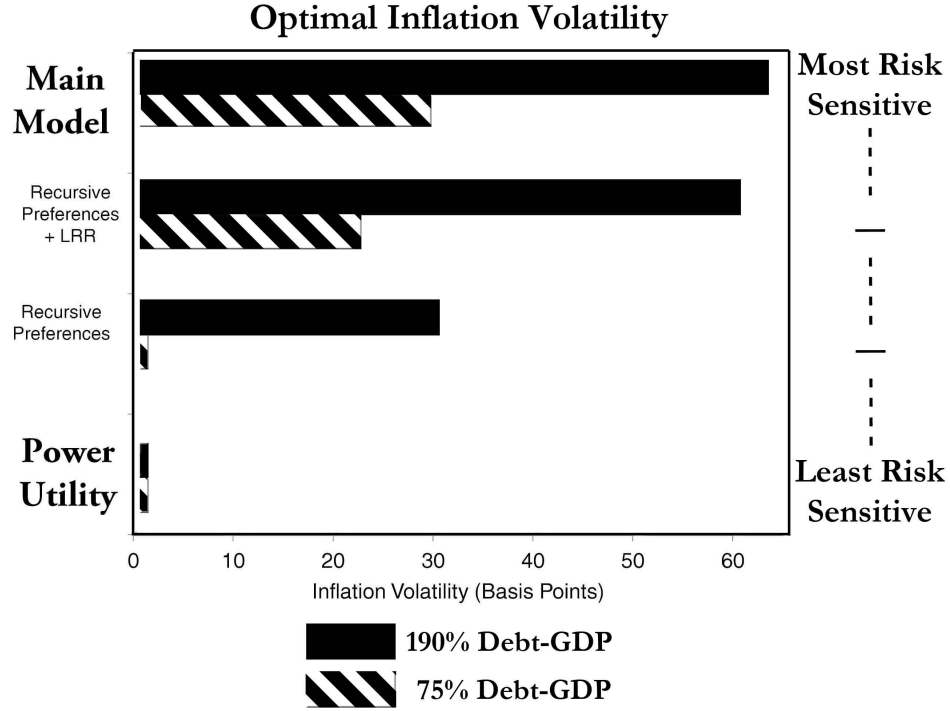
Figure 4.7: Higher Cost of Tax Risk $\implies$ Higher Optimal Inflation Volatility

This panel shows the optimal inflation volatility for all of the models over two levels of Debt-GDP: present day (75%) and CBO 2039's projection (190%). The bottom model is indicative of the framework typically studied in the optimal fiscal and monetary policy literature. As one moves up the panel, additional asset pricing features are incorporated up to the Main Model, which is representative of the framework for the production-based asset pricing literature. The calibrations for each model can be found in Table 4.1

debt levels. In contrast, the results of the Main Model suggest that with higher levels of debt-GDP, tax risk becomes a first-order concern. It would be optimal for monetary policy to become less Hawk and more Dove to help reduce tax risk at both current and extreme levels of debt.[15]

4.6.3 "Inflating Away Debt" with Time Varying Inflation Target

The focus now shifts from the second moment of inflation to the first moment. I assume that monetary policy is allowing the inflation target to fluctuate and respond positively to the debt-GDP ratio. In other words, the following equations govern monetary policy:

$$ln\left(\frac{R_t}{R*}\right) = 0.6 \cdot ln\left(\frac{R_{t-1}}{R*}\right) + 0.6 \cdot ln\left(\frac{\pi_t}{\pi*}\right) + 0.5 \cdot ln\left(\frac{\Delta y_t}{\Delta y*}\right)$$

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[15]More Dove is in reference to the optimal policy under the Power Utility setting.

$$\pi_t^* = \pi * + \alpha_G \cdot ln(\frac{b_t}{y_t}/\frac{b*}{y*})$$

where $\alpha_G > 0$ would indicate monetary policy increasing the inflation target with higher levels of the debt-GDP ratio.

While fluctuations in the inflation target are related to the first moment, it also clearly impacts the second moment. Monetary policy is now stabilizing inflation around a moving target, which would also increase the volatility of inflation. The intuition is the following: holding all else constant, an increase in the debt-GDP ratio elevates the inflation target, which acts to lower the nominal rate. This reduces the costs of debt while also boosting GDP.

Mechanism. To understand better the impact of $\alpha_G > 0$, one can observe the effects of an exogenous increase in government spending. In Figure 4.8 there are four panels and three cases. The solid blue line represents the case in which the inflation coefficient is set optimally, and there is no alteration to the inflation target. The dotted green line represents the case when $\alpha_G > 0$ and is "Inflating Away Debt" by increasing the inflation target as debt-GDP rises. The dotted red line (lower α_π case) is included for sake of comparison to the "Inflating Away Debt" case so both have identical volatilities of inflation. However, the acceleration of inflation (volatility of $\frac{\pi_t}{\pi_{t-1}}$) for the lower α_π case is higher than the "Inflating Away Debt" case. This is important for distortion because when price indexation is perfect, it is the change in inflation rates that matter for welfare.

As can be seen from the second panel, the dotted green line representing the "Inflating Away Debt" case is elevated for a longer duration. This is due to the inflation target picking up the extended increase in Debt-GDP as fiscal policy smoothes taxes. In the third panel, one can see that while the lower α_π case (dotted red line) results in lower Debt-GDP in the short term, the increased distortion (due to greater acceleration) reduces efficiency of production so that Debt-GDP is higher in the medium to long term. This translates into a higher distortionary tax rates in the medium to long term. Higher tax risk in the medium to long term is captured by the risk-sensitive preferences of the Main Model, and the agent dislikes these long-term risks.

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Growth in Govt.

Inflation

"Inflating Away Debt"
-Elevated inflation rate
→ for higher duration
-Lower π acceleration
→ lower distortion

Debt-GDP

Lower α_π , Greater Distortion
→ Higher Debt-GDP

"Inflating Away Debt"
→Lower Debt-GDP

Distortionary Tax Rate

—— Optimal α_π , $\alpha_G = 0$

--- Optimal α_π , $\alpha_G > 0$
"Inflating Away Debt"

····· Lower α_π , $\alpha_G = 0$
-Same $\sigma(\pi)$ as above
-Higher Acceleration

"Inflating Away Debt"
→ Lower long-run tax rate

Figure 4.8: G Shock: Lower Inflation Acceleration: $\alpha_G > 0$ Compared to Lower α_π
The four panels show how allowing the target rate of inflation to be affected by debt-GDP brings about welfare gains. The reduction in acceleration of inflation compared to the lower α_π results in lower Debt-GDP ratio and tax rates in the medium to long term.

When is it optimal to alter the inflation target?   I find that if this question is addressed in the context of the Power Utility model, the answer is never. Debt levels up to 500% of GDP were tested, and in each case, the welfare costs of price dispersion dominated the gains of reduced tax risk. When moving to the rich asset-pricing Main Model, for debt levels below 200% of GDP, the reductions in tax risk are quantitatively small. For example, as α_G increases in the low debt

setting (44% of GDP), tax rate volatility decreases by less than a basis point and the volatility of the consumption-leisure bundle declines by less than a basis point. The effect is less than a basis point because at low debt levels, interest payments are smaller, and the volatility of the tax rate is low at 1.14 %.

However, with debt-GDP ratios beyond 200% of GDP, "inflating away debt" becomes optimal because tax-rate volatility falls by 12 times as much as in the low debt scenario. Furthermore, the volatility of the consumption-leisure bundle falls by 5 times as much in the low-debt scenario. Hence, the reduction in tax risk increases with the level of debt. And this reduction in tax risk leads to a greater reduction in consumption-leisure volatility under the Main Model compared to the Power Utility model (5 vs 0.9 basis points).

Quantitative welfare differences. Up until this point, all discussion of welfare gains and losses across different policies have been qualitative in nature. This is because the welfare gains have been at most a few basis points (hundredths of a percentage point). For instance, when tax rate volatility is matched to the high end of the data (close to 6%), the welfare gains of inflating away debt are at best 8 basis points.

The small differences across policies is not just unique to monetary policy. Tax smoothing combined with removal of all uncertainty with respect to government spending shocks results in a gain of only 25 basis points. This is an issue that has plagued the business cycle literature since the discussion of Lucas (1987). That study showed that welfare gains from removing all business cycle fluctuations were less than a basis point. This issue has been addressed by papers such as Tallarini (2000) and Croce (2012), in which they use asset pricing facts to discipline the model. They show that welfare gains from removing business cycle fluctuations are orders of magnitude larger when agents' concern for risk matches the data. If monetary and fiscal policy were capable of removing all fluctuations in the Main Model (which has many of the same features as Croce (2012)), then there would be sizable welfare gains in this study as well. However, it is not possible for fiscal or monetary policy to remove all uncertainty, so these welfare improvements represent best-case scenarios that are impossible to match.

Therefore, the small differences in policies are not unique to my model. Schmitt-Grohe and Uribe (2006) also point out that the majority of policies they studied have welfare differences less than a basis point. When growth is exogenous and agents have the ability to smooth consumption through endogenous investment and labor, it is expected that policy differences are more qualitative than quantitative in nature. If one is concerned about the quantitative welfare differences across policies, the model must move towards endogenous growth. Other fiscal policy papers such as Croce et al. (2012) and Croce et al. (2012) only obtain sizable welfare differences once they incorporate endogenous growth in some form. This is an avenue I plan to leave for future research.

4.7 Conclusion

This study evaluates optimal inflation dynamics while departing from the existing fiscal and monetary policy literature in just one dimension -- risk considerations. Risk considerations include the equity premium and the nominal term structure as found in the data, and these are captured by introducing recursive preferences, long-run risk, and heterogeneous vintages of capital.

I have shown that when accounting for risk and tax uncertainty as in the data, central bankers' optimal inflation toughness dramatically changes for a fixed inflation target. This is especially true at higher levels of debt where interest payments increase tax risk. Furthermore, I find it becomes optimal for monetary policy to directly react to the debt-GDP ratio but only at high levels (greater than 200%). This contrasts with the findings of the Power Utility model that suggests it is never optimal. Overall, the results of this study convey the need to account for risk in monetary policy analysis.

In addition, this is the first study to evaluate the potential effects of monetary policy on the intertemporal distribution of the aggregate equity premium. I find that Hawk policy (stabilizing inflation) decreases short term risk while increasing long term risk. This occurs because Hawk policy stabilizes markups, so that labor rises and the total payout to the household falls in good times. This makes short-run dividends less risky while increasing tax risk for long-term dividends.

Potential areas of improvement include endogenous growth, the zero lower bound, richer fiscal policies, and uncertainty about government policy. Policies that affect endogenous growth have

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been shown to yield sizable welfare difference as in Croce et al. (2012) and Croce et al. (2012). Although the zero lower bound is not explicitly modeled in this study, I consider it to be a fruitful avenue for future research. In addition, richer fiscal policies beyond the simple rule used in this study as in Leeper et al. (2010) could potentially alter the conclusions of this study. Finally, uncertainty about government policy is abstracted from as commitment and perfect information about policy is assumed for this study. Moving towards uncertainty and learning about policy as in Pastor and Veronesi (2011), Pastor and Veronesi (2012), and Kelly, Pastor, and Veronesi (2013) is another channel that should be considered in future research.

Table 4.1: Model Features and Parameter Values

		Main Model	Rec. Prefs. +LRR	Rec. Prefs.	Power Utility
Recursive Preferences		✓	✓	✓	
Long Run Risk		✓	✓		
Capital Vintages		✓			
Preference parameters					
Discount factor	β	0.99	0.99	0.99	0.99
Effective risk aversion	$\gamma \cdot o$	10	10	10	6
Intertemporal elasticity of substitution	ψ	2.0	2.0	2.0	1/6
Leisure weight	o	0.35	0.35	0.35	0.35
Technology parameters					
Capital share	θ	0.25	0.25	0.25	0.25
Depreciation rate	δ	15%	15%	15%	15%
Productivity parameters					
Risk exposure of new investment	ϕ_0	0	1	1	1
Average growth rate	μ	2.0%	2.0%	2.0%	2.0%
Volatility of short-run risk	σ_a	3.71%	3.71%	3.71%	3.71%
Volatility of long-run risk	σ_x	0.52%	0.52%	0%	0%
AR(1) of expected growth	ρ	0.925	0.925	0.925	0.925
New Keynesian parameters					
Price elasticity of demand	η	7	7	7	7
Probability firm cannot change price	α	10%	10%	10%	10%
Policy parameters					
Steady state Debt to GDP	S_B	0.44	0.44	0.44	0.44
Steady state $\frac{G}{Y}$	S_G	0.17	0.17	0.17	0.17
Monetary Policy Inflation Coefficient	α_π	0.6	0.6	0.6	0.6
Output Growth Gap Coefficient	$\alpha_{\Delta y}$	0.5	0.5	0.5	0.5
Inertia Coefficient	α_r	0.6	0.6	0.6	0.6

I will be comparing a total of four models that are ordered from most risk-sensitive to least risk sensitive, left to right. Additional results will be found in the Appendix for the models re-calibrated to match GDP risk and the risk free rate. Preliminary analysis indicates little to no changes in results upon re-calibrating.

Table 4.2: Main Model Moments

	Data	Main Model
$E(I/Y)$	00.15	00.20
$\sigma(\Delta c)$	02.16 (0.17)	02.34
$\sigma(\Delta i)$	16.40 (1.26)	16.18
$\sigma(\Delta n)$	03.66 (0.29)	03.05
$\sigma(\Delta y)$	03.59	03.75
$AC_1(\Delta c)$	00.49	00.36
$AC_1(\Delta y)$	00.35	00.30
$\sigma(\tau^D)$	03.10	01.40
$AC_1(\frac{B}{Y})$	00.94	00.90
$E(\pi)$	03.50	03.10
$\sigma(\pi)$	02.32	02.19
$\sigma(r^f)$	01.35	01.20
$E[r^f]$	00.89	01.55
$E[r^{L,ex}]$	05.70 (2.25)	3.84
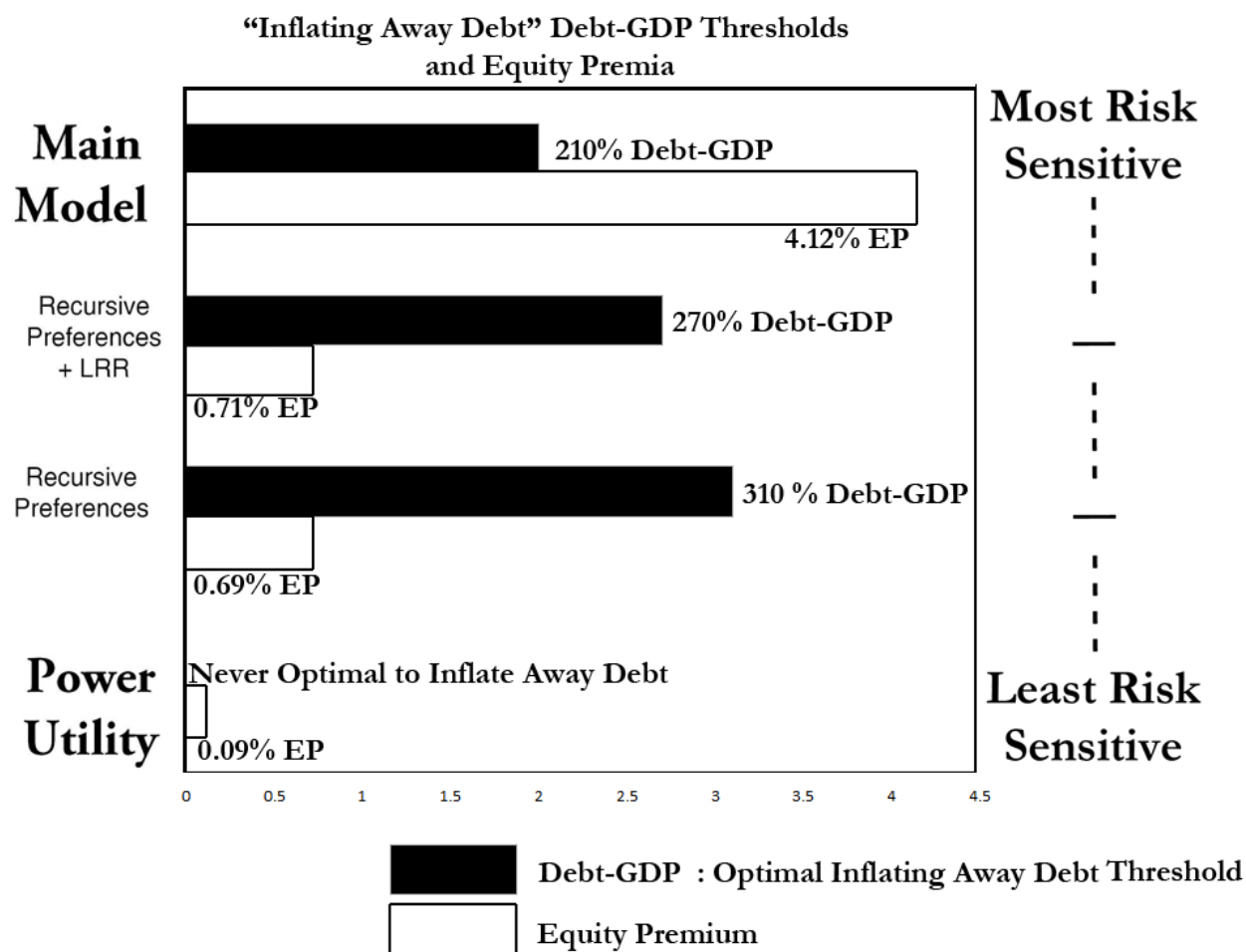
Figure 4.9: Tipping Points: When it is Optimal for Monetary Policy to Respond to Debt-GDP
This panel shows the debt thresholds for when welfare gains start to be realized from inflating away debt. The bottom model is indicative of the framework typically studied in the optimal fiscal and monetary policy literature. As one moves up the panel, additional asset pricing features are incorporated up to the Main Model, which is representative of the framework for the production-based asset pricing literature. Note that as model risk-sensitivity increases, the threshold for optimal monetary policy responding to debt-GDP falls.

APPENDIX TO CHAPTER 2: ASSET PRICING AND THE WELFARE EFFECTS OF
MONETARY POLICY

A.1 Model

The economy consists of a continuum of identical households, a continuum of intermediate-
goods firms, and a government that conducts monetary and fiscal policy. The structure of the model
is the standard neoclassical growth model augmented with real and nominal frictions. The nominal
friction is sticky prices. The real friction is monopolistic competition, which results in a markup
of price over marginal costs. Monetary policy assumes full commitment to an interest rate rule
that is a function of inflation and output growth. Fiscal policy raises lump-sum taxes to pay for
exogenous expenditures.

Preferences.   The households have Epstein-Zin preferences defined over consumption goods, c_t,
and leisure, $1-h_t$. These preferences exhibit a CES aggregate of current and future utility certainty
equivalent weighted by $(1-\beta)$ and β, respectively.

$$v_t = \max_{\{c_j,h_j,i_j,b_j,k_{j+1}\}_{j=t}^\infty} \left\{ (1-\beta)(c_t^\iota(1-h_t)^{1-\iota})^{1-\frac{1}{\psi}} + \beta(E_t[v_{t+1}^{1-\gamma}])^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}$$

s.t.

$$b_t + c_t + i_t + \tau_t = R_{t-1}\frac{b_{t-1}}{\pi_t} + w_t h_t + u_t k_t + \check{\phi}_t$$

The real value of debt is b_t; c_t is consumption; i_t is investment; R_{t-1} is the risk-free rate; π_t is the
inflation rate $\frac{P_t}{P_{t-1}}$; τ_t is the lump-sum tax; w_t is the real wage; h_t is labor hours; u_t is the rental rate
of capital; k_t is capital; and $\check{\phi}_t$ is profits.

Unlike standard preferences, Epstein-Zin preferences allow for the disentanglement of γ, the
coefficient of relative risk aversion, and ψ, the elasticity of intertemporal substitution. When $\frac{1}{\psi} =$
γ, the utility collapses to standard preferences with additively separable expected utility both in
time and state. When $\gamma > \frac{1}{\psi}$, the agent prefers early resolution of uncertainty, so the agent dislikes
shocks to long-run expected growth rates.

Intermediate good bundling. The consumption good is assumed to be a composite made of a continuum of differentiated goods c_{it} indexed by $i \in [0, 1]$ via the aggregator:

$$c_t = \left[\int_0^1 c_{it}^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}$$

The elasticity of substitution across different varieties of consumption goods is $\eta > 1$ (also the price elasticity of demand for good j). As $\eta \to \infty$, the goods become closer and closer substitutes, so that individual firms have less market power.

The household minimizes total expenditures subject to an aggregation constraint, where P_{jt} is price of intermediate good j:

$$\min_{c_{jt}} \int_0^1 P_{jt} c_{jt} dj$$

s.t.

$$\left[\int_0^1 c_{it}^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}} \geq c_t$$

The optimal demand for the level of intermediate consumption good c_{jt} is given by

$$c_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\eta} c_t$$

where P_t is the nominal price index

$$P_t \equiv \left[\int_0^1 P_{jt}^{1-\eta} dj \right]^{\frac{1}{\eta-1}}$$

Productivity. The law of motion of the productivity process captures both short-run and long-run productivity risks:

$$\log \frac{A^0_{t+1}}{A^0_t} \equiv \Delta a_{t+1} \;=\; \mu + x_t + \sigma_a \varepsilon_{a,t+1}, \tag{A.1}$$

$$x_{t+1} \;=\; \rho x_t + \sigma_x \varepsilon_{x,t+1}, \tag{A.2}$$

$$\begin{bmatrix} \varepsilon_{a,t+1} \\ \varepsilon_{x,t+1} \end{bmatrix} \;\sim\; i.i.d.N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \right), \quad t = 0,1,2,\cdots. \tag{A.3}$$

According to the above specification, short-run productivity shocks, $\varepsilon_{a,t+1}$, affect contemporaneous output directly but have no effect on future productivity growth. Shocks to long-run productivity, represented by $\varepsilon_{x,t+1}$, carry news about future productivity growth rates but do not affect current output.

Capital Accumulation Technology. Assume that investments in different vintages of capital have heterogeneous exposure to aggregate productivity shocks.[1] In other words, there will be vintage-specific productivity growth that is going to depend on the age $j = 0, 1, ..., t - 1$ of the vintage of capital

$$\frac{A^{t-j}_{t+1}}{A^{t-j}_t} = e^{\mu + \phi_j (\Delta a_{t+1} - \mu)}$$

Under the above specification, production units of all generations have the same unconditional expected growth rate. Also, $A^{t-0}_t = A^0_t$ is set to ensure that new production units are on average as productive as older ones. The log growth rate of the productivity process for the initial generation of production units, Δa_{t+1}, is given by equation (A.1). Heterogeneity is driven solely by differences in aggregate productivity risk exposure, ϕ_j.

The empirical findings in Ai et al. (2012) suggests that older production units are more exposed

---

[1]Multiple frictions for capital accumulation have been tested, and this friction was chosen because standard capital adjustment costs result in counterfactually low investment growth volatility. The friction in this paper does not suffer from this issue.

to aggregate productivity shocks than younger ones, i.e., the exposure ϕ_j is increasing in j. To capture this fact, a parsimonious specification for ϕ_j is adopted:

$$\phi_j = \begin{cases} 0 & j = 0 \\ 1 & j = 1, ... \end{cases}.$$

$$\overbrace{\frac{A_{t+1}^{t-0}}{A_t^{t-0}}}^{\text{new vintage of capital, j=0}} = e^{\mu} \qquad \overbrace{\frac{A_{t+1}^{t-j}}{A_t^{t-j}}}^{\text{all other older vintages of capital, j=1,2..}} = e^{\mu + x_t + \sigma_a \epsilon_{a,t+1}} \qquad (A.4)$$

New production units have zero exposure to aggregate productivity shocks in the first period of life. Every period thereafter, they have 100% exposure to aggregate productivity shocks as do all other existing vintages.

Let K_t denote the productivity-adjusted physical capital stock. Despite the heterogeneity in productivity, aggregate production can be represented as a function of K_t and N_t. The law of motion of the productivity-adjusted physical capital stock K_t, takes the following form:

$$K_1 = I_0, \quad K_{t+1} = (1 - \delta)K_t + \omega_{t+1}I_t$$

$$\omega_{t+1} = \left(\frac{A_{t+1}^{t-0}}{A_{t+1}^0} \right)^{\frac{1-\alpha}{\alpha}} = e^{-\frac{1-\alpha}{\alpha}(x_t + \sigma_a \epsilon_{a,t+1})(1-\phi_0)}$$

where I_t is the total mass of new vintage capital produced at time t, and ω_{t+1} is an endogenous process that accounts for the productivity gap between the newest vintage of capital and all older vintages. Note that when $\phi_0 = 1$, the new capital vintage has the same exposure to aggregate productivity shocks as older ones. In this case, $\omega_{t+1} = 1$ for all t and capital of all generations are identical.

The Government. The government issues one-period nominal risk-free bonds, b_t, collects taxes in the amount of τ_t, and faces an exogenous expenditure and transfers stream, g_t and tr_t. Its period by period budget constraint is given by

$$b_t = \frac{R_{t-1}}{\pi_t} b_{t-1} + g_t - \tau_t + tr_t$$

The exogenous expenditure streams are formulated as in Croce et al. (2012)

$$\frac{G}{Y} = \frac{1}{1 + e^{-\bar{gy}}}$$

$$gy_t = (1 - \rho_g)\bar{gy} + \rho_g gy_{t-1} + \epsilon_{G,t}, \quad \epsilon_{G,t} \sim N(0, \sigma_{gy}^2)$$

$$try_t = (1 - \rho_g)\bar{try} + \rho_{tr} try_{t-1} + \epsilon_{tr,t}, \quad \epsilon_{tr,t} \sim N(0, \sigma_{try}^2)$$

Total tax revenues, τ_t, consist of lump-sum tax revenues.

Tax smoothing by the government consists of tax revenues rising whenever the previous period's debt rises

$$\tau_t - \tau* = \gamma_1(b_{t-1} - b*)$$

where $\gamma_1 > 0$ ensures that the debt-GDP ratio is bounded and there is a unique solution.

The monetary authority sets short-term nominal interest rate according to a simple Taylor rule

$$ln(R_t/R*) = \alpha_r ln(R_{t-1}/R*) + \alpha_\pi ln(\pi_t/\pi*) + \alpha_{\Delta y} ln(\Delta y_t/\Delta y*)$$

where α_r is the inertia coefficient, α_π is the inflation coefficient, α_{Δ_y} is the output growth gap coefficient, $\pi*$ is the inflation target, and $\Delta y*$ is the output growth target.

Firms. Each variety $i \in [0, 1]$ is produced by a single firm in a monopolistically competitive environment. Each firm i produces output using as factor inputs capital services, k_{it}, and labor services, h_{it}. It is assumed that the firm must satisfy demand at the posted price. Formally,

$$k_{it}^\theta (A_t h_{it})^{1-\theta} \geq \left(\frac{P_{it}}{P_t}\right)^{-\eta} y_t$$

The objective of the firm is to choose P_{it}, h_{it}, k_{it} to maximize the present discounted value of

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profits, given by

$$E_t \sum_{s=t}^{\infty} m_{t,s} P_s \phi_{is}$$

where real profits of firm i are

$$\phi_{it} \equiv \frac{P_{it}}{P_t} y_{it} - u_t k_{it} - w_t h_{it}$$

Prices are assumed to be sticky as in Calvo (1983). Each period, a fraction $\alpha \in [0, 1)$ of randomly picked firms is not allowed to optimally set the nominal price of the good they produce. Instead, these firms index their prices to past inflation according to the equation

$$P_{it} = P_{it-1} \pi_{t-1}^{\chi}.$$

Note, that in all settings $\chi = 0$, which implies there is no price indexation. The remaining $1 - \alpha$ firms choose $\check{P}_t$ to maximize the expected present discounted value of profits:

$$E_t \sum_{s=0}^{\infty} d_{t,t+s} P_{t+s} \alpha^s \left\{ \left(\frac{\check{P}_t}{P_t} \right)^{1-\eta} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}^{\chi}}{\pi_{t+k}} \right)^{1-\eta} y_{t+s} - u_{t+s} k_{it+s} - w_{t+s} h_{it+s} \right.$$
$$\left. + mc_{it+s} \left(k_{it+s}^{\theta} (A_t h_{it+s})^{1-\theta} - \left(\frac{\check{P}_t}{P_t} \right)^{-\eta} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}^{\chi}}{\pi_{t+k}} \right)^{-\eta} y_{t+s} \right) \right\}$$

The firm's first-order conditions for labor, capital, and optimal price are

$$mc_t(1 - \theta)\left(\frac{\tilde{k}_t}{h_t}\right)^{\theta} = \tilde{w}_t \tag{A.5}$$

$$mc_t\theta\left(\frac{\tilde{k}_t}{h_t}\right)^{\theta-1} = u_t \tag{A.6}$$

The firm's optimal price is set such that marginal revenues are equal to some markup over marginal costs

$$\frac{\eta}{\eta - 1} x_t^1 = x_t^2 \tag{A.7}$$

where

$$\tilde{x}_t^1 = p_t^{*-1-\eta}\tilde{y}_t mc_t + \alpha E_t D_{t,t+1}\pi_{t+1}^{\eta+1}\pi_t^{\chi(-\eta)}\left(\frac{p_t^*}{p_{t+1}^*}\right)^{-1-\eta}\tilde{x}_{t+1}^1 e^{\Delta a_{t+1}} \tag{A.8}$$

$$\tilde{x}_t^2 = p_t^{*-\eta}\tilde{y}_t + \alpha E_t D_{t,t+1}\pi_{t+1}^{\eta}\pi_t^{\chi(1-\eta)}\left(\frac{p_t^*}{p_{t+1}^*}\right)^{-\eta}\tilde{x}_{t+1}^2 e^{\Delta a_{t+1}} \tag{A.9}$$

Aggregation and Equilibrium. This period's price level is a weighted average of the firm's optimal price and the previous period's price level:

$$1 = \alpha\pi_t^{-1+\eta}\pi_{t-1}^{\chi(1-\eta)} + (1-\alpha)p^{*(1-\eta)} \tag{A.10}$$

It can be shown that the resource costs of inefficient price dispersion are characterized as follows

$$s_t = (1-\alpha)p_t^{*-\eta} + \alpha\left(\frac{\pi_t}{\pi_{t-1}^{\chi}}\right)^{\eta} s_{t-1} \tag{A.11}$$

Given the price dispersion, output is described by

$$\tilde{y}_t = \frac{1}{s_t}[\tilde{k}_t^{\theta}(A_t h_t)^{1-\theta}] \tag{A.12}$$

and aggregate demand is the following sum

$$\tilde{y}_t = \tilde{c}_t + \tilde{i}_t + \tilde{g}_t \tag{A.13}$$

A.2 Optimal Inertia Coefficient

In the New Keynesian model, forward-looking expectations are a crucial component through which monetary policy can influence the economy. This is because consumption and investment (i.e., aggregate demand) are dependent upon not just the current real interest rate, but also all future expected real interest rates. Given that the policymaker in my model is committing to a rule in which it has complete credibility, monetary policy is fully capable of altering the expectations of the households and firms.

Since firms are forward looking when resetting their prices, inflation (which is a function of the firms optimal prices) will not rise by as much if the firms are promised by monetary policy that future output gaps and marginal costs will be lower (which is what commitment allows). This improves the short-run trade-off between inflation and output and is the reason that policies under commitment welfare-dominate discretionary policies. It is in this spirit that a positive inertia coefficient could potentially improve welfare.

With a positive inertia coefficient, dependence on a lagged term permits the policy maker to manipulate long-term interest rates with more modest movements in the short-term rate than would otherwise be necessary. One way to influence the future path of short-term rates is to maintain a higher level of interest rates for a period of time after they have been raised. Hence, given the agents' forward-looking expectations, monetary policy can impose significant effects on aggregate demand without using extremely volatile movements in the short-term interest rate. In my model, a high coefficient on the lagged interest rate reduces the variance of both inflation and consumption growth, and the optimal value is 0.9.

A.3   Asymmetric, persistent responses to long-run shocks

If all of the above dynamics were symmetric with respect to positive and negative shocks, policy would have no impact on the stochastic steady state of any of the endogenous variables. The second-order approximation is crucial because it captures nonlinearities that are inherent to the data. Nonlinearities imply asymmetric responses of endogenous variables. This potential asymmetry means that a greater variance can impact the steady-state values of variables such as the average markup, which is important for my welfare analysis.

Figure A1 shows the response of inflation and the average markup to both a positive and negative shock. The differences in responses have been magnified for pedagogical reasons. The red line is the difference in magnitude between the positive and negative long-run shock for the model with a high IES. It is clear that the red line follows the negative shock, which implies that the negative shock dominates. The magnitude of the difference is greater for the high IES model than for the low IES model. In the high IES model, the more forward-looking firms are choosing a
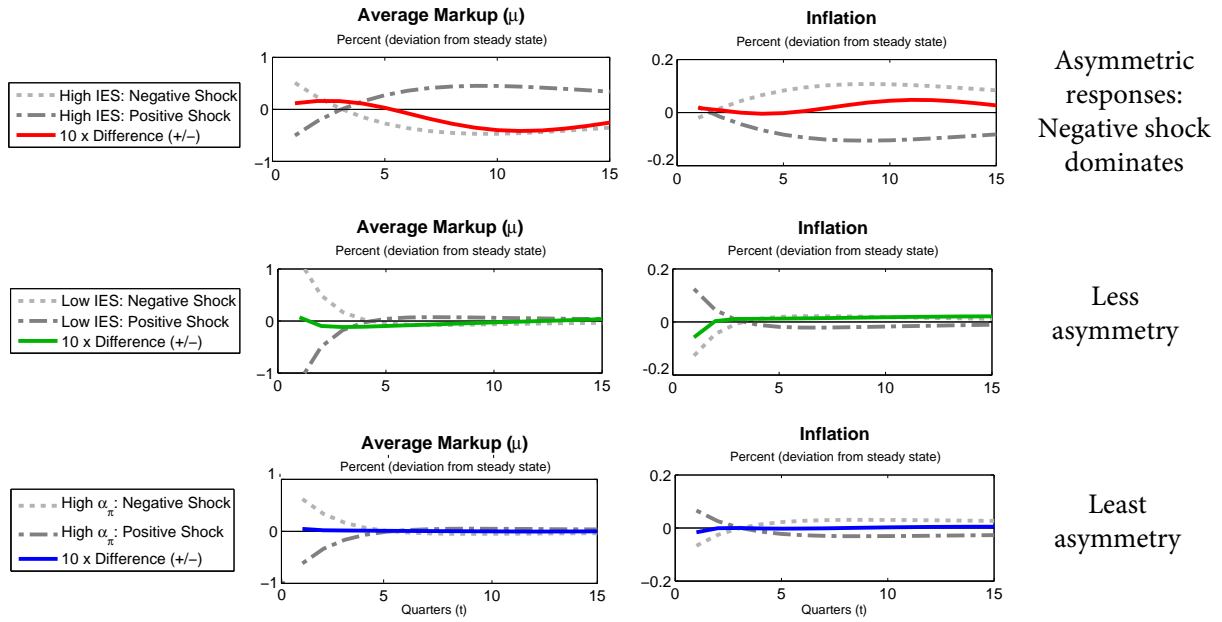
Figure A1: Asymmetric Responses to Positive and Negative Long-Run Shock

This figure shows the asymmetric endogenous responses to a negative long-run productivity shock on inflation and the markup. The parameterization is based on the calibration in table 4.1 and focuses on the policy that yields the highest welfare in equation 2.4. The colored line shows the difference between the positive and negative shocks. This asymmetry is greatest for the high IES setting and decreases with a low IES or high inflation coefficient. The implication is that the steady state markup will be close to the markup that occurs in the linear, symmetric setting. The negative shock dominating for the high IES implies that the average markup would be lower in that setting.

higher optimal price in response to the long-run negative productivity shock, and this erodes the average markup to a greater extent. The responses are practically symmetric with respect to the setting with a high inflation coefficient. This implies that the steady-state markup will be close to the markup that would occur in a linear, symmetric setting. Although not shown, the first-order approximations were perfectly symmetrical so the difference was precisely zero for every period.

A.4 Sensitivity Analysis

In terms of robustness, I test how sensitive the optimal inflation volatility and optimal inflation coefficients are to changes in the risk aversion coefficient and the intertemporal elasticity of substitution. Figure A2 shows that both a high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) are necessary for monetary policy to find it optimal to place less weight on stabilizing inflation. As these two parameters rise, monetary policy finds it optimal to stabilize consumption to a greater extent to lessen the severity of recessions and also to more effectively reduce the markup in bad

times.

First- vs. Second-Order Approximation, Low IES

The first studies of New Keynesian monetary policy (e.g. Goodfriend and King (1997), Woodford (2001)) used linear approximations. Studies thereafter used second-order approximations (e.g. Kollmann (2008), Schmitt-Grohé and Uribe (2007)) and they came to the same conclusions: it is optimal to focus solely on stabilizing inflation. All of the studies mentioned use standard preferences, where the IES is low and typically below one because it represents the inverse of the risk aversion coefficient.

To understand the negligible difference, note that the second-order approximation captures the effect of the variance of future shocks. Given the relatively low patience of the agent, it stands to reason that future effects would play a minor role in determining the optimal allocations, and this is confirmed by the impulse response functions in Figure A3. Overall, my findings suggest that one should expect to see very little difference in dynamics and outcomes when moving from first order to second order for a model with a low IES and relatively high risk free rate. This finding is roughly consistent with the notion that the typical macroeconomic model that abstracts from financial data can be well approximated with a first-order approximation.

First- vs. Second-Order Approximation, High IES

There are sizable differences between the first- and second-order approximations for the high IES ($\psi = 2$) case, as shown in Figure A3. The growth of the consumption-leisure bundle reacts more and does not revert to steady state as quickly as the first-order approximation. This is intuitive, because the second-order approximation yields a greater motive for precautionary savings, so that the agent works more and decreases leisure more at the onset of bad news. Firms also become more forward looking and are choose much higher prices as the negative productivity shock continues well into the future. For the second-order approximation, the average markup no longer quickly reverts to steady state but instead stays low for an extended period of time.

By taking into account the future shocks to the variance along with a greater precautionary savings motive, the second-order approximation implies much lower average markups are associated

with negative long-run productivity shocks. Recall that the average markup acts as an implicit tax on factors of production, so that a decrease in its value is positive for welfare. This substantial drop in the average markup is missing from the previous section that focuses on the low IES and is also missing in the literature. By allowing inflation to rise so that the average markup falls, monetary policy is providing good long-run news to counter the bad productivity shock.
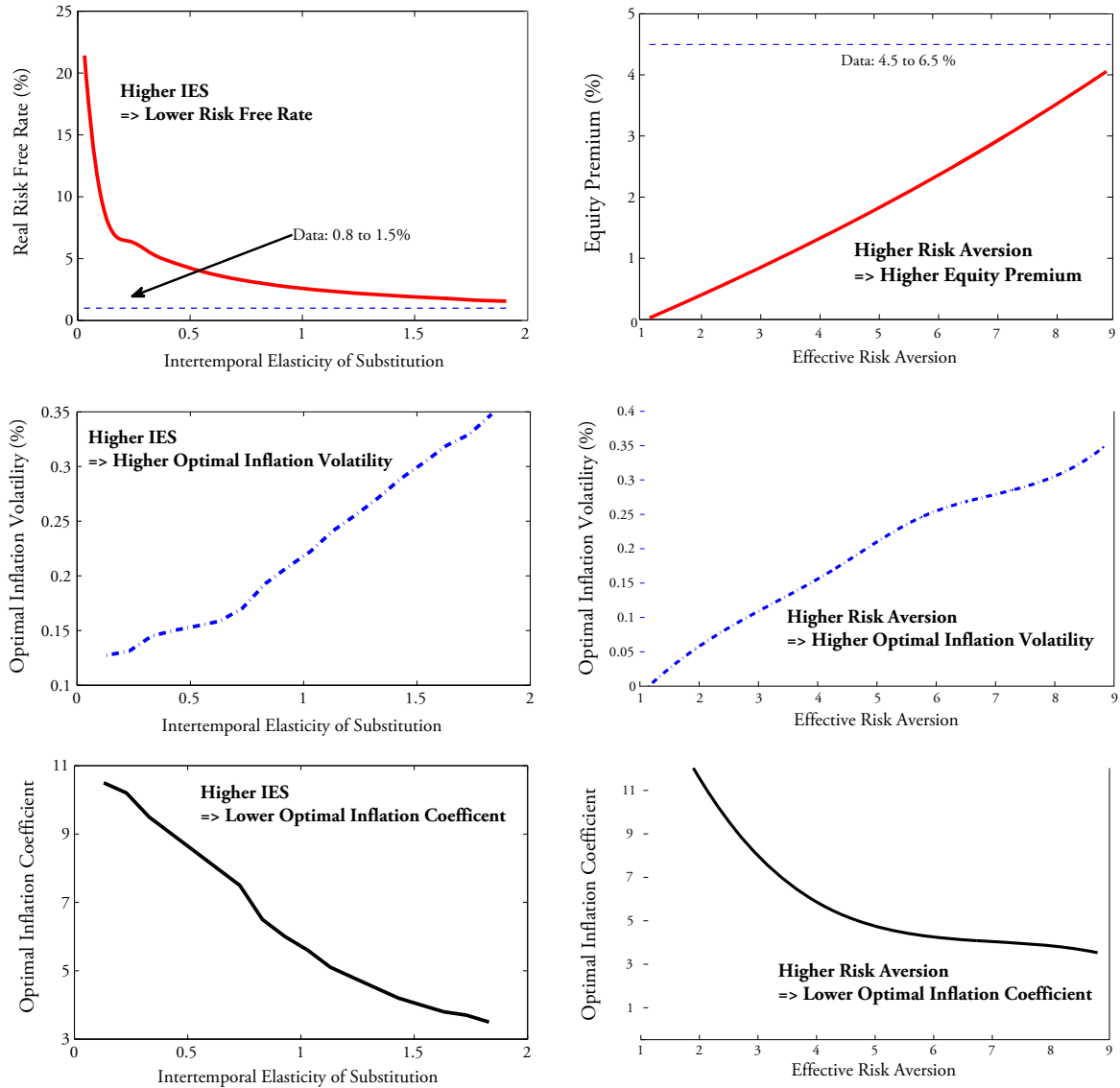
Figure A2: Effects of Increasing IES and Risk Aversion with Long-Run Shocks Only

This figure shows the effects of increasing the intertemporal elasticity of substitution and risk aversion. The setting is a world with only long-run shocks to productivity. The other coefficients are set to match the rule that yields the highest welfare for the high IES ($\psi = 2$) and high risk aversion ($\gamma = 10$) case as in table 4.1. The higher IES increases the patience of households and lowers the risk-free rate. This also makes firms more forward looking and reduces the average markup. The lower markup combined with the greater sensitivity of consumption to changes in real rates leads to higher optimal inflation volatility and a lower inflation coefficient as the IES rises, as shown in the bottom two panels. The higher risk aversion increases the equity premium, which coincides with higher welfare costs of recessions.

Low IES (ψ = 0.2)　　　　　　　　　　　　　　　**High IES　(ψ = 2)**
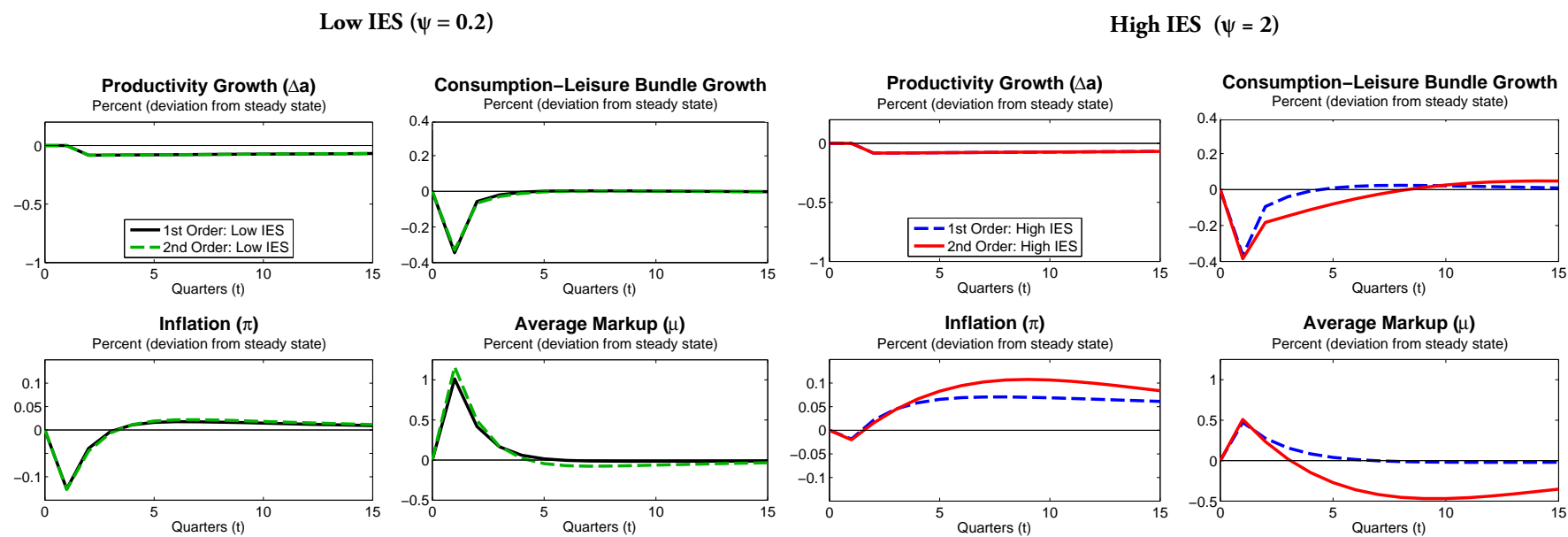
Figure A3: First- vs. Second-Order Approximation: Negative Long-Run Shock

This figure shows the effects of a negative long-run productivity shock on the three key channels for welfare: inflation volatility, markup, and consumption-leisure volatility. The parameterization is based on the calibration in table 4.1 and around the policy that yields the highest welfare in equation 2.4. When moving from a first- to second-order approximation, if the IES is low, the differences are negligible. If the IES is high, the effect on the average markup is significant.

APPENDIX TO CHAPTER 3: TAXES, SPENDING, AND MARKET RETURNS

B.1 Equity Return Decomposition: Derivation

Below is the derivation following Campbell and Shiller (1988) and Campbell (1991) that is based on the accounting definition of the stock return. The stock return is defined as

$$R_{t+1} = \frac{P_{t+1} + D_{t+1}}{P_t} \tag{B.1}$$

where P_t represents the price at time t, and D_t represents the dividend. This equation can be written using the price-dividend ratio and the dividend growth rate, such that

$$
\begin{aligned}
R_{t+1} &= \frac{P_{t+1} + D_{t+1}}{P_t} \\
&= \frac{\frac{P_{t+1}}{D_t}\frac{D_{t+1}}{D_{t+1}} + \frac{D_{t+1}}{D_t}}{\frac{P_t}{D_t}} \\
&= \frac{(1 + PD_{t+1})\Delta D_{t+1}}{PD_t}
\end{aligned}
\tag{B.2}
$$

where going from the first line to the second line, everything was divided by D_t. Going from the second line to the third line, $\frac{P_t}{D_t} \equiv PD_{t+1}$ and ΔD_{t+1} represents the dividend growth rate.

Logs can be taken to both sides so that

$$r_{t+1} = \Delta d_{t+1} + \log(1 + e^{pd_{t+1}}) - pd_t \tag{B.3}$$

where lower case variables indicate log-versions of the original variable i.e. $\log(R_{t+1}) \equiv r_{t+1}$.

This leads to a nonlinear function $\log(1 + e^{pd_{t+1}})$ that can be log-linearized as follows

$$
\begin{aligned}
\log(1 + e^{pd_{t+1}}) &\approx \log(1 + e^{\overline{pd}}) + \frac{e^{\overline{pd}}}{1 + e^{\overline{pd}}}(pd_{t+1} - \overline{pd}) \\
&= \log(1 + e^{\overline{pd}}) - \frac{e^{\overline{pd}}}{1 + e^{\overline{pd}}}\overline{pd} + \frac{e^{\overline{pd}}}{1 + e^{\overline{pd}}}pd_{t+1} \\
&= \kappa_0 + \rho \cdot pd_{t+1}
\end{aligned}
\tag{B.4}
$$

where $\kappa_0 = \log(1 + e^{\overline{pd}}) - \frac{e^{\overline{pd}}}{1+e^{\overline{pd}}} \cdot \overline{pd}$ and $\rho = \frac{e^{\overline{pd}}}{1+e^{\overline{pd}}}$

Plug this back into the definition of the return

$$
r_{t+1} \approx \Delta d_{t+1} + \kappa_0 + \rho \cdot pd_{t+1} - pd_t
\tag{B.5}
$$

and solve the difference equation forward, imposing terminal condition

$$
\lim_{j \to \infty} \rho^j \cdot pd_{t+j} = 0
\tag{B.6}
$$

and you end up with

$$
pd_t = \frac{\kappa_0}{1 - \rho} + \sum_{j=0}^{\infty} \rho^j \left[\Delta d_{t+1+j} - r_{t+1+j} \right]
\tag{B.7}
$$

Note this is simply an approximate dynamic accounting identity. Take the difference in expectations between time t and t+1 to both sides

$$
\begin{aligned}
(E_{t+1} - E_t)pd_t &= (E_{t+1} - E_t) \left[\frac{\kappa_0}{1 - \rho} + \sum_{j=0}^{\infty} \rho^j \left[\Delta d_{t+1+j} - r_{t+1+j} \right] \right] \\
0 &= (E_{t+1} - E_t) \left[\sum_{j=0}^{\infty} \rho^j \left[\Delta d_{t+1+j} - r_{t+1+j} \right] \right]
\end{aligned}
\tag{B.8}
$$

Then split up the two terms and isolate the term r_{t+1} by taking it out of the sum

$$(E_{t+1} - E_t)r_{t+1} = (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j\left[\Delta d_{t+1+j}\right] - (E_{t+1} - E_t)\sum_{j=1}^{\infty}\rho^j\left[r_{t+1+j}\right] \tag{B.9}$$

$$r_{t+1} - E_t(r_{t+1}) = (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j\left[\Delta d_{t+1+j}\right] - (E_{t+1} - E_t)\sum_{j=1}^{\infty}\rho^j\left[r_{t+1+j}\right] \tag{B.10}$$

The equity return r_t can be further decomposed into the sum of a risk-free rate and an excess return

$$r_{t+1} = r_{real,t+1} + r_{ex,t+1} \tag{B.11}$$

Plugging this into the equation for the unexpected return

$$\begin{aligned}
r_{real,t+1} + r_{ex,t+1} - E_t(r_{real,t+1} + r_{ex,t+1}) =& (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j\Delta d_{t+1+j} \\
& - (E_{t+1} - E_t)\sum_{j=1}^{\infty}\rho^j\left[r_{real,t+1} + r_{ex,t+1}\right]
\end{aligned} \tag{B.12}$$

But we assume that $r_{real,t+1}$ is known at time t, so the unexpected excess return $r_{exr,t+1} - E_t(r_{exr,t+1})$ is the same as the overall unexpected return $r_{t+1} - E_t(r_{t+1})$, hence

$$\begin{aligned}
r_{ex,t+1} - E_t(r_{ex,t+1}) =& (E_{t+1} - E_t)\sum_{j=0}^{\infty}\rho^j\Delta d_{t+1+j} - (E_{t+1} - E_t)\sum_{j=1}^{\infty}\rho^j r_{real,t+1} \\
& - (E_{t+1} - E_t)\sum_{j=1}^{\infty}\rho^j r_{ex,t+1}
\end{aligned} \tag{B.13}$$

which is equivalent to

$$r_{ex,t+1} - E_t(r_{ex,t+1}) = N_{CF,t+1} - N_{ex,t+1} - N_{real,t+1} \tag{B.14}$$

B.2 Bond Return Decomposition: Derivation

The log nominal 1-period holding return on a bond with n periods to maturity at time t, held from t to t+1, as

$$r_{n,t+1}^b = p_{n-1,t+1} - p_{n,t} \tag{B.15}$$

This can be solved forward to the maturity date of the bond, and at this date the bond price is unity so that its log price is zero ($p_{0,t+n} = 0$) which means

$$
\begin{aligned}
p_{n,t} &= - \left[r_{n,t+1}^b + \cdots + r_{t+n}^b \right] \\
&= - \sum_{j=0}^{n-1} r_{n-i,t+1+i}^b
\end{aligned} \tag{B.16}
$$

Taking the difference of expectations between t and t+1 and isolating the t+1 nominal bond return yields

$$r_{n,t+1}^b - E_t r_{n,t+1}^b = -(E_{t+1} - E_t) \sum_{j=1}^{n-1} r_{n-i,t+1+i}^b \tag{B.17}$$

The nominal bond holding return can be written as the sum of the real interest rate, inflation, and excess return

$$r_{n,t+1}^b = r_{n,t+1}^{b,ex} + \pi_{t+1} + r_{real,t+1} \tag{B.18}$$

We then plug this into unexpected nominal return above and write the equation in terms of the unexpected excess bond return. Note the summations for inflation and real interest rates could start at zero rather than 1, and the equation would remain valid. The two extra terms would cancel out because they add to the nominal interest rate, which is known at time t.

$$
\begin{aligned}
r_{n,t+1}^{b,ex} - E_t r_{n,t+1}^{b,ex} &= (E_{t+1} - E_t) \left[-\sum_{j=1}^{n-1} r_{n-i,t+1+i}^{b,ex} - \sum_{j=1}^{n-1} \pi_{t+1+i} - \sum_{j=1}^{n-1} r_{real,t+1} \right] \\
&= - N_{t+1}^{b,ex} - N_{\pi,t+1} - N_{real,t+1}
\end{aligned} \tag{B.19}
$$

B.3 Variance Decomposition Results

B.3.1 Variance Decomposition for Excess Stock Returns

Table B.4 provides the variance decomposition implied by the VAR for excess stock returns. The variance decomposition can be derived as follows:

$$
\begin{aligned}
Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right] =& Var\left(N_{CF,t+1}\right) + Var\left(N_{ex,t+1}\right) + Var\left(N_{real,t+1}\right) \\
& - 2Cov\left(N_{CF,t+1},\ N_{ex,t+1}\right) - 2Cov\left(N_{CF,t+1},\ N_{real,t+1}\right) \quad \text{(B.20)} \\
& + 2Cov\left(N_{ex,t+1},\ N_{real,t+1}\right)
\end{aligned}
$$

which in percentage terms is given by

$$
\begin{aligned}
1 =& \frac{Var\left(N_{CF,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]} + \frac{Var\left(N_{ex,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]} + \frac{Var\left(N_{real,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]} \\
& - \frac{2Cov\left(N_{CF,t+1},\ N_{ex,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]} - \frac{2Cov\left(N_{CF,t+1},\ N_{real,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]} \\
& + \frac{2Cov\left(N_{ex,t+1},\ N_{real,t+1}\right)}{Var\left[r_{ex,t+1} - E_t(r_{ex,t+1})\right]}
\end{aligned}
$$

$$\text{(B.21)}$$

where it is clear the weights can be greater than one in absolute value.

Similar to Campbell and Ammer (1993) and Bernanke and Kuttner (2005), 92% of the variance of stock returns is attributed to the variance of news about future excess returns for the full sample. This represents a sizable contrast to the variance of news about future real interest rates and dividends, which explain only 3% and 8% respectively. Regardless of the time period, the variance of news about future excess returns dominates the news about future real interest rates and dividends in terms of the decomposition. The often cited reason (see (Campbell 1991)) for the dominance of future excess return news is that changes in expected excess returns are highly persistent. This persistence comes from the dividend price ratio, which is a state variable used in our VAR.

The bottom three rows of Table B.4 give the implied R-squared statistic for simple regressions of the unexpected stock return on each news component. Compared to the full sample period,

both of the Post-Volcker periods (beginning in 1980) yield sizably higher R-squared values for the dividend news and real interest rate news. This is the only major difference across time periods and can be attributed to the increased forecastability of real interest rates and dividends in the later time periods.

B.3.2 Variance Decomposition for Excess Bond Returns

Table B.5 provides the variance decomposition implied by the VAR for excess bond returns. The variance decomposition can be derived as follows:

$$
\begin{aligned}
Var\left[r_{Bond\,ex,t+1} - E_t(r_{Bond\,ex,t+1})\right] =& Var\left(N_{\pi,t+1}\right) + Var\left(N_{Bond\,ex,t+1}\right) + Var\left(N_{real,t+1}\right) \\
& + 2Cov\left(N_{\pi,t+1},\ N_{Bond\,ex,t+1}\right) \\
& + 2Cov\left(N_{\pi,t+1},\ N_{real,t+1}\right) \\
& + 2Cov\left(N_{real,t+1},\ N_{real,t+1}\right)
\end{aligned}
$$

$$\tag{B.22}$$

For every sample, the R-squared for the simple regression of the unexpected bond return on inflation dominates. However, the share of variation explained by future inflation news falls by a factor of ten when moving from Pre-Volcker to Post-Volcker. This is a logical consequence of the significantly greater inflation volatility in the earlier period. The change in monetary policy is most evident with the measure of covariance between inflation news and real interest rate news. A monetary policy that does not forcefully respond to higher inflation would result in lower real interest rates being associated with higher inflation, which is consistent with our findings for the Pre-Volcker era. In the Post-Volcker era, monetary policy strongly reacts to inflation by raising nominal rates by a greater amount than inflation. From a theoretical point of view, this would be equivalent to a coefficient on inflation that is greater than one in the monetary policy reaction function, resulting in a positive covariance between inflation and real interest rate news.

Other items worth mentioning include the intuitive result that higher inflation news is negatively correlated with future excess bond return news across all time periods. This is in contrast to the

change in sign (depending on the time period) for the covariance of real interest rate news and future excess bond returns. The change in sign could again be attributed to the change in monetary policy. Higher future real interest rates indicate future capital losses, but if higher real interest rate news is associated with lower expected inflation news, as is the case in the Pre-Volcker era, then it is possible for higher future real interest rates to have a positive covariance with future excess bond returns. The opposite occurs during the Post-Volcker era, where the capital losses channel dominates as higher expected inflation news co-varies positively with higher real interest rate news so that both effects move in the same direction.

Table B.1: VAR Coefficients for Excess Stock Returns

This table reports the coefficients of equation 3.13 using quarterly variables that include excess stock returns. The six-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. The ϕ coefficients denote the response to the contemporaneous fiscal policy shocks defined in the text. Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

	$r_{ex,t-1}$	$r_{real,t-1}$	Δr_{t-1}	$SPREAD_{t-1}$	$d_{t-1} - p_{t-1}$	REL_{t-1}	ΔD_{t-1}	ϕ_t^{tax}	$\phi_t^{defense}$
Panel A: 1947q1-2012q4									
$r_{ex,t}$	0.091	0.014	0.154	0.518	3.146*	−0.620	–	1.771	0.118
$r_{real,t}$	−0.006	0.356***	−0.091	−0.088	−0.222	−0.162	–	0.727	−0.143*
Δr_t	0.015**	−0.005	−0.088	0.083	0.053	0.010	–	−0.437	0.003
$SPREAD_t$	−0.007	0.005	−0.020	0.837***	−0.058	0.009	–	0.317	0.000
$d_t - p_t$	−0.001	−0.002	−0.004	−0.004	0.977***	0.011	–	−0.017	0.001
REL_t	0.015**	−0.004	0.056	0.101*	0.060	0.590***	–	−0.332	0.004
ΔD_t	0.115**	–	–	–	0.048	–	0.614***	1.099	0.442**
Panel B: 1947q1-1980q2									
$r_{ex,t}$	0.077	0.254	0.864	0.393	8.193**	−1.814	–	−3.772	0.109
$r_{real,t}$	0.015	0.340***	1.539***	−0.326	−2.271*	−1.315**	–	2.032*	−0.105
Δr_t	0.005	−0.006	0.098	−0.442	−0.118	–	−0.338	0.007
$SPREAD_t$	0.005	0.001	−0.182**	0.726***	0.334	0.091	–	0.252	−0.006
$d_t - p_t$	0.000	−0.003*	−0.015	0.002	0.947***	0.029**	–	0.041	0.001
REL_t	0.005	−0.001	0.287***	0.214*	−0.406	0.459***	–	−0.301	0.007
ΔD_t	0.082	–	–	–	1.977	–	0.459***	1.270	0.486*

Table B.2: VAR Coefficients for Excess Stock Returns (cont.)

	$r_{ex,t-1}$	$r_{real,t-1}$	Δr_{t-1}	$SPREAD_{t-1}$	$d_{t-1} - p_{t-1}$	REL_{t-1}	ΔD_{t-1}	ϕ_t^{tax}	$\phi_t^{defense}$
Panel C: 1980q3-2012q4									
$r_{ex,t}$	0.081	-0.160	-0.006	0.137	2.808	-0.289	–	7.762**	-0.362
$r_{real,t}$	-0.012	0.038	-0.375	-0.731***	3.166***	0.025	–	-2.132	-0.454
Δr_t	0.019*	0.012	-0.148	0.127	-0.047	0.093	–	-0.390	-0.021
$SPREAD_t$	-0.013	-0.005	0.025	0.806***	0.015	-0.038	–	0.235	0.084
$d_t - p_t$	-0.001	0.001	-0.002	-0.001	0.969***	0.006	–	-0.078**	0.002
REL_t	0.018**	0.012	-0.007	0.144**	-0.046	0.662***	–	-0.202	-0.007
ΔD_t	0.141***	–	–	–	-0.787	–	0.832***	1.135	-0.144
Panel D: 1980q3-2008q2									
$r_{ex,t}$	0.023	-0.073	0.097	0.203	2.172	-0.634	–	8.236**	-0.918
$r_{real,t}$	-0.010	0.093	-0.418	-0.502*	2.935***	0.220	–	-2.151*	-0.322
Δr_t	0.025*	-0.006	-0.136	0.137	-0.026	0.087	–	-0.433	-0.044
$SPREAD_t$	-0.019*	0.004	0.008	0.794***	-0.008	-0.028	–	0.251	0.070
$d_t - p_t$	0.000	-0.001	-0.002	-0.001	0.978***	0.009	–	-0.083**	0.009
REL_t	0.024**	-0.008	0.003	0.155*	-0.025	0.660***	–	-0.252	-0.026
ΔD_t	0.132***	–	–	–	0.098	–	0.644***	1.572	-0.205

Table B.3: VAR Coefficients for Excess Bond Returns

This table reports the coefficients of equation 3.13 using quarterly variables that include excess bond returns. The five-variable VAR(1) used to construct excess equity return and real interest rate forecasts is estimated over the sample indicated in the column headings. The VAR state variables are defined in the text. The ϕ coefficients denote the response to the contemporaneous fiscal policy shocks defined in the text. Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

	$r_{Bond\,ex,t-1}$	$r_{real,t-1}$	π_{t-1}	$SPREAD_{t-1}$	$CREDIT_{t-1}$	ϕ_t^{tax}	$\phi_t^{defense}$
Panel A: 1947q1-2012q4							
$r_{Bond\,ex,t}$	−0.085	0.940***	0.028	−0.544	0.047	1.130	−0.035
$r_{real,t}$	0.008	0.764***	−0.023	0.494***	−0.033*	0.304	−0.005
π_t	−0.014	−0.112	0.315***	0.745	−0.103	0.521	−0.153*
$SPREAD_t$	−0.005**	0.003	0.006	0.843***	0.020***	0.075	−0.001
$CREDIT_t$	−0.014	−0.124**	−0.023	−0.045	0.893***	−0.512*	0.046
Panel B: 1947q1-1980q2							
$r_{Bond\,ex,t}$	−0.249***	0.221	−0.074	2.778**	−0.166	0.248	−0.023
$r_{real,t}$	0.015	0.643***	−0.021	0.940***	−0.020	0.109	−0.004
π_t	−0.069	−0.232	0.132	1.337	−0.386***	1.733	−0.158*
$SPREAD_t$	−0.011***	−0.049***	−0.002	0.971***	0.007	0.055	−0.001
$CREDIT_t$	−0.021	−0.416***	−0.074*	0.603	0.863***	−0.946**	0.040
Panel C: 1980q3-2012q4							
$r_{Bond\,ex,t}$	−0.019	1.102**	−0.031	−2.116	0.307	0.309	−0.649
$r_{real,t}$	0.006	0.719***	−0.019	0.346*	−0.113***	0.285	0.059
π_t	0.014	−0.122	0.204**	−0.424	0.569***	−2.159	−0.620**
$SPREAD_t$	−0.002	0.021	0.002	0.766***	0.044***	0.005	−0.015
$CREDIT_t$	−0.012	−0.049	0.019	−0.254	0.836***	−0.265	0.119
Panel D: 1980q3-2008q2							
$r_{Bond\,ex,t}$	−0.064	0.774*	0.084	−0.852	−0.066	0.842	−0.131
$r_{real,t}$	0.010	0.702***	−0.031	0.511*	−0.139***	0.315	0.038
π_t	0.008	−0.167	0.207**	0.814	0.308	−1.752	−0.563*
$SPREAD_t$	−0.007**	0.001	−0.001	0.827***	0.024**	−0.007	0.009
$CREDIT_t$	−0.015	−0.055	0.011	0.042	0.829***	−0.176	0.075

Table B.4: Variance Decomposition for Excess Stock Returns

This table is based on a quarterly VAR that includes excess stock return, real interest rate, change in the 3-month bill rate, 10-year and 3-month yield spread, log dividend-price ratio, and relative bill rate (the difference between the bill rate and a 12-month backwards moving average). $Return\ R^2$ is the implied R^2 in a regression of the excess stock return on the VAR explanatory variables. The VAR is used to calculate the components of the unexpected excess stock return. The components are divided up into N_{CF}, news about future cash-flows or dividends; N_{real} is news about future real interest rates; N_{exr} is news about future excess stock returns. The table provides the variances and covariances of each component, normalized by the variance of the current unexpected excess return, and the numbers reported add up to one. The bottom three rows give the R^2 statistics for simple regressions of the unexpected excess return on each news component. Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Return R^2	0.052	0.136	0.030	0.031
Shares of:				
$Var(N_{CF})$	0.090***	0.330	0.094	0.073
$-2Cov(N_{CF}, N_{real})$	−0.021	0.161	0.071	0.084
$-2Cov(N_{CF}, N_{exr})$	0.078	−1.410	0.244	0.237
$Var(N_{real})$	0.032**	0.077	0.068	0.052
$+2Cov(N_{exr}, N_{real})$	−0.104	−0.689	0.190	0.197
$Var(N_{exr})$	0.925***	2.530	0.332	0.357*
$R^2\ (N_{CF})$	0.156	0.262*	0.675***	0.746***
$R^2\ (N_{real})$	0.029	0.451**	0.580**	0.713***
$R^2\ (N_{exr})$	0.900***	0.867***	0.909***	0.923***

Table B.5: Variance Decomposition for Excess Bond Returns

This table is based on a quarterly VAR that includes excess bond return, real interest rate, change in the 3-month bill rate, 10-year and 3-month yield spread, log dividend-price ratio, and relative bill rate (the difference between the bill rate and a 12-month backwards moving average). $Return\ R^2$ is the implied R^2 in a regression of the excess stock return on the VAR explanatory variables. The VAR is used to calculate the components of the unexpected excess bond return. The components are divided up into N_π, news about future inflation; N_{real} is news about future real interest rates; N_{exr} is news about future excess bond returns. The table provides the variances and covariances of each component, normalized by the variance of the current unexpected excess return, and the numbers reported add up to one. The bottom three rows give the R^2 statistics for simple regressions of the unexpected excess return on each news component. Standard errors are calculated by the bootstrap algorithm discussed in Section 3.3. *, **, and *** denote significance at the 10 percent, 5 percent and 1 percent levels respectively.

Time Periods:	1947q1 - 2012q4	1947q1 - 1980q2	1980q3 - 2012q4	1980q3 - 2008q2
Return R^2	0.055	0.065	0.076	0.049
Shares of:				
$Var(N_\pi)$	3.965**	8.556	0.843	0.813*
$+2Cov(N_\pi, N_{real})$	−1.114	−7.088	1.389*	1.011*
$+2Cov(N_\pi, N_{exr})$	−5.020*	−7.324	−2.192	−1.898
$Var(N_{real})$	0.245	1.577	0.599	0.361
$+2Cov(N_{exr}, N_{real})$	0.270	3.161	−1.970	−1.438
$Var(N_{exr})$	2.654**	2.119	2.331*	2.151**
$R^2\ (N_\pi)$	0.204***	0.213**	0.231**	0.168*
$R^2\ (N_{real})$	0.128	0.095	0.159	0.060
$R^2\ (N_{exr})$	0.029	0.001	0.027	0.108

APPENDIX TO CHAPTER 4: INFLATING AWAY DEBT: TRADING OFF INFLATION RISK
AND TAXATION RISK

C.1 Welfare Effects of Tax Risk and Equity Risk

Isolating welfare effect of tax risk. In order to isolate the welfare effect of increased tax risk, I will impose an exogenous shock on the tax rate to compare how it affects welfare in the Power Utility and Main Model. Specifically, I place a shock in the following equation and I increase its volatility to determine its effect on welfare.

$$\tau_t = \tau_t^D \cdot y_t + \epsilon_\tau$$

The purpose of this exercise is simply to measure the welfare impact of increased tax rate uncertainty. Note the total amount of tax revenues is pinned down by another equation ($\tau_t - \tau* = \gamma_1(B_{t-1} - B*)$), so that the key variable is the tax rate τ_t^D.

I find that for a given 25 basis point exogenous increase in tax volatility, the Main Model's welfare falls 2.25 times more than the Power Utility model. This is because the Main Model's consumption-leisure bundle becomes more volatile as a result of the higher intertemporal elasticity of substitution. With a higher IES, the agent is more willing to substitute both leisure and consumption to the future, so that the lower distortionary tax rate leads to a greater decrease in leisure (increase in labor) combined with a small increase in consumption (investment sizably increases due to substitution effect with IES> 1). This leads to the consumption-leisure bundle significantly falling in the first period. In the following period with the tax cut expired, both consumption and leisure are higher (investment and labor fall) which both significantly increase the consumption-leisure bundle. The volatility of the growth of consumption-leisure bundle increases by 10 basis points under the Main Model while it only increases 0.4 basis points under the Power Utility model. The higher volatility of the consumption-leisure bundle leads to lower welfare due to concave utility.

Isolating welfare effect of equity risk. In order to isolate the welfare effect of increased equity risk, I will impose an exogenous shock on the return of capital that is perfectly correlated with the short run shock. This will result in a higher equity return in good times, which will increase the equity premium.

The exogenous equity shock increases the equity premium by approximately 4 percent in both models. This entails an increase from 6.9 basis points to 7.2 basis points for the Power Utility model, and 3.81 to 3.96 percent in the Main Model. However, the impacts on welfare are quite different. Welfare falls by 0.66 basis points for the Main Model while welfare falls by 0.02 basis points in the Power Utility model. Therefore, the fall in welfare for the Main Model is approximately 33 times larger than the fall in welfare for the Power Utility model with respect to increased equity risk. What explains the difference in welfare? The increased cost of capital depresses capital accumulation. Lower capital accumulation means less consumption, less welfare. and in the Main Model, the stochastic steady state level of capital falls 41 basis points. In comparison, the Power Utility model's steady state level of capital falls by 0.6 basis points. So in percentage terms, steady state capital falls approximately 70 times more in the Main Model. This explains why the fall in welfare is 33 times greater for an exogenous increase in the equity premium.

To summarize, the Main Model's fall in welfare due to increased tax risk is 2.25 times greater and 33 times greater for increased equity risk. The two exercises of isolating the welfare effects of each risk provide ample evidence for why optimal inflation volatility is much higher in the Main Model. The increased tax and equity risk eventually dominate the benefits of decreased inflation risk.

The effect of faster repayment of debt. By increasing $\gamma_1 = 0.2, 0.4, 0.6$ in the equation $\tau_t - \tau* = \gamma_1(B_{t-1} - B*)$, tax risk is increasing due to the higher tax volatility. Optimal tax volatility in the Main Model jumps from 1.21 to 1.51 to 1.89. Likewise, the optimal inflation volatility also increases from 0.21 to 0.31 to 0.49. Optimal inflation volatility is increasing with the speed of repayment because more and more debt can be retired through surprise bouts of inflation. More debt can be retired through unexpected inflation because debt becomes less persistent because it is

paid off quicker. In contrast, the results for Power Utility preferences do not change, as it is still optimal to have zero inflation volatility regardless of the speed of repayment.

The effect of price indexation. When price indexation is turned off, the optimal inflation volatility is zero for the Main Model, just as in the Power Utility model. Without indexation, firms that are not able to optimally choose their price will keep the same price in the previous year. This significantly increases price dispersion in the model. For instance, there will be significant welfare costs when annual inflation is 2%, which seems extreme. With full indexation, the firm that is unable to optimally choose its price is allowed to update its price based on the previous period's inflation rate. The welfare costs of price dispersion are still present, but costs come from acceleration of inflation rather than the level. In addition, there exists empirical evidence supporting full price indexation (Giannoni and Woodford 2003).

C.2 Detailed description of the government and bond market

The government's goal is to use monetary policy to determine the optimal inflation volatility. I take fiscal policy as given, spending exogenous amounts and changing taxes sufficiently to maintain equilibrium so that debt does not explode to infinity. The speed with which fiscal policy repays taxes is set conservatively to ensure that the debt to GDP ratio has a high autocorrelation (as in the data) and not to overstate the tax-rate volatility. In the benchmark model, the tax rate volatility is less than 1.5%, which is half of the observed volatility in the data. The fiscal rule for taxation, after adjusting for growth, is assumed to be

$$T_t - T^* = \gamma_1(B_{t-1}e^{-\Delta a_t} - B^*e^{-\mu})$$

where $T_t = \tau_t^D Y_t$ reflects tax revenues from income taxes.

The budget constraint of the fiscal branch of government in nominal terms is the following identity:

$$B_t^T = G_t + (1 + i_{t-1})B_{t-1}^T - T_t - RCB_t$$

The left hand side is the interest bearing debt issued today (the superscript T denotes total debt, assumed to be one period maturity), G_t is government expenditures on goods and services, T_t is total tax revenues, i_{t-1} is the nominal interest rate, and RCB_t is the direct receipts from the central bank. These direct receipts consist of interest earnings on the U.S. Federal Reserves portfolio of government debt, which it gives back to the treasury.

The budget constraint of the central bank in nominal terms is the following identity:

$$B_t^M - B_{t-1}^M + RCB_t = i_{t-1}B_{t-1}^M + M_t - (1 + i_{t-1}^m)M_{t-1}$$

$B_t^M - B_{t-1}^M$ is equal to the central bank's purchases of government debt (the change in assets), $i_{t-1}B_{t-1}^M$ is the interest paid from the treasury to the central bank (change in capital), M_t is the central bank's own liabilities or base money, and i_{t-1}^m is the nominal interest rate paid on base money balances held at the end of period t-1.

Note that from the perspective of the government, only debt held by the public represents an interest-bearing liability. By letting $B_t = B^T - B_t^M$ be the amount of interest bearing debt held by the public, the budget identities of the fiscal branch and central bank can be combined to produce the government budget constraint

$$B_t = G_t + (1 + i_{t-1})B_{t-1} - T_t - (M_t - (1 + i_{t-1}^m)M_{t-1})$$

Letting lowercase letters denote real terms, the budget constraint can be rewritten as

$$b_t = g_t + ((1 + i_{t-1}))/\pi_t b_{t-1} - t_t - (m_t - ((1 + i_{t-1}^m))/\pi_t m_{t-1})$$

In the current setting, the household budget constraint is defined as follows

$$b_t + c_t + iv_t + m_t = \frac{(1 + i_{t-1})}{\pi_t}b_{t-1} + \frac{(1 + i_{t-1}^m)}{\pi_t}m_{t-1} + (1 - \tau_t^D)(w_t h_t + u_t k_t) + \delta q_t \tau_t^D k_t + \phi_t$$

Note, there are also an infinite number of state-contingent securities that the agent may trade due to the assumption of complete markets. According to Woodford (2003), since any pattern of future state-contingent payoffs that a household may desire can be arranged (for the appropriate price), the household's budget constraint can be written without any explicit reference to the quantities that it holds of these particular assets. Furthermore, if there are redundant assets, there will not be determinate demands for individual assets (the assumption in the case of the monetary base).

In the standard setting with monetary transactions frictions, monetary policy can be carried out either through paying interest on reserves or by varying the money supply. It is typically assumed that there exists a demand for money, either due to the transaction friction or the utility derived from transaction services. This results in a liquidity preference function that can be used to pin down the price level for a given money supply. The central bank may freely choose any two of the variables i_t, i_t^m, and m_t^s, leaving the third to be endogenously determined by the liquidity preference function. For instance, the current setting for the United States consists of setting $i_t^m = 0$, choosing a short-run target for i_t while allowing the monetary base to be endogenously determined by the liquidity preference function.

In my model, I assume there is no non-pecuniary benefit to holding money balances and no liquidity preference function. Furthermore, changes in the quantity of base money through open market operations of government securities have no consequences for the equilibrium determination of interest rates or other variables, as base money is assumed to be a perfect substitute for riskless government debt. In addition, the money supply does not appear in any equilibrium conditions in my model and is assumed to be some positive exogenous process. Given that markets must clear at all dates, the household's demand for base money must equal the supply of base money.

Monetary policy implements an interest rate target by adjusting the return on base money through the following monetary policy rule:

$$ln(i_t^m/i^{m*}) = \alpha_r ln(i_{t-1}^m/i^{m*}) + \alpha_\pi ln(\pi_t/\pi^*) + \alpha_{\Delta y} ln(\Delta y_t/\Delta y^*)$$
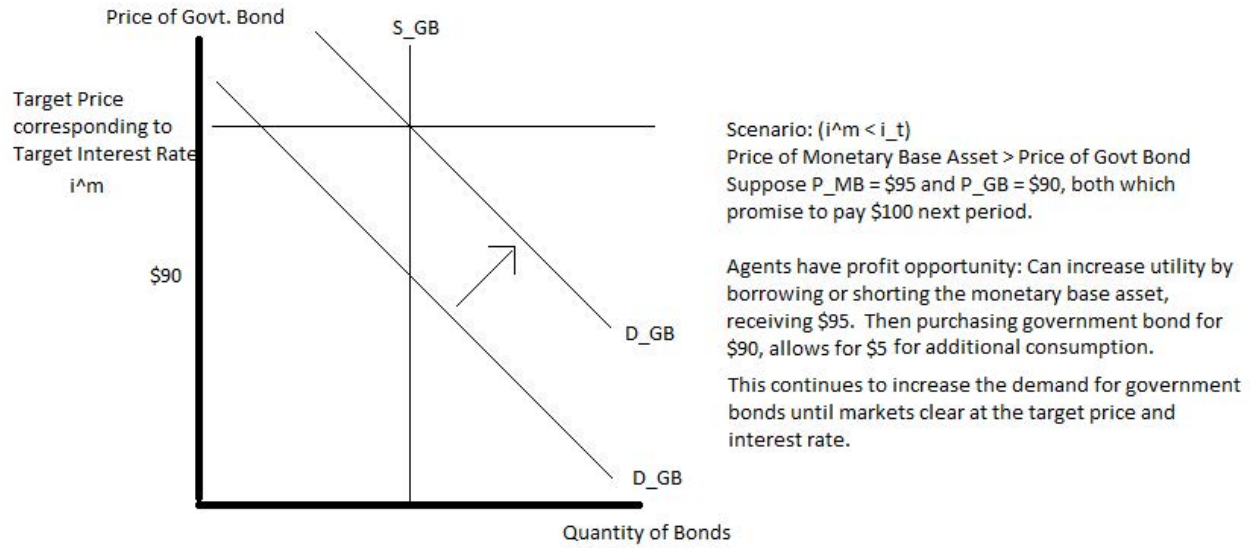
Figure A1: Monetary Policy and the Debt Market

This panel shows how monetary policy impacts the debt market and maintains control over the nominal rate on bonds.

In addition, $i_t^m = i_t$ at all times due to the assumption of no arbitrage in equilibrium. Otherwise an arbitrage opportunity exists. If $i_t^m > i_t$, a household could finance unlimited consumption by shorting riskless one-period government bonds, and using the proceeds partly to hold cash to repay its debt in one period and partly to finance additional consumption. Since utility is strictly increasing in consumption, an infinite amount of consumption is affordable and the household would have no budget constraint.

Thus, the household optimally holds all public government debt, as not doing so would lead to untapped profit opportunities that an optimizing agent would not pass up. In addition, any bond demand curve that results in a price of the government bond in which $i_t^m \neq i_t$ results in an arbitrage opportunity that cannot exist in equilibrium. The income remaining after purchasing the government debt is optimally directed towards consumption and investment based on the intertemporal Euler equation. A no Ponzi scheme transversality condition also holds so that the productivity adjusted debt cannot be increased without bound.

The above scenario is specific to a setting where fiscal policy is passive and ensures the budget balances, while monetary policy targets inflation. An alternative scenario, the Fiscal Theory of

the Price Level (FTPL), would exist if monetary policy were passive and fiscal policy were active. This would entail monetary policy not reacting to inflation, which would lead to an indeterminate equilibrium if fiscal policy was also passive. However, fiscal policy is assumed to be active, so that the budget constraint of the government pins down the price level so that today's real debt is equal to the sum of future surpluses. With active fiscal policy, inflation primarily adjusts in order for the government's budget constraint to hold.

The FTPL setting represents an extreme form of inflating away debt. Upon examining the FTPL scenario, I found that inflation volatility is exceptionally high. This leads to costs of price dispersion over fifty times greater than a similar setting with passive fiscal policy and active monetary policy. Therefore, from a policy perspective, the welfare losses due to high price dispersion make this policy far from optimal.

C.3 Alternative formulation for incorporating debt into monetary policy rule

As previously shown, the intertemporal Euler equation and the nominal interest rate rule can be combined to form a stochastic difference equation that governs the evolution of inflation.

$$\pi_t = \left(\pi^* + \alpha_G \cdot ln \left(\frac{BY_t}{BY*} \right) \right) \left[\frac{\left(E_t \left[\frac{M_{t+1}}{\pi_{t+1}} \right] \right)^{-1}}{R_{t-1}^{\alpha_r} R^{*1-\alpha_r} \left(\frac{\Delta y_t}{\Delta y_s s} \right)^{\alpha_y}} \right]^{\frac{1}{\alpha_\pi}}$$

Instead of implementing the effect of government debt through the inflation target, the debt also can be incorporated separately as its own term into the Taylor Rule:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*} \right)^{\alpha_r} \left(\frac{\pi_t}{\pi_t^*} \right)^{\alpha_\pi} \left(\frac{\Delta y_t}{\Delta y_{ss}} \right)^{\alpha_y} \left(\frac{BY_t}{BY^*} \right)^{\alpha_G}$$

If this is the case, then inflation would be rewritten as

$$\pi_t = \left(\pi^* \right) \left[\frac{\left(E_t \left[\frac{M_{t+1}}{\pi_{t+1}} \right] \right)^{-1}}{R_{t-1}^{\alpha_r} R^{*1-\alpha_r} \left(\frac{\Delta y_t}{\Delta y_s s} \right)^{\alpha_y} \left(\frac{BY_t}{BY^*} \right)^{\alpha_G}} \right]^{\frac{1}{\alpha_\pi}}$$

where α_G would now be negative if the goal of policy was for inflation to rise with deviations of the

debt to output ratio. Given the similar structure of the stochastic difference equation for inflation, it does not matter exactly how the debt to output ratio is incorporated.

Table C.1: RECALIBRATED: Model Features and Parameter Values

		Main Model	Rec. Prefs. +LRR	Rec. Prefs.	Power Utility
Recursive Preferences		✓	✓	✓	
Long Run Risk		✓	✓		
Capital Vintages		✓			
Preference parameters					
Discount factor	β	0.99	0.985	0.989	0.995
Effective risk aversion	$\gamma \cdot o$	10	10	10	2
Intertemporal elasticity of substitution	ψ	2.0	2.0	2.0	1/2
Leisure weight	o	0.35	0.35	0.35	0.35
Technology parameters					
Capital share	θ	0.25	0.25	0.25	0.25
Depreciation rate	δ	12%	8%	8%	8%
Adjustment Costs on Capital	τ_j	0	1.75	1.75	0
Productivity parameters					
Risk exposure of new investment	ϕ_0	0	1	1	1
Average growth rate	μ	2.0%	2.0%	2.0%	2.0%
Volatility of short-run risk	σ_a	3.71%	5.00%	5.25%	5.00%
Volatility of long-run risk	σ_x	0.52%	0.52%	0%	0%
AR(1) of expected growth	ρ	0.925	0.925	0.925	0.925
New Keynesian parameters					
Price elasticity of demand	η	7	7	7	7
Probability firm cannot change price	α	10%	10%	10%	10%
Policy parameters					
Steady state Debt to GDP	S_B	0.44	0.44	0.44	0.44
Steady state $\frac{G}{Y}$	S_G	0.17	0.17	0.17	0.17
Monetary Policy Inflation Coefficient	α_π	0.6	0.6	0.6	0.6
Output Growth Gap Coefficient	$\alpha_{\Delta y}$	0.5	0.5	0.5	0.5
Inertia Coefficient	α_r	0.6	0.6	0.6	0.6

The four models were re-calibrated to match the level of GDP risk, the level of the risk free rate, and the equity premium if possible. Analysis indicates little to no changes in results upon re-calibrating.

Table C.2: Calibrated and Uncalibrated Model Moments

	Data	Main Model	EZ+LRR Uncalib.	EZ+LRR Calib.	EZ Uncalib.	EZ Calib.	Std. Uncalib.	Std. Calib.
$E(I/Y)$	0.15	0.21	0.21	0.19	0.21	0.19	0.16	0.14
$\sigma(\Delta c)$	02.16 (0.17)	2.33	2.64	3.56	2.38	3.44	2.51	3.30
$\sigma(\Delta i)$	16.40 (1.26)	16.76	10.84	4.35	7.89	4.21	3.00	4.79
$\sigma(\Delta n)$	03.66 (0.29)	3.55	2.84	1.62	2.39	1.56	1.39	1.89
$\sigma(\Delta y)$	3.59	3.79	3.48	3.74	3.03	3.62	2.59	3.48
$AC_1(\Delta c)$	0.49	0.34	0.24	0.31	0.13	0.21	0.23	0.22
$AC_1(\Delta y)$	0.35	0.34	0.40	0.31	0.36	0.22	0.27	0.28
$\sigma(\tau^D)$	3.1	1.19	1.07	0.98	1.10	1.06	1.20	1.23
$AC_1(\frac{B}{Y})$	0.94	0.90	0.92	0.92	0.94	0.92	0.93	0.91
$E(\pi)$	3.5	2.26	2.52	2.20	3.44	3.13	3.10	2.93
$\sigma(\pi)$	2.32	2.18	2.52	3.04	2.24	2.93	1.48	2.23
$\sigma(r^f)$	1.35	1.25	0.98	1.41	0.59	0.91	0.80	0.84
$E[r^f]$	00.89	1.55	1.47	1.20	1.90	1.16	6.03	5.35
$E[r^{L,ex}]$	05.70 (2.25)	3.72	0.36	3.57	0.40	3.96	0.06	0.09

The four models were re-calibrated to match the level of GDP risk, the level of the risk free rate, and the equity premium if possible. Analysis indicates little to no changes in results upon re-calibrating. All entries for the models are obtained from repetitions of small samples. Data refer to the U.S. and include pre-World War II observations (1930–2012). Annual calibrations are reported in Table C.1. Excess returns are levered by a factor of three, consistent with Garcia-Feijo and Jorgensen (2010).

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