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Financial Crises, Unconventional Monetary Policy Exit Strategies, and Agents' Expectations

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Abstract

This paper considers a model with financial frictions and studies the role of expectations and unconventional monetary policy response to financial crises. During a financial crisis, the financial sector has reduced ability to provide credit to productive firms, and the central bank may help lessen the magnitude of the downturn by using unconventional monetary policy to inject liquidity into credit markets. The model allows parameters to change according to a Markov process, which gives agents in the economy expectations about the probability of the central bank intervening in response to a crisis, as well as expectations about the central bank's exit strategy post-crisis. Using this Markov regime switching

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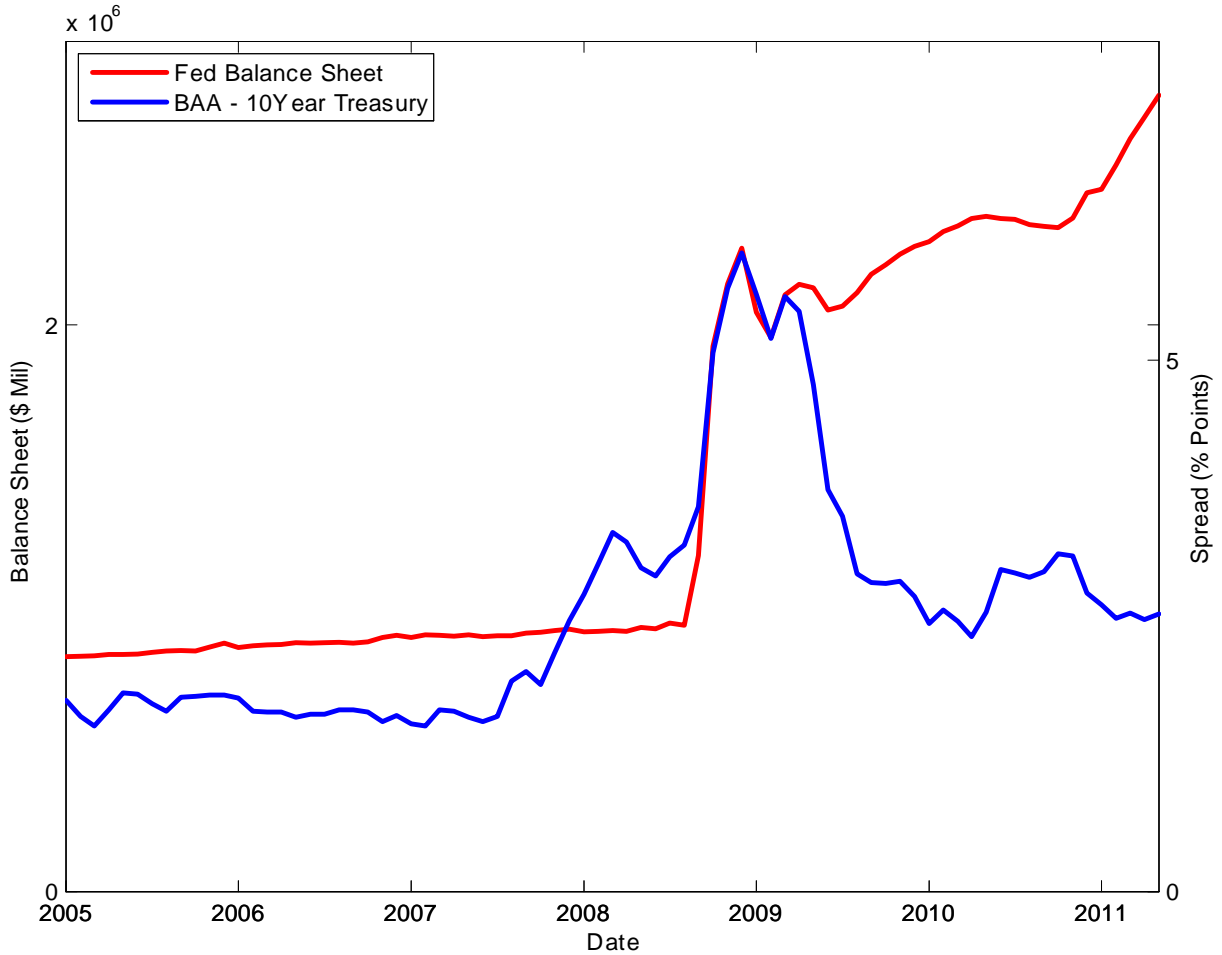
specification, the paper addresses three issues. First, it considers the effects of different exit strategies, and shows that, after a crisis, if the central bank sells off its accumulated assets too quickly, the economy can experience a double-dip recession. Second, it analyzes the effects of expectations of intervention policy on pre-crisis behavior. In particular, if the central bank increases the probability of intervening during crises, this increase leads to a loss of output in pre-crisis times. Finally, the paper considers the welfare implications of guaranteeing intervention during crises, and shows that providing a guarantee can raise or lower welfare depending upon the exit strategy used, and that committing before a crisis can be welfare decreasing but then welfare increasing once a crisis occurs.

1 Introduction

In the fall of 2008, the US economy experienced a financial crisis, which was marked by a rapid slowing of real economic activity, along with a deterioration in financial conditions. In response, the Federal Reserve expanded its purchases of financial assets in order to inject additional capital into the economy. The increase in demand for financial assets provided by the Federal Reserve helped bolster asset values and alleviate some of the pressure on financial institutions by lessening the drop in the value of assets on their respective balance sheets. The Federal Reserve accomplished this expansion in asset purchases by instituting a number of new lending facilities, such as expanding its purchases of mortgage backed securities and commercial paper. This response is deemed "unconventional monetary policy" because of the wide range of assets purchased, in contrast to "conventional monetary policy" which typically consists of purchasing short-term Treasuries to manage short-term interest rates. In total, the size of the Federal Reserve's balance sheet grew by over \$1 trillion. Figure 1 shows the sizeable increase in the balance sheet along with a measure of interest rate spreads that jumped during the crisis, which illustrates the increased level of uncertainty during that time.

An additional feature of the financial crisis and balance sheet expansion is that even after the crisis ended and interest rate spreads came down from their peak, the size of the Federal Reserve's balance sheet remained elevated and currently remains high. In other words, the

Figure 1: Federal Reserve's Balance Sheet



financial crisis triggered a start in unconventional monetary policy, but the end of the crisis did not trigger an end in the unconventional policy. Consequently, it remains to be seen how the Federal Reserve will unwind the size of its balance sheet, and what the effects of this unwind are for the macroeconomy. Current debate has focused on how long the Federal Reserve should hold its accumulated assets, when to start selling them off, and at what rate.

In addition to exit strategies, given that the Federal Reserve has intervened with unconventional policy during this latest crisis, one concern is how expectations about intervention policy during crises affects pre-crisis economic behavior. That is, if the central bank is expected to intervene during crises, does this expectation distort economic outcomes prior to a crisis occurring, and if so, what are the magnitudes of those distortions? Many of the concerns about

intervention during the crisis revolved around the concern of setting a precedent, and that this precedent would have negative repercussions during non-crisis times by encouraging reckless risk-taking. Even if intervention is considered good policy during crises, if setting a precedent of intervention has negative effects during non-crisis times, it may be that setting this precedent is on whole a poor policy choice. On the other hand, if expectations of intervention allow agents in the economy to be less worried about small probability events and allow credit to flow more freely, then guaranteeing intervention may be an entirely positive policy choice.

This consideration of the effects of intervention expectations along with the effects during crises motivates an analysis of the welfare benefits of guaranteeing intervention during crises. The main concern with this welfare analysis is a form of time inconsistency of a guarantee: it may be the case that *ex-ante* – that is, before a crisis occurs – guaranteeing intervention is welfare decreasing relative to guaranteeing no intervention, but *ex-post* – when a crisis occurs – guaranteeing intervention is welfare increasing over a no intervention guarantee.

This paper addresses these questions about exit strategies, effects of pre-crisis expectations, and welfare costs by building a dynamic stochastic general equilibrium (DSGE) model with a financial sector where financial crises occasionally occur, and then conditional on a crisis occurring, the central bank may or may not intervene in credit markets. If the central bank does intervene, it will not do so forever, but instead, at some point it will start exiting the credit market, selling off its accumulated assets at a specified rate. Using Markov regime switching, the model developed in this paper allows agents to have rational expectations about transitions between regimes where the central bank intervenes and does not. This Markov switching framework then allows the study of exit strategies after intervention occurs, the effects of expectations on pre-crisis economic activity, and the welfare gain or loss from different policy guarantees.

There has been a rapidly growing literature on the implications of financial frictions in the macroeconomy. Many DSGE models, such as Christiano *et al.* (2005) and Smets & Wouters (2007), do not incorporate a financial sector, and are therefore unable to explain movements associated with the banking system. A standard framework to incorporate a financial sector

is to use a financial accelerator model, as developed in Bernanke & Gertler (1989), Kiyotaki & Moore (1997), and Bernanke *et al.* (1999), which allows for frictions in the financial sector that slow the flow of funds from households to firms. Gertler & Karadi (2010) build upon the financial accelerator literature by incorporating a central bank equipped with a mechanism to intervene in credit markets during crises, and show that intervention can lessen the magnitude of downturns associated with financial crises. Other models that allow for financial frictions or government intervention during crises are Brunnermeier & Sannikov (2009), Christiano *et al.* (2009), or Del Negro *et al.* (2010).

Many of the papers that consider government intervention during financial crises lack the expectations and transitions between the intervention and no intervention regimes that are included in this paper. When expectations and transitions are ignored, any change in policy is entirely unexpected and considered permanent. Therefore, without the regime switching introduced in this paper, the effects of exit strategies and pre-crisis expectations have to be ignored as well. Following the rare event literature (Rietz (1988), Barro (2006), and Barro (2009)) this paper allows financial crises to occur with a small probability. Agents form expectations over the central bank's decision to intervene conditional upon that rare event occurring. However, as in Barro *et al.* (2010), the model also allows crises to be persistent – that is, to last several periods before ending – and studies the implications of uncertain crisis duration. This uncertainty over crisis duration may have implications for the magnitude of the drop in real activity: if agents are uncertain about how long asset prices will remain suppressed, the economy may not rebound as quickly as if agents know that the crisis will be brief.

Markov switching in government policies has become a popular way to model discrete changes in government policy that are expected with some probability. Perhaps the most widely used application is changing conventional monetary policy rules, such as Davig & Leeper (2007), Farmer *et al.* (2008), and Bianchi (2009). With Markov switching, since policy changes are expected with some probability, expectations over future policy rules affect current dynamics of the economy. For example, in the context of switches in conventional monetary policy, expected changes in the inflation target or response to inflation can affect current inflation.

In this paper, the probability of changing to a regime where the central bank intervenes with unconventional policy can affect pre-crisis dynamics, and expectations on exit strategies can affect effectiveness in the initial portion of the crisis. Foerster *et al.* (2011) develop perturbation methods for Markov switching models, which allows a high degree of flexibility in the modelling of the regime switching in order to capture the various specifications of regime switching to be considered here, and also allows for second- or higher-order approximations, which are important for welfare analysis

The paper proceeds as follows. Section 2 discusses the model, with special emphasis on the financial sector. Section 3 details how the parameters of the economy change according to a Markov Process, and the transitions between regimes. The response of the economy to crises with and without intervention is discussed in Section 4, as are the effects of different exit strategies. Section 5 analyzes the effects of expectations of crisis policies on the pre-crisis economy. Section 6 discusses the welfare implications of policy announcements, and Section 7 concludes. All tables and plots are included in the Appendices.

2 Model

This section describes the basic model, which is developed in Gertler & Karadi (2010). It is a standard DSGE model, similar to Christiano *et al.* (2005) and Smets & Wouters (2007), with the addition of a financial sector. The purpose of the financial sector is to serve as an intermediary between households and nonfinancial firms, channeling funds from households to the firms.

At this point in time, the parameters that will change with regime switching are described simply as time-varying parameters. The next section will describe regime-switching in more detail.

2.1 Households

The economy is populated by a continuum of households of unit measure. These households consume, supply labor, and save by lending money to financial intermediaries or potentially to the government.

Each household is comprised of a fraction $(1 - f)$ of workers, and a fraction f of bankers. Workers supply labor to nonfinancial firms, earning wages for the household in the process. Each banker is the owner of a financial intermediary that returns its earnings to the household. Bankers become workers with probability $(1 - \theta)$, so a total fraction of $(1 - \theta)f$ transition to become workers; the same fraction transition from being workers to being bankers to keep the measure of each type constant. In addition, the probability of transitioning occupations is independent of duration. Upon exit, bankers transfer their net worth to the household, and new bankers receive some initial funds from the household. Within the household, there is perfect consumption insurance.

The households maximize their lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(C_t - hC_{t-1}) - \frac{\varkappa}{1 + \varphi} L_t^{1+\varphi} \right\} \quad (1)$$

where \mathbb{E}_0 is the conditional expectations operator, $\beta \in (0, 1)$ is the discount factor, C_t is household consumption at time t , h controls the degree of habit formation in consumption, L_t is household labor supply, \varkappa controls the disutility of labor, and φ is the inverse of the Frisch labor supply elasticity.

As previously noted, workers earn a wage W_t on their labor supplied L_t , there is an amount Δ_t of net profits from financial and nonfinancial firms, which is profits and banker earnings returned to the household from exiting bankers less some start-up funds for new bankers, and lump sum transfers T_t . Households save by purchasing bonds B_t either from financial intermediaries or the government, these bonds pay a gross real return of R_t in period $t + 1$. In equilibrium, both sources of bonds are riskless and hence identical from the household's perspective, so R_t is the risk-free rate of return. Households then have income $R_{t-1}B_{t-1}$ from bonds. Consequently,

the household's budget constraint is given by

$$C_t + B_t = W_t L_t + \Delta_t + T_t + R_{t-1} B_{t-1}. \quad (2)$$

Using a multiplier ϱ_t on the budget constraint, the household's optimality conditions are given by an equation for the marginal utility of consumption

$$(C_t - hC_{t-1})^{-1} - \beta h \mathbb{E}_t (C_{t+1} - hC_t)^{-1} = \varrho_t, \quad (3)$$

one for the marginal utility of savings

$$\beta R_t \mathbb{E}_t \frac{\varrho_{t+1}}{\varrho_t} = 1, \quad (4)$$

and an equation for the marginal disutility of labor

$$\varkappa L_t^\varphi = \varrho_t W_t. \quad (5)$$

2.2 Financial Intermediaries

The purpose of financial intermediaries is to serve as a channel for funds between the households and nonfinancial firms. Financial intermediaries, which are indexed by j , accumulate net worth $N_{j,t}$ and collect deposits from households $B_{j,t}$. Using these two sources of funding, they purchase claims on non-financial firms $S_{j,t}$ which have relative price Q_t . The intermediaries' balance sheet dictates that the overall value of claims on non-financial firms must equal the value of the intermediaries net worth plus deposits, so

$$Q_t S_{j,t} = N_{j,t} + B_{j,t}. \quad (6)$$

As discussed in the previous subsection, in period $t + 1$ deposits made by the household at time t pay a risk-free rate R_t . The claims on non-financial firms purchased at time t , on the other hand, pay out at $t + 1$ a stochastic return of R_{t+1}^k . The evolution of net worth is the difference in interest received from non-financial firms and interest paid out to depositors:

$$\begin{aligned} N_{j,t+1} &= R_{t+1}^k Q_t S_{j,t} - R_t B_{j,t} \\ &= (R_{t+1}^k - R_t) Q_t S_{j,t} + R_t N_{j,t}. \end{aligned} \quad (7)$$

Hence, the intermediary's net worth will grow at the risk-free rate, with any growth above that level being the excess return on assets $(R_{t+1}^k - R_t) Q_t S_{j,t}$. Faster growth in net worth therefore must come from higher realized interest rate spreads $R_{t+1}^k - R_t$ or an expansion of assets $Q_t S_{j,t}$.

Given that the evolution in net worth depends upon the interest rate spread, a banker will not fund assets if the discounted expected return is less than the discounted cost of borrowing. So, the banker's participation constraint is

$$\mathbb{E}_t \beta^{i+1} \frac{\varrho_{t+1+i}}{\varrho_t} (R_{t+1+i}^k - R_{t+i}) \geq 0, \text{ for } i \geq 0, \quad (8)$$

where $\beta^{i+1} \frac{\varrho_{t+1+i}}{\varrho_t}$ is the stochastic discount factor applied to returns in period $t + 1 + i$. Note here the inequality is a key differential with financial frictions. In a standard economy without constrained financial intermediaries this participation constraint exactly binds by no arbitrage. In a model with financial frictions, financial intermediaries may be unable to take advantage of positive expected interest rate spreads due to constraints on their borrowing.

As noted previously, each period bankers exit the financial intermediary sector and become standard workers with probability $(1 - \theta)$. This probability limits the lifespan of bankers, and hence eliminates their ability to build up net worth to a point where they would forego deposits and fund their purchase of claims entirely out of their own net worth. If the participation constraint (8) holds, a banker has incentive to accumulate as much net worth as possible upon exit. The banker's objective function is to maximize the present value of their net worth at exit. The expected terminal net worth is then

$$\begin{aligned} V_{j,t} &= \mathbb{E}_t (1 - \theta) \beta \sum_{i=0}^{\infty} \beta^i \theta^i \frac{\varrho_{t+1+i}}{\varrho_t} N_{j,t+1+i} \\ &= \mathbb{E}_t (1 - \theta) \beta \sum_{i=0}^{\infty} \beta^i \theta^i \frac{\varrho_{t+1+i}}{\varrho_t} ((R_{t+1+i}^k - R_{t+i}) Q_{t+i} S_{j,t+i} + R_{t+i} N_{j,t+i}) \end{aligned} \quad (9)$$

This expression shows that, following from the expression (7) describing growth in net worth, the value of being a financial intermediary is increasing in expected future interest rate spreads, $(R_{t+1+i}^k - R_{t+i})$, future asset levels $Q_{t+i} S_{j,t+i}$, plus the risk-free return on net worth.

Now, to formulate the expected terminal net worth (9) in terms of a banker's current position,

define the growth of assets from $t - 1$ to t as

$$x_t = \frac{Q_t}{Q_{t-1}} \frac{S_{j,t}}{S_{j,t-1}} \quad (10)$$

and the growth of net worth from $t - 1$ to t as

$$z_t = \frac{N_{j,t}}{N_{j,t-1}}. \quad (11)$$

Then (9) can be expressed as a function of current assets $Q_t S_{j,t}$ and net worth $N_{j,t}$ as

$$V_{j,t} = v_t Q_t S_{j,t} + \eta_t N_{j,t} \quad (12)$$

where the discounted marginal gain from expanding assets $Q_t S_{j,t}$ is given by v_t :

$$v_t = \mathbb{E}_t \left[(1 - \theta) \beta \frac{\varrho_{t+1}}{\varrho_t} (R_{t+1}^k - R_t) + \beta \theta \frac{\varrho_{t+1}}{\varrho_t} x_{t+1} v_{t+1} \right] \quad (13)$$

and the discounted marginal gain from expanding net worth $N_{j,t}$ is given by η_t :

$$\eta_t = \mathbb{E}_t \left[(1 - \theta) \beta \frac{\varrho_{t+1}}{\varrho_t} R_t + \theta \beta \frac{\varrho_{t+1}}{\varrho_t} z_{t+1} \eta_{t+1} \right] \quad (14)$$

In a frictionless environment, if the expected interest rate spread $(R_{t+1}^k - R_t)$ is positive, financial intermediaries will want to expand their assets infinitely by borrowing additional funds from the household. However, consider the following constraint that will limit a banker's ability to expand without limit. In each period, the banker can divert a fraction λ of its assets $Q_t S_{j,t}$ back to the household. If the banker does choose to divert assets, depositors are able to recover the remaining fraction $(1 - \lambda)$ of assets. Consequently, the incentive constraint for the banker requires that the expected value of not diverting and remaining until exit exceeds the value of diverted funds in each period:

$$V_{j,t} \geq \lambda Q_t S_{j,t} \quad (15)$$

The constraint (15) binds so long as $\lambda > v_t$, which implies that marginal increases in assets have more benefit to the banker being diverted than as an increase in expected terminal wealth. For the purposes of this paper, this constraint will always bind, which implies, using (12) with (15), that assets can be expressed as a function of net worth by

$$Q_t S_{j,t} = \phi_t N_{j,t} \quad (16)$$

where

$$\phi_t = \frac{\eta_t}{\lambda - v_t} \quad (17)$$

denotes the leverage ratio of the financial intermediary. Consequently, the incentive constraint puts a limit on the amount of assets, and hence deposits, that an intermediary can have relative to its net worth.

To continue the characterization of the financial sector, consider again the evolution of net worth in (7), which can be expressed using the leverage ratio (17) as

$$N_{j,t} = [(R_t^k - R_{t-1}) \phi_{t-1} + R_{t-1}] N_{j,t-1}. \quad (18)$$

Then the growth in net worth of the an intermediary, defined in (11) is written as

$$z_t = (R_t^k - R_{t-1}) \phi_{t-1} + R_{t-1} \quad (19)$$

and, similarly, the growth in assets defined in (10) is expressed as

$$x_t = \frac{\phi_t}{\phi_{t-1}} z_t. \quad (20)$$

Since the price Q_t and the leverage ratio ϕ_t are independent of banker-specific characteristics, total intermediary demand is a result of summing over all independent intermediaries j :

$$Q_t S_{I,t} = \phi_t N_t. \quad (21)$$

So the total value of intermediated assets $Q_t S_{I,t}$ is equal to the economy's leverage ratio ϕ_t times aggregate intermediary net worth N_t . The key feature of this expression is that the total amount of assets supplied by the financial intermediaries is in part determined by their net worth. During financial crises, sharp declines in financial intermediary net worth therefore limit the amount of assets the sector can provide for the economy.

Now, to determine the law of motion for aggregate intermediary net worth N_t , note that total assets are equal to those of existing bankers $N_{e,t}$ plus new bankers $N_{n,t}$:

$$N_t = N_{e,t} + N_{n,t}. \quad (22)$$

Since bankers exit with probability $(1 - \theta)$, existing banker net worth makes up a fraction θ of the growth in net worth from the previous period,

$$N_{e,t} = \theta [(R_t^k - R_{t-1}) \phi_{t-1} + R_{t-1}] N_{t-1} \quad (23)$$

In every period, a fraction $(1 - \theta)$ of bankers exit and become workers, transferring their accumulated net worth to the household. At the same time, an identical measure of workers become bankers, and receive an initial level of net worth from the household. Specifically, new bankers receive start-up funds equal to a fraction $\frac{\omega}{1-\theta}$ of the assets of exiting bankers $(1 - \theta) Q_t S_{t-1}$:

$$N_{n,t} = \frac{\omega}{1 - \theta} (1 - \theta) Q_t S_{t-1} = \omega Q_t S_{t-1} \quad (24)$$

Combining the decomposition of net worth (22), the expression for existing net worth (23), and the expression for new net worth (24), the law of motion for net worth is given by

$$N_t = \theta [(R_t^k - R_{t-1}) \phi_{t-1} + R_{t-1}] N_{t-1} + \omega Q_t S_{t-1}. \quad (25)$$

2.3 Credit Policy

The previous section discussed the financial intermediary sector, and how bankers use their net worth and borrowing from households to purchase claims on nonfinancial firms. Now consider that sometimes the central bank may enter the credit market to assist in the flow of funds from households to nonfinancial firms. In particular, the government owns an amount of claims $S_{g,t}$ on nonfinancial firms, these have relative price Q_t , and so the total value of central bank assets is $Q_t S_{g,t}$. Since $Q_t S_{I,t}$ is the total value of privately intermediated assets, the total value of all assets in the economy is $Q_t S_t$, where

$$Q_t S_t = Q_t S_{I,t} + Q_t S_{g,t} \quad (26)$$

The central bank purchases these assets in a manner similar to private financial intermediaries: by issuing debt to households $B_{g,t}$ at time t that pays the risk free rate R_t in period $t + 1$. In addition, the central bank's claims on nonfinancial firms earn the stochastic rate R_{t+1}^k in period $t + 1$. The government then will earn returns equal to $(R_{t+1}^k - R_t) B_{g,t}$.

Unlike private financial intermediaries, which are balance sheet constrained because of the constant opportunity to divert a fraction λ of their assets, the government does not face a similar moral hazard problem – it always repays its debts. Consequently, the central bank faces no constraints on its balance sheet, it can borrow and lend without limit. However, for every unit of assets that the central bank owns, they pay a resource cost of τ . This resource cost captures any possible inefficiencies from government intervention, such as costs of raising government debt or managing the assets on its balance sheet.

For the moment, assume that the government has a rule – which will be discussed in Section 2.7 – that determines the fraction ψ_t of total intermediated assets it will supply. That is, it sets its purchases such that

$$Q_t S_{g,t} = \psi_t Q_t S_t. \quad (27)$$

To characterize the full leverage ratio of the economy, that which includes private plus public assets, first note that using the government share (27) and the private intermediaries' total demand (21) in the decomposition of total assets (26) yields

$$Q_t S_t = \phi_t N_t + \psi_t Q_t S_t.$$

So the total funds are equal to the total leverage ratio ϕ_t^c times intermediary net worth

$$Q_t S_t = \phi_t^c N_t. \quad (28)$$

The total leverage ratio, which is that for private and public funds, is given by

$$\phi_t^c = \frac{\phi_t}{1 - \psi_t}. \quad (29)$$

Note here that by setting ψ_t , the central bank manipulates the private leverage ratio ϕ_t . If the central bank increases its fraction of supplied assets given a fixed private leverage ratio, the total leverage ratio increases at an increasing rate.

2.4 Intermediate Goods Firms

Intermediate goods firms operate in a competitive environment, producing using capital and labor. Firms purchase capital by issuing claims S_t to financial intermediaries, and then use the funds from issuing those claims to purchase capital for next period. After production, the firm then pays to repair its depreciated capital and sells its entire capital on the open market. The price of a unit of capital and the price of a claim are Q_t , so

$$Q_t K_t = Q_t S_t$$

Given a level of capital K_{t-1} , the firm decides on labor demand, which pays wage W_t , and a capital utilization rate U_t , and produces the intermediate good Y_t^m using a Cobb-Douglas production function

$$Y_t^m = A_t (U_t \xi_t K_{t-1})^\alpha L_t^{1-\alpha} \quad (30)$$

and sells this output at price P_t^m . Firms are also subject to changes in total factor productivity A_t , where

$$\log A_t = \rho_A \log A_{t-1} + \sigma_A \varepsilon_{A,t} \quad (31)$$

and changes in a capital quality measure ξ_t which evolves according to the process

$$\log \xi_t = (1 - \rho_\xi(s_t)) \log \xi_{ss}(s_t) + \rho_\xi(s_t) \log \xi_{t-1} + \sigma_\xi \varepsilon_{\xi,t} \quad (32)$$

where s_t indicates a hidden Markov state at time t . This Markov process affects the mean of the process $\log \xi_{ss}(s_t)$, as well as persistence around the mean $\rho_\xi(s_t)$. The role of the capital quality shock ξ_t is to alter the effective capital stock of the economy $\xi_t K_{t-1}$ and thereby exogenously change the value of capital in the economy. A more detailed description of the Markov Process is in Section 3.

Since the firm faces no adjustment costs, its problem is static, and so period-by-period the firm chooses its labor demand and capital utilization such that

$$W_t = P_t^m (1 - \alpha) \frac{Y_t^m}{L_t} \quad (33)$$

and

$$P_t^m \alpha \frac{Y_t^m}{U_t} = \delta'(U_t) \xi_t K_{t-1}. \quad (34)$$

The depreciation rate varies with utilization and is assumed to follow the functional form

$$\delta(U_t) = \bar{\delta} - \frac{\tilde{\delta}}{1 + \zeta} + \frac{\tilde{\delta}}{1 + \zeta} U_t^{1+\zeta}$$

where $\tilde{\delta}$ is determined by the steady state.

After producing in time t , the firm sells its non-depreciated capital at price Q_t less a replacement price of depreciated capital of 1. The firm earns zero profits state-by-state, it pays the realized return on capital to the intermediary, which is given by

$$R_t^k = \frac{\left[P_t^m \alpha \frac{Y_t^m}{\xi_t K_{t-1}} + Q_t - \delta(U_t) \right] \xi_t}{Q_{t-1}}. \quad (35)$$

This expression highlights how changes in the capital quality measure ξ_t produce exogenous changes in the return on capital.

2.5 Capital Producing Firms

Capital producers are competitive firms that buy used capital from intermediate goods firms, repair depreciated capital, build new capital, and sell it to the intermediate goods firms. So gross investment is defined as

$$I_t = K_t - (1 - \delta(U_t)) \xi_t K_{t-1} \quad (36)$$

which is simply the total change in capital. Net investment is gross investment less depreciation:

$$I_t^n = I_t - \delta(U_t) \xi_t K_{t-1}. \quad (37)$$

Firms face quadratic adjustment costs on construction of new capital but not depreciated capital. In particular, the costs are quadratic in deviations of the growth in net investment plus steady-state gross investment from a value of unity:

$$f\left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}}\right) = \frac{\eta_i}{2} \left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}} - 1\right)^2 \quad (38)$$

The present value of profits for a capital producer are

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\varrho_t}{\varrho_0} \left\{ (Q_t - 1) I_t^n - f \left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}} \right) (I_t^n + \bar{I}) \right\}$$

The optimal choice of net investment implies the price of capital is given by

$$\begin{aligned} Q_t = & 1 + f \left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}} \right) + f' \left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}} \right) \left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}} \right) \\ & - \mathbb{E}_t \beta \Lambda_{t+1} f' \left(\frac{I_{t+1}^n + \bar{I}}{I_t^n + \bar{I}} \right) \left(\frac{I_{t+1}^n + \bar{I}}{I_t^n + \bar{I}} \right)^2. \end{aligned} \quad (39)$$

2.6 Retail Firms

Retail firms repackage intermediate output Y_t^m into differentiated products $Y_{f,t}$ which they sell at price $P_{f,t}$, where $f \in [0, 1]$ denotes differentiated products. Final output is a CES aggregate of retail firm goods, so

$$Y_t = \left(\int_0^1 Y_{f,t}^{\frac{\varepsilon-1}{\varepsilon}} df \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (40)$$

Consumers of the final good use cost minimization, so standard optimality conditions imply that demand for good f is a function of the relative price of the good times aggregate demand:

$$Y_{f,t} = \left(\frac{P}{P_{f,t}} \right)^{-\varepsilon} Y_t. \quad (41)$$

and that the aggregate price level is related to the individual prices by

$$P_t^{1-\varepsilon} = \int_0^1 P_{f,t}^{1-\varepsilon} df$$

Since retail firms repackage intermediate output, their marginal cost is P_t^m . Firms set their price according to Calvo pricing, meaning a firm can re-optimize their price each period with probability $(1 - \gamma)$. Those firms that do not re-optimize prices re-index prices with respect to inflation and the parameter μ . A firm that can choose its price at time t maximizes the present value of profits according to

$$\max_{P_{f,t}} \sum_{i=0}^{\infty} \gamma^i \beta^i \frac{\varrho_{t+i}}{\varrho_t} \left(\prod_{k=1}^i \Pi_{t+k-1}^{\mu} \frac{P_{f,t}}{P_{t+i}} - P_{t+i}^m \right) Y_{f,t+i} \quad (42)$$

subject to

$$Y_{f,t+i} = \left(\prod_{k=1}^i \Pi_{t+k-1}^\mu \frac{P_{f,t}}{P_{t+i}} \right)^{-\varepsilon} Y_{t+i} \quad (43)$$

The first-order condition produces the optimal price setting level $P_{f,t}^*$ and using the symmetric equilibrium $P_{f,t}^* = P_t^*$:

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \frac{\varrho_{t+i}}{\varrho_t} \left((\varepsilon - 1) \left(\prod_{k=1}^i \frac{\Pi_{t+k-1}^\mu}{\Pi_{t+k}} \right)^{1-\varepsilon} \frac{P_t^*}{P_t} - \varepsilon \left(\prod_{k=1}^i \frac{\Pi_{t+k-1}^\mu}{\Pi_{t+k}} \right)^{-\varepsilon} P_{t+i}^m \right) Y_{t+i} = 0.$$

Defining the auxiliary variable a_t , this term is written in recursive form as two expressions, the first being

$$a_t = \tilde{P}_t^* Y_t + \gamma \beta \frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*} \left(\frac{\Pi_t^\mu}{\Pi_{t+1}} \right)^{1-\varepsilon} \frac{\varrho_{t+1}}{\varrho_t} a_{t+1} \quad (44)$$

and the second

$$a_t = \frac{\varepsilon}{(\varepsilon - 1)} P_t^m Y_t + \gamma \beta \left(\frac{\Pi_t^\mu}{\Pi_{t+1}} \right)^{-\varepsilon} \frac{\varrho_{t+1}}{\varrho_t} a_{t+1}. \quad (45)$$

where the relative price is defined as $\tilde{P}_t^* = P_t^*/P_t$.

Given indexation and the fact that a fraction $(1 - \gamma)$ of firms change their prices, the evolution of the price level satisfies

$$P_t^{1-\varepsilon} = (1 - \gamma) (P_t^*)^{1-\varepsilon} + \gamma (\Pi_{t-1}^\mu P_{t-1})^{1-\varepsilon}$$

and putting the expression in terms of relative price

$$1 = (1 - \gamma) \tilde{P}_t^{*1-\varepsilon} + \gamma \left(\frac{\Pi_{t-1}^\mu}{\Pi_t} \right)^{1-\varepsilon} \quad (46)$$

Finally, the domestic rate of absorption ς_t is defined by

$$\begin{aligned} \varsigma_t &= \int_0^1 \left(\frac{P_{f,t}}{P_t} \right)^{-\varepsilon} df \\ &= (1 - \gamma) \left(\tilde{P}_t^* \right)^{-\varepsilon} + \gamma \left(\frac{\Pi_{t-1}^\mu}{\Pi_t} \right)^{-\varepsilon} \varsigma_{t-1} \end{aligned} \quad (47)$$

and since $Y_{f,t} = Y_t^m$, then intermediate output and final output are related by

$$Y_t^m = \varsigma_t Y_t. \quad (48)$$

2.7 Government Policy

There are two aspects to government policy: standard monetary policy and the unconventional policy rule. Conventional monetary policy sets the nominal interest rate r_t according to a Taylor rule

$$\left(\frac{r_t}{\bar{r}}\right) = \left(\frac{r_{t-1}}{\bar{r}}\right)^{\rho_r(s_t)} \left(\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\kappa_\pi} \left(\frac{Y_t}{Y_t^*}\right)^{\kappa_y} \right)^{1-\rho_r(s_t)} \exp(\sigma_r \varepsilon_{r,t}) \quad (49)$$

where the smoothing parameter $\rho_r(s_t)$ follows a Markov Process to be discussed in Section 3, $\bar{\Pi}$ is the target inflation rate, \bar{r} is the steady state nominal rate, and κ_π and κ_y control responses to the inflation and output gap, respectively. The nominal and risk-free interest rates satisfy the Fisher equation

$$r_t = R_t \mathbb{E}_t \Pi_{t+1} \quad (50)$$

Second, as discussed in Section 2.3, the government sets its level of credit market intervention ψ_t according to the rule

$$\psi_t = (1 - \rho_\psi(s_t)) \psi_{ss}(s_t) + \rho_\psi(s_t) \psi_{t-1} \quad (51)$$

where the mean of the process $\psi_{ss}(s_t)$ and its persistence $\rho_\psi(s_t)$ change according to a Markov Process to be discussed in Section 3.

Finally, the government has a fixed amount of spending G every period, plus it must pay a resource cost τ on any assets it purchases. It finances these via lump-sum taxes and the return from its previously held assets, which, as discussed previously, is the realized interest rate differential. Consequently, the government's budget constraint is given by

$$G + \tau \psi_t Q_t K_t = T_t + (R_t^k - R_{t-1}) B_{g,t-1} \quad (52)$$

The economy wide resource requires that output be used for consumption, investment plus capital adjustment costs, and government spending including the resource cost of intervention. Assume that the level of government spending G equals a fraction g of steady state output \bar{Y} . Therefore, the economy's resource constraint is

$$Y_t = C_t + I_t + f\left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}}\right) (I_t^n + \bar{I}) + G + \tau \psi_t Q_t K_t \quad (53)$$

and the economy wide evolution of capital is

$$K_t = \xi_t K_{t-1} + I_t^n - f\left(\frac{I_t^n + \bar{I}}{I_{t-1}^n + \bar{I}}\right) (I_t^n + \bar{I}) \quad (54)$$

This concludes the discussion of the core model.

3 Regime Switching and Equilibrium

Having discussed the core model, this section shows how the core model is embedded into a regime switching framework. There are three equations that have parameters that switch according to a Markov process: the exogenous process for capital quality (32), the Taylor rule of conventional monetary policy (49), and the rule for unconventional policy (51). The next three subsections discuss the switching in these equations, then subsection 3.4 discusses the assumptions on timing and transitions, and subsection 3.5 covers the full model equilibrium and solution method.

3.1 Markov Switching in the Capital Quality Process

The first equation that has switching is the exogenous process for capital quality

$$\log \xi_t = (1 - \rho_\xi(s_t)) \log \xi_{ss}(s_t) + \rho_\xi(s_t) \log \xi_{t-1} + \sigma_{\xi} \varepsilon_{\xi,t}.$$

This process allows for changes in the mean of the process through the term $\xi_{ss}(s_t)$, and changes in the persistence $\rho_\xi(s_t)$, where s_t denotes the state of the Markov Process. By allowing for changes in the mean and the persistence, this equation can capture a wide variety of possible switching dynamics. As mentioned in Section 2.4, this capital quality measure will drive exogenous fluctuations in the value of capital, and significant declines will create a financial crisis.

For the purposes of this paper, the two switching parameters $\xi_{ss}(s_t)$ and $\rho_\xi(s_t)$ will each take on two values, depending on whether the economy is in a financial crisis or not. Specifically, if the economy is not in a financial crisis, then the mean of the process is assumed to be $\xi_{ss}^n = 1$,

and the persistence is assumed to be $0 < \rho_\xi^n < 1$, where the superscript n denotes "normal times." During a financial crisis, the mean of the process is a crisis level $\xi_{ss}^c < 1$, where the superscript c indicates "crisis" and the persistence is $\rho_\xi^c = 0$.

This dual change in parameters between normal and crisis times has two effects. First, when the economy enters a crisis, the fact that the crisis mean is less than one implies that the capital quality measure moves to a lower level than in normal times. The fact that the crisis persistence $\rho_\xi^c = 0$ implies that the capital quality jumps downward to the new, lower mean. Second, when the economy leaves a crisis, the mean of the process $\xi_{ss}^n = 1$ implies that the capital quality measure is at its higher normal level, but the persistence ρ_ξ^n implies that the reversion to this high mean is slow. These two features are meant to capture the fact that entry into financial crises tends to be rapid, with a quick transition to a low capital quality, while after the crisis ends the economy takes time to return back to its pre-crisis levels.

3.2 Markov Switching in the Taylor Rule

The second equation that contained parameters that switch along with the Markov Process is the Taylor Rule

$$\left(\frac{r_t}{\bar{r}}\right) = \left(\frac{r_{t-1}}{\bar{r}}\right)^{\rho_r(s_t)} \left(\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\kappa_\pi} \left(\frac{Y_t}{Y_t^*}\right)^{\kappa_y} \right)^{1-\rho_r(s_t)} \exp(\sigma_r \varepsilon_{r,t})$$

where the switching affects the interest rate smoothing $\rho_r(s_t)$. Similar to the assumptions on switching for the process of capital quality, the smoothing parameter takes two different values depending upon whether the economy is in a financial crisis or not. If the economy is in normal times, then $\rho_r(s_t)$ is equal to $0 < \rho_r^n < 1$, which indicates that the central bank is smoothing when setting the nominal interest rate. When the economy enters a crisis, the central bank ceases to smooth interest rates however, making their policy decision completely dependent upon current conditions, and sets the smoothing parameter $\rho_r(s_t) = \rho_r^c = 0$.

3.3 Markov Switching in Credit Policy

The third equation that has Markov Switching in the parameters is the equation governing the level of credit intervention by the central bank:

$$\psi_t = (1 - \rho_\psi(s_t)) \psi_{ss}(s_t) + \rho_\psi(s_t) \psi_{t-1}$$

where again the Markov Switching affects the mean of the process $\psi_{ss}(s_t)$ and its persistence $\rho_\psi(s_t)$. In contrast to the previous two Markov Switching equations, which changed depending upon whether the economy was in a crisis or not, the level of credit intermediation will need to allow for the fact that the economy may not intervene during crises. Consequently, the distinction will be between "intervene" and "not intervene."

When the central bank intervenes, it sets the mean of the process to be $0 < \psi_{ss}^b < 1$ and persistence to be $\rho_\psi^b = 0$, where the superscript b denotes "bailout." This rule implies that when the central bank intervenes, it always does so by purchasing a fraction ψ_{ss}^b of total assets. When the central bank does not intervene, it sets the mean $\psi_{ss}^{nb} = 0$ and $0 \leq \rho_\psi^{nb} < 1$. These values imply two features about the no intervention case. First, if $\psi_{t-1} = 0$, so the central bank previously had no assets, then it will continue to have no assets. Second, even if the central bank is not actively intervening, if it does have assets, so $\psi_{t-1} > 0$, then it will continue to hold assets, but will be unwinding them according to an AR process. This unwinding has important implications for when the central bank is exiting the credit market after a crisis. If $0 < \rho_\psi^{nb} < 1$, when the intervention rule switches from intervention to no intervention, there will be a gradual unwind of the accumulated assets. On the other hand, if $\rho_\psi^{nb} = 0$ then when the intervention rule switches to the no intervention parameters, then instantly $\psi_t = 0$, meaning the central bank exits the credit market with an immediate sell-off of its assets.

3.4 Transitions and Timing

Having discussed the nature of the switching in parameters governed by a Markov Switching process, this subsection discusses exactly how the switches in the three equations coincide, and transitions between the various regimes. There are five regimes in the economy. Figure 2 depicts

Table 1: Markov Switching Parameters

s_t	$\rho_r(s_t)$	$\xi_{ss}(s_t)$	$\rho_\xi(s_t)$	$\psi_{ss}(s_t)$	$\rho_\psi(s_t)$
1) "Normal"	$\rho_r^n > 0$	$\xi_{ss}^n = 1$	$\rho_\xi^n > 0$	$\psi_{ss}^n = 0$	$\rho_\psi^n \geq 0$
2) "Crisis w/o Intervention"	$\rho_r^c = 0$	$\xi_{ss}^c < 1$	$\rho_\xi^c = 0$	$\psi_{ss}^c = 0$	$\rho_\psi^c \geq 0$
3) "Policy Cont w/o Intervention"	$\rho_r^c = 0$	$\xi_{ss}^n = 1$	$\rho_\xi^n > 0$	$\psi_{ss}^c = 0$	$\rho_\psi^n \geq 0$
4) "Crisis w/ Intervention"	$\rho_r^c = 0$	$\xi_{ss}^c < 1$	$\rho_\xi^c = 0$	$\psi_{ss}^b > 0$	$\rho_\psi^b = 0$
5) "Policy Cont w/ Intervention"	$\rho_r^c = 0$	$\xi_{ss}^n = 1$	$\rho_\xi^n = 0$	$\psi_{ss}^b > 0$	$\rho_\psi^b = 0$

these transitions as a flow chart, Table 1 summarizes the discussion of how the parameters change according to the state of the Markov Process, and Table 2 summaries the transition probabilities.

Figure 2: Flow Chart of the Economy

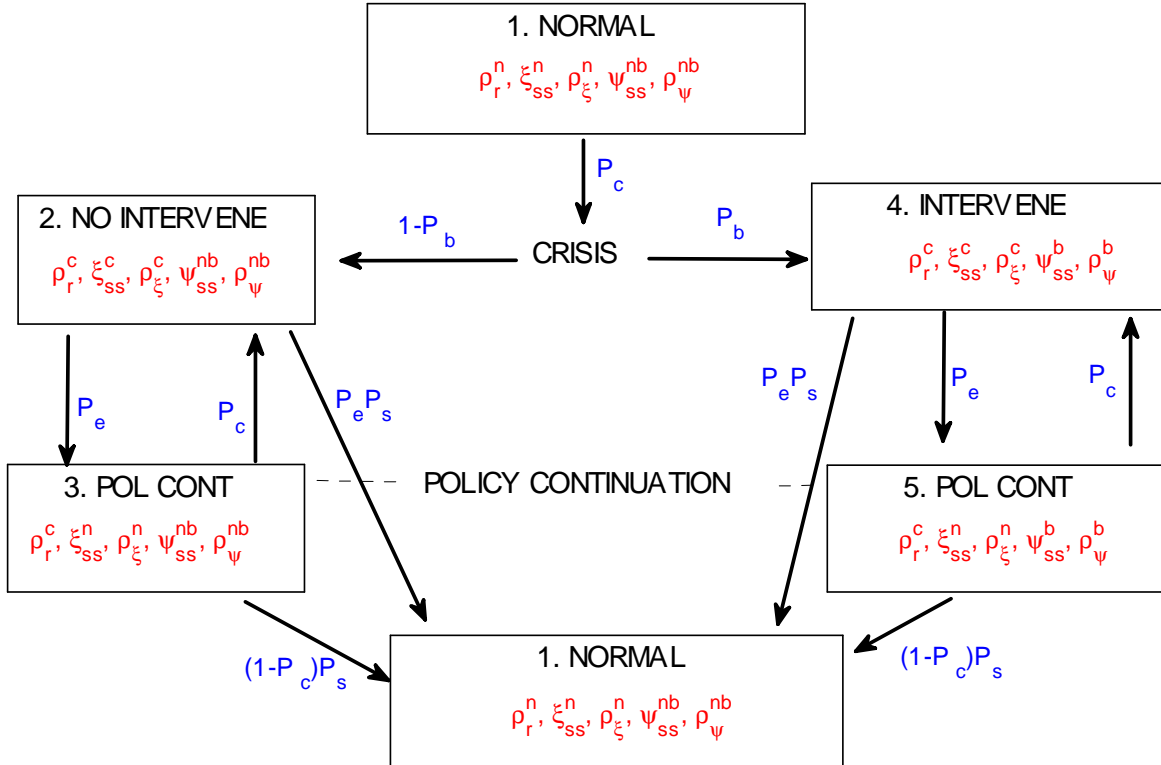


Table 2: Markov Switching Probabilities

		s_{t+1}				
		1	2	3	4	5
s_t	1	$1 - p_c$	$p_c(1 - p_b)$	0	p_cp_b	0
	2	p_ep_s	$1 - p_e$	$p_e(1 - p_s)$	0	0
	3	$(1 - p_c)p_s$	p_c	$(1 - p_c)(1 - p_s)$	0	0
	4	p_ep_s	0	0	$1 - p_e$	$p_e(1 - p_s)$
	5	$(1 - p_c)p_s$	0	0	p_c	$(1 - p_c)(1 - p_s)$

The first regime ($s_t = 1$) is defined as "Normal Times" and can be thought of as the pre-crisis regime the economy is in a high percentage of the time. In this regime, the capital quality measure has a high mean ($\xi_{ss}(1) = \xi_{ss}^n = 1$), and positive persistence ($\rho_\xi(1) = \rho_\xi^n \in (0, 1)$). The monetary authority practices smoothing of nominal interest rates ($\rho_r(s_t) = \rho_r(1) > 0$) and the central bank either is not intermediating or decreasing its level of intermediation ($\psi_{ss}(1) = \psi_{ss}^n = 0$ and $\rho_\psi(1) = \rho_\psi^n \in [0, 1)$).

With a small exogenous probability, p_c , which can be thought of as a rare event in the form of Barro (2006), the economy experiences a financial crisis. Conditional on this crisis occurring, there is an immediate decision by the central bank to intervene or not, which it does with probability p_b .

If the central bank does not intervene, which occurs with probability $1 - p_b$, the economy moves to the second regime ($s_t = 2$), which is "Crisis Without Intervention." In this regime, there is a financial crisis, so the capital quality measure drops immediately ($\rho_\xi(2) = \rho_\xi^c = 0$) to a lower steady state ($\xi_{ss}(2) = \xi_{ss}^n < 1$). The monetary authority ceases its policy of smoothing interest rates in order to react rapidly to current conditions ($\rho_r(2) = \rho_r^c = 0$), but the central bank does not intervene in credit markets, leaving the credit policy rule as during normal times ($\psi_{ss}(2) = \psi_{ss}^n = 0$ and $\rho_\psi(2) = \rho_\psi^n \in [0, 1)$).

After a crisis occurs, the economy exits the crisis with probability p_e each period. If the economy is in regime 2, then upon exiting the crisis, it moves to the third regime ($s_t = 3$),

called "Policy Continuation Without Intervention." In this regime, the crisis has ended, but the policy rules are still in their crisis modes. That is, the capital quality measure has high mean ($\xi_{ss}(3) = \xi_{ss}^n = 1$) and positive persistence ($\rho_\xi(3) = \rho_\xi^n \in (0, 1)$), which implies that after the drop in capital quality from the crisis, quality is gradually moving to its original pre-crisis level. However, since policy is still in crisis mode, the monetary authority does not smooth interest rates ($\rho_r(3) = \rho_r^c = 0$), and the central bank still does not intervene, leaving the credit policy rule as during normal times ($\psi_{ss}(2) = \psi_{ss}^n = 0$ and $\rho_\psi(2) = \rho_\psi^n \in [0, 1)$).

Now consider that, instead of not intervening when a crisis occurs, the central bank does choose to intervene in credit markets, which occurs conditional on a crisis with probability p_b . Then, instead of moving to regime 2, the economy moves to the fourth regime ($s_t = 4$), called "Crisis with Intervention." In this regime, the financial crisis has the capital quality measure dropping ($\rho_\xi(4) = \rho_\xi^c = 0$) to a lower steady state ($\xi_{ss}(4) = \xi_{ss}^n < 1$). The monetary authority ceases its smoothing of interest rates ($\rho_r(4) = \rho_r^c = 0$) and the central bank intervenes in credit markets, purchasing a fixed fraction of assets ($\psi_{ss}(4) = \psi_{ss}^c > 0$ and $\rho_\psi(4) = \rho_\psi^c = 0$).

Again, the crisis ends with probability p_e , and if the economy is in regime 4 it moves to the fifth regime ($s_t = 5$), "Policy Continuation with Intervention." Similar to the third regime, this regime is what happens after the crisis ends, and capital quality is slowly moving to the high steady state again ($\xi_{ss}(5) = \xi_{ss}^n = 1$, $\rho_\xi(5) = \rho_\xi^n \in (0, 1)$), but policy is still in crisis mode. That is, the monetary policy still does not smooth interest rates ($\rho_r(5) = \rho_r^c = 0$) and the central bank continues to hold a fixed fraction of assets ($\psi_{ss}(5) = \psi_{ss}^c > 0$ and $\rho_\psi(5) = \rho_\psi^c = 0$).

Finally, when the economy is in the policy continuation regimes, either without intervention ($s_t = 3$) or with intervention ($s_t = 5$), the policy continuation stops with probability p_s each period. Then the economy returns to the "Normal" regime ($s_t = 1$), and interest rate smoothing resumes and the central bank sets its credit policy parameters to the no intervention levels. Importantly, when the economy leaves policy continuation with intervention, the parameter ρ_ψ^n determines the rate at which the credit market intervention ends.

Table 3: Fixed Parameters

Parameter	Description	Value
β	Discount Factor	0.99
h	Degree of Habit Persistence	0.815
\varkappa	Disutility of Labor	3.409
φ	Inverse Frisch Elasticity of Labor	0.276
λ	Divertable Fraction of Banker Assets	0.381
ω	Transfer to New Bankers	0.002
θ	Survival Rate of Bankers	0.972
α	Capital Share	0.33
\bar{U}	Steady State Capital Utilization	1.00
$\bar{\delta}$	Steady State Depreciation	0.025
ζ	Elasticity of Depreciation to Utilization	7.2
η_i	Inverse Elasticity of Net Invest. to Capital Price	1.728
ε	Elasticity of Substitution Between Final Goods	4.167
γ	Probability of No Optimization of Prices	0.779
μ	Degree of Price Indexation	0.241
\bar{g}	Fraction of Steady State Output for Government	0.2
κ_π	Response of Interest Rate to Inflation	2.043
κ_y	Response of Interest Rate to Output Gap	0.5
ρ_A	Persistence of TFP	0.95
σ_A	Std Dev of TFP	0.005
σ_ξ	Std Dev of Capital Quality Process	0.005
σ_R	Std Dev of Monetary Policy Shock	0.0025

3.5 Equilibrium and Model Solution

The described DSGE model with Markov Switching is solved using the perturbation method of Foerster *et al.* (2011). One advantage of this method is that it allows for the equilibrium

Table 4: Regime Switching Parameters

Parameter	Description	Value
p_c	Probability of Crisis Occurring	0.005
p_b	Probability of Intervention	$[0, 1]$
p_e	Probability of Exiting Crisis	$\{\frac{1}{4}, 1\}$
p_s	Probability of Stopping Crisis Policy	$\{\frac{1}{16}, \frac{1}{19}\}$
ρ_r^n	Interest Rate Smoothing, Normal	0.80
ρ_r^c	Interest Rate Smoothing, Crisis	0.00
ξ_{ss}^n	Capital Quality Mean, Normal	1.00
ξ_{ss}^c	Capital Quality Mean, Crisis	0.95
ρ_ξ^n	Capital Quality Persistence, Normal	0.66
ρ_ξ^c	Capital Quality Persistence, Crisis	0.00
ψ_{ss}^{nb}	Credit Market Intermediation Share Mean, No Intervention	0.00
ψ_{ss}^b	Credit Market Intermediation Share Mean, Intervention	0.06
ρ_ψ^{nb}	Credit Market Intermediation Share Persistence, No Intervention	$[0, 1]$
ρ_ψ^b	Credit Market Intermediation Share Persistence, Intervention	0.00

conditions to be written with Markov Switching in a transparent manner. Table 3 lists the calibrated parameters that are fixed across regimes, and Table 4 . In addition, since the processes for unconventional policy and the exogenous capital quality include shifts in steady state, perturbation has the advantage that it considers the effects of switches in steady state parameters. In particular, first-order expansions of Markov Switching models with different regime-specific steady states are not certainty equivalent, so constructing approximations to the solution of the economy require an additional term that captures the effects of the parameters that switch.

4 Crisis Responses

Having discussed the basic model and the nature of regime switching, this section now turns to considering what happens during and immediately after financial crises. These impulse responses are responses to a "typical" crisis. In this experiment, agents know that financial crises occur with probability p_c , and that when a crisis occurs, the credit market intervention occurs with probability p_b . Agents also know that the crisis ends with probability p_e each period; in a typical crisis considered, the responses depict the case where the crisis lasts the expected duration.

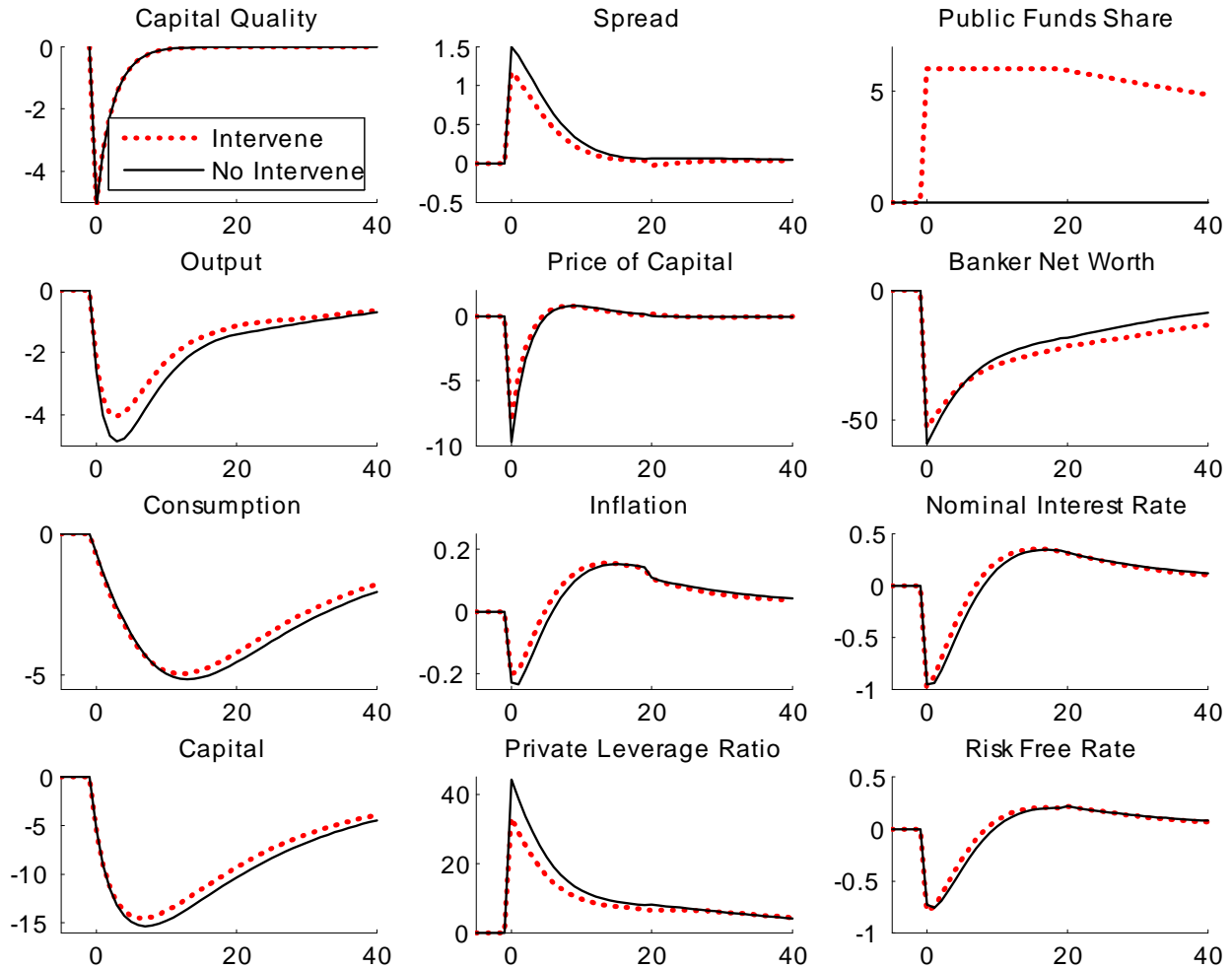
More specifically, two different assumptions on crisis duration will be considered: in the first, crises last one period only, so $p_e = 1$; in the second, crises end with probability $p_e = \frac{1}{4}$ and the typical crisis response is for a crisis that lasts exactly four periods. Similarly, policy continuation is such that the expected duration of intervention totals 20 periods, meaning the probability p_s is chosen so that $\frac{1}{p_s} + \frac{1}{p_e} = 20$. In the typical crisis, after 20 periods of crisis policies in place, policies return to the "normal" regime.

For both assumptions on crisis duration, the results below will consider two different specifications. First, they will consider the differences for the central bank in guaranteeing no intervention ($p_b = 0$) and intervention ($p_b = 1$) with a slow unwind of assets ($\rho_\psi^n = 0.99$) and how these change the effects of crises. Second, the results will suppose that the central bank has guaranteed intervention, and then look at the effects of different types of exit strategies: one in which the central bank slowly unwinds assets after deciding to exit the credit market ($\rho_\psi^n = .99$) versus one in which they immediately exit the credit market ($\rho_\psi^n = 0$).

4.1 Single-Period Crisis

This section describes the response to a typical crisis when crises last one period. Agents know that the probability of exiting a crisis is $p_e = 1$, and so they realize that when a crisis occurs, the following period capital quality will move back towards its pre-crisis level.

Figure 3: Single Period Crisis: Responses Under a Guarantee



4.1.1 Intervention Versus No Intervention

Figure 3 displays the impulse responses to a crisis when the government has guaranteed intervention versus guaranteed no intervention. When the crisis lasts a single period, upon entering the crisis, there is an immediate five-percent decline in capital quality. In subsequent periods, however, the capital quality moves back up to its original level.

When the central bank guarantees it will not intervene, the effect of the crisis is to diminish the net worth of financial intermediaries, which also causes a decline in the price of capital. Since bankers have a major decline in net worth, they are unable to take deposits from households and purchase claims on capital, and so the capital stock falls dramatically, and the interest

rate spread increases. Output decreases about 5 percent at its trough, and takes a significant amount of time to recover.

The central bank guaranteeing intervention helps alleviate the crisis by injecting credit into the economy by immediately purchasing six percent of assets. The resulting increase in demand for capital over the no intervention case implies that the price of capital does not fall as dramatically, and as a result the net worth of financial intermediaries does not fall as far, and the widening of the interest rate spread is diminished. The resulting loss of output is approximately 4 percent, and the rebound is slightly faster than in the case without intervention.

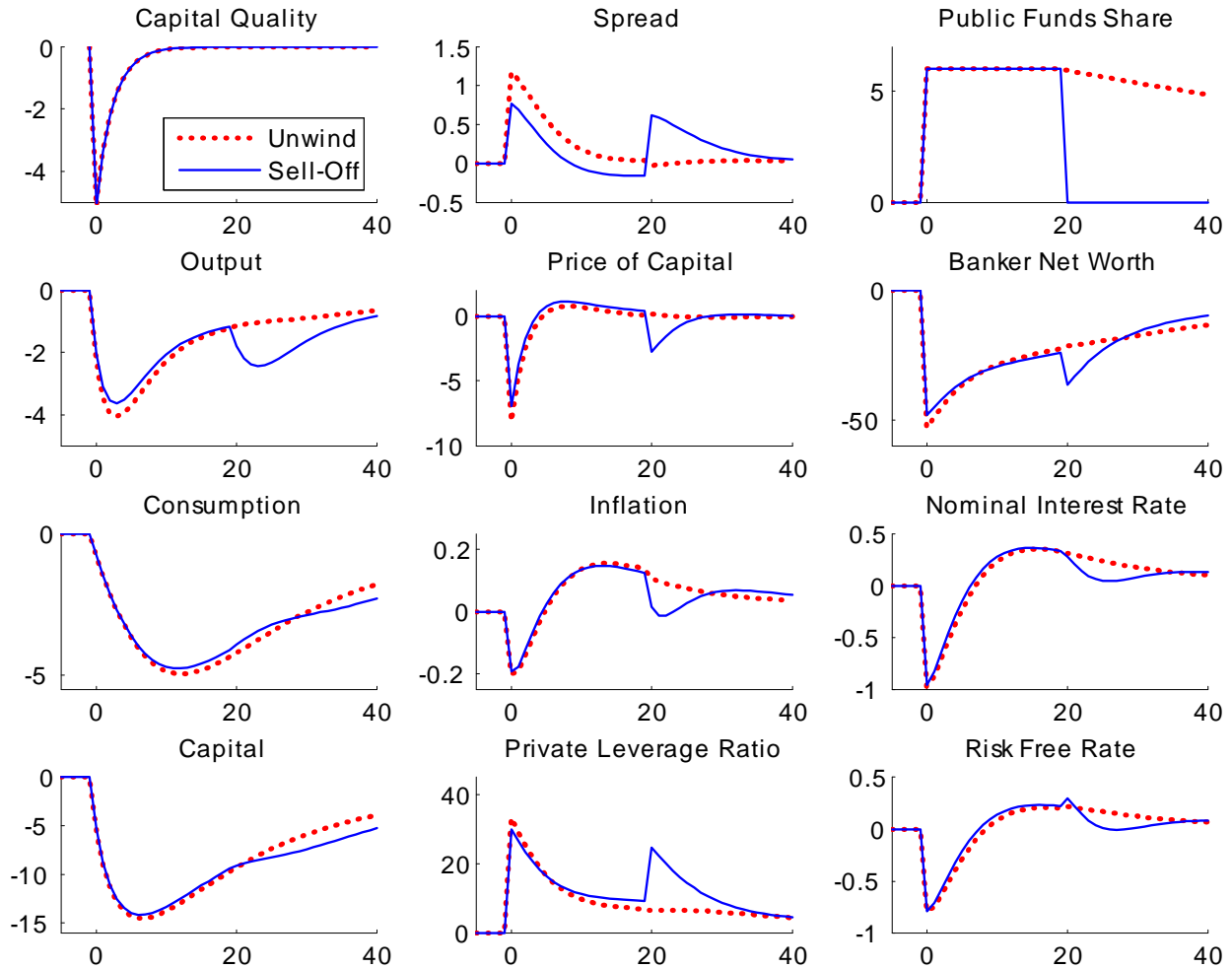
In the typical crisis, 20 periods after the crisis, the central bank ends its policy continuation. In the case with no intervention, interest rate smoothing begins again. In the case with intervention, the ending of crisis policies means that the central bank needs to unwind its assets, and in the current setup, does so according to an autoregressive process with coefficient $\rho_{\psi}^n = .99$, which implies they hold assets for a significant amount of time beyond the crisis. Because they unwind so gradually, when policy continuation ends, there is little response from the economy – all the plotted responses exhibit no noticeable jumps at $t = 20$.

4.1.2 Exit Strategies

Having determined that a guarantee to intervene helps during crisis times because the injection of central bank funds lowers the strain on financial intermediaries and reduces the loss in output, now consider the effects of the exit strategy. In the previous crisis response, when the central bank ended its crisis policies, it unwound its accumulated assets very slowly; the persistence of the unconventional policy rule during normal times was $\rho_{\psi}^n = .99$. Suppose, on the other hand, that instead of unwinding its asset position gradually, the central bank completely exited the credit market when policy continuation ended. In terms of parameterizations, this policy is characterized by $\rho_{\psi}^n = 0$. Figure 4 depicts the differences between these two cases.

In both cases, agents' expectations about the duration of policy continuation are the same, the only difference is the that agents know the difference in exit strategies once the central bank decides to stop intervention. It is important to note that during policy continuation, so between

Figure 4: Single Period Crisis: Exit Strategies



$t = 0$ and $t = 20$ in the plots, both policies are identical. When agents expect a rapid sell-off of assets ($\rho_{\psi}^n = 0$) the initial downturn is slightly less significant when compared to when agents expect a gradual unwind ($\rho_{\psi}^n = .99$). The drop in the price of capital is slightly less, so the loss in financial intermediary net worth is not quite as dramatic, and the resulting loss of output is lower under the sell-off policy.

The big difference between the two policies occurs when the central bank decides to unwind. In the typical crisis, 20 periods after the initial crisis, the central bank ends its crisis policies. As seen previously, when the central bank unwinds slowly, the transition back to the "normal" regime is relatively seamless: there is a resumption of interest rate smoothing, and because the

central bank unwinds its positions very gradually, there is no abrupt change. In contrast, when the central bank ends policy intervention in the sell-off case, there is a rapid decrease in the demand for capital, the price of capital drops again, and output falls. The quick sell-off creates a "double-dip" recession with a trough in output roughly half of that for the initial crisis.

4.2 Multi-Period Crisis

Having considered the effects of policy guarantees and different unwind strategies in an environment where the initial crisis lasts only a single period, this subsection considers the possibility that crises last several periods. The motivation for this specification is seen in Figure 1 and comparing it to the crisis response functions for one-period crises. The crisis responses show a sharp spike in interest rate spreads that declines fairly rapidly, while the data on interest rate spreads show that interest rate spreads remained high after the initial spike for nearly a year. Consequently, the responses in this section will consider the possibility that crises last longer than one period. In the parameterization considered, the probability of exit is $p_e = \frac{1}{4}$, and so the typical crisis responses considered below have the crisis lasting four periods.

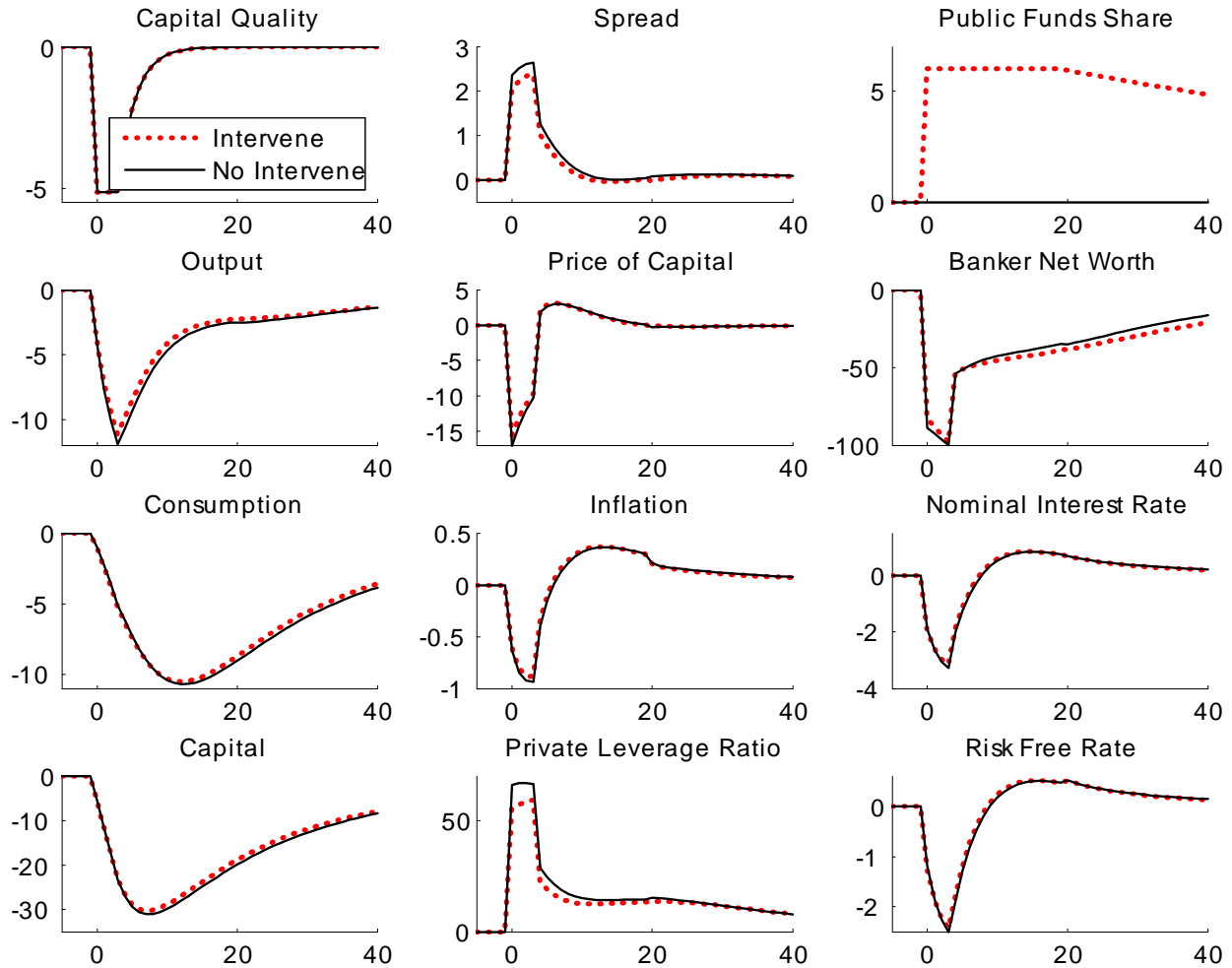
4.2.1 Intervention Versus No Intervention

Figure 5 displays the responses of variables to a typical crisis when the central bank has guaranteed intervention versus guaranteed no intervention. The initial impulse is again a five percent decline in capital quality, although in this case it remains at this level for four periods before gradually returning to its pre-crisis levels.

The effects of a crisis and intervention are similar in this case to the one-period crisis, only magnified because of the persistence of the crisis. The initial drop in capital quality causes a massive decline in this case, almost eliminating the entire net worth of the financial intermediaries. The price of capital declines significantly in the process, and the interest rate spread jumps and stays elevated for several periods before declining. In all, output falls by over 10 percent, although the rebound is relatively fast.

The big difference between the multi-period crisis case and the single-period case is that

Figure 5: Multi-Period Crisis: Responses Under a Guarantee



multi-period crises have a second discontinuity in the responses that occurs when the crisis ends. Banker net worth declines significantly during the crisis, but then upon exiting the crisis rebounds to levels similar to in the one-period crisis almost immediately. Similarly, the interest rate spread has a rapid decline when the crisis ends.

In this environment, guaranteeing to intervene serves the same purpose as it did in the one-period crisis environment. The guarantee of intervention implies that when the crisis occurs, the central bank purchases six percent of assets, this helps ease the downturn by mitigating the decline in the price of capital, which reduces the downturn of in banker net worth and ends with a smaller loss of output.

Figure 6: Multi-Period Crisis: Exit Strategies

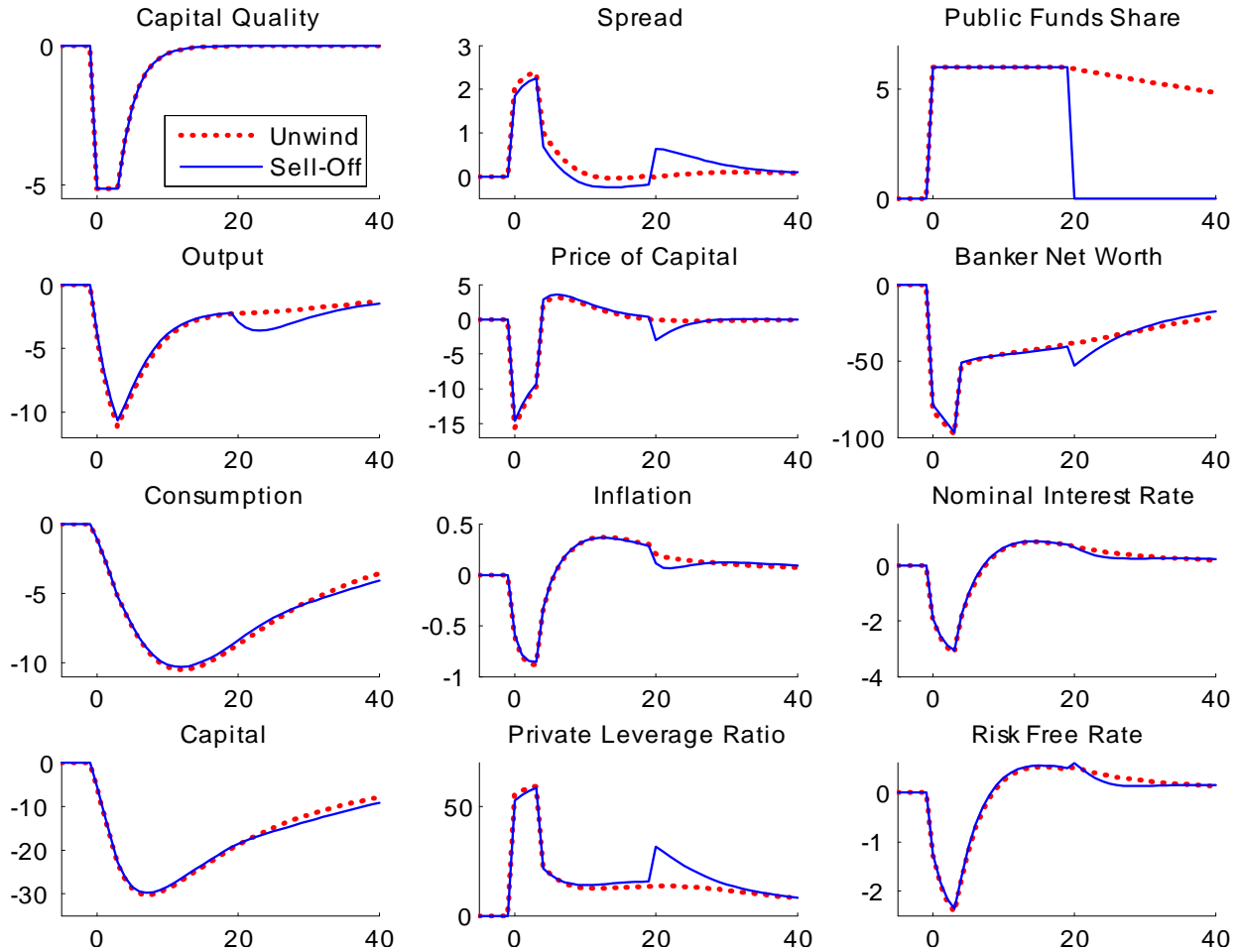


Figure 7:

4.2.2 Exit Strategies

Considering again the effects of exit strategies in an environment of multi-period crises, the effects are similar. Figure 7 depicts the differences in crisis responses when the credit policy rule during normal times is slow unwind ($\rho_\psi^n = .99$) versus fast sell-off ($\rho_\psi^n = 0$).

Again, the only difference between the two cases is that agents know that when policy continuation ends there will be differing exit strategies pursued by the central bank. When agents expect the rapid sell-off, the magnitude of the initial drop is slightly less than when agents expect the gradual unwind. The big difference is again when policy continuation ends.

If the central bank exits completely upon transition back to the normal regime, there is a "double dip" recession. Unlike the single period crisis, where the double dip was approximately half the size of the original drop, the second dip in this case is not half as large as the initial crisis. This difference is because of the large magnitude of the original crisis, the size of the drop in this case is actually comparable to the single-period crisis case.

5 Pre-Crisis: Effects of Expectations

The crisis responses in the previous section considered the effects of guaranteed intervention on the economy during financial crises, as well as the effects of different exit strategies. Having considered what happens with these different policy specifications, the analysis now turns to how expectations about these policy responses to crises affect the economy in the "normal times" regime. In other words, this section asks the question: are there distortionary effects from announcing a policy of guaranteed intervention during crises *ex-ante*?

Since the Markov switching processes discussed in Section 3 include switches in the steady state of some of the processes, there is a difference between the regime-specific stochastic steady state of the economy and the long-run steady state of the economy. The long-run steady state is the ergodic mean of the economy, which allows for the consideration of the long-run distribution of the economy across regimes. In contrast, the regime-specific steady state is the average level the economy would operate around if it remained in one regime indefinitely, although agents perceive that regime switches may occur. Put another way, the long-run steady state of the economy would be the unconditional mean, whereas the regime-specific steady state would be the mean conditional on a given regime.

Consequently, this section considers the regime-specific steady state for the "normal times" regime ($s_t = 1$). Tables 5 and 6 displays the normal regime's conditional mean of several variables for different types of policy announcements. Table 5 shows the conditional mean if crises are assumed to last only one period, Table 6 has the values if crises occur for multiple periods. For each crisis assumption, the baseline is a policy announcement of guaranteed no

Table 5: Normal Regime Conditional Mean, Single-Period Crisis

Variable	No Intervention	Uncertain		Intervention	
		Unwind	Sell-Off	Unwind	Sell-Off
Output (y)	0.0	-0.0091	-0.0134	-0.0148	-0.0269
Consumption (c)	0.0	-0.0104	0.0049	-0.0198	0.0099
Capital (k)	0.0	-0.0338	0.0149	-0.0183	0.0300
Leverage (ϕ)	0.0	-0.3539	-0.2046	-0.6978	-0.4094
Net Worth (N)	0.0	0.3108	0.2049	0.6161	0.4107

intervention when crises occur. Using this benchmark, the table displays the percent change in the "normal times" steady state if a different policy is announced. One policy announcement is uncertain intervention where intervention occurs in half of crises ($p_b = .5$), the second is where intervention is guaranteed ($p_b = 1$). For each intervention probability, the two different unwind strategies, unwind and sell-off, are considered.

The results for both panels are similar in that the effects of the different policy announcements and strategies are small. When agents believe crises occur with probability p_c , there are two competing effects. First, since output and consumption drop significantly during crises, households wish to boost their savings as a precautionary motive for smoothing consumption. This precautionary savings motive expands the supply of funds available in the economy, which

Table 6: Normal Regime Conditional Mean, Multi-Period Crisis

Variable	No Intervention	Uncertain		Intervention	
		Unwind	Sell-Off	Unwind	Sell-Off
Output (y)	0.0	-0.0088	-0.0175	-0.0140	-0.0351
Consumption (c)	0.0	-0.0102	0.0042	-0.0196	0.0084
Capital (k)	0.0	-0.0341	0.0118	-0.0645	0.0237
Leverage (ϕ)	0.0	-0.3572	-0.2323	-0.7060	-0.4649
Net Worth (N)	0.0	0.3143	0.2300	0.6244	0.4613

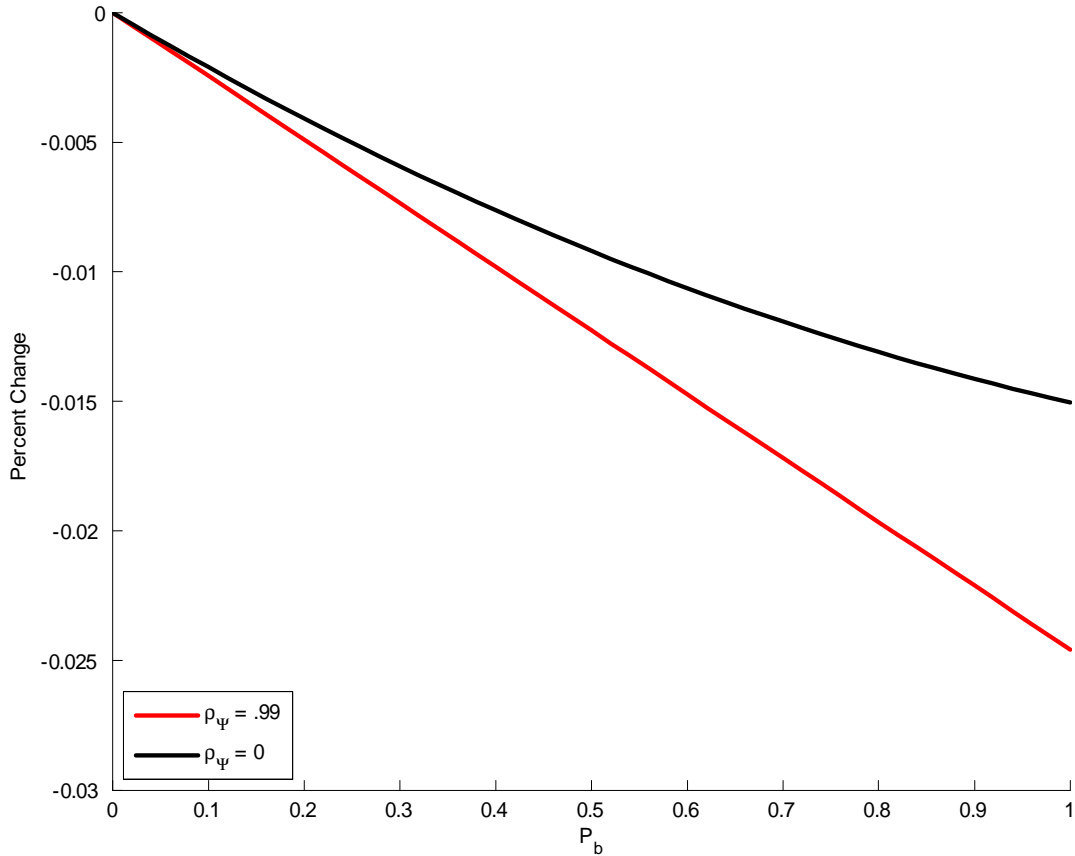
increases the stochastic steady state level of capital, and hence the total output. On the other hand, if agents expect crises to occur with nonzero probability, and when crises happen there is a very low return on equity, which implies a lower leverage ratio and a lower amount of capital in the economy unless bankers hold a higher level of net worth.

The extent to which expectations about intervention policy during crises are beneficial or not depends upon whether policy announcements negate the precautionary motive of households or the leverage ratio constraint on the banks. In both crisis scenarios, the effects on capital are mixed dependent upon the exit strategy. For both uncertain and certain intervention, expectations of a slow unwind lower the capital stock, while expectations of a fast sell-off increase the capital stock. Recall the fast sell-off case produced a slightly less significant initial drop when a crisis occurred, but then upon the end of policy continuation, the rapid exit of the central bank from credit markets created a "double dip" recession. This second drop dominates the slight initial difference, and the economy builds slightly more precautionary capital in this case.

On the other hand, Tables 5 and 6 also shows a difference in net worth and leverage in the economy when intervention is either uncertain or guaranteed. In all cases, the percent change in leverage is negative and the percent change in banker net worth is positive and of a slightly lower magnitude. This difference implies that when intervention is uncertain or guaranteed, bankers hold more net worth and are less levered than when the central bank guarantees no intervention.

Finally, the effect of expectations on output is always negative but small. In both the unwind and sell-off cases for the two different crisis assumptions expecting intervention with uncertainty or certainty lessens output, but the magnitudes are small. Figures 8 and 9 both show how the loss in output increases with the probability of intervention. Consumption, however, has an ambiguous effect, depending upon the exit strategy. The change in consumption is positive if the exit strategy is to sell-off assets immediately, but negative if the central bank unwinds gradually.

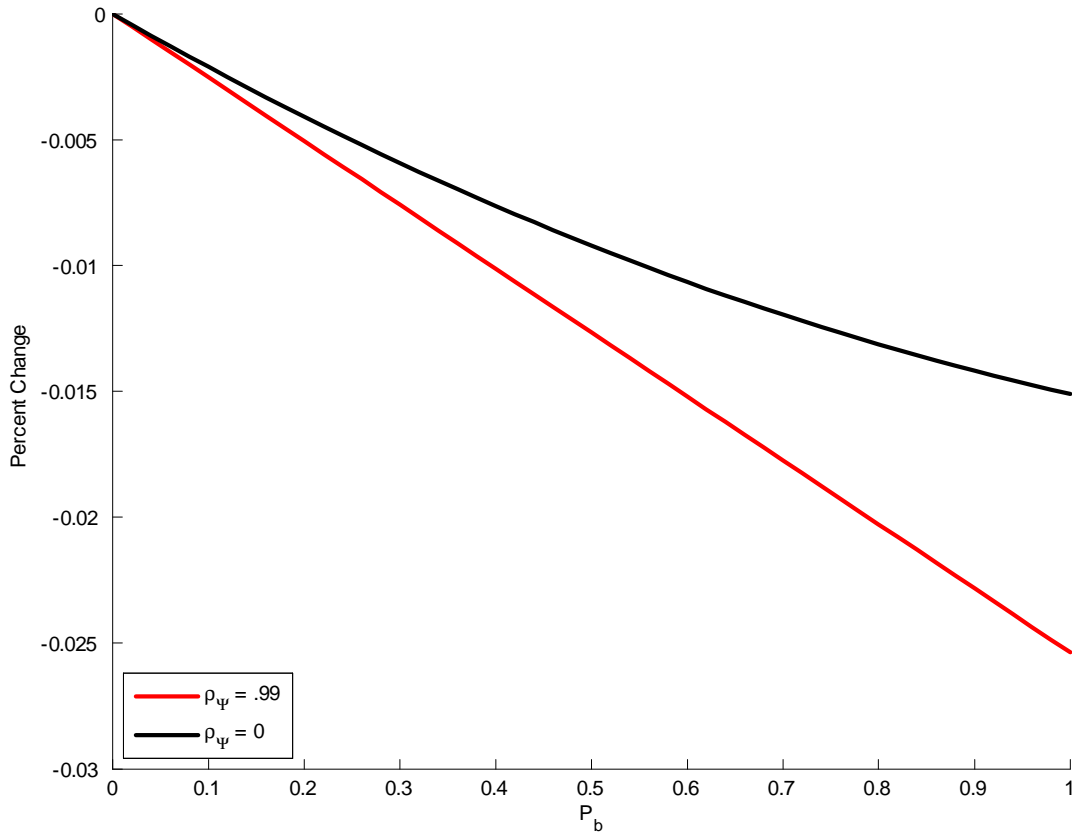
Figure 8: Effects of Expectations on Pre-Crisis Output - Single Period Crisis



6 Welfare Calculations

Having considered the effects of policy announcements and expectations during and before crises, this section turns to evaluating the overall welfare gains or losses from different policy announcements. In particular, Section 4 discussed the fact that guaranteed intervention had benefits relative to no intervention during crises, since intervention helps bolster the economy and alleviate the crisis. However, there was a slight trade-off depending upon the exit strategy: the immediate sell-off case produced a slightly lower drop in output and consumption, but upon exit, the economy experienced a double-dip recession. In addition, as shown in Section 5, the effects of policy announcements prior to crises was mixed depending upon the exit strategy pursued. Consequently, this section will ask: what are the welfare gains or losses from the various policy specifications?

Figure 9: Effects of Expectations on Pre-Crisis Output - Multi Period Crisis



Importantly, in addition to the probability of intervention and the exit strategy considered, welfare costs will be affected by two factors. First, the resource cost τ of central bank intermediation will matter for welfare in that, if the cost is high, then a larger portion of output is lost, which may lower welfare. Second, the timing of the calculation matters for welfare costs. Specifically, the household's gain or loss in welfare from different policies will depend upon whether they are in the midst of a crisis or not. In other words the *ex-ante* welfare costs measure the willingness to pay for intervention before a crisis, while the *ex-post* welfare costs measure willingness to pay when a crisis occurs.

For both *ex-ante* and *ex-post* welfare calculations, the welfare cost measure used is, for a given probability of intervention and exit strategy, the percent increase in lifetime consumption that would make households indifferent between the increase in consumption and a change to an environment of guaranteed intervention with the same exit strategy. Positive welfare measures

indicate that guaranteed intervention is welfare-increasing, since households need additional consumption under the given specification to mimic guaranteed intervention. Negative welfare measures then imply guaranteed intervention is welfare-decreasing, as households are willing to give up consumption rather than have guaranteed intervention.

Returning to the households's preferences (1), the value function for a given policy A can be expressed as

$$V_t^A = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t^A, L_t^A) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \log(C_t^A - hC_{t-1}^A) - \frac{\varkappa}{1+\varphi} (L_t^A)^{1+\varphi}.$$

and the welfare measure is Υ such that, for some other policy B ,

$$V_t^A = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t^B (1 + \Upsilon), L_t^B)$$

Consequently Υ is the percentage increase in lifetime consumption that makes the representative agent indifferent between a policy environment B – an uncertain intervention level in this case – and policy environment A – guaranteed intervention in this setup. Positive values of Υ indicate that guaranteed intervention is welfare improving, and negative values indicate that guaranteed intervention is welfare decreasing. The value function can be expressed recursively as

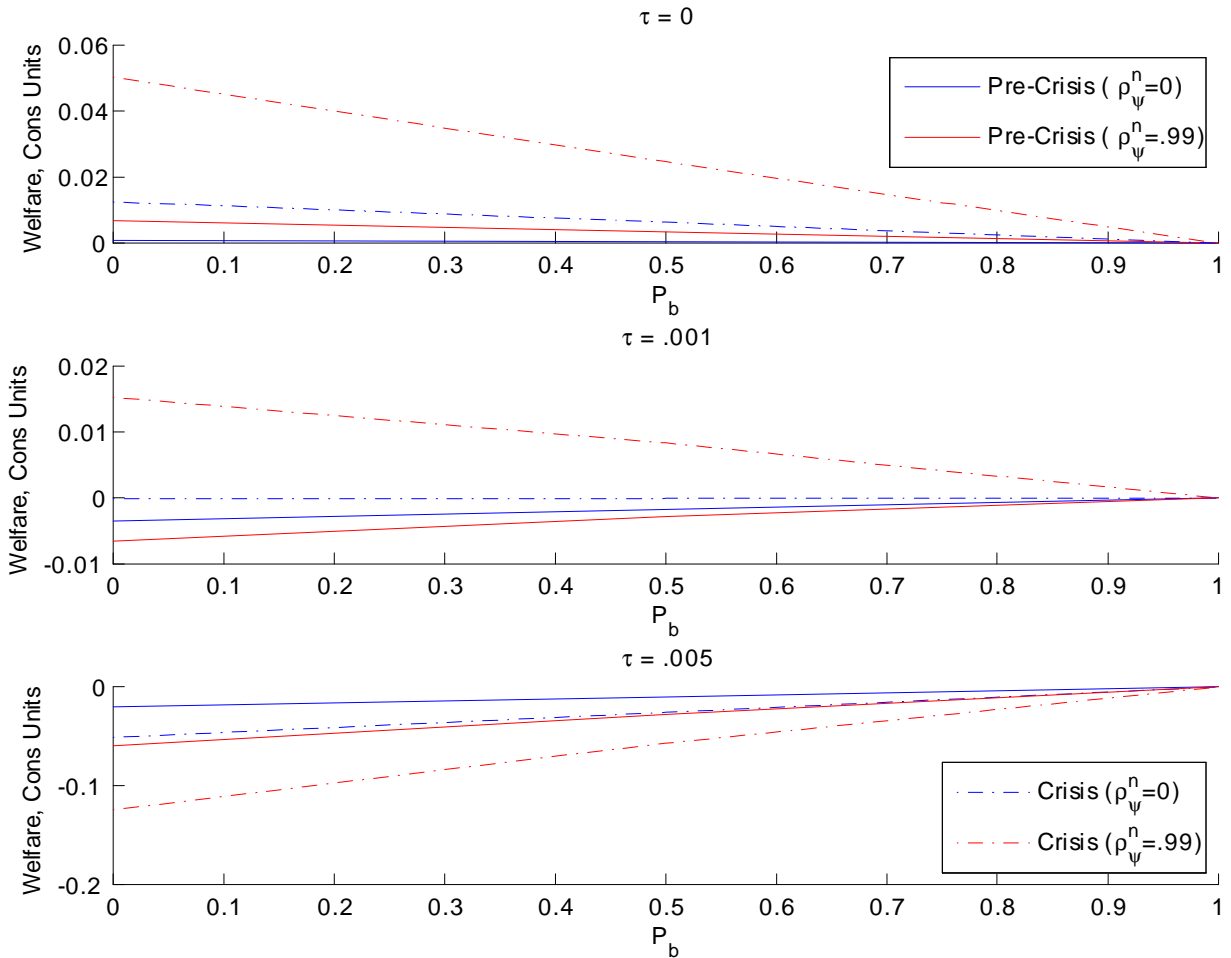
$$V_t = \log(C_t^A - hC_{t-1}^A) - \frac{\varkappa}{1+\varphi} (L_t^A)^{1+\varphi} + \beta \mathbb{E}_t V_{t+1}. \quad (55)$$

and this can be added to the equilibrium conditions to solve for Υ .

Figures 10 and 11 show the welfare costs for both single and multi-period crises, respectively. The top panel shows the case when $\tau = 0$, which corresponds to no efficiency loss from intermediation, the second and third panels show $\tau = .001$ and $\tau = .005$, respectively. Each panel shows the welfare gain in consumption units from guaranteeing intervention, both with the slow unwind ($\rho_\psi^n = .95$) and the fast sell-off ($\rho_\psi^n = 0$) cases. In addition, the solid lines show the welfare gain when the economy is in the normal regime, and the dotted line shows the welfare gain conditional on a crisis occurring and the intervention decision being unrealized.

The first panel of Figure 10 shows that both types of intervention are welfare improving in both crisis and pre-crisis scenarios. Since there is no resource cost of intervention, this fact is

Figure 10: Welfare Costs - Single Period Crisis



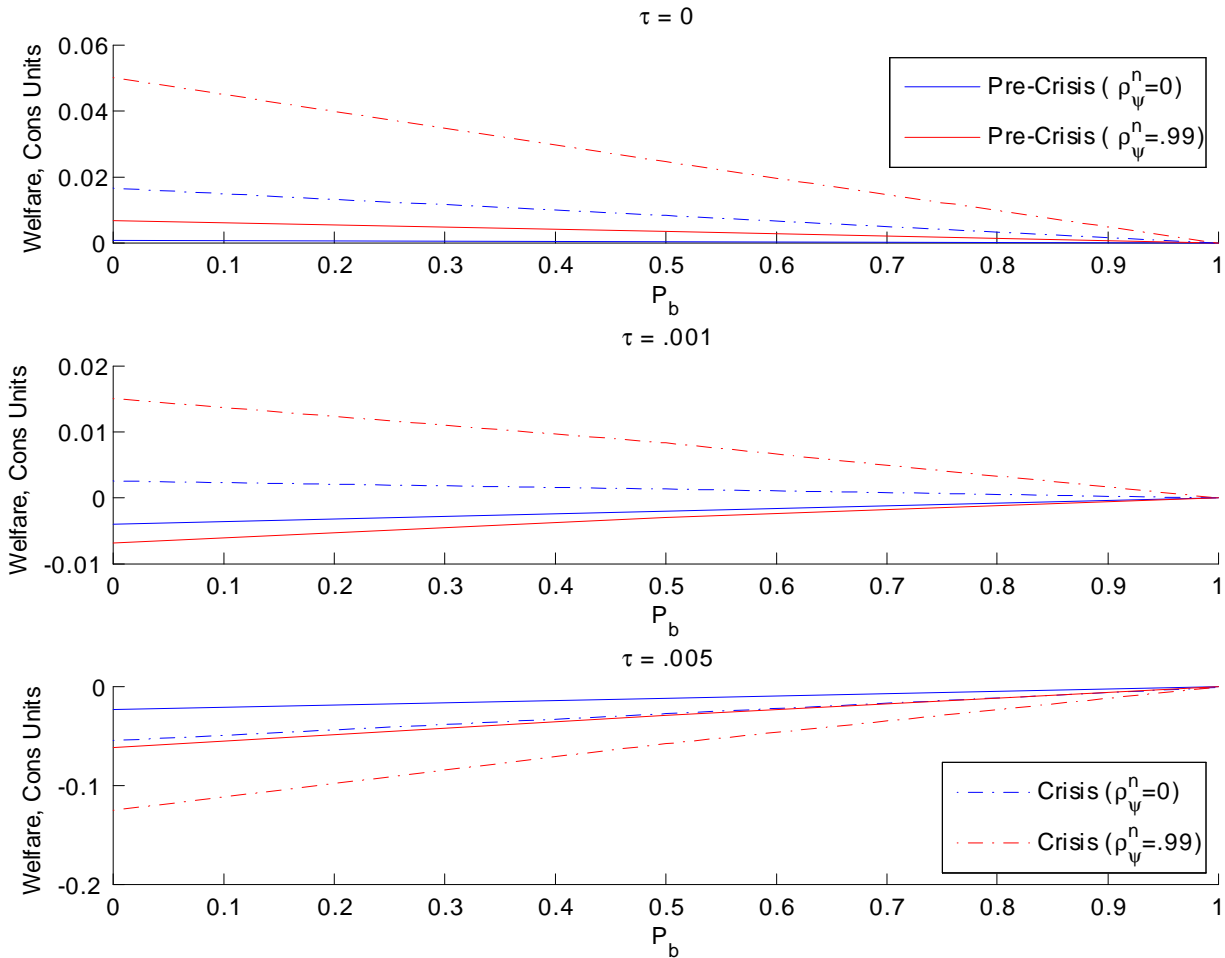
not surprising. However, it is interesting to note that the slow unwind exit strategy dominates the fast sell-off strategy in both circumstances. Since the slow unwind tended to smooth output after crises, this fact implies that agents place emphasis on avoiding the double-dip recession that the sell-off can produce. In addition, conditional on an exit strategy, the benefit from having a guarantee is higher once a crisis occurs. Again, this result is not surprising, as there is no resource cost to intervention, and so when a crisis occurs, the benefit of intervening is highest. Finally, the benefit of guaranteeing intervention is decreasing as the intervention probability of intervention increases, simply because as p_b approaches one the two alternatives become indistinguishable.

Considering the second and third panels of Figure 10 changes the implications of intervention however. In the second panel, when $\tau = .001$, the results about the type of intervention and timing change. For both types of exit strategy, the welfare benefits of a guarantee are negative when the economy is in the "normal times" regime, and positive when the economy enters a crisis. This case then shows a type of time-inconsistency in the guarantee by the central bank. Before a crisis, it is welfare-improving to not guarantee intervention because of the distortions caused by this guarantee and the resource cost of intervention, but when a crisis occurs, it is welfare improving for guaranteeing intervention to occur. Further, conditional upon intervention, the welfare-preferred exit strategy changes from preferring slow unravel before a crisis to fast unwind when a crisis occurs. Because of the resource cost of intervention, welfare improves if the central bank exits as soon as possible, and the slow unwind strategy, while helping credit markets during crises, creates a drag on the economy that lowers output and welfare in the longer term.

Finally, in the third panel of Figure 10, which has $\tau = .005$, the welfare benefits are negative for all the cases, meaning guaranteeing intervention is welfare decreasing. This fact holds true regardless of the exit strategy used, and regardless of whether the economy is in the normal times regime or has just entered a crisis. Further, the welfare losses are higher when the economy enters a crisis, and the losses are higher when the exit strategy is to unwind assets slowly. Both of these results stem from the relatively high resource cost of intervention: when intervention is costly in terms of output, there is a welfare loss from guaranteeing intervention, especially when a crisis occurs – because intervention is immediately guaranteed – and welfare losses are higher when the intervention takes longer to unwind.

The three panels of Figure 11 have similar results to those in Figure 10. When the resource cost is zero, guaranteeing intervention is welfare improving, and the slow unwind strategy is better from a welfare perspective. Increasing the resource cost slightly implies a difference in welfare benefits based upon the regime the economy is in, and which exit strategy is preferred depends upon the timing. When the resource cost is high, then guaranteeing intervention is always welfare decreasing and the welfare-dominant exit strategy is to unwind assets as fast as possible.

Figure 11: Welfare Costs - Multi Period Crisis



Under both assumptions about single versus multi-period crises, then the different levels of the resource cost dictate which policy environment is best from a welfare perspective. Importantly, under the $\tau = 0.001$ parameterization for both types of crises, the better rule in terms of welfare changed *ex-ante* versus *ex-post*. Prior to a crisis occurring, guaranteeing intervention is welfare decreasing, and the better rule is the fast unwind, but when a crisis occurs guaranteeing intervention is welfare increasing, and the welfare preferred rule is the slow unwind. These changes between the *ex-ante* versus *ex-post* welfare implications suggest that there may be a time-inconsistency in optimal policy and hence commitment may be difficult.

7 Conclusion

This paper has used a model of unconventional monetary policy along with regime switching to study the effects of exit strategies and agents pre-crisis expectations. It has shown that after intervention, if the central bank exits the credit market too quickly, the economy can experience a double-dip recession. In addition, it has shown that the effects of guaranteeing intervention may cause slight distortions in pre-crisis activity by altering agents' expectations about intervention during crises. Finally, it has analyzed the welfare implications of guaranteeing intervention, and argued that providing a guarantee can raise or lower welfare, and that the timing of the welfare calculation matters as well as the type of exit strategy used.

One interesting avenue for future research is to endogenize the probability and magnitude of intervention depending on the extent of the crisis. This paper has assumed that the magnitude of crises are fixed, although they may be persistent, the level of intervention is fixed, and all the probabilities are fixed. One might expect that crises of greater magnitude are accompanied by higher levels and probabilities of intervention. Similarly, the decision by the central bank to exit credit markets is governed by an exogenous probability in this paper, it is reasonable to think that this transition probability depends upon how quickly the economy rebounds from the initial drop from a crisis. Finally, this paper has focused on a given class of policy, optimal policy within this class is left for future work.

References

- BARRO, R. 2006. Rare Disasters and Asset Markets in the Twentieth Century. *Quarterly Journal of Economics*, **121**(3), 823–866.
- BARRO, R. 2009. Rare Disasters, Asset Prices, and Welfare Costs. *American Economic Review*, **99**(1), 243–264.
- BARRO, R., NAKAMURA, E., STEINSSON, J., & URSUA, J. 2010. Crises and Recoveries in an Empirical Model of Consumption Disasters. *NBER Working Paper*.

- BERNANKE, B., & GERTLER, M. 1989. Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, **79**(1), 14–31.
- BERNANKE, B., GERTLER, M., & GILCHRIST, S. 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. *Handbook of Macroeconomics*, **1**, 1341–1393.
- BIANCHI, F. 2009. Regime Switches, Agents’ Beliefs, and Post-World War II US Macroeconomic Dynamics. *Working Paper*.
- BRUNNERMEIER, M., & SANNIKOV, Y. 2009. A Macroeconomic Model with a Financial Sector. *Working Paper*.
- CHRISTIANO, L., EICHENBAUM, M., & EVANS, C. 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*.
- CHRISTIANO, L., MOTTO, R., & ROSTAGNO, M. 2009. Financial Factors in Economic Fluctuations. *Working Paper*.
- DAVIG, T., & LEEPER, E. 2007. Generalizing the Taylor Principle. *American Economic Review*, **97**(3), 607–635.
- DEL NEGRO, M., EGGERTSSON, G., FERRERO, A., & KIYOTAKI, N. 2010. The Great Escape? A Quantitative Evaluation of the Fed’s Non-Standard Policies. *Working Paper*.
- FARMER, R, WAGGONER, D., & ZHA, T. 2008. Minimal State Variable Solutions to Markov-Switching Rational Expectations Models. *Working Paper*.
- FOERSTER, A., RUBIO-RAMIREZ, J., WAGGONER, D., & ZHA, T. 2011. Perturbation Methods for Markov Switching Models. *Working Paper*.
- GERTLER, M., & KARADI, P. 2010. A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, **58**(1), 17–34.
- KIYOTAKI, N., & MOORE, J. 1997. Credit Cycles. *Journal of Political Economy*, **105**(2), 211–248.

RIETZ, T. 1988. The Equity Risk Premium: A Solution. *Journal of Monetary Economics*, **22**(1), 117–131.

SMETS, R., & WOUTERS, F. 2007. Shocks and Frictions in US Business Cycles: a Bayesian DSGE Approach. *American Economic Review*, **97**(3), 586–606.