Jobless Recovery, Liquidity Trap, Tight Monetary Policy and the Cost Channel

Lasitha R.C. Pathberiya[1]

Central Bank of Sri Lanka and School of Economics, University of Queensland, Australia

Abstract

In this study, I examine the robustness of an unconventional monetary policy in a cost channel economy.[2] The unconventional monetary policy proposed by Schmitt-Grohé and Uribe (2017, American Economic Journal: Macroeconomics, SGU henceforth), recommends a tight monetary policy during a liquidity-trapped recession to stimulate the economy and to avoid jobless recovery. The results of my study show that the existence of the cost channel implies that the SGU policy induces sharp initial contractions in the employment rate and the growth rate, and a sharp increase in inflation following a negative confidence shock. Welfare is lower in cost channel economies compared to no-cost channel economies due to the SGU policy recommendation. Two alternative interest rate-based exit policies are also examined. The Overshoot interest rate policy, irrespective of the presence of the cost channel, is superior to the SGU policy with regard to welfare. The Staggered policy has lower immediate pain in the cost channel economy compared to the SGU policy or the Overshoot policy. However, welfare-wise, the Staggered policy is inferior to the other two policies examined in both economies considered.

Keywords: cost channel of monetary policy, zero rates on interest rates, liquidity trap, jobless recovery, downward nominal wage rigidity, Taylor rule

JEL Classification: E31, E32, E52, E58

[1]Email: lasitha@cbsl.lk and lasitha.pathberiya@uqconnect.edu.au

[2]The supply-side effect of monetary policy is generally considered as transmitted through the cost channel of monetary policy.

1 Introduction

Recently, Stephanie Schmitt-Grohé and Martín Uribe (2017, SGU henceforth) prescribed a tight monetary policy during a recession[3] to take an economy out of the slump. According to these scholars, this policy prescription is *truly unconventional*,[4] as it is in contrast to the wide consensus that expansionary monetary and fiscal policies should be implemented during a recession. The main aim of the present study is to extend the SGU model to incorporate the cost channel of monetary policy – which incorporates the supply-side effect of monetary policy – and reexamine the robustness of SGU's unconventional policy prescription.

The Great Recession officially started during 2007 and ended in 2009. Although the recession is officially over now, eight years on, unemployment levels in some affected countries have not yet been stabilised to their pre-crisis levels. In the post-war economic history, the recovery following recession due to a financial crisis has been mostly jobless or wageless (Calvo et al., 2012). A jobless recovery is defined as high and persistent unemployment, although following the recession the output growth has recovered to its pre-crisis level. This has been true for Japan in the 1990s and for many countries including the USA after the Great Recession.

In the Great Recession, the nominal interest rate fell almost to the zero level in many major economies due to a series of interest rate cuts by central banks. By having interest rate cuts, central banks expect a resultant increase in aggregate demand that would stimulate the economy. When the interest rate is at zero, central banks are reluctant to reduce interest rates any further.[5] This is because a negative nominal interest rate would not motivate potential lenders to lend; rather they would hold money. This situation is referred to as the zero lower bound for nominal interest rates (ZLB). In such circumstances, a conventional approach to monetary policy does not work. As agents are indifferent between holding zero interest rate bonds and holding money, when the interest rate is zero, the central bank fails to stimulate the economy by increasing money supply. This situation is called a liquidity trap. In such a situation, the real interest rate rises as a result of lower inflation, encouraging household savings. This would cause output to fall.

[3]The SGU's policy recommendation was only for recessions casued by a nonfundamental shock. This is discussed later in the study.

[4]See the PowerPoint presentation of an earlier working paper version (Schmitt-Grohé and Uribe, 2012) of the SGU paper available at: https://www.gc.cuny.edu/CUNY_GC/media/CUNY-Graduate-Center/PDF/Programs/Economics/Seminar%20Fall%202012/slides-11-5-13.pdf (Accessed on 15-06-2016).

[5]A few central banks including the Bank of Japan have recently reduced nominal short-term interest rates to slightly below zero, however, this practice is not in commonplace.

The sources of a recession with a liquidity trap can be mainly divided into two, namely: recession caused by a fundamental shock; and recession caused by a nonfundamental shock. A fundamental economic shock causes sufficient deflation such that the ZLB on the short-term nominal interest rate becomes binding. A consumer taste shock can be considered as a fundamental shock. In such a situation, the consumer tastes shift. For example, consumers might prefer future consumption to current consumption, which would reduce the current consumption and increase savings. A typical central bank would now cut the short-term nominal interest rates to encourage consumption and investment while discouraging savings. The central bank would not be able to stimulate the economy, as much as required, if the shock is sufficiently severe and the ZLB constrains the central bank's action. A lower inflation rate increases real interest rates and households increase their savings. Accordingly, to equilibrate the savings market, current output has to fall, opening the path to recession (see Mertens and Ravn, 2014).

On the other hand, a nonfundamental shock is a situation where agents revise their expectations which produce deflationary pressure. A low-confidence shock can be considered as a nonfundamental shock. In a low-confidence situation, households expect a persistent drop in income. This revised expectations can lead to a decrease in current consumption and in higher savings. To stimulate economic activities, the central bank cuts interest rates. In extreme conditions, due to series of interest rate cuts, the ZLB binds. The ZLB, accompanied with deflationary expectations, increase real interest rates. Accordingly, households tend to save more, and so the output must fall, opening the path to recession (see Mertens and Ravn, 2014).

The type of policy that should be instigated to avoid a jobless recovery has been one of the main focuses of the literature in the last few decades. The work of Eggertsson and Woodford (2003) and Woodford (2012), among others, proposes to increase inflationary expectations in a liquidity trap to stimulate the economy and create jobs. Eggerston and Woodford (2003) showed that inflationary expectations can be raised by maintaining short-term interest rates at the zero level for a longer time in a liquidity trap. However, SGU argue that this policy prescription would not work if the initial shock which caused the recession was nonfundamental. SGU mention that in a liquidity trap driven by a lack-of-confidence shock, the behaviour of agents is different compared to that in normal situations. In such situations where a liquidity trap is driven by a lack-of-confidence shock, low interest rates would not increase inflationary expectations, but rather would induce deflation. Therefore, SGU prescribe an unconventional policy to increase nominal interest rates to the target interest rate in a liquidity-trapped ZLB situation that is due to a confidence shock. This policy prescription is also supported by the new but growing literature of neo-fisherianism. The neo-fisherian literature suggests that central banks can increase private sector inflation expectations in the liquidity trap by increasing nominal interest rates (see Williamson, 2016).

The SGU policy prescription, according to their model, increases inflationary expectations and facilitates a recovery with jobs. However, some important elements are absent in their model that would otherwise affect the economy negatively in a tight monetary policy stance. One such factor is the financial market. It is widely accepted that financial factors affect economic decisions due to the existence of information asymmetries (Laeven and Valencia, 2013). For example, the credit view of the monetary policy transmission argues that financial market imperfections, specifically informational asymmetry in credit markets, worsen during tight monetary periods in adverse economic conditions (Bernanke and Gertler, 1989, 1995).

Related to that, another important element missing in the SGU model is the supply-side effect of monetary policy, which is generally identified as the cost channel of monetary policy. As shown by Barth and Ramey (2001), Christiano et al. (2005), and Ravenna and Walsh (2006) and others, the cost channel of monetary policy has been an important channel to explain the supply-side effect of monetary policy. To incorporate the cost channel, economists generally assume that firms have to borrow part or all of their cost of working capital from the financial market. Accordingly, a tight monetary policy during the recession – as suggested by SGU – in a cost channel economy, may aggravate the recession. Therefore, it is useful to analyse the impact of the presence of the cost channel in the SGU set-up.

This study extends the SGU model by incorporating the cost channel of monetary policy and to reexamine the robustness of the policy conclusions of the SGU study. Further, this study evaluates two alternative interest rate-based policy options in both cost and no-cost channel economies.

The main findings are as follows: The existence of the cost channel implies that the SGU policy induces sharp initial contractions in the employment rate and the growth rate and a sharp increase in inflation following a lack-of-confidence shock. In the two alternative interest based exit policies, the following were observed: i) Irrespective of the presence of the cost channel, an alternative policy of increasing interest rates significantly above the SGU target rate and reduce gradually to target rate

(Overshoot policy) is welfare-wise superior to the SGU policy and, ii) An exit policy characterised by a staggered interest rate increase (Staggered policy) lowers immediate pain to the economy than under the SGU policy or Overshoot policy. However, welfare-wise the Staggered policy is inferior to the other two policies reviewed.

The rest of the paper is organised as follows: Section 2 reviews the related literature. First, I review the literature on jobless recoveries and then review the studies focussing on the policy options to avoid jobless recoveries. Later, I discuss the SGU study and then the literature which discusses on issues of tight monetary policy in a recession, focussing on financial markets. Section 3 specifies the model. Section 4 calibrates the model to the US economy, performs simulations, welfare analysis and discusses the results. Section 5 concludes the study with a brief discussion.

2 Literature Review

In the following literature review, first I discuss the literature on jobless recoveries. Then I review policy options, including the SGU policy, which are designed to avoid jobless recoveries. Finally, I discuss the relevant literature on the cost channel.

Jobless Recovery

In two seminal papers, Benhabib, Schmitt-Grohé and Uribe (Benhabib et al., 2001a,b) have shown that active interest-rate feedback rules in the spirit of the Taylor rule can easily lead to unexpected consequences. Specifically, these studies show that there can be multiple steady states with interest-rate rules, in which, one of the steady states could converge to a liquidity trap. This is what many countries might have experienced in the Great Recession, i.e. unintended low inflation steady state with a liquidity trap. One important characteristic of this steady state is, it is jobless.

Economists have attempted to explain the jobless recovery in several ways. First, they associate the recession with structural changes in the economy. Accordingly, they assume permanent shifts in the distribution of workers throughout the economy would contribute significantly to the slow job recovery. Sahin et al. (2012) attribute the slow employment recovery to the mismatch between job seekers and vacancies in the labour market. Groshen and Potter (2003) argue that the sectors that lost jobs during the recession have continued to narrow down during the recovery process. Accordingly, such unemployed workers had to find new jobs in new industries, which can be time consuming.

Second, many studies have given cyclical explanations for the jobless recovery. One strand of such literature explains the jobless phenomena as a consequence of real wage rigidities. Shimer (2012) shows that in the presence of real wages rigidities, a shock to the capital stock can cause a permanent decline in real economic activities such as employment, output and investment. In this type of modeling with real rigidities, by construct, monetary policy is inactive and plays no role in the recovery process. In contrast, some studies have found that labour market outcomes in recoveries are affected by the monetary policy stance (see McCallum and Smets, 2007). In addition, the empirical literature suggests that real wage rigidities are not prevalent in the US economy. For example, Daly et al. (2012) have shown that real wage growth has stayed relatively stable despite the recession and modest recovery in the US recently.

The other strand of the literature providing cyclical explanations for the jobless recovery is nominal rigidities, especially nominal wage rigidities. Nominal wage rigidities were examined, mainly due to the above mentioned empirical failures of validating real rigidity models in cyclical explanation for the jobless recovery. Calvo et al. (2013), Schmitt-Grohé and Uribe (2013) and SGU are the main proponents of this claim. They have shown that downward nominal wage rigidity makes real wages too high to be compatible with full employment in a deflationary situation. This causes involuntary unemployment in the economy.

Last, some scholars explain the jobless recovery by pointing to financial frictions. Calvo et al. (2012) claim that the contraction of collateral values, which is generally experienced in financial crises, could be one of the reasons for jobless recoveries. They argue that if profit-maximising firms are subject to credit constraints of this form, they become more capital intensive as technology grows, making the recovery jobless.

Policy Options

Any government has two main policy options at their disposal, namely, monetary policy and fiscal policy, to use in a recession. In the jobless recovery literature, scholars propose policy prescriptions using both these tools. However, they argue that the exact policy to deploy in the liquidity trap situation depends mainly on the *cause* of the recession (see SGU). The cause can be either a fundamental shock or a nonfundamental shock. Since recessions caused by nonfundamental shocks are relevant to the present study, I emphasise such literature in the following.

Mertens and Ravn (2014) studied the effects of fiscal policy interventions in a liquidity trap in a model with nominal rigidities and an interest rate rule. They show, in a liquidity trap caused by a nonfundamental shock, higher government spending has deflationary effects that reduce the spending multiplier when the ZLB is binding. Instead, cuts in marginal labour tax rates are inflationary and become more expansionary when the ZLB is binding.

Most of the monetary economists recommend that the way out of the jobless recovery is to increase inflationary expectations (for example, see Eggertsson and Woodford, 2003). This has been shown empirically by Calvo et al. (2013). If the shock is fundamental, expansionary monetary policy, i.e. keeping interest rates low for a long time, would increase the inflationary expectations of the agents. However, if the shock is nonfundamental, such expansionary monetary policy may not work. SGU explain why a low interest rate regime for an extended period may not work in a recession caused by a nonfundamental shock as: "...in these circumstances the negative relationship between nominal interest rates and inflationary expectations ceases to be valid and might indeed reverse sign." (SGU, p.167). SGU relate their argument to the recent experience of liquidity traps in major economies and the growing literature about neo-fisherianism. Proponents of the neo-fisherian idea propose that the Fisher equation[6] corresponds to a steady state in which higher interest rates can achieve higher inflationary expectations (see Williamson, 2016; Cochrane, 2016; Bullard, 2015).

Accordingly, SGU, in their theoretical model, suggest that increasing interest rates to the target level during a recession would lead to increased inflationary expectations and thus to have a recovery with jobs.

SGU Model and Financial Markets

The model that SGU builds is in the tradition of Benhabib et al. (2001b). It consists of following elements: downward nominal wage rigidity, a confidence shock, a Taylor-type interest rate rule and the ZLB constraint. The model shows that monetary policy can lift the economy from the slump by increasing nominal interest rates during the recession.

However, the SGU model abstracts from several elements that would otherwise affect the economy negatively when increasing interest rates. One such element is financial market imperfections. For example, the presence of information asymmetries may cause financial factors matter real economic

[6]The Fisher equation says that the nominal interest rate equals the real interest rate plus expected inflation.

decisions (see Laeven and Valencia, 2013). The credit view of the monetary policy transmission mechanism states that financial market imperfections worsen during tight monetary periods in adverse economic conditions (see Bernanke and Gertler, 1989, 1995).

In relation to financial markets, Mishkin (2013) lists four such main channels, which worsen economic conditions due to monetary tightening. They are: the bank lending channel, the balance sheet channel, the cash flow channel and the unanticipated price level channel. In the bank lending channel, tight monetary policy lowers bank deposits, which in turn lowers bank lending and investments. The ultimate result is a reduction in output. The other three channels affect the real economy mainly due to the asymmetric information effects in the credit markets. For example, in the balance sheet channel, tight monetary policy reduces stock prices, which in turn increases the moral hazard and adverse selection issues in the credit market, affecting the lending activity adversely. This reduces investment and in turn, output. All the credit channels reduce the aggregate demand and output following tight monetary policy. This fact has been supported by the empirical literature. Recently Jiménez et al. (2012) showed that higher short-term interest rates reduce credit supply. Further, they show that the negative effect of higher short-term interest rates on credit availability is stronger for banks with low capital or liquidity.

Related to that, another important element that is missing in the SGU model is the cost channel of monetary policy, which is the main focus of the present study. The cost channel may generate negative economic effect in a tight monetary policy environment. The importance of the cost channel of monetary policy has been shown extensively both empirically and theoretically by studies such as Barth and Ramey (2001), Gaiotti and Secchi (2006), Chowdhury et al. (2006) and Ravenna and Walsh (2006). In early studies, Fuerst (1992) and Christiano and Eichenbaum (1992, 1995) introduced the cost channel in a basic cash-in-advance (CIA) model. Walsh (2010, p.211) pointed out that in these type of models the interest rate increase generated by the liquidity effect increases the marginal cost of labour and thereby decreases labour demand. Consequently, equilibrium employment and output fall. Christiano et al. (2010) constructed an otherwise standard New Keynesian model with the cost channel without a CIA constraint.

Fiore and Tristani (2013) assumed asymmetric information among banks and firms with regard to loan contracts, in addition to incorporating the cost channel of monetary policy in a New Keynesian model. Among other results, they concluded that worsening financial market conditions increase the spread of corporate borrowing and adversely affect output and inflation, mainly due to the cost channel of monetary policy.

3 The Model

I extend the SGU model to incorporate the cost of working capital as of Christiano et al. (2010). Christiano and others assume that both the cost of labour as well as of material input must be financed at the beginning of the period. However, for simplicity and following much of the literature, I assume only the cost of labour must be financed at the beginning of the period. The model consists of four main types of agents, namely, households, production, monetary authority and fiscal authority.

3.1 Households

There is a large number of identical infinitely-lived households in the economy. These households supply labour inelastically, without any opportunity cost. The preferences of a representative household are described by the following objective function, while the household seeks to maximise utility:

$$E_0 \sum_{t=0}^{\infty} e^{\xi_t} \beta^t U(C_t), \tag{3.1}$$

where ξ_t is an exogenous taste shock, which is an iid random variable with unit variance and zero mean. $\beta \in \{0, 1)$ is a subjective rate of discount. The smaller β is, the less the household values future consumption relative to current consumption. C_t denotes real consumption at time t. U is the utility function assumed to be strictly increasing and strictly concave. More specifically, the utility function is assumed to be:

$$U(C) = \frac{C^{1-\sigma} - 1}{1 - \sigma}, \tag{3.2}$$

where $\sigma > 0$ is the coefficient of relative risk aversion.

The household budget constraint is:

$$P_t C_t + B_t + T_t = W_t^n h_t + R_{t-1} B_{t-1} + \Phi_t, \tag{3.3}$$

where P_t denotes the price of the consumption good in period t, B_t represents the quantity of one period nominal risk-free discount bonds purchased in period t and maturing in period $t+1$. R_t is the gross nominal interest rate earned for government bonds for holding from period t to $t+1$. W_t^n denotes the nominal wage rate, h_t denotes the hours employed by households and Φ_t is nominal profits received in time t from the ownership of firms and financial intermediaries. T_t is the nominal lump sum taxes paid by the household in time t.

Although households supply labour inelastically, they are only able to supply $h_t \leq \bar{h}$ hours of labour in each period due to nominal wage rigidities. Households are endowed with a constant number of maximum hours of work, $\bar{h}$ per period.

The Maximisation Problem of a Representative Household

The optimisation problem of the household is to maximise the objective function given by Equation (3.1) subject to the budget constraint given by Equation (3.3) as given below:

$$Max_{\{C_t,B_t\}} E_0 \sum_{t=0}^{\infty} e^{\xi_t} \beta^t U(C_t),$$

subject to:

$$P_t C_t + B_t + T_t - [W_t^n h_t + R_{t-1} B_{t-1} + \Phi_t] = 0.$$

Further, it is assumed that the household is constrained from engaging in Ponzi type schemes as follows:

$$lim_{j \to \infty} E_t \left(\prod_{s=0}^{j} (R_{t+s}^{-1}) B_{t+j+1} \geq 0 \right).$$

The Lagrangian method is used to solve the household's constrained optimisation problem. Accordingly, the Lagrangian problem is:

$$L = E_0 \sum_{t=0}^{\infty} e^{\xi_t} \beta^t \left\{ U(C_t) - \lambda_t \left[P_t C_t + B_t + T_t - (W_t^n h_t + R_{t-1} B_{t-1} + \Phi_t) \right] \right\}, \tag{3.4}$$

where λ_t is the Lagrange multiplier.

First Order Necessary Conditions for Maximisation

In an interior solution, to derive the first order conditions, it is necessary to set equal to zero the partial derivatives of the function (3.4) with respect to the choice variables, B_t and C_t. When Equation (3.4) is concave in these variables, the necessary conditions are also sufficient for maximisation.

First, consider the partial derivative with respect to C_t:

$$\frac{\partial L}{\partial C_t} = e^{\xi_t}\beta^t \left[U_{c,t} - \lambda_t(P_t)\right] = 0,$$

$$\lambda_t = \frac{U_{c,t}}{P_t},$$

where $U_{c,t}$ is the first derivative of the utility function with respect to consumption at time t.

Now consider the partial derivative with respect to B_t:

$$\frac{\partial L}{\partial B_t} = -e^{\xi_t}\beta^t\lambda_t + E_t\left(e^{\xi_{t+1}}\beta^{t+1}R_t\lambda_{t+1}\right) = 0,$$

$$\lambda_t = E_t\left(\frac{e^{\xi_{t+1}}\beta R_t\lambda_{t+1}}{e^{\xi_t}}\right).$$

Using the above results with regard to the Lagrange multiplier, it is possible to derive the following equation:

$$\frac{U_{c,t}}{P_t} = E_t\left(\frac{e^{\xi_{t+1}}\beta R_t}{e^{\xi_t}}\frac{U_{c,t+1}}{P_{t+1}}\right),$$

$$e^{\xi_t}U_{c,t} = \beta R_t E_t\left(\frac{e^{\xi_{t+1}}U_{c,t+1}}{\pi_{t+1}}\right),$$

where $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ is gross inflation, which gives the change in the price level between period t and $t+1$, i.e., the gross rate of inflation between period t and $t+1$. The above equation represents the Euler equation for the maximisation problem of the household. Given $U_{c,t} = C_t^{-\sigma}$, the Euler equation can be re-written as follows:

$$e^{\xi_t}C_t^{-\sigma} = \beta R_t E_t\left(\frac{e^{\xi_{t+1}}C_{t+1}^{-\sigma}}{\pi_{t+1}}\right). \tag{3.5}$$

The Euler equation states that the marginal benefit of the bond equals to the marginal cost of the bond.

3.2 Production Sector

Firms in this model use no capital in the production process and exist in competitive product and labour markets. Each firm produces a homogeneous product using the following technology:

$$Y_t = X_t F(h_t),$$

where X_t denotes the deterministic trend in productivity, assumed to be common to all firms in the market. Productivity grows at the constant exogenous gross rate of $\mu \geq 1$. Accordingly,

$$X_t = \mu X_{t-1}. \tag{3.6}$$

It is assumed that the production technology satisfies decreasing returns to scale and takes the following form:

$$F(h) = h^{\alpha},$$

where $\alpha \in (0, 1)$.

Borrowing for Working Capital

In this economy, firms have to borrow for working capital. This is the main departure point of this study from SGU. The worker sells labour services h_t to firms, but firms must pay wages prior to receiving the sales proceeds of production. To accomplish this, firms must take out exogenous loans from competitive financial intermediaries, which are owned by households. Accordingly, the wage-in-advance constraint in nominal terms is:

$$q_t^n \geq J W_t^n h_t, \tag{3.7}$$

where q_t^n is nominal loans taken out from the financial intermediary. In this set-up, I assume firms may not ask for loans to cover their full wage bill. That is, they may finance part of their wage bill internally. Accordingly, J denotes the portion of the wage bill covered by firms using external loans.

It is assumed that J is fixed over time. If $J = 0$, that means the firm does not ask for any loans to cover the wage bill. This situation is identical to the SGU model. However, if $J = 1$, firms borrow the full wage bill externally. I consider values between 0 and 1, inclusive, for J.

Since firms borrow their wage bill externally, they have to incur an interest bill. The gross rate of interest is R_t, which is the rate for nominal bonds. I assume the corporate interest rate is the same as the risk free interest rate. Accordingly, nominal profits for a representative firm are:

$$\Phi_t = P_t X_t F(h_t) - \left[W_t^n h_t + q_t^n (R_t - 1)\right]. \tag{3.8}$$

The Maximisation Problem of a Representative Firm

A representative firm in this economy has two choice variables: h_t and q_t^n. The optimisation problem of a representative firm is to maximise the profit given by Equation (3.8) subject to the wage-in-advance constraint given by Equation (3.7). Accordingly, in each period, the problem is:

$$Max_{\{h_t, q_t^n\}} = P_t X_t F(h_t) - \left[W_t^n h_t + q_t^n (R_t - 1)\right],$$

subject to:

$$q_t^n \geq J W_t^n h_t.$$

The firm's constrained optimisation problem is solved using the Lagrangian method. The Lagrangian of the problem is:

$$L = P_t X_t F(h_t) - \left[W_t^n h_t + q_t^n (R_t - 1)\right] - \delta_t \left[J W_t^n h_t - q_t^n\right], \tag{3.9}$$

where δ_t is the Lagrange multiplier.

First Order Necessary Conditions for Maximisation

In an interior solution, to derive the first order conditions, it is necessary to set equal to zero the partial derivatives of Equation (3.9) with respect to the choice variables, h_t and q_t^n.

First, consider the partial derivative with respect to h_t:

$$\frac{\partial L}{\partial h_t} = P_t X_t F^{'}(h_t) - W_t^n - \delta_t W_t^n J = 0,$$

$$P_t X_t F^{'}(h_t) = W_t^n \left(1 + \delta_t J\right).$$

Now consider the partial derivative with respect to q_t^n:

$$\frac{\partial L}{\partial q_t^n} = -(R_t - 1) + \delta_t = 0,$$

Using these results, it is possible to write:

$$P_t X_t F^{'}(h_t) = W_t^n \left[1 + J(R_t - 1)\right],$$

or

$$F^{'}(h_t) = \frac{W_t^n}{P_t X_t} \left[1 + J(R_t - 1)\right].$$

The last equation shows how competitive firms equate the marginal product of labour to the real marginal cost. This equation further shows, everything else being constant, an increase in the nominal interest rate increases the marginal cost of labour. To equate the marginal cost of labour to the marginal product of labour, firms have to reduce employment, as the production function has the characteristic of decreasing returns to scale. Therefore, in this model, an increase in the nominal interest rate implies a reduction in output, *ceteris paribus*.

3.3 Downward Nominal Wage Rigidity

Nominal wages are assumed to be downwardly rigid, as in SGU. In any given period, nominal wages can fall by at most the factor $\gamma(u_t)$, where $u_t = \frac{\bar{h} - h_t}{\bar{h}}$ is the employment ratio in the economy. Nominal wage dynamics take the following form:

$$W_t^n \geq \gamma(u_t) W_{t-1}^n,$$

where $\gamma(u_t) \geq 1$ represents an absolute wage rigidity and $\gamma(u_t) = 0$ represents full wage flexibility. Here, it is assumed that nominal wages become more flexible when unemployment increases, formally: $\gamma^{'}(u_t) < 0$. Also, it is assumed $\gamma(0) > \tilde{\beta}\mu$ where $\tilde{\beta} = \beta\mu^{-\sigma}$. The latter assumption ensures both the existence of a steady state with unemployment and the uniqueness of the steady state with full employment.

The nominal wage rigidity function, $\gamma(u_t)$, is assumed to take the following form: $\gamma(u_t) = \gamma_0(1-u_t)^{\gamma_1}$ where γ_0 and γ_1 are positive constants.

The following slackness condition is imposed on wage and employment:

$$(\bar{h} - h_t)\left[W_t^n - \gamma(u_t)W_{t-1}^n\right] = 0.$$

This condition confirms that whenever there is involuntary unemployment, the lower bound on the nominal wage is binding. On the other hand, whenever nominal wages are not bound by its lower bound, the economy is at the full employment level.

3.4 The Government and the Monetary Authority

The government consumes no goods, but raises taxes and issues public debt. The budget constraint of the government is therefore given by:

$$B_t + T_t = R_{t-1}B_{t-1}.$$

A no-Ponzi game constraint is also imposed on the government.

Monetary policy confirms that the nominal interest rate is bounded below by zero and takes the following Taylor rule:

$$R_t = Max\left[1, R^* + \alpha_\pi(\pi_t - \pi^*) + \alpha_y \ln\left(\frac{Y_t}{Y_t^*}\right)\right],$$

where π^* is the inflation target, R^*, α_π and α_y are positive constants. $Y_t^* = X_t\bar{h}^\alpha$ is the flexible wage level of employment. Following SGU, it is assumed that (i) $R^* = \frac{\pi^*}{\tilde{\beta}} > 1$, which ensures the compatibility of the inflation target with the deterministic steady state, (ii) $\alpha_\pi\tilde{\beta} > 1$, which is the Taylor principle and (iii) $\pi^* > \frac{\gamma(0)}{\mu}$, which is necessary for the existence of a steady state with full employment.

3.5 Equilibrium

Since the model abstracts from aggregate demand components like capital, investments, government purchases and net exports, the goods market clearing condition is given by:

$$C_t = X_t F(h_t),$$

which confirms that all the output must be consumed. Real consumption and real wages are scaled down by the deterministic productivity trend: $c_t = \frac{C_t}{X_t}$ and $w_t = \frac{W_t^n}{P_t X_t}$.

The real consumption in the Euler equation given by (3.5) is scaled down by the deterministic trend to obtain:

$$e^{\xi_t} c_t^{-\sigma} = \left(\frac{X_t}{X_{t+1}}\right)^{-\sigma} \beta R_t E_t \left(\frac{e^{\xi_{t+1}} c_{t+1}^{-\sigma}}{\pi_{t+1}}\right),$$

and by substituting productivity growth μ as given in Equation (3.6) yields:

$$e^{\xi_t} c_t^{-\sigma} = \mu^{-\sigma} \beta R_t E_t \left(\frac{e^{\xi_{t+1}} c_{t+1}^{-\sigma}}{\pi_{t+1}}\right).$$

Finally, substituting $\tilde{\beta}$, yields:

$$e^{\xi_t} c_t^{-\sigma} = \tilde{\beta} R_t E_t \left(\frac{e^{\xi_{t+1}} c_{t+1}^{-\sigma}}{\pi_{t+1}}\right). \tag{3.10}$$

Accordingly, a competitive equilibrium is satisfied by Equation (3.10) and the following set of equations:

$$c_t = F(h_t), \tag{3.11}$$

$$F^{'}(h_t) = w_t \left[1 + J(R_t - 1)\right], \tag{3.12}$$

$$h_t \leq \bar{h}_t, \tag{3.13}$$

$$w_t \geq \frac{\gamma(u_t) w_{t-1}}{\mu \pi_t}, \tag{3.14}$$

$$(\bar{h} - h_t)\left[w_t - \frac{\gamma(u_t) w_{t-1}}{\mu \pi_t}\right] = 0, \tag{3.15}$$

$$u_t = \frac{\bar{h} - h_t}{\bar{h}}, \tag{3.16}$$

$$R_t = Max\left[1, \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi_t - \pi^*) + \alpha_y ln\left(\frac{F(h_t)}{F(\bar{h})}\right)\right]. \tag{3.17}$$

3.6 Non-stochastic Steady State Equilibria

At the steady state all variables are constant over time. Accordingly, the steady state values of real consumption, real wages, employment, nominal interest rate and inflation are given by c, w, h, R and π, respectively. In this specification, real consumption and real wages are adjusted for the productivity trend, as was done in the equilibrium specification above. The exogenous taste shock ξ_t takes the value of zero. In the steady state, the system of equations specified in the equilibrium simplifies to the following set of equations:

$$R = \frac{\pi}{\tilde{\beta}}, \tag{3.18}$$

$$c = F(h), \tag{3.19}$$

$$F^{'}(h) = w[1 + J(R-1)], \tag{3.20}$$

$$h \leq \bar{h}, \tag{3.21}$$

$$\pi \geq \frac{\gamma(u)}{\mu}, \tag{3.22}$$

$$(\bar{h} - h)(1 - \frac{\gamma(u)}{\mu\pi}) = 0, \tag{3.23}$$

$$u = \frac{\bar{h} - h}{\bar{h}}, \tag{3.24}$$

$$R = \text{Max}\left\{1, \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi - \pi^*) + \alpha_y ln\left(\frac{F(h)}{F(\bar{h})}\right)\right\}. \tag{3.25}$$

In the following two propositions, the proof for which are supplied in Appendix A.1, I show that there exist two steady states in the cost channel economy, as in the SGU economy. The first one is the intended full employment steady state while the other one is the unintended steady state with unemployment.

Proposition 1

There exists a unique full employment steady state for any $J \in [0, 1]$. At this steady state, inflation rate equals inflation target π^* and $R = \frac{\pi^*}{\tilde{\beta}}$.

Proof: See Appendix A.1

At the full employment steady state, the real wage is determined by the following equation, which is derived from Equation (3.20):

$$w = \frac{F^{'}(\bar{h})}{\left[1 + J\left(\frac{\pi^*}{\tilde{\beta}} - 1\right)\right]}.$$

Everything else being constant, the above equation shows that the full employment steady state real wage is determined by the value of J.

Proposition 2

There exists a unique unemployment steady state for any $J \in [0, 1]$. At this steady state, the economy is in a liquidity trap with $R = 1$ and $\pi = \tilde{\beta}$.

Proof: See Appendix A.1

At the unemployment steady state, the real wage is determined by the following equation, which is derived from Equation (3.20):

$$w = F^{'}(h).$$

This equation shows that real wages in the unemployment steady state are not affected by J. Further, no variable in the model is affected by J in the unemployment steady state. The reason for this is, in the unemployment steady state the nominal interest rate becomes zero and the firm's borrowings are costless, as per the model assumptions. Therefore, borrowing for working capital does not affect the real wages in the unemployment steady state.

The two propositions show that J is affected in the full employment steady state but not in the unemployment steady state.

4 Simulations and Welfare Analysis

In this section, I consider model simulations and welfare analysis.[7] The simulation is divided into two sections, namely, baseline simulation and the simulation of alternative interest rate-based exit strategies. I start with the baseline calibration and simulation, then describe and present the results of the welfare analysis before moving to alternative exit strategies.

4.1 Baseline Simulation

To facilitate the simulation exercise, I first calibrate parameters. I use the parameter values in the standard range used in the previous literature and also used by SGU. The parameter values are set as follows: coefficient of relative risk aversion σ to 1.25, output elasticity of labour α to 0.75, exogenous productivity growth μ to 2% per annum, long run real interest rate $\tilde{\beta}$ to 4% per annum, inflation target π^* to 2% per annum and the parameters of the Taylor rule α_π to 1.5 and α_y to 0.125. The elasticity of the wage rigidity with respect to unemployment γ_1 is set at 0.1942, following SGU. SGU calculated γ_1 assuming nominal wages fall frictionlessly by 2% per annum at an unemployment rate of 5%. The parameter used for downward rigidity factor γ_0 is set at π^*.

In the baseline simulation exercise, I examine the dynamics of a cost channel economy and a no-cost channel economy following a confidence shock. First, I examine the dynamics of the economy moving to an unintended unemployment steady state following a confidence shock. Second, I examine the dynamics of the economy following the implementation of the SGU exit strategy.

In this analysis, following SGU, I assume a confidence shock reduces inflation expectations. Quantitatively, it is assumed that this confidence shock results in a drop in inflation by 10 basis points from the target rate in Quarter 1. I consider a perfect foresight equilibrium path. The frequency of the simulation period is quarterly.

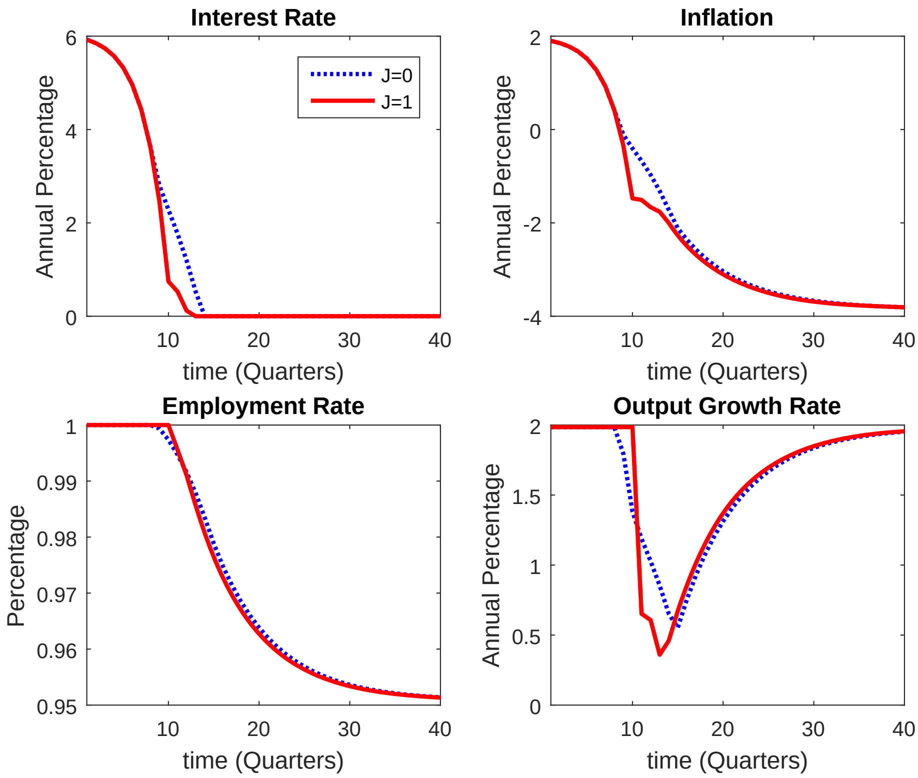
4.1.1 Unintended Unemployment Steady State

In this section, I consider the dynamics of the economy moving to an unintended steady state following a lack-of-confidence shock.

[7] I used the software Matlab (version R2015b) to facilitate simulations and the welfare analysis.

Consider an economy which is at the full employment steady state at the beginning. Then, a confidence shock ($\pi_1 < \pi^*$) is introduced in Quarter 1. This shock takes the economy into an unintended steady state with a liquidity trap. Figure 4.1 depicts the dynamics. Appendix A.2 shows the steps to solve the exact dynamics of the non-linear model.

Figure 4.1: Contraction with a Jobless Recovery



In Figure 4.1, the solid line depicts the dynamics of the case when the cost channel is active (i.e., $J = 1$) while the dashed line depicts the dynamics of the case where the cost channel is not active (i.e., $J = 0$, which is identical to the SGU model). The economy begins at full employment, while inflation and nominal interest rates are at their target rates. Output is growing at the long-term growth rate of 2%. Following the confidence shock in Quarter 1, inflation decreases monotonically. The Taylor rule responds to the decrease in inflation by reducing interest rates. When the cost channel is active, the interest rate hits its lower bound in 3.25 years, otherwise it occurs in 3.75 years. The reason that the economy hits the ZLB early when the cost channel is included, is explained as follows: When the cost channel is active, a decrease in nominal interest rates reduces the marginal cost of production, making firms hire relatively more people to equate the real marginal cost of production to the marginal product of labour. This allows for an increase in current consumption relative to the previous period and reduces inflation more relative to the case when the cost channel is not active. A large drop in inflation leads the central bank to cut nominal rates further through the Taylor rule. Ultimately, the interest rate hits the lower bound in 3.25 years from the initial shock. The dynamics show that the economy with a cost channel ultimately converges to the unintended unemployment steady state, which is identical to the SGU model.

4.1.2 The SGU Exit Strategy

In this section, I consider the implementation of the SGU exit strategy when the economy is at the unintended unemployment steady state.

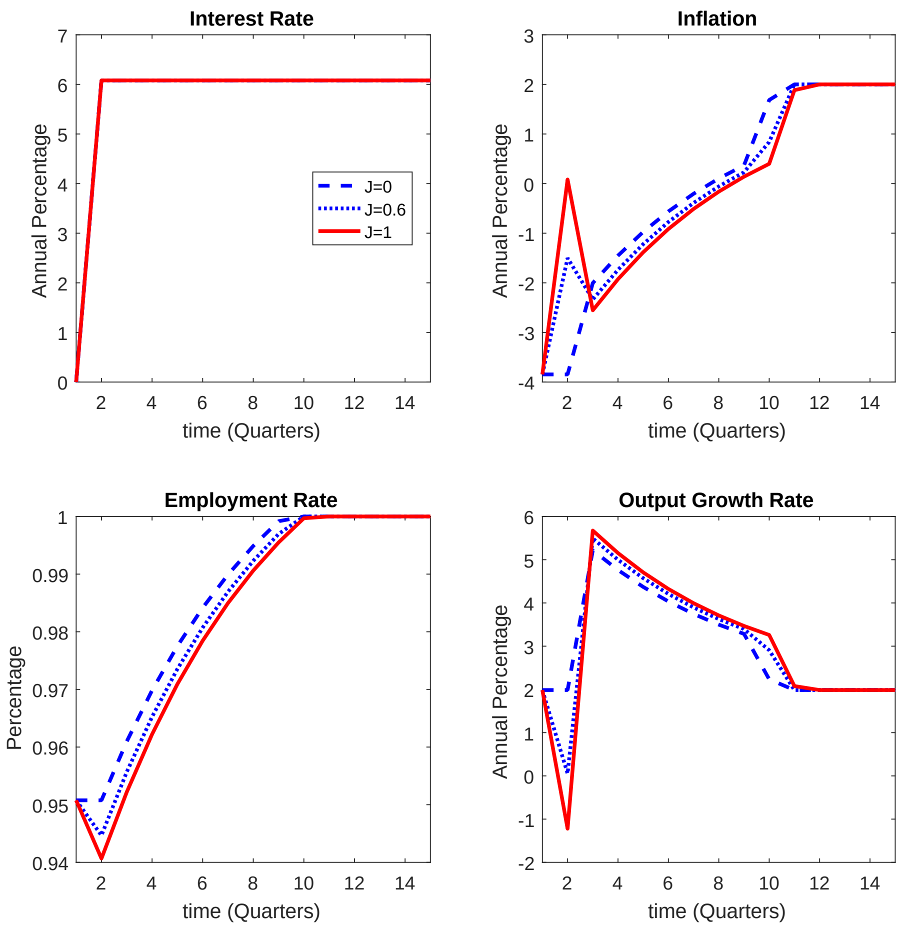
Consider the case that the economy is at the unintended steady state. At the beginning of Quarter 1, the nominal interest rate is at the ZLB, inflation is at its lower bound ($\tilde{\beta}$), unemployment is high, while output is growing at its long-term growth rate of 2%. Under these conditions, the monetary authority implements the SGU exit strategy, i.e. they set the net nominal interest rate at their target rate of 6% in Quarter 2 and maintain it. The dynamics of the interest rate shock are depicted in Figure 4.2. The dashed line shows the dynamics of the no-cost channel economy $(J = 0)$ while the solid line shows the dynamics of the cost channel economy $(J = 1)$. The dotted line depicts a more empirically relevant value of $J = 0.6$.[8] The interest rate shock to the economy initially affects firms' marginal cost, as firms have to borrow to pay wages. Since the marginal cost increases significantly and firms are always on their labour demand curve, firms have no option but to cut employment to equate the real marginal cost to the marginal product of labour. The employment cut by firms affects the current employment level and production of firms, consequently negatively affecting the economy-wide employment and output growth in Quarter 2. This was not observed under the SGU model, where $J = 0$, as depicted in Figure 4.2. It is clear from the Euler equation that a drop in current consumption relative to the previous period consumption, increases current inflation. This effect is evident in the dynamics, which shows that inflation picks up significantly in Quarter 2. However, moving into Quarter 3, the relative effect of the cost channel between Quarter 2 and 3 becomes null as the interest rate is unchanged. Inflation drops again in Quarter 3, before increasing monotonically to its target value. Employment too increases monotonically to its target value after the sudden drop in Quarter 2. Output growth picks up in Quarter 3 and decreases monotonically to its long-term growth

[8] As mentioned before, Christiano et al. (2015) estimated that firms borrowed around 56.2% of their working capital externally in the post-war USA economy. Accordingly, I consider the more empirically relevant value of $J = 0.6$.

rate.

This analysis shows that the SGU exit strategy induces a substantial initial pain to the economy, although the strategy is able to take the economy out of slump in a cost channel economy.

Figure 4.2: Dynamics of the SGU Exit Strategy when the Economy is in the Unintended Steady State with a Liquidity Trap



In the next section, I analyse the welfare implications.

4.2 Welfare Analysis

The simulation exercises performed in the above section to analyse the dynamics of the economy showed that there is a significant reduction in employment and output growth following a sharp increase in the nominal interest rate in a cost channel economy. This section considers the implication of the SGU exit strategy for household welfare in both cost channel and no-cost channel economies.

The Methodology

In the following analysis, I compare welfare due to different policy options and under different economic environments. The welfare calculation method is in the tradition of Robert E. Lucas (see Lucas, 2003). The method is called *consumption equivalent of welfare comparison,* which is based on the aggregate utility of households. The welfare of a household with perfect foresight is formulated as follows:

$$\sum_{t=2}^{\infty} \beta^{t-2} \frac{\left(C_t^{1-\sigma} - 1\right)}{1-\sigma}.$$

Consumption equivalent welfare is measured as the change in consumption due to policy option or the economic environment. It is calculated by solving the following non-linear equation for x. Here, $x * 100$ is the additional percentage of consumption required in the unintended steady state[9] to have the same level of welfare in the policy consumption path (The detailed derivation of the consumption equivalent welfare measure is given in Appendix A.3):

$$wf = \frac{1}{1-\sigma} \left(\frac{\left[c_{uss} \left(1+x\right)^{1-\sigma}\right]}{1-\beta\mu^{1-\sigma}} - \frac{1}{1-\beta} \right),$$

where wf is the welfare of the policy action, c_{uss} is the real consumption in the unintended steady state scaled down by the productivity growth.

Welfare Implications of the SGU Exit Strategy

In this section, the welfare implication of the SGU exit policy in a cost channel and a no-cost channel economy is considered. Table 4.1 presents consumption equivalence welfare and other economic measures in each case. The table shows that the welfare level decreases when the cost channel is introduced to the model. Further, as found in the simulation exercise above, significant contraction in the initial employment level and in output growth is also observed in a cost channel economy compared to a no-cost channel economy. As depicted in Figure 4.2, these contractions occur just after the introduction of the SGU exit policy.

[9]Note that the welfare level is identical irrespective of the value of J in the unintended steady state. This is because, at the unintended steady state, net nominal interest rate is at the zero level.

Table 4.1: Welfare and Economic Measures of SGU Exit Policy

Economic Measure	Without Cost Channel ($J = 0$)	With Cost Channel ($J = 1$)
Consumption Equivalent Welfare	0.0379	0.0377
Maximum Unemployment	4.92	5.93
Maximum Inflation	2	2
Minimum Output Growth	1.98	-1.22

Two alternative interest rate strategies are considered in the following section to analyse two different issues described below.

4.3 Alternative Interest-rate based Exit Strategies

In this section, I examine two alternative interest rate-based exit strategies. First, I study an overshoot interest rate policy. This strategy examines whether the quantitative increase in nominal interest rates in the SGU exit policy is optimal. Then, I study a staggered interest rate increase policy. This strategy examines whether it is possible to reduce the initial pain to the economy in the cost channel economy as the cost channel worsens the initial economic conditions just after the introduction of the SGU exit strategy.

4.3.1 Alternative Exit Policy 1 - Overshoot Policy

In the *Overshoot policy*, I propose to increase the interest rate above the level of the target rate of 6% (overshoot). This alternative policy has also been proposed by Roberto M. Billi in his discussion of the SGU paper (see Billi, 2013).[10] Under this policy, I propose to increase the interest rate to above the level of the target rate in Quarter 2. Then reduce interest rates to the long-run target level in a step-wise fashion in eight quarters and maintain the target level thereafter. In this analysis, I examine several Overshoot policies based on the interest rate increase and the SGU policy in a no-cost channel economy with regard to welfare and other economic conditions. The results are given in Table 4.2.

Table 4.2: Welfare of SGU Exit Policy and Overshoot Interest Rate Policies ($J = 0$)

Economic Measure	Interest Rate Overshoot Policy (in terms of net nominal values)					
	6% (SGU Policy)	7%	8%	10%	25%	50%
Consumption Equivalent Welfare	**0.0379**	0.0380	0.0381	0.0382	0.0384	0.0384
Maximum Unemployment	**4.9237**	4.9237	4.9237	4.9237	4.9237	4.9237
Maximum Inflation	**2**	2.1106	2.4615	3.8846	15.6442	38.95
Minimum Output Growth	**1.9852**	1.9852	1.9852	1.9852	1.9852	1.9852

[10]The Roberto M. Billi's discussion is based on an earlier version of the SGU paper: Schmitt-Grohé and Uribe (2012).

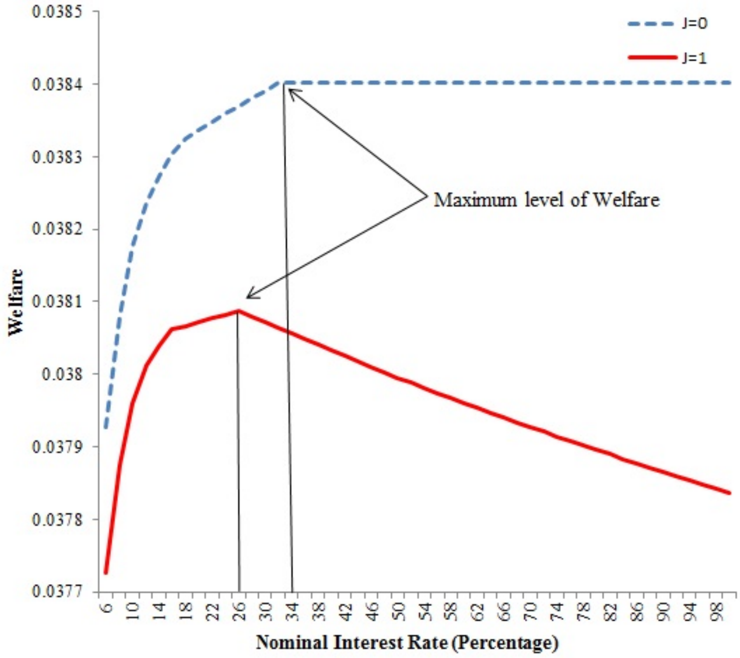
Table 4.2 shows that in the SGU economy (no-cost channel economy), the welfare-wise better interest rate strategy is not to increase the interest rate to its long-run target level of 6%, but to increase more and reduce in a step-wise fashion. This result shows that the SGU exit strategy is inferior with regard to consumption equivalent welfare value.

However, the higher the increase in interest rates, the larger the violation of the inflation target initially. For example, if the central bank decides to increase nominal interest rates suddenly to 10%, Table 4.2 shows that initial increase in inflation would be 3.88%, or 188 basis points above the target value of 2%.

Moreover, I consider the welfare analysis to find the optimum level of nominal interest rate increase in cost channel and no-cost channel economies under the Overshoot policy. The focus here is only on welfare of households but not on other economic measures such as breach of the inflation target, initial reduction of output growth. Figure 4.3 depicts nominal interest rates versus welfare in economies with and without cost channel. It shows that the welfare of the cost channel economy is always lower to the no-cost channel economy for any given nominal interest rate. In addition, the optimal level of the nominal interest rate to achieve maximum welfare level is also lower in cost channel economies than in no-cost channel economies.

Further, in the cost channel economy, the welfare level is non-monotonic in the nominal interest rate. The welfare level increases up to a certain level of interest rate (around 26%), and then begins to decrease in cost channel economies. This is because the negative effect of the initial increase in inflation and also of the decrease in output growth due to the cost channel, exceeds at that point, over positive effects.

Figure 4.3: Nominal Interest Rates Vs Welfare



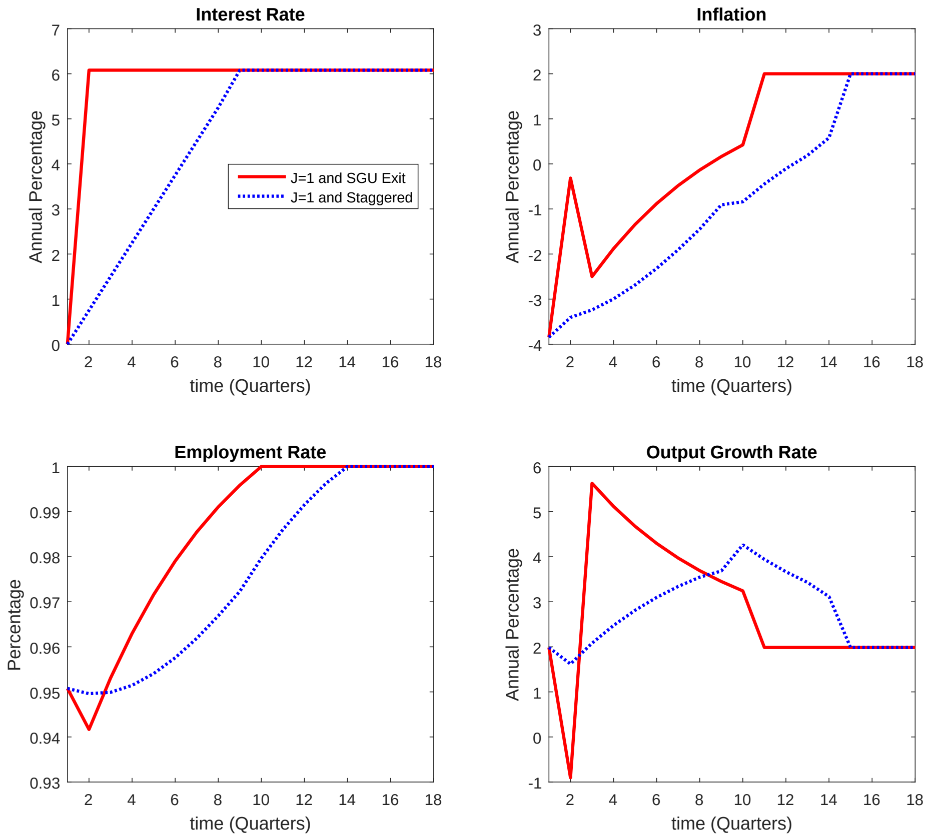
However, according to Figure 4.3, under the Overshoot policy, welfare-maximising initial increase in the interest rate is absolutely high: a staggering 34% in the original SGU setting and a somewhat lower 26% in the model with the cost channel. This could be due to the missing elements in my analysis (as well as in SGU model), which is briefly discussed in the conclusion section. Therefore, these results in nominal terms are to be interpreted with care.

In the comparison analysis of the three interest rate-based strategies reported later in Section 4.3.3, I consider an 8% increase in the Overshoot policy taking into account the welfare level as well as the initial increase in inflation.

4.3.2 Alternative Exit Policy 2 - Staggered Policy

Since both the SGU exit strategy as well as the Overshoot strategy discussed in the section above worsen economic conditions initially, this section considers a second alternative exit strategy, which is named as *the Staggered policy*. Under this policy, the monetary authority increases interest rates to its long-run target value in a staggered fashion. This type of monetary policy was implemented by the Fed during the period from 2004 to 2006, when it increased nominal interest rates by 4% in eight quarters. During that period, on average, the Fed has increased interest rates by 0.5% quarterly. Under the Staggered policy, I propose to increase the interest rate by 75 basis points in each of eight consecutive quarters to reach its target value of 6%. The economy is at the unintended steady state at the beginning, i.e., in Quarter 1, before introducing the alternative strategy in Quarter 2. The dynamics of the Staggered policy and the SGU exit policy in a cost channel economy are depicted in Figure 4.4. It is clear from the dynamics of the employment rate and output growth rate that the initial pain of contraction of employment, output growth and increase in inflation is substantially less in the Staggered policy compared to the SGU policy in a cost channel economy.

Figure 4.4: Dynamics of Staggered Interest Policy and SGU Policy



4.3.3 Comparison of the Three Exit Strategies

Welfare and other economic conditions of the three exit strategies under examination, namely the SGU policy, the Overshoot interest rate policy[11] and the Staggered policy are given in Table 4.3. The

[11] As mentioned before, I consider the initial increase of interest rate as 8% under the Overshoot policy, considering the initial pain to the economy of an even higher initial increase in interest rates. Note that the welfare-wise optimal level of an initial increase in a no-cost channel economy is 34% and the value for a cost channel economy is 26%, as shown above.

table confirms that the better monetary policy strategy in a no-cost channel economy (when $J = 0$) is to increase the interest rate to 8%, i.e. two percentage points above the target rate of 6%. However, in a cost channel economy (consider $J = 1$), the answer is not straight forward. In cost channel economies, although the welfare is maximised in the Overshoot policy, initial economic conditions given by minimum level of unemployment, maximum inflation and maximum unemployment are worse compared to conditions under the other two strategies.

Table 4.3: Comparison of Welfare and Economic Measures in the Three Policy Strategies

Exit Strategy		Amount of Wage Bill to be Borrowed					
		J=0	J=0.25	J=0.5	J=0.75	**J=1**	% Change (bet. J=0 & J=1)
SGU Exit Policy	Welfare	**0.0379**	0.0379	0.0378	0.0378	**0.0377**	-0.53
	Max. Unemp.	**4.9237**	5.1786	5.4319	5.6835	**5.9336**	1.01
	Max. Inf.	**2**	2	2	2	**2**	-
	Min. Out. Gr.	**1.9852**	1.1766	0.3726	-0.4268	**-1.2217**	-3.21
Overshoot Policy Int. Rate inc. 8%	Welfare	**0.0381**	0.0380	0.0380	0.0379	**0.0379**	-0.52
	Max. Unemp.	**4.9237**	5.2565	5.5865	5.9138	**6.2384**	1.31
	Max. Inf.	**2.4615**	2.4615	2.4615	2.4615	**2.4615**	-
	Min. Out. Gr.	**1.9852**	0.9294	-0.1185	-1.1587	**-2.1912**	-4.18
Staggered Policy	Welfare	**0.0373**	0.0373	0.0372	0.0372	**0.0371**	-0.54
	Max. Unemp.	**4.9237**	4.9558	4.9880	5.0201	**5.0521**	0.13
	Max. Inf.	**2**	2	2	2	**2**	-
	Min. Out. Gr.	**1.9852**	1.8832	1.7813	1.6795	**1.5778**	-0.41

5 Conclusion

In this study, I extended the SGU model to incorporate the cost channel of monetary policy and reexamined the robustness of SGU's unconventional policy prescription. SGU recommended implementing a tight monetary policy in a liquidity-trapped recession followed by a nonfundamental shock. The present model for a cost channel economy has two steady states: one is the intended steady state with full employment and the other one is the unintended steady with unemployment. This result is identical to the SGU study for a no-cost channel economy.

The simulation exercise confirmed that the exit strategy suggested by SGU is able to take the economy out of the slump even when the cost channel of monetary policy is present in the economy. However, the SGU exit strategy takes the cost channel economy to the full employment steady state with some initial pain compared to the no-cost channel economy. The unexpected increase in the nominal interest rate, as suggested by SGU, would induce sharp initial contractions in the employment rate and the growth rate and a sharp increase in inflation in a cost channel economy. In line with this result, the welfare analysis showed that the welfare of economic agents in a cost channel economy is less compared to that of economic agents in a no-cost channel economy under the SGU exit policy.

Two alternative interest rate-based exit policies were also explored. First, the Overshoot policy suggests increasing interest rates above the long-run target interest rate considered by SGU and reducing it to the target rate in a step-wise fashion. The welfare analysis showed that the SGU policy is inferior compared to the Overshoot policy, irrespective of the cost channel. Under the Overshoot policy, the welfare-maximising initial increase in interest rates is absolutely high: a staggering 34% in the original SGU setting and somewhat lower at 26% in the model with the cost channel.

Second, the Staggered policy suggests a step-wise increase in interest rates, rather than sudden large increase as suggested by the SGU exit policy. The following results hold, irrespective of the cost channel: Under the Staggered policy, the initial pain to the economy in terms of other economic conditions such as unemployment, economic growth and inflation is lower than under the SGU policy or the Overshoot policy. However, welfare-wise, the Staggered policy is inferior, compared to the other two policies considered.

In this analysis, I have included only the cost channel of monetary policy in the model as a negative effect of the sudden increase in nominal interest rates (as prescribed by the SGU) in a recession. However, there are several other factors that would negatively affect the welfare of the household in such a situation. For example, an increase in nominal interest rates would negatively affect: cost of existing borrowing contracts, borrowing constraints faced by firms due to decline in the net worth of the firm and subsistence levels of consumption. Therefore, the welfare calculated in this study under the SGU exit policy and the other two alternative policies may be overestimated.

I have considered a perfect foresight equilibrium path in the analysis. The main reason to choose the perfect foresight assumption, beside the simplicity, was to compare results with the SGU study. SGU, in their analysis, consider a perfect foresight equilibrium path.

Two possible extensions to this research in the future, worth noting. First, how the cost channel economy would react to the SGU policy under a fundamental shock would be interesting to analyse. Second, how the results would change if capital is incorporated into the economy would be interesting to consider.

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Appendix

A.1

Proof of Proposition 1

The first section of the proof follows SGU's proof of Proposition 1. For the sake of completeness, I briefly state the entirety in the following exposition.

At the full employment level, by definition $u = 0$. Therefore, $h = \bar{h}$ and $c = F(\bar{h})$ are the unique solutions to Equations (3.21) and (3.19). Slackness condition (3.23) is also satisfied. Consider Equations (3.18) and (3.25). Eliminating R and solving for π yields:

$$\frac{\pi}{\tilde{\beta}} = 1,$$

or

$$\frac{\pi}{\tilde{\beta}} = \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi - \pi^*).$$

The first equation above yields $\pi = \tilde{\beta}$. However, under downward wage rigidity, it is assumed $\gamma(0) > \tilde{\beta}\mu$. Incorporating $\pi = \tilde{\beta}$ in this inequality yields $\pi < \frac{\gamma(0)}{\mu}$. However, this result is in contradiction with Equation (3.22).

Now turn to the other solution for π given by the second equation above. It can be re-arranged as follows:

$$(\pi - \pi^*)(1 - \tilde{\beta}\alpha_\pi) = 0 \tag{5.1}$$

An assumption in the Taylor Rule specifies: $\alpha_\pi\tilde{\beta} > 1$. Therefore, the solution for Equation (5.1) is $\pi = \pi^*$. This solution should satisfy the Taylor Rule given by Equation (3.25). The Taylor Rule simplifies to the following problem:

$$R = Max\left\{1, \frac{\pi^*}{\tilde{\beta}}\right\}.$$

The assumption in the Taylor Rule specification confirms that $\frac{\pi^*}{\tilde{\beta}} > 1$. Therefore, $\pi = \pi^*$ is the unique solution.

Now it has been shown that the unique solution for π in the full employment steady state is $\pi = \pi^*$ and $R = \frac{\pi^*}{\tilde{\beta}}$ for all the steady state equations except Equation (3.20). By substituting $R = \frac{\pi^*}{\tilde{\beta}}$ in Equation (3.20) becomes:

$$F'(\bar{h}) = w\left[1 + J\left(\frac{\pi^*}{\tilde{\beta}} - 1\right)\right].$$

Accordingly, $R = \frac{\pi^*}{\tilde{\beta}}$ is a unique solution for Equation (3.25).

This completes the proof of the proposition.

Proof of Proposition 2

The first section of the proof follows SGU's proof of Proposition 2. For the sake of completeness, I briefly state the entirety in the following exposition.

Since it is the unemployment steady state, consider the employment ratio, $\bar{u} > 0$. Then from Equation (3.24), it is evident that $h < \bar{h}$. Consider Equations (3.18) and (3.25). Eliminating R and solving for π yields following:

$$\frac{\pi}{\tilde{\beta}} = \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi - \pi^*) + \alpha_y ln\left(\frac{F(h)}{F(\bar{h})}\right),$$

or

$$\frac{\pi}{\tilde{\beta}} = 1.$$

The first equation above can be re-arranged as follows:

$$(\pi - \pi^*)(1 - \alpha_\pi\tilde{\beta}) = \alpha_y\tilde{\beta} ln\left(\frac{F(h)}{F(\bar{h})}\right).$$

Since $h < \bar{h}$, the right hand side of the last equation is negative. By the assumption $\alpha\tilde{\beta} > 1$, if the left hand side is to be negative, $\pi > \pi^*$ is required. However, the following argument shows that $\pi > \pi^*$ is not possible in the unemployment steady state.

From the slackness condition (3.23), it follows that $\pi = \frac{\gamma(\bar{u})}{\mu}$. However, according to the properties of the wage fall factor of downward wage rigidity, it is possible to show that $\frac{\gamma(\bar{u})}{\mu} < \frac{\gamma(0)}{\mu}$. However, according to the assumption on the parameters of the Taylor rule, the following holds: $\frac{\gamma(0)}{\mu} < \pi^*$. Therefore, $\pi < \pi^*$.

Accordingly, it has been shown that the unique solution for π in the unemployment steady state is $\pi = \tilde{\beta}$ and $R = 1$ for all the steady state equations except Equation (3.20). Substituting $R = 1$ in Equation (3.20) yields:

$$F'(h) = w.$$

Therefore, the marginal cost Equation (3.20) is also uniquely determined when $R = 1$ and $\pi = \tilde{\beta}$.

This completes the proof of the proposition.

A.2

The Dynamics of the Economy moving to an Unintended Unemployment Steady State following a Confidence Shock

Set $\xi = 0$ for all t. Consider the case $\pi_1 < \pi^*$, where $h_0 = \bar{h}$. Following SGU, it is possible to show $u_1 = 0$ and $h_1 = \bar{h}$. It is also possible to find R_1 from Equation (3.17). The dynamics for $t = 2$ and onwards are calculated as follows:

Equality holds for the wage rigidity condition given in Equation (3.14). This follows from the fact that $h_t < \bar{h}$ and from using the slackness condition (3.15). Therefore, Equation (3.14) can be written as follows:

$$w_{t+1} = \frac{\gamma(u_{t+1})w_t}{\pi_{t+1}\mu}.$$

If we combine Equation (3.12) and the last equation, following yields:

$$\frac{F'(h_{t+1})}{1 + J(R_{t+1} - 1)} = \frac{\gamma(u_{t+1})}{\pi_{t+1}\mu} \frac{F'(h_t)}{1 + J(R_t - 1)}. \tag{5.2}$$

Deriving an Equation for u_t

Combining Equations (3.10) and (3.11) and substituting $\xi = 0$ yields:

$$\pi_{t+1} = \tilde{\beta} R_t \frac{F(h_{t+1})^{-\sigma}}{F(h_t)^{-\sigma}}. \tag{5.3}$$

It is possible to eliminate π_{t+1} by combining Equations (5.2) and (5.3) as follows:

$$\frac{\gamma(u_{t+1})}{\mu} = \frac{[1+J(R_t-1)]F'(h_{t+1})}{[1+J(R_{t+1}-1)]F'(h_t)}\tilde{\beta}R_t\frac{F(h_{t+1})^{-\sigma}}{F(h_t)^{-\sigma}}. \tag{5.4}$$

The functional specifications of the production function and the wage rigidity factor in Equation (5.4) yields:

$$\frac{(1-u_{t+1})^{\gamma_1}}{\mu} = \frac{\tilde{\beta}R_t}{\gamma_0}[\frac{\bar{h}(1-u_{t+1})}{h_t}]^{-\sigma\gamma+\alpha-1}\frac{[1+J(R_t-1)]}{[1+J(R_{t+1}-1)]}$$

This equation can be re-written in terms of u_t as follows:

$$\frac{(1-u_t)^{\gamma_1}}{\mu} = \frac{\tilde{\beta}R_{t-1}}{\gamma_0}[\frac{\bar{h}(1-u_t)}{h_{t-1}}]^{-\sigma\gamma+\alpha-1}\frac{[1+J(R_{t-1}-1)]}{[1+J(R_t-1)]} \tag{5.5}$$

This is a non-linear function of u_t. However, the last Equation (5.5) cannot be solved for u_t as R_t is unknown.

Deriving an Interim Value for R_t

The Taylor Rule specifies R_t, as given by Equation (3.17) is as follows:

$$R_t = Max\left\{1, \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi_t-\pi^*) + \alpha_y ln\left(\frac{F(h_t)}{F(\bar{h})}\right)\right\}.$$

Now assume $R_t > 1$. In this case R_t is equal to:

$$R_t = \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi_t-\pi^*) + \alpha_y ln\left(\frac{F(h_t)}{F(\bar{h})}\right).$$

Substituting the functional form of $F(h)$ into this equation yields:

$$R_t = \frac{\pi^*}{\tilde{\beta}} + \alpha_\pi(\pi_t-\pi^*) + \alpha_y ln\left(\frac{h_t}{\bar{h}}\right)^\alpha. \tag{5.6}$$

Using Equations (3.16), (5.3) and (5.6), it is possible to express R_t as a function of u_t as follows:

$$R_t = \frac{\frac{\pi^*}{\tilde{\beta}} - \alpha_\pi\pi^* + \alpha_y ln(1-u_t)}{1-\alpha_\pi\tilde{\beta}\left(\frac{\bar{h}(1-u_t)}{h_{t-1}}\right)^{-\alpha\sigma}}.$$

The function for R_t given in the last equation is substituted in Equation (5.5) and solved for u_t

using numerical methods. Then it is possible to find h_t and π_t. The solution for h_t and π_t is then substituted in Equation (5.6) and the value for R_t is found. If the solution for $R_t < 1$, I assume the economy is in a liquidity trap hence use $R = R^*$ and revise the calculation of u_t accordingly.

A.3

Consumption Equivalent Welfare Comparison

Welfare of the Household following a Policy Action

Assume that the policy action is carried out in Period 2. Accordingly, the welfare of the household is:

$$w_1 = \sum_{t=2}^{\infty} \beta^{t-2} \frac{(C_t^{1-\sigma} - 1)}{1-\sigma}, \tag{5.7}$$

where C_t is the real consumption given by:

$$C_t = c_t X_t, \tag{5.8}$$

and

$$X_t = \mu X_{t-1}.$$

Without loss of generality, let $X_2 = 1$. Then $X_3 = \mu$, $X_4 = \mu^2$ and so on. In period t:

$$X_t = \mu^{t-2},$$

for $t \geq 2$. Combining this equation with Equation (5.8) yields:

$$C_t = c_t \mu^{t-2}.$$

Incorporating this result in Equation (5.7) yields:

$$wf = \sum_{t=2}^{\infty} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma}.$$

Since the economy converges to the full employment steady state before the 99th period,[12] the above equation can be expressed as follows:

$$wf = \sum_{t=2}^{99} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma} + \sum_{t=100}^{\infty} \beta^{t-2} \frac{(c_{fss} \mu^{t-2})^{1-\sigma} - 1}{1-\sigma}, \tag{5.9}$$

where c_{fss} is the full employment steady state consumption. Since at the full employment steady state $h_{fss} = 1$, it implies $c_{fss} = 1$, because $c_{fss} = h_{fss}^{\alpha}$. Incorporating this result in Equation (5.9), I obtain:

$$wf = \sum_{t=2}^{99} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma} + \sum_{t=100}^{\infty} \beta^{t-2} \frac{(\mu^{t-2})^{1-\sigma} - 1}{1-\sigma}.$$

Further manipulation yields:

$$wf = \sum_{t=2}^{99} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma} + \sum_{t=100}^{\infty} \frac{\beta^{t-2}(\mu^{t-2})^{1-\sigma} - \beta^{t-2}}{1-\sigma},$$

$$wf = \sum_{t=2}^{99} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma} + \frac{1}{1-\sigma}(\sum_{t=2}^{\infty}(\beta\mu^{1-\sigma})^{t-2} - \beta^{t-2}) - \frac{1}{1-\sigma}(\sum_{t=2}^{99}(\beta\mu^{1-\sigma})^{t-2} - \beta^{t-2}).$$

Since $\beta\mu^{1-\sigma}, \beta < 1$, incorporating Taylor series approximation, I find:

$$wf = \sum_{t=2}^{99} \beta^{t-2} \frac{(c_t \mu^{t-2})^{1-\sigma} - 1}{1-\sigma} + \frac{1}{1-\sigma}(\frac{1}{1-\beta\mu^{1-\sigma}} - \frac{1}{1-\beta}) - \frac{1}{1-\sigma} \sum_{t=2}^{99}((\beta\mu^{1-\sigma})^{t-2} - \beta^{t-2}). \tag{5.10}$$

Now it is possible to calculate a numerical value for the welfare using Equation (5.10), given real consumption in each period until Period 99, as well as consumption at steady state.

Welfare of the Household in the Unintended Steady State

The welfare of the unintended steady state is given by:

$$w_{uss} = \sum_{t=2}^{\infty} \beta^{t-2} \frac{(c_{uss} \mu^{t-2})^{1-\sigma} - 1}{1-\sigma}, \tag{5.11}$$

[12]The simulation exercise confirms that the model economy converges to the full employment steady state well before the 99th period for the given calibration.

where c_{uss} is real consumption in the unintended steady state scaled down by the productivity growth. This equation can be expressed as follows:

$$w_{uss} = \frac{1}{1-\sigma}(c_{ss}^{1-\sigma}\sum_{t=2}^{\infty}(\beta\mu^{1-\sigma})^{t-2} - \sum_{t=2}^{\infty}\beta^{t-2}).$$

Since $\beta\mu^{1-\sigma}, \beta < 1$, using Taylor series approximation yields:

$$w_{uss} = \frac{1}{1-\sigma}(\frac{c_{uss}^{1-\sigma}}{1-\beta\mu^{1-\sigma}} - \frac{1}{1-\beta}). \tag{5.12}$$

Accordingly, the consumption equivalent of welfare is calculated as:

$$wf = \frac{1}{1-\sigma}(\frac{(c_{uss}(1+x))^{1-\sigma}}{1-\beta\mu^{1-\sigma}} - \frac{1}{1-\beta}), \tag{5.13}$$

where $x * 100$ is the additional percentage of consumption required in the unintended steady state to have the same level of welfare in the policy consumption path. By solving the non-linear Equation (5.13) it is possible to find x.