Loss Aversion, Inefficiencies and Policy Interventions*

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Abstract

I study a standard production economy with loss aversion preferences which macroeconomists seldom consider. Loss aversion, justified by empirical researches, implies that agents tend to hold safe assets, which may shed lights on theoretical results and policy prescriptions. I uncover that the competitive equilibrium is inefficient as long as the agent is loss averse. Numerical results show that capital stock, consumption and output decrease as loss aversion parameters increase. The Ramsey allocation rationalizes a policy intervention: the government should subsidize capital accumulation.

JEL classication: D03, E32, E62

Key words: Loss aversion, real business cycle model, inefficiency, optimal policy analysis

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1 Introduction

Macroeconomists have paid profound attention to the business cycle and policy analysis. However, an assumption pervades the majority of studies that economic agents care only about allocations, such as individual consumption, leisure and public goods. This convention possibly omits some components which may play a role in the welfare. Evidence suggests that people feel excited if they gain in the investment; in addition, a loss affects a person more than the same amount of gain[1]. This phenomenon is named as "loss aversion".

Kahneman and Tversky (1979) propose loss aversion as a part of prospect theory. Loss aversion postulates that economic agents evaluate decisions based on a reference point, which implies that utility can be generated from not only the absolute value, but also the change of assets. Besides, economic agents value gains differently from the way in which they value losses as experimental evidence shows. They obtain a greater disutility from loss than a utility from the same amount of gain. If we use the utility function representation,

$$-U(-x) > U(x), \text{ when } x > 0 \text{ and } U(0) = 0,$$

where x indicates the gain from investment and U denotes the psychological utility from gain.

Experiments and empirical studies have confirmed this concept. For instance, Pope and Schweitzer (2011) test for the presence of loss aversion using a large sample of professional golfers' performance on the PGA Tour. They verify that even the best golfers show loss aversion. Camerer et al (1997) use data on cabdrivers in New York City to reveal that drivers are afraid of falling below a target income, consistent with loss aversion. The driver decides working hours of a day largely depending on the comparison between actual daily income and the target: the driver stops sooner if he gets the target income more quickly; furthermore, earning less than the target shows more effect than the same amount of earning more than the same target.

Loss aversion is often employed in finance and behavioral economics. For example, Benartzi and Thaler (1995) apply loss aversion to explain the equity premium puzzle. They focus on a certain assets market and claim that a reasonable loss aversion degree generates the equity premium if agents check their account once a year. Ang, Chen and Xing (2006) show that agents who place greater weight on downside risk, indicating loss aversion in individual investors. O'Connell and Teo (2009) recover that large institutional investors exhibit loss aversion by matching investment behaviors with prospect theory.

Macroeconomic researches still rarely adopt loss aversion. A model without loss aversion may misunderstand agents' behaviors and lead to an inefficient policy. So I ask whether a model with loss aversion behaves differently in the competitive equilibrium. I also investigate the efficiency of competitive equilibrium and derive Ramsey fiscal policy.

I characterize the competitive equilibrium in the well-studied real business cycle framework incorporating a preference component which features loss aversion. Then I construct a social planner's problem in which the planner has the same preferences with the household but endogenizes the prices. The social optimum differs from the competitive equilibrium as long as the agent is loss averse. The

[1] Such an example can be found in Kahneman and Tversky (1979)

first welfare theorem fails because the atomistic household does not consider the general equilibrium effect through asset prices.

I carry on a quantitative analysis. I document the dynamics of the model and plot long-run means as a function of loss aversion parameters. The numerical result shows that an increase in either loss aversion parameter provokes a drop in capital stock, output and consumption. Given asset prices, a larger impact from loss causes the household to invest less on capital. Then less capital input results in less output and consumption.

I wonder whether the policy intervention can correct the inefficiency in competitive equilibrium. I add into the model a government sector which finances its spending by a lump-sum tax and distortionary capital income tax and explore the Ramsey fiscal policy. Judd (1985) and Chamley (1986) demonstrate that the optimal capital income tax rate tends to zero in the long run, which has been confirmed aslo when relaxing a number of assumptions. Chari, Christiano and Kehoe (1994) study the optimal policy in the business cycle quantitatively and show that the long-run mean of capital tax rate is close to zero even with a relatively high risk aversion. In my model, the Ramsey policy requires a proportional capital income subsidy (negative tax rate) which encourages the household to invest on capital. Simultaneously, the government should levy a higher lump-sum tax to offset the larger expenditure. The impulse response to a negative productivity shock generates two different qualitative behaviors of policy instruments. Without loss aversion, both the capital income tax rate and the lump-sum tax remain constant after the shock. With loss aversion, they move dramatically in an opposite direction: the tax rate increases while the lump-sum tax drops.

This paper is in line with a great literature of business cycle and policy analysis, especially works on fiscal policies in the business cycle. In addition to what I have mentioned above, for example, Aiyagari and McGrattan (1998) study the optimum quantity of debt based on a model of a large number of infinitely-lived households whose saving behavior is influenced by precautionary saving motives and borrowing constraints. They find that the welfare gains from reaching the optimum level of debt are small. Schmitt-Grohé and Uribe (2004a), Schmitt-Grohé and Uribe (2004b), Chugh (2006) and Arseneau and Chugh (2012) address the optimal policy issues by considering imperfect competition, sticky prices, sticky wages and sticky prices together, and frictional labor markets in the cycle, respectively. Nevertheless, none of them incorporate exotic preferences.

This paper belongs to macroeconomic studies that use exotic preferences in a business cycle model. Angeletos and Calvet (2006) and Angeletos (2007) both apply Epstein-Zin preferences to see the effect of idiosyncratic production risk on the business cycle and growth. Epstein-Zin preferences, by differentiating the elasticity of intertemporal substituion from risk aversion, help to figure out that the underlying factor lies in the elasticity of intertemporal substitution. Croce et al (2012) investigates the optimal fiscal policies which function through the channel of asset prices. They also use Epstein-Zin preferences to generate a realistic equity premium. Chugh (2007) derives Ramsey fiscal and monetary policies with habit formation. Habit persistence partly predicts highly persistent inflation. But above researches never apply loss aversion preferences: asymmetric in gains and losses and discontinuous at the reference point, which differ from Epstein-Zin preferences.

The closest studies to my paper are from a growing literature that uses loss aversion in the general equilibrium. Barberis, Huang and Santos (2001) study asset pricing considering loss aversion in financial wealth and discover that their framework can explain the high mean, excess volatility and predictability of stock returns. Barberis and Huang (2001), and Berkelaar and Kouwenberg (2009) explore equilibrium firm-level stock returns with loss aversion in two different economies. Andries (2012) and Pagel (2013a) readdress asset pricing with loss aversion. Pagel (2013b) uses the expectation-based reference-dependent preference featuring in loss aversion to explain empirical observations about life-cycle consumption. Ahrens, Pirschel and Snower (2014) develop a theory under loss aversion which successfully explains why prices are more sluggish upwards than downwards in response to temporary demand shocks, while they are more sluggish downwards than upwards in response to permanent demand shocks as the empirical evidence uncovers. Lepetyuk and Stoltenberg (2014) reconcile the changes in consumption inequality in the data in response to the increase in income inequality with loss aversion preference. Yet none of these papers construct models in a production economy; in addition, government policies are not involved in these settings. Thus I consider that this paper is a novel attempt in the theoretical aspect.

The paper is organized as follows. I develop a private economy model with loss aversion in Section 2 and determine the competitive equilibrium. I construct a social planner's problem to study the efficiency of equilibrium. I also uncover the steady state of this economy. Section 3 is devoted to the numerical analysis. Section 4 formulates a model with a government and obtains the Ramsey policy. I derive the optimal policy both in the long run and in the impulse response. Section 5 concludes.

2 A Model with Loss Aversion

This section presents a real business cycle model with preferences encompassing consumption and utility from shifts in asset returns. The latter features loss aversion. I first figure out the effect of loss aversion on individual consumption and investment behavior. To model the investment choice of a loss averse household, two assets are traded in investment markets: one is risky while the other is riskfree. I characterize the competitive equilibrium and prove that loss aversion induces inefficiency of equilibrium. I then derive that loss aversion does not affect the deterministic steady state.

2.1 Economy

The economy is populated by an infinitely-lived representative household who is endowed with one unit of time in each period. The household maximizes expected lifetime utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t,\ \beta \in (0,1). \tag{1}$$

A representative firm produces a single consumption good with labor n_t and capital k_t. The household consumes or augments the capital stock subject to the total output Y_t. The feasibility constraint is

$$c_t + k_{t+1} = Y_t + (1-\delta)k_t, \tag{2}$$

where $\delta \in (0,1)$ is the depreciation rate.

I assume that the production function $Y_t = Z_t F(k_t, n_t)$ has constant returns to scale and that it is increasing and concave in each argument. Exogenous aggregate productivity Z_t follows an AR(1) process,

$$\ln Z_{t+1} = \rho_z \ln Z_t + \sigma_{\epsilon^z} \epsilon^z_{t+1}, \tag{3}$$

where ρ_z denotes the autoregressive parameter for the moving process of productivity, σ_{ϵ^z} represents the standard deviation of one-time technological innovation and the innovation ϵ^z_{t+1} is independently distributed as a standard normal for any $t \geq 0$.

Product and factor markets are assumed to be competitive.

2.2 Firm

The firm takes as given the wage rate w_t and the rental rate r_t, rents labor and capital from the household, produces final consumption goods and maximizes its profit,

$$\Pi_t = Z_t F(k_t, n_t) - r_t k_t - w_t n_{t.} \tag{4}$$

2.3 Household

The representative household is endowed with some initial capital k_0. At period t, the household receives income from labor supply, capital rental and non-state-contingent private bonds traded among individuals, and then determines the amount of consumption, labor provided, capital accumulation and the purchase of next period's individual assets by maximizing (1) subject to the following sequence of budget constraints and nonnegativity constraints:

$$c_t + k_{t+1} + a_{t+1} = w_t n_t + r_t k_t + (1-\delta) k_t + R^f_t a_t, \tag{5}$$

$$c_t \geq 0,\ k_t \geq 0,\ 0 \leq n_t \leq 1. \tag{6}$$

R^f_t is the gross return of private bonds from $t-1$ to t, depending only on the state at $t-1$, so that individual assets are riskfree. The uncertainty of the return from capital rental arises from unknown productivity shocks. To summarize, when the household makes investment decisions, she takes risks if she augments capital stock while avoids risks if purchasing bonds.

2.4 Preference Specification

As the main feature of this paper, I assume that the household enhances her utility level, in addition to consumption, if she gains in investment. It implies that the household cares about fluctuations in investment markets independent of total wealth. It reflects the observation that individuals in reality feel excited when they succeed in the capital market. Mathematically, I express the instantaneous utility at t consisting of consumption at the current period, c_t and expected gain from capital investment next period with respect to a reference point defined later, X_{t+1} as

$$U_t = u(c_t) + \eta\beta E_t v(X_{t+1}),$$

where u is strictly increasing, concave and two times continuously differentiable in c, and v reflects loss aversion utility. η represents the relative weight on the utility from expected gain compared to consumption. The preference returns to the standard model merely containing consumption when $\eta = 0$. I formulate preferences over consumption and expected gain of capital investment in the spirit of Barberis, Huang and Santos (2001), whose preference specification consists of two additively separable terms: utilities from consumption and expected one-period-after fluctuations in financial asset values. I also consider the scenario when the agent obtains the loss aversion utility from realized gain, that is, $\eta v(X_t)$. The corresponding first order conditions show that the timing alternative does not affect savings decisions.

In particular,

$$v(X_{t+1}) = \begin{cases} X_{t+1}, & \text{if } X_{t+1} \geq 0; \\ \lambda X_{t+1}, & \text{if } X_{t+1} < 0. \end{cases}$$

The parameter λ denotes the loss aversion degree and it is assumed to be strictly larger than 1, indicating that a certain amount of loss impacts greater in absolute values than the same amount of gain. The functional form of v, a linear function with a kink, is a simplification from the literature of prospect theory. Kahneman and Tversky (1992) suggest the utility function over gains and losses:

$$\tilde{v}(X) = \begin{cases} X^{\gamma}, & \text{if } X_{t+1} \geq 0; \\ -\lambda(-X)^{\gamma}, & \text{if } X_{t+1} < 0. \end{cases}$$

Yet it only improves the quantitative behavior with prospects of only gains or only losses. Loss aversion remains as long as the link exists. For simplicity, I assume a linear form. In addition, I filter out some other distinctive features of prospect theory since I only focus on loss aversion in the production economy. To summarize, my use of $v(X)$ captures a central idea of prospect theory by Kahneman and Tversky (1979) that people care about changes in financial wealth and that they are loss averse over these changes. Some recent studies such as Pagel (2013a, 2013b) model loss aversion with the expected consumption as the reference point. I argue that this modeling way has modified the original prospect theory. My paper still targets on financial wealth instead of consumption in the preference component of loss aversion.

I define the gross returns of capital rental as $R_t^k = r_t + 1 - \delta$. In this paper, X_{t+1} is assumed to have the form:

$$X_{t+1} = k_{t+1} R_{t+1}^k - k_{t+1} R_{t+1}^f.$$

At $t+1$, the household receives $k_{t+1} R_{t+1}^k$ from the investment on risky assets. In fact, $k_{t+1} R_{t+1}^k$ is also the total financial wealth in equilibrium. I use the gross return of private bonds as the reference point for the household. $k_{t+1}R^f_{t+1}$ is the opportunity cost of investment in risky assets: suppose that an agent has already invested k_{t+1} on risky assets and expects to earn $k_{t+1}R^k_{t+1}$, yet she would get $k_{t+1}R^f_{t+1}$ if investing on bonds. Then if $R^k_{t+1} > R^f_{t+1}$, it is defined as a gain; if $R^k_{t+1} < R^f_{t+1}$, a loss. Denote $D_{t+1} = R^k_{t+1} - R^f_{t+1}$ as the equity premium, so I can interprete X_{t+1} as a product of equity premium and capital stock and rewrite $X_{t+1} = D_{t+1} \cdot k_{t+1}$. Then $v(X_{t+1}) = v(D_{t+1}) \cdot k_{t+1}$ as the result of linear transformation. At t, the agent only has one unknown, $t+1$'s productivity Z_{t+1}. Since the distribution of innovation is common knowledge, the agent computes the next period's expected gain conditional on current information.[2]

Since my paper concentrates on how loss aversion influences savings and adjustment of capital income taxation, I simplify the model by an exogenous labor supply in equilibrium. I choose incomplete markets because of several reasons. First, the reference point of loss aversion utility may be unclear in complete markets. An investor could consider various measurements as the psychological benchmark of gain. Second, incomplete markets better mirror the real world.

2.5 Competitive Equilibrium Characterization

In equilibrium labor $n_t = 1$. The production function becomes

$$Y_t = Z_t f(k_t). \tag{7}$$

Factor prices are determined by solving the representative firm's problem.

$$r_t = Z_t f_k(k_t), \tag{8}$$

$$w_t = (1-\alpha) Z_t f(k_t). \tag{9}$$

The representative household holds zero bond stock in equilibrium, thus the household budget constraint becomes:

$$c_t + k_{t+1} = w_t n_t + r_t k_t + (1-\delta) k_t, \tag{10}$$

Following Euler equations characterize the competitive equilibrium:

$$u'(c_t) = \beta E_t[R^k_{t+1} u'(c_{t+1})] + \eta \beta E_t v(D_{t+1}), \tag{11}$$

[2]Take a simple example: the agent knows that at t, the bond is sold at \$0.9; from today's high productivity and the distribution of its evolution process, she calculates that next period the gross return of risky assets will reach \$1.3 with a probability of 80% while may decline to \$0.7 otherwise. Then the total after-one-period expected gain net of the opportunity cost equals to $\$(0.32 - 0.04\lambda)$.

$$u'(c_t) = \beta R^f_{t+1} E_t[u'(c_{t+1})], \tag{12}$$

together with output and prices expressions (7)-(9), the household budget constraint (10), the feasibility condition (2) and the autoregression of technology shocks (3).

2.6 Inefficiency of Competitive Equilibrium

This subsection discusses efficiency. I first construct a social planner's problem to compare the solutions to the household's problem and the planner's. Since these two solutions are different in the case of loss aversion, I state that competitive equilibrium is inefficient when agents are loss averse. At last I explain the intuition.

In line with Bianchi and Mendoza (2013), I consider a constrained-efficient social planner who assigns capital stock for the representative agent facing identical preferences and lacking the ability to commit to future policies. The key issue in constructing the social planner's problem is how to determine the asset prices because they appear in the utility function. I assume that the prices are decided in a competitive market, thus the planner can only internalize how capital accumulation affects prices instead of directly choosing them.

The planner transfers $T_t = R^k_t k_t - k_{t+1}$ to the household after choosing the amount of next period's capital stock. The household now only decides consumption, labor supply and riskfree asset holdings given the transfer.

Problem 1. (Household's Problem in Constrained-Efficient Equilibrium)

$$\max_{\{c_t, n_t, a_{t+1}\}_{t\geq 0}} E_0 \sum_{t=0}^{\infty} \beta^t \{u(c_t) + \eta\beta v(k_{t+1}R^k_{t+1} - k_{t+1}R^f_{t+1})\}$$

$$s.t. \quad c_t + a_{t+1} = w_t n_t + R^f_t a_t + T_t$$

The household chooses labor supply $n_t = 1$, $\forall t \geq 0$ and zero bond holdings $a_{t+1} = 0$, $\forall t \geq 0$. The intertemporal condition with respect to bonds is as Equation (12) shows

$$u'(c_t) = \beta R^f_{t+1} E_t[u'(c_{t+1})].$$

The planner's problem takes it as an implementability constraint. The planner's policy connects with asset prices by this constraint because what the planner determines would affect the future consumption and today's asset prices.

I formulate an optimal macroprudential policy as a time-consistent problem of the planner and set Markov stationary policy rules - consumption c_t, capital stock k_{t+1} and the gross return of bonds R^f_{t+1}- as functions of state variables (k_t, Z_t). The planner who lacks the ability to commit to future policies will choose the present policy rules taking as given the policy rules which represent the future planner's decisions. I characterize a Markov perfect equilibrium by a fixed point at which the policy rules of future planners that the current planner takes as given to solve its optimization problem match the policy rules that the current planner finds optimal to choose. Hence, these rules are time-consistent since the planner does not have the incentive to deviate from other planners' policy rules.

Specifically, I denote $k_{t+2}(k_{t+1}, Z_{t+1})$ the policy rule for capital accumulation chosen by the future planner that the current planner takes as given. From the feasibility condition,

$$c_t(k_t, Z_t) = Z_t f(k_t) + (1-\delta)k_t - k_{t+1}(k_t, Z_t).$$

The implementability constraint derives

$$R^f_{t+1}(k_t, Z_t) = \frac{u'(Z_t f(k_t) + (1-\delta)k_t - k_{t+1}(k_t, Z_t))}{\beta E_t[u'(Z_{t+1} f(k_{t+1}) + (1-\delta)k_{t+1} - k_{t+2}(k_{t+1}, Z_{t+1}))]}.$$

A higher level of capital stock at $t+1$ will push up the gross return according to the assumption of function u.

Problem 2. (Planner's Problem) Given the policy rule of the future planner $k_{t+2}(k_{t+1}, Z_{t+1})$, the planner's problem is characterized by

$$\max_{\{c_t, k_{t+1}, R^f_{t+1}\}_{t\geq 0}} E_0 \sum_{t=0}^{\infty} \beta^t \{u(c_t) + \eta\beta v(k_{t+1}(Z_{t+1} f_k(k_{t+1}) + 1 - \delta) - k_{t+1} R^f_{t+1})\}$$

$$s.t. \quad c_t + k_{t+1} = Z_t f(k_t) + (1-\delta)k_t,$$

$$u'(c_t) = \beta R^f_{t+1} E_t[u'(Z_{t+1} f(k_{t+1}) + (1-\delta)k_{t+1} - k_{t+2}(k_{t+1}, Z_{t+1}))].$$

The planner chooses policy rules to maximize the same household's lifetime utility as in the household problem with two constraints. The feasibility condition generalizes the household budget constraint, factor prices and market clearing evaluated at equilibrium. The implementability constraint states that the policy rules must be consistent with the optimality condition in the riskfree asset market. I put μ_t and ξ_t in front of these two constraints, respectively.

Solving the planner's problem gives us following equations:

$$\{c_t\}: \quad \mu_t = u'(c_t) - \xi_t u"(c_t); \tag{13}$$

$$\begin{aligned} \{k_{t+1}\}: \quad u'(c_t) = {} & \beta E_t[R^k_{t+1} u'(c_{t+1}) - \xi_{t+1} R^k_{t+1} u"(c_{t+1})] \\ & + \eta\beta E_t[v(D_{t+1}) + Z_{t+1} k_{t+1} v'_{t+1} f_{kk}(k_{t+1})] \\ & + \beta \xi_t R^f_{t+1} E_t[R^k_{t+1} u"(c_{t+1})] + \xi_t u"(c_t) \qquad ; \end{aligned} \tag{14}$$

$$\{R^f_{t+1}\}: \quad \xi_t = \frac{\eta E_t[v'_{t+1}]}{E_t[u'(c_{t+1})]}. \tag{15}$$

I define R^k_{t+1}as the same way as in the competitive equilibrium, $R^k_{t+1} = Z_{t+1} f_k(k_{t+1}) + 1 - \delta$. v'_{t+1} denotes the derivative of the function v with respect to its argument, the equity premium at period $t+1$, thus it is positive because in either the gain region or the loss region, an increase in the equity premium raises the utility. I further denote $E_t[v'_{t+1}]$ as the conditional expectation of such a derivative weighted by the probability of gain and loss. Hence the value must between 1 and λ.

Now I show the difference between the competitive equilibrium and the social optimum by comparing the first-order conditions. First notice that the planner improves the social welfare from relaxing the implementability constraint if and only if loss aversion shows up in the preferences, $\eta > 0$. If agents are not loss averse as in the standard model, ξ_t always equals 0 from Equation (15). Then the solutions to the household's and planner's problems coincide, manifesting that the competitive equilibrium is efficient in the case of no loss aversion.

Equation (13) states that with loss aversion the shadow value of wealth equals the effect by which an increase in consumption relaxes the implementability constraint besides the marginal utility of consumption. On the contrary, the household would instead only equate the shadow value of wealth and the marginal utility of consumption.

Equation (14) and Equation (11) differ in three dimensions. First, the second term shows that planner attaches a higher social marginal cost of increasing capital other than $\beta E_t[R^k_{t+1} u'(c_{t+1})]$ in the non-loss-aversion case since now an increase in capital will tighten the implementability constraint, which lowers the welfare. Second, the fourth term tells us that with loss aversion, although the planner withholds the fear of potential loss as the household, an increase in capital will lower the marginal cost of saving through the channel of interest rate. Third, additional dynamic effect from current saving choices results from the forward looking nature of asset prices. Because of its inability to commit, the planner influences future marginal utilities by changing the endogenous state variable of the next period's planner, as reflected in the fifth term.

In general, the total effect of loss aversion on social optimum is ambiguous. Nonetheless, it is different from the competitive equilibrium because it cannot be completely balanced out at every period, which can be seen from different Ramsey policies in Section 4. Hence I obtain the follow result:

Proposition 1. *Competitive equilibrium is inefficient when agents are loss averse.*

I describe the intuition as follows. The inefficient competitive equilibrium lies in the atomistic household who does not internalize the prices. She only optimizes her own allocations regardless of the effect of her action on the whole economy through the channel of prices. It has a similar characteristic and explanation with the pecuniary externality discussed a lot in the literature of financial frictions. However, the externality in my model does not come from any friction. In a standard model, the competitive equilibrium without any friction can reach social efficiency since standard preferences only include allocations, say, consumption and leisure. In my model, loss averse agents directly acquire utility from the gap of prices between risky and riskfree assets. The first welfare theorem may fail even if I relax the assumption of linear form of loss aversion utility $v(X_{t+1})$, the product form of X_{t+1} or even loss aversion itself.

2.7 Steady State

This subsection briefly discusses the effect of loss aversion on agents' decisions at the deterministic steady state. It shows that consumption and savings choices in a loss aversion environment are the same as the case without loss aversion.

Proposition 2. *At the deterministic steady state of the competitive equilibrium, with and without loss aversion the representative household determine the same consumption and investment allocations.*

The intuition is as follows. I formulate loss aversion in an intertemporal environment based on uncertainty. The deterministic steady state rules out unpredictable shocks on future productivity. The household no longer loses so loss aversion disappears. Equation (11) does not contain the second expectation term regarding loss aversion.

3 Dynamics

I have uncovered the unchanged deterministic steady state result with loss aversion incorporated. Nonetheless, the steady state value fails to represent the optimal choices in a loss aversion economy I intend to study in that the pure deterministic steady state loses the feature of loss aversion by the argument from above. So I document by means of simulated variables instead after solving the model numerically in the real business cycle model. This section describes what functional forms I employ and how I calibrate the model. Then it presents dynamic results.

3.1 Functional Form Assumptions

I assume the consumption preference as a standard CRRA function, $u(c_t) = \frac{c_t^{1-\theta}}{1-\theta}$, where θ determines the degree of risk aversion and $\theta > 0$. The production function is Cobb-Douglas production function, $Y_t = Z_t k_t^{\alpha} n_t^{1-\alpha}$, where α denotes the capital's share of output and $\alpha \in (0, 1)$.

Rewriting the gross return of capital accumulation R_t^k with (8) in the specified form, $R_t^k = r_t + 1 - \delta = \alpha Z_t k_t^{\alpha-1} + 1 - \delta$. By construction, only Z_{t+1} remains unknown at period t. Then if we focus on the utility from gain, the individual is indifferent from investing in risky and riskfree assets when the realized value of Z_{t+1}, denoted by z_{t+1}, equals to $z_{t+1}^{idf} = \frac{R_{t+1}^f - 1 + \delta}{\alpha k_{t+1}^{\alpha-1}}$, the solution to the equation $R_{t+1}^k = R_{t+1}^f$. z_{t+1}^{idf} will be larger if the agent accumulates more capital. Only if the realization of next period's productivity surpasses this cutoff can the agent gain from her investment. Thus, a large cutoff squeezes the gain possibility, bringing about pessimistic beliefs about the expected payoff. It implies that more capital investment leads to more psychological disutility given the same expected productivity.

With the above analysis, I rewrite the expected utility from next period's investment gain conditional on t's information as

$$E_t v(X_{t+1}) = k_{t+1} E_t v(D_{t+1}) = k_{t+1} [\int_0^{z_{t+1}^{idf}} \lambda (R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) + \int_{z_{t+1}^{idf}}^{\infty} (R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1})],$$

where $\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1})$ is the conditional cumulative distribution function of the shock Z_{t+1} in period t. Simply put, I separate gain from loss and calculate each conditional expectation. The formulation is motivated by Köszegi and Rabin (2009), where the reference point of unknown future consumption is defined as continually updated conditional expectations of future consumption in a dynamic environment. Hence this modeling way can be viewed as a special case of their more general setting, in the sense that at a certain period, the reference point is fixed according to the history up to that period with only productivity unsure, while their model embraces both uncertain realizations and uncertain reference points.

Given the stochastic process of productivity, I simplify the expression of $E_t v(D_{t+1})$ in a fashion of certainty equivalence in the appendix. I record the result here:

$$E_t v(D_{t+1}) = (1-\delta-R^f_{t+1})[1+(\lambda-1)\Phi\left(\frac{lnz^{idf}_{t+1} - \rho lnz_t}{\sigma_\epsilon}\right)]+\alpha k^{\alpha-1}_{t+1} z^\rho_t e^{\frac{\sigma^2_\epsilon}{2}}[1+(\lambda-1)\Phi\left(\frac{lnz^{idf}_{t+1} - (\rho lnz_t + \sigma^2_\epsilon)}{\sigma_\epsilon}\right)],$$

where $\Phi(\cdot)$ represents the cumulative distribution function of standard normal distribution. Technically speaking, to compute the conditional expectation avoids the discussion of kinks around the reference point so that it facilitates further analysis.

3.2 Parameter Values

Most of the parameter values that I use are in line with yearly data of the United States or other estimates in the literature. I set capital share of income $\alpha = 0.32$. My selection of δ is 0.1, which is in accordance to the annual depreciation rate.

Furthermore, the discount factor β is calibrated to be 0.98 so that in a non-loss-aversion economy, given the above parameters, the ratio of capital over output is roughly 2.7 at the deterministic steady state. I keep the discount factor unchanged when I introduce loss aversion in the model since loss aversion plays no role at the steady state.

The risk aversion degree θ is set to be 6 to generate a relatively high equity premium in the simulation. Note that the equity premium generated from the US data is 6 percentage points which only high risk aversion degree could get the same result in the business cycle framework.

I assume that the autoregressive parameter for the technology shock ρ_z and the standard deviation for innovations σ_{ϵ^z} are 0.81 and 0.04, respectively, in keeping with the real business cycle literature.

Experiments report that the relative weight η is nearly 1 and some applications I know also take 1 as a reasonable parameter value or as the upper bound of a series of values. Researches document that the loss aversion degree λ varies between 2 and 3, most of which are approximately 2.5. So I set baseline values of two parameters as 1 and 2.5. My exercise aims to understand the effect of loss aversion on the business cycle, so I play loss aversion parameters. I first stablize the loss aversion degree λ equal to 2.5 and change the relative weight η from 0 to 1 with an interval of 0.1 to see how more emphasis on investment fluctuations impacts the behavior. I then fix η as 1 and change λ from 2 to 3 with an interval of 0.1 to see the influence of greater loss aversion.

Table 1 summarizes the parameter values in the economy.

3.3 Results

Figure 1 presents my first numerical result. The means of all allocations decrease with the relative weight η and loss aversion degree λ though the scale is small. Supposing that good and bad shocks hit the economy symmetrically, loss aversion provokes a negative summed utility of accumulating capital over the whole business cycle given a positive relative weight. An increase in either of these two parameter values enlarges the gap of the absolute utility from losses and gains, which discourages the household to invest on capital stock, resulting in less output and henceforth less consumption.

Table 1: Parameter values for model without government

Parameter Name	Value	Description
α	0.32	capital share
β	0.98	discounted rate
θ	6	risk aversion degree
δ	0.1	annual depreciation rate
ρ_z	0.81	persistence of productivity
σ_{ϵ^z}	0.04	standard deviation of innovation on productivity
λ	2.5	baseline loss aversion degree
η	1	baseline relative weight of psychological utility over consumption

λ and η are varied from 2 to 3, and from 0 to 1, respectively with the interval of 0.1.

Note that average expected psychological utility from risky assets, $E_t(v(D_{t+1}))$, unlike the equity premium $R_t^k - R_t^f$, is ex ante. A larger effect of loss determines the negative sign. The positive mean of the equity premium originates from a lower capital stock which pushes up the capital return. Both a greater relative weight and loss aversion degree, followed by even less capital, lead to a higher equity premium. Average expected psychological utility gets less negative when the relative weight η gets larger while it decreases when loss aversion degree λ becomes larger. The difference derives from the fact that a higher loss aversion degree aggravates the domination of loss over gain, whose effect surpasses the improvement from the price gap. The numerical values of equity premium in all cases appear small because of a small volatility of interest rates in the business cycle framework. But I stick to real business cycle framework since it is easy to understand the mechanism of my new element.

I conclude that the stronger fear of loss on risky assets contributes to less investment. It has two welfare effects: first, less investment guarantees a smaller amount of loss in a bad situation; second, less capital lowers next period's output and consumption. The last effect dominates the former in this simple neoclassical growth framework, pulling down the welfare.

I have obtained the second-order moments results. However, they are quantitatively negligible, thus I choose not to report the results and not to further explore the mechanism.

4 Government Intervention

Inefficiency of competitive equilibrium due to loss aversion implies that the private economy accumulates less capital than what the first-best requires. It poses the questions of whether the government should intervene and how. This section answers these questions by adding a government sector to the model with loss aversion and exploring a Ramsey problem. In this section I describe the model directly with the functional forms used in Section 3 to uncover the Ramsey allocations in the business cycle by quantitative analysis.

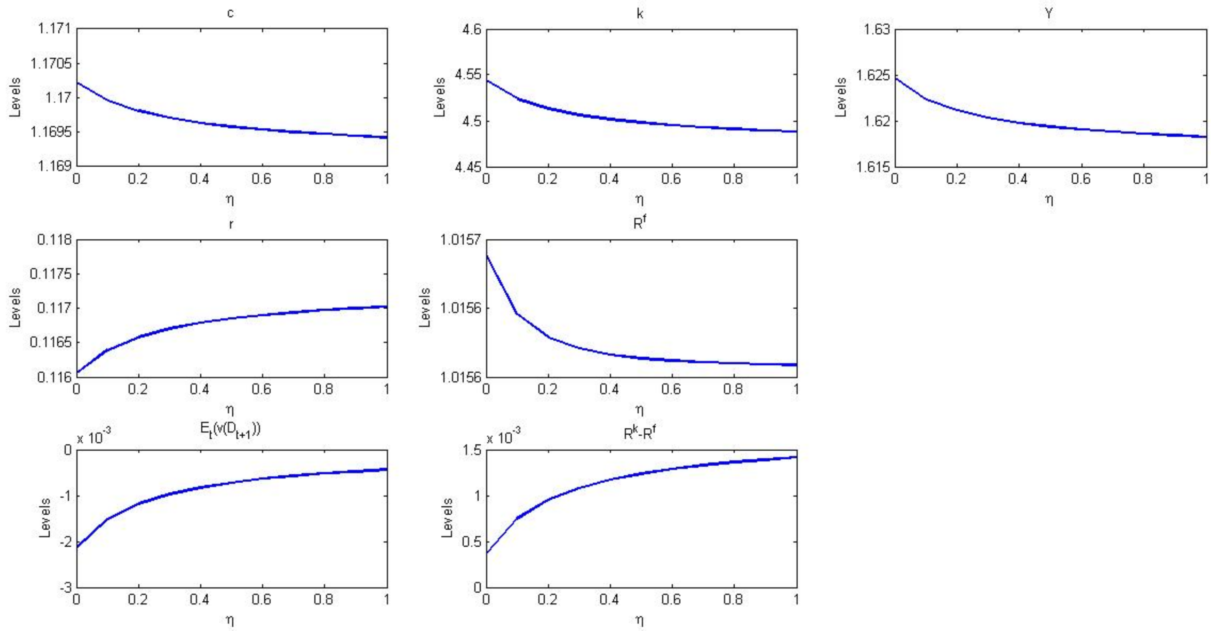


Figure 1 (a): Means with Relative Weight

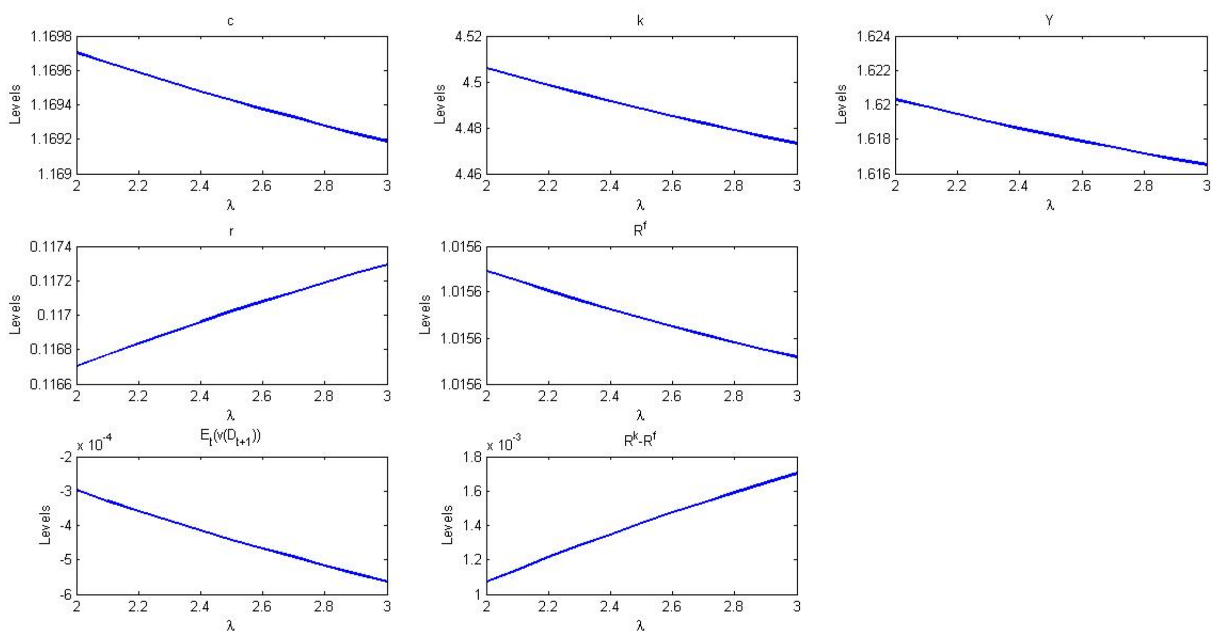


Figure 1 (b): Means with Loss Aversion Degree

c, k, Y, r, R^f, $E_t(v(D_{t+1}))$, $R^k - R^f$ denote consumption, capital stock, output, interest rate of capital rental, gross return of riskfree bonds, expected psychological utility and ex-post equity premium, respectively.

4.1 Economy

With the government in the economy the feasibility condition of this economy becomes

$$c_t + g_t + k_{t+1} = Y_t + (1-\delta)k_t, \tag{16}$$

where $\{g_t\}_{t=0}^{\infty}$ represents a sequence of government purchases.

Government consumption is modelled as an exogenous AR(1) process,

$$\ln g_{t+1} = (1-\rho_g)\ln \bar{g} + \rho_g \ln g_t + \sigma_{\epsilon^g}\epsilon_{t+1}^g, \tag{17}$$

where ρ_g denotes the autoregressive parameter for government consumption evolution, σ_{ϵ^g} represents the standard deviation of one-time innovation on government spending and ϵ_{t+1}^g is distributed as an independent standard normal, that is, $\epsilon_{t+1}^g \sim N(0,1)$ for any $t \geq 0$. $\bar{g}$ captures the average level of government consumption.

4.2 Government

A natural guess for the optimal policy is that the government promotes capital accumulation by a subsidy which aims to improve the net revenue from capital. I model it as follows: the government finances its expenditure by levying distortionary taxes on earnings from capital at rate τ_t^k and a lump-sum tax T_t; if a negative τ_t^k appears, it refers to the proportional subsidy from the government to the private sector. I assume that the tax rate τ_t^k is predetermined according to the information updated until period $t-1$, which implies that tax policies are non-state-contingent. This assumption reflects the norm of fiscal policies: policymakers usually propose and decide a taxation policy before the policy enters into force. The non-state-contingent tax rate makes it possible to derive a simple form z_{t+1}^{idf} necessary in the quantitative analysis. The lump-sum tax is state-contigent to support the Ramsey allocation. I further assume that the government does not hold any debt since the lump-sum tax is available. Then the government budget constraint is

$$T_t + \tau_t^k r_t k_t = g_t. \tag{18}$$

4.3 Household

At period t, the household receives the income from labor supply, capital rental and interest of private bonds, learns the news of next period's taxation proposal and then determines the amount of consumption, labor provided, capital accumulation and the purchase of next period's bonds. The representative household compares the expected gross returns of two assets in the fashion described in the last section except that the household considers the gross return of risky assets net of capital taxation, $R_t^k = (1-\tau_t^k)r_t + 1 - \delta$. The productivity indifference level to invest on risky and riskfree assets $z_{t+1}^{idf} = \frac{R_{t+1}^f - 1 + \delta}{(1-\tau_{t+1}^k)\alpha k_{t+1}^{\alpha-1}}$. Providing that the government imposes a high tax on capital income, the value of z_{t+1}^{idf} will be large. Hence, a higher capital tax rate not only undermines the desire of accumulating capital, but also directly heightens the expectation of losses.

With government, the household budget constraint becomes

$$c_t + k_{t+1} + a_{t+1} = w_t n_t + (1 - \tau_t^k) r_t k_t + (1 - \delta) k_t + R_t^f a_t - T_t. \tag{19}$$

4.4 Competitive Equilibrium Conditions

The production function remains the same as (7) and so do the factor prices as (8) and (9). I rewrite the expected equity premium $E_t v(D_{t+1})$ given the tax rate,

$$E_t v(D_{t+1}) = (1-\delta-R_{t+1}^f)[1+(\lambda-1)\Phi\left(\frac{lnz_{t+1}^{idf} - \rho lnz_t}{\sigma_\epsilon}\right)]+(1-\tau_{t+1}^k)\alpha k_{t+1}^{\alpha-1} z_t^\rho e^{\frac{\sigma_\epsilon^2}{2}}[1+(\lambda-1)\Phi\left(\frac{lnz_{t+1}^{idf} - (\rho lnz_t + \sigma_\epsilon^2)}{\sigma_\epsilon}\right)].$$

Euler equations show the same forms as (11) and (12).

4.5 Ramsey Problem

This subsection sets up the Ramsey problem, presents quantitative dynamics of the optimal policy and derives the impulse responses to a productivity shock.

4.5.1 Formulation of Ramsey Problem

I first clarify the timing of fiscal polices in this Ramsey problem. At Time 0, the government sets fiscal policies of every period from Time 1 onwards. Particularly, the capital income tax rate of $t+1$ depends on the state of t, which is different from the normal setting in the Ramsey literature. For example, the usual formulation requires that the government should announce at 0 to levy a high tax when the present productivity is high; the government in my model, instead, claims to tax much when the productivity of last period appears high, even if the current productivity ends up with a low level. I formulate the Ramsey problem as follows:

$$\begin{aligned}\max_{c_{t+1},k_{t+1},\tau_{t+1}^k,T_{t+1},g_t} \quad & E_0 \sum_{t=0}^{\infty} \beta^t \{ \tfrac{c_t^{1-\theta}}{1-\theta} + \eta\beta k_{t+1} E_t v(D_{t+1}) + \\ & +\psi_t [T_t + \tau_t^k r_t k_t - g_t] + \\ & +\theta_t [z_t k_t^\alpha + (1-\delta) k_t - c_t - g_t - k_{t+1}] + \\ & +\mu_t [c_t^{-\theta} - \beta R_{t+1}^k c_{t+1}^{-\theta} - \eta\beta E_t v(D_{t+1})] + \\ & +\xi_t (c_t^{-\theta} - \beta R_{t+1}^f c_{t+1}^{-\theta}) \} \quad .\end{aligned} \tag{20}$$

given

$$\log z_{t+1} = \rho \log z_t + \sigma_\epsilon \epsilon_{t+1}.$$

4.5.2 Parameter values

$\bar{g}$ is chosen to be 0.29 so that the government spending accounts for roughly 18% of output in the steady state of Ramsey allocations in line with the US observation. I set $\rho_g = 0.89$ and $\sigma_{\epsilon^g} = 0.07$ as Chari, Christiano and Kehoe (1994) do. I summarize the parameters for the government sector in Table 2.

Table 2: Parameter values for government sector.

Parameter Name	Value	Description
$\bar{g}$	0.29	average government consumption
ρ_g	0.89	persistence of government consumption
σ_{ϵ^g}	0.07	standard deviation of innovation on government spending

Other parameter values are kept the same as Section 3. I use the baseline values 1 for the relative weight η and 2.5 for the loss aversion degree.

4.5.3 Quantitative results

Table 3: Moments results.

Variable	Means	Std. Dev.	Auto corr	Corr(x,Y)	Corr(x,g)	Corr(x,z)
$\eta = 0$						
Consumption	0.88	0.07	0.97	0.92	-0.37	0.59
Capital	4.75	0.83	0.99	0.78	-0.17	0.31
Output	1.65	0.17	0.92	1	-0.10	0.83
Interest rate	0.11	0.02	0.93	-0.35	0.17	0.22
Bond gross return	1.01	0.01	0.96	-0.52	0.21	0.03
Capital income tax rate	-0.38	0.00	0.39	-0.01	0.07	-0.21
Lump-sum tax	0.29	0.04	0.88	-0.10	1.00	0.00
$\eta = 1$						
Consumption	0.89	0.06	0.97	0.92	-0.38	0.59
Capital	5.26	0.95	1.00	0.79	-0.14	0.25
Output	1.71	0.18	0.92	1	-0.09	0.78
Interest rate	0.10	0.02	0.94	-0.42	0.13	0.22
Bond gross return	1.01	0.02	0.77	-0.14	0.21	0.37
Capital income tax rate	-8.25	13.85	0.73	-0.38	-0.10	-0.40
Lump-sum tax	0.34	0.09	0.78	0.28	0.58	0.33

The rows of capital income tax rate are measured in percentage points while others are in levels.

I report the Ramsey dynamics and compare the statistics in a non-loss-aversion and loss-aversion economy in Table 3. I compute all the quantitative results by the second-order approximation method. I approximate the model in levels around the non-stochastic Ramsey steady state described by Schmitt-Grohé and Uribe (2012)[3]. I assume the model period as one year. I simulate an economy with time

[3]The nonstochastic steady state of this Ramsey equilibrium can be obtained by the following procedure. First, the steady state capital income tax rate is zero by Judd-Chamley result. Then I derive an analytical solution to the steady state capital stock and other allocations. At last the steady state lump-sum tax is as large as the government spending.

series length of 500 in total and the first 100 are dropped. I repeat the simulation process 1000 times and compute the average values of moments.

Table 3 presents my second major numerical result: in an environment with loss aversion, the government should subsidize capital income. Nearly zero capital tax rate almost all the time as in a standard model is not optimal. To overcome the inefficiency from loss aversion, the government needs to employ proportionary subsidies (negative tax rates) to encourage the household to invest more on risky assets. This engenders a higher capital level and slightly larger output and consumption. The volatility increases a lot from almost zero to a high level to accomodate the change in productivity.

In the non-loss-aversion model, the government equalizes the lump-sum tax and its spending. In contrast, with loss aversion the government collects revenues to also finance the subsidy expenditure so that it imposes a heavier lump-sum tax. Since the subsidy is associated to boom and bust, the lump-sum tax gets more cyclical. For the same reason, its correlation to government spending decreases.

The result rationalizes the government's distortion in the capital accumulation. Although a larger lump-sum tax triggers a larger crowd-out effect, the capital income subsidy even raises the consumption by reversing the unwillingness of increasing capital stock.

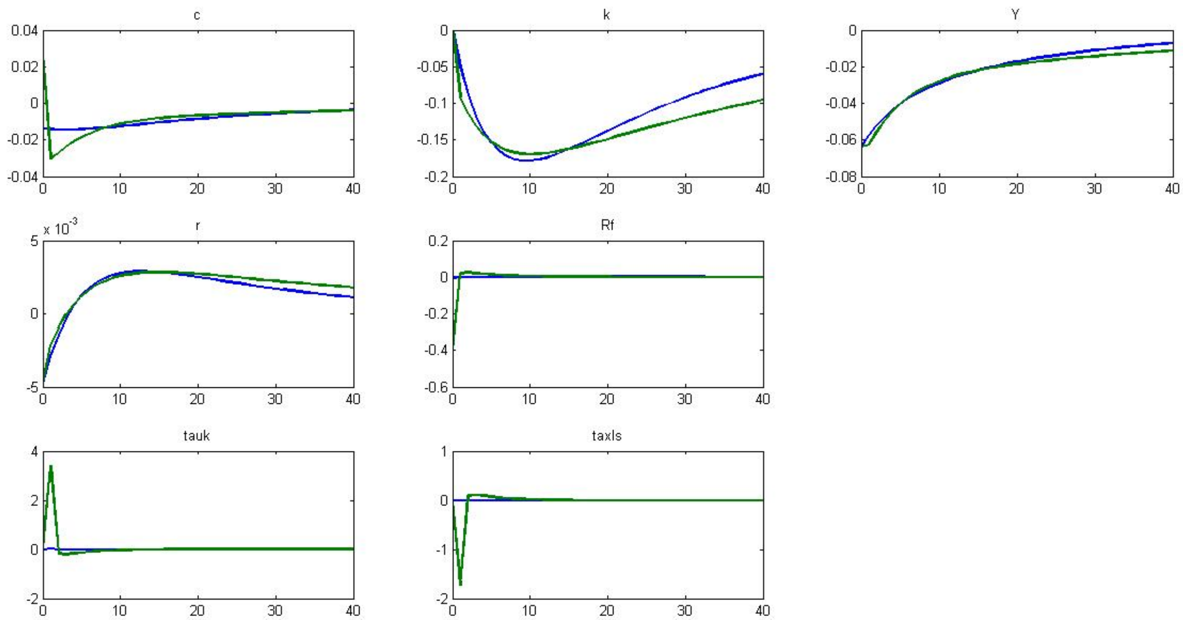
4.5.4 Impulse Response to Productivity Innovation

What should the government react if an adverse productivity shock happens in this economy? I investigate this question by the impulse response of policy instruments in the Ramsey setting when a negative technology innovation takes place in the first period.

The shock is assumed to be negative one standard deviation and the government consumption in this experiment is set to be constant, equal to $\bar{g}$, to get rid of the disturbance of government spending innovation. Figure 2 plots the impulse response of allocations, prices and policy instruments with the time series of 41 periods in two scenarios: $\eta = 0$ and $\eta = 1$.

The graphs of policy instruments differ in qualitative properties. Without loss aversion, when facing a negative shock at 0, the government should stabilize the tax rate and lump-sum tax since the shock impacts little the government budget constraint. Yet when the preferences incorporate loss aversion, the government needs to raise the tax rate while reduce the lump-sum tax at time 1. The result corresponds to the procyclical property of distortionary taxes in the business cycle literature. The capital stock and output with loss aversion recover more slowly as a consequence of the distortion on the investment decision and the fear of loss.

I study the impulse response to an innovation on government spendings as well. I simulate a positive shock of one standard deviation in Period 0. No apparent difference shows up with and without loss aversion. In both cases the government will increase the lump tax to accomodation the sudden increase in its spendings. The reason is that the demand shock only exerts the income effect and that the prices, especially the return of capital stock, remain unchanged. Then the utility from loss aversion keeps independent from this demand shock. Thus the government should not distort the price by taxation.



c-consumption; k-capital stock; Y-output; r-interest rate of capital rental; Rf-gross return of bonds; tauk-capital income tax rate; taxls-lump-sum tax.
The green curve depicts the loss-aversion economy and the blue, non-loss-aversion.

Figure 2: IMPULSE RESPONSE TO PRODUCTIVITY SHOCK

5 Conclusion

Researchers have never applied prospect theory in a production economy and policy analysis. This paper fills the gap by providing a framework of modelling a stochastic dynamic production economy with a representative loss averse household and exploring business cycle behaviors, welfare effects and optimal policy interventions.

I first focus on the private economy without government and show that the competitive equilibrium is inefficient. This is because the loss averse household takes as given prices. The household invests less on capital compared with social optimum, resulting in less output and consumption.

I then add the government sector and investigate the Ramsey policy. The nearly zero capital tax in the long run becomes suboptimal. The government should subsidize capital accumulation to stimulate production.

The impulse response analysis indicates that in the transition period, loss aversion induces a jump in the capital income tax rate and a drop in the lump-sum tax, which does not exist in a non-loss-aversion economy. It also slows down the recovery.

Some quantitative results seem less distinctive compared with standard models. This is because the neoclassical growth framework generates a small gap between prices of two assets with plausible parameter values. However, this framework offers a simple tool to analyze the mechanism of loss aversion and it is enough to obtain qualitative results. For future study, I may apply another workhorse to improve quantitative behaviors.

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Appendix

Simplification of $E_t v(D_{t+1})$

Since $lnZ_{t+1} = \rho lnZ_t + \sigma_\epsilon \epsilon_{t+1}$ and ϵ_{t+1} is distributed as a standard normal, Z_{t+1} follows a log-normal distribution conditional on t's information.We replicate here the expression of $E_t v(D_{t+1})$,

$$E_t v(D_{t+1}) = \int_0^{z_{t+1}^{idf}} \lambda(R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) + \int_{z_{t+1}^{idf}}^{\infty} (R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}),$$

where the conditional cumulative distribution function of shock Z_{t+1} with the known history until period t, $\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) = \Phi\left(\frac{lnz_{t+1}-\rho lnz_t}{\sigma_\epsilon}\right)$ when $\Phi(\cdot)$ denotes the cumulative distribution function of the standard normal distribution. We can also derive the conditional probability density function as $\mathrm{f}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) = \frac{\varphi\left(\frac{lnz_{t+1}-\rho lnz_t}{\sigma_\epsilon}\right)}{\sigma_\epsilon z_{t+1}}$ with $\varphi(\cdot)$ representing the probability density function of the standard normal distribution.

Let us focus on the first term of $E_t v(D_{t+1})$.

$$\begin{aligned}
\int_0^{z_{t+1}^{idf}} \lambda(R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) &= \lambda \int_0^{z_{t+1}^{idf}} (1 + \alpha z_{t+1} k_{t+1}^{\alpha-1} - \delta - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) \\
&= \lambda\left[\int_0^{z_{t+1}^{idf}} (1 - \delta - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) + \int_0^{z_{t+1}^{idf}} \alpha k_{t+1}^{\alpha-1} \cdot z_{t+1} d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1})\right] \\
&= \lambda\left[(1 - \delta - R_{t+1}^f)\Phi\left(\frac{lnz_{t+1}^{idf} - \rho lnz_t}{\sigma_\epsilon}\right) + \alpha k_{t+1}^{\alpha-1} \int_0^{z_{t+1}^{idf}} z_{t+1} \frac{\varphi\left(\frac{lnz_{t+1}-\rho lnz_t}{\sigma_\epsilon}\right)}{\sigma_\epsilon z_{t+1}} dz_{t+1}\right]
\end{aligned}.$$

$$\begin{aligned}
\int_0^{z_{t+1}^{idf}} z_{t+1} \frac{\varphi\left(\frac{lnz_{t+1}-\rho lnz_t}{\sigma_\epsilon}\right)}{\sigma_\epsilon z_{t+1}} dz_{t+1} &= \int_0^{z_{t+1}^{idf}} \frac{1}{\sqrt{2\pi}\sigma_\epsilon} e^{-\frac{(lnz_{t+1}-\rho lnz_t)^2}{2\sigma_\epsilon^2}} dz_{t+1} \\
&= \int_{-\infty}^{lnz_{t+1}^{idf}} \frac{1}{\sqrt{2\pi}\sigma_\epsilon} e^{-\frac{(y_{t+1}-\rho lnz_t)^2}{2\sigma_\epsilon^2}} e^{y_{t+1}} dy_{t+1} \qquad (\text{Let } lnz_{t+1} = y_{t+1}) \\
&= \int_{-\infty}^{lnz_{t+1}^{idf}} \frac{1}{\sqrt{2\pi}\sigma_\epsilon} e^{-\frac{(y_{t+1}-(\rho lnz_t+\sigma_\epsilon^2))^2}{2\sigma_\epsilon^2} + \rho lnz_t + \frac{\sigma_\epsilon^2}{2}} dy_{t+1} \\
&= z_t^\rho e^{\frac{\sigma_\epsilon^2}{2}} \int_{-\infty}^{lnz_{t+1}^{idf}} \frac{1}{\sqrt{2\pi}\sigma_\epsilon} e^{-\frac{(y_{t+1}-(\rho lnz_t+\sigma_\epsilon^2))^2}{2\sigma_\epsilon^2}} dy_{t+1} \\
&= z_t^\rho e^{\frac{\sigma_\epsilon^2}{2}} \Phi\left(\frac{lnz_{t+1}^{idf} - (\rho lnz_t + \sigma_\epsilon^2)}{\sigma_\epsilon}\right)
\end{aligned}.$$

Thus, $\int_0^{z_{t+1}^{idf}} \lambda(R_{t+1}^k - R_{t+1}^f) d\mathrm{F}_{\mathrm{Z_{t+1}|Z_t=z_t}}(z_{t+1}) = \lambda[(1-\delta-R_{t+1}^f)\Phi\left(\frac{lnz_{t+1}^{idf}-\rho lnz_t}{\sigma_\epsilon}\right) + \alpha k_{t+1}^{\alpha-1} z_t^\rho e^{\frac{\sigma_\epsilon^2}{2}} \Phi\left(\frac{lnz_{t+1}^{idf}-(\rho lnz_t+\sigma_\epsilon^2)}{\sigma_\epsilon}\right)]$. With the same argument, we calculate the second term as well. Summing up two parts gives us the result:

$$E_t v(D_{t+1}) = (1-\delta-R_{t+1}^f)[1+(\lambda-1)\Phi\left(\frac{lnz_{t+1}^{idf} - \rho lnz_t}{\sigma_\epsilon}\right)] + \alpha k_{t+1}^{\alpha-1} z_t^\rho e^{\frac{\sigma_\epsilon^2}{2}} [1+(\lambda-1)\Phi\left(\frac{lnz_{t+1}^{idf} - (\rho lnz_t + \sigma_\epsilon^2)}{\sigma_\epsilon}\right)].$$