Welfare Effects of Unanticipated Policy Changes with Complete Asset Markets

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Abstract

This paper analyzes the welfare effects of unanticipated policy changes. The analysis focuses on an infinite-horizon model with complete asset markets and agents with heterogeneous asset holdings. I consider the welfare measure introduced by Lucas (1987). There are two effects on individuals: an effect through the change in wealth, and a direct effect from the price change. Several aggregate welfare measures are also examined.

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1 Introduction

This paper evaluates the welfare effects of unanticipated policy changes on agents with heterogeneous asset holdings. Recently, there has been an increasing interest in analyzing the effects of unanticipated policy changes (or changes in the economic environment) in the heterogeneous-agent framework. For example, Doepke and Schneider (2006) consider the welfare effects of an unanticipated change in the inflation rate when agents' nominal asset positions are different. They emphasize that a "surprise" change in inflation generates a transfer across agents, who have various nominal asset positions. Krusell et al. (2009) analyzes an unanticipated stabilization of the business cycle. They highlight the importance of the price effects—because levels of the wage and the interest rate change after the stabilization, stabilization creates "winners" and "losers" among agents depending on whether their income mainly comes from capital or from labor. Other examples include Domeij and Heathcote (2004) on capital income taxation, Young (2004) on unemployment insurance, and Heathcote et al. (2008) on the change in wage dispersion.

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Here, I consider an infinite-horizon model with complete asset markets. The completeness of the market means that all idiosyncratic shocks are insured away.[1] I focus on the heterogeneity in wealth (asset) levels, where wealth includes both physical asset (physical wealth) and future earnings (human capital). As a welfare criterion, I use the consumption-based welfare measure originally used by Lucas (1987). This measure has popularly been used in macroeconomic literature. I calculate this welfare measure for each agent.

In the cases of a constant relative risk aversion (CRRA) utility function and a log utility function, I derive a closed-form expression for this welfare measure as a function of wealth levels and prices before and after the policy change. The expression makes it clear how the welfare effects can be decomposed into the effect due to the wealth change and the direct effect from the price change.

Furthermore, since these utility functions permit aggregation,[2] I can construct a representative agent of the economy. I calculate the Lucas welfare measure of the policy change for the representative agent. Then I compare the Lucas measure calculated for each agent and the one calculated for the representative agent. It turns out that the arithmetic average of the Lucas welfare measure for each agent is not the same as the value of the Lucas welfare measure for the representative agent. In particular, the average measure favors a policy which tends to equalize the wealth level among the agents. I also consider another aggregate welfare measure proposed in the literature.

The paper is organized as follows. In Section 2, I set up the model. In Section 3, two special cases—CRRA utility and log utility—are analyzed. In Section 4, I construct two simple examples to highlight the properties of the welfare measures. Section 5 concludes.

2 Model

2.1 Setup

Normalize the population to 1, and index the agents by i. The utility function is

$$E\left[\sum_{t=0}^{\infty} \beta^t u(c_{it}(s^t))\right],$$

where $c_{it}(s^t)$ is the consumption level of agent i at time t when the history is s^t. In period 0, all the agents get together and trade the state-contingent (Arrow) securities. Let the period-0 price of the state-s^t security (that is, the right to receive one unit of period-t consumption good when the history is s^t) be $p_t(s^t)$. The present value budget constraint is

$$\sum_{t=0}^{\infty} \int p_t(s^t) c_{it}(s^t) ds^t \leq W_{i0}, \tag{1}$$

[1]Many of the above papers work with incomplete market models, which makes the analysis more complex because the policy change may affect the opportunities to insure against idiosyncratic risk.

[2]See Gorman (1953), Chatterjee (1994), and Caselli and Ventura (2000), among others.

where $W_{i0} > 0$ is the initial asset holding by agent i. This includes physical asset holdings as well as future earnings (human capital). I assume that consumers are heterogeneous only in W_{i0}.

The Euler equation is:

$$\pi(s^t)u'(c_{it}(s^t)) = \beta \frac{p_t(s^t)}{p_{t+1}(s^{t+1})} \pi(s^{t+1})u'(c_{i,t+1}(s^{t+1})) \quad \text{for all } s^{t+1} \in S^{t+1}(s^t), \tag{2}$$

where $\pi(s^t)$ is the probability of s^t given s_0, and S^{t+1} is the set of possible s^{t+1} given s^t. Let $\mathbf{p}$ be the vector of all Arrow security prices $p_t(s^t)$ for all t and s^t. Then, the optimal consumption of consumer i, solved using (1) and (2), can be denoted as $c_{it}(s^t) = C_t(s^t; \mathbf{p}, W_{i0})$.

2.2 Welfare criterion

In the following, I evaluate the welfare effect of an unanticipated policy change. The policy change occurs at the beginning of period 0. Throughout this paper, I use the welfare criterion λ_i, originally used by Lucas (1987), which satisfies

$$E\left[\sum_{t=0}^{\infty} \beta^t u((1+\lambda_i)c_{it}(s^t))\right] = E\left[\sum_{t=0}^{\infty} \beta^t u(\tilde{c}_{it}(s^t))\right],$$

where $c_{it}(s^t)$ is the consumption without policy changes, and $\tilde{c}_{it}(s^t)$ is the consumption with the policy changes. Therefore λ_i indicates how large of a fraction of consumption the consumer i is willing to give up for this policy change. If λ_i is positive then the consumer benefits from this policy change, and if λ_i is negative then the consumer suffers from a welfare loss.[3]

Once the decision rule for consumption is known, λ_i can be computed from

$$E\left[\sum_{t=0}^{\infty} \beta^t u((1+\lambda_i)C_t(s^t; \mathbf{p}, W_{i0}))\right] = E\left[\sum_{t=0}^{\infty} \beta^t u(C_t(s^t; \tilde{\mathbf{p}}, \tilde{W}_{i0}))\right], \tag{3}$$

where $\tilde{\mathbf{p}}$ and $\mathbf{p}$ denote the prices with and without the policy change, and $\tilde{W}_{i0}$ and W_{i0} denote the period-0 wealth with and without the policy change. From (3), λ_i can be solved as

$$\lambda_i = \Lambda(\mathbf{p}, W_{i0}, \tilde{\mathbf{p}}, \tilde{W}_{i0}).$$

It is difficult to make a further progress without specifying the utility function. In the following, I will limit the class of utility functions.

[3] Lucas (1987) uses this criterion to evaluate the welfare effect of business cycles.

3 Special cases

3.1 CRRA utility

In this section, I consider the constant relative risk aversion (CRRA) utility function.[4] The period utility function is specified as

$$u(c_{it}(s^t)) = \frac{c_{it}(s^t)^{1-\nu} - 1}{1-\nu}, \tag{4}$$

where $\nu > 0$ and $\nu \neq 1$. Then, (2) can be rewritten as:

$$c_{it}(s^t) = \left(\beta \frac{p_t(s^t)/\pi(s^t)}{p_{t+1}(s^{t+1})/\pi(s^{t+1})}\right)^{-\frac{1}{\nu}} c_{i,t+1}(s^{t+1}) \quad \text{for all } s^{t+1} \in S^{t+1}(s^t).$$

This implies

$$c_{it}(s^t) = \left(\beta^t \frac{\pi_t(s^t)}{p_t(s^t)}\right)^{\frac{1}{\nu}} c_{i0}(s_0). \tag{5}$$

Plugging this into the budget constraint (1), c_{i0} can be solved as

$$c_{i0}(s_0) = \left(\sum_{t=0}^{\infty} \int p_t(s^t) \left(\beta^t \frac{\pi_t(s^t)}{p_t(s^t)}\right)^{\frac{1}{\nu}} ds^t\right)^{-1} W_{i0}. \tag{6}$$

From this and (5), the decision rule for $c_t(s^t)$ can be solved as

$$C_t(s^t; \mathbf{p}, W_{i0}) = g_t(s^t, \mathbf{p}) W_{i0}, \tag{7}$$

where

$$g_t(s^t, \mathbf{p}) \equiv \left(\beta^t \frac{\pi_t(s^t)}{p_t(s^t)}\right)^{\frac{1}{\nu}} \left(\sum_{\tau=0}^{\infty} \int p_\tau(s^\tau) \left(\beta^\tau \frac{\pi_\tau(s^\tau)}{p_\tau(s^\tau)}\right)^{\frac{1}{\nu}} ds^\tau\right)^{-1}.$$

Now consider the welfare effect of a policy change, λ_i. From (3) and (7), it is straightforward to derive

$$\lambda_i = \Lambda(\mathbf{p}, W_{i0}, \tilde{\mathbf{p}}, \tilde{W}_{i0}) = \frac{\tilde{W}_{i0}}{W_{i0}} \Omega(\mathbf{p}, \tilde{\mathbf{p}}) - 1, \tag{8}$$

where

$$\Omega(\mathbf{p}, \tilde{\mathbf{p}}) \equiv \left(\frac{E\left[\sum_{t=0}^{\infty} \beta^t g_t(s^t, \tilde{\mathbf{p}})^{1-\nu}\right]}{E\left[\sum_{t=0}^{\infty} \beta^t g_t(s^t, \mathbf{p})^{1-\nu}\right]}\right)^{\frac{1}{1-\nu}}. \tag{9}$$

Note that $\Omega(\mathbf{p}, \tilde{\mathbf{p}}) = 1$ when prices are not affected by the policy.

When λ_i is close to zero, since $\lambda_i \approx \log(1 + \lambda_i)$, λ_i can be approximated by λ_i^a where

$$\lambda_i^a \equiv \log(\tilde{W}_{i0}/W_{i0}) + \log(\Omega(\mathbf{p}, \tilde{\mathbf{p}})), \tag{10}$$

[4] Lucas (1987), Young (2004), Domeij and Heathcote (2004), and Heathcote et al. (2008) use this utility specification.

where the superscript a stands for "approximation." This is a natural decomposition: the first term is the effect of the change in wealth, which includes (implicit or explicit) wealth transfers; the second term is the direct effect of the price change.[5] Note that the price effect is common to everyone. Therefore, only wealth matters when the welfare effects are compared across individuals. In particular, from (10),

$$\lambda_i - \lambda_j \approx \lambda_i^a - \lambda_j^a = \log(\tilde{W}_{i0}/W_{i0}) - \log(\tilde{W}_{j0}/W_{j0}) = \log(\tilde{W}_{i0}/\tilde{W}_{j0}) - \log(W_{i0}/W_{j0})$$

and only the wealth ratios matter for this comparison.

In models with heterogeneous agents, the average value of λ_i is often used as the aggregate welfare criterion.[6] Let us denote $\bar{\lambda}$ as the average of λ_i across the population. Then, from (8), $\bar{\lambda}$ can be calculated as

$$\bar{\lambda} \equiv \int \lambda_i di = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \int \frac{\tilde{W}_{i0}}{W_{i0}} di - 1. \tag{11}$$

If there is no change in prices, then $\bar{\lambda} = \int(\tilde{W}_{i0}/W_{i0})di - 1$. Therefore, even if the total wealth $\int W_{i0} di$ is the same with or without the policy change, it may be the case that $\bar{\lambda}$ is not zero.

One corollary of this result is that the welfare effect for the representative agent is different from $\bar{\lambda}$ here. The representative agent's wealth is $\int \tilde{W}_{i0} di$ with the policy change and $\int W_{i0} di$ without the policy change. Therefore, the welfare effect for the representative agent, λ_R, is

$$\lambda_R = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \frac{\int \tilde{W}_{i0} di}{\int W_{i0} di} - 1. \tag{12}$$

In contrast to $\bar{\lambda}$, this measure equals zero if the price effect is absent and the total wealth $\int W_{i0} di$ is unchanged. To make the comparison clearer, one can rewrite $\bar{\lambda}$ as

$$\bar{\lambda} = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \int \frac{\tilde{W}_{i0}}{\bar{W}_0} \frac{\bar{W}_0}{W_{i0}} di - 1 = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \int \frac{\tilde{W}_{i0}}{\bar{W}_0} \phi(i) di - 1$$

where $\bar{W}_0 \equiv \int W_{i0} di$ is the average wealth before the policy change, $\phi(i) \equiv \bar{W}_0 / W_{i0}$, and

$$\lambda_R = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \frac{\int \tilde{W}_{i0} di}{\bar{W}_0} - 1 = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \int \frac{\tilde{W}_{i0}}{\bar{W}_0} di - 1.$$

Therefore, the difference between $\bar{\lambda}$ and λ_R is whether or not $\phi(i)$ is multiplied before taking the integral of $\tilde{W}_{i0}/\bar{W}_0$. $\phi(i)$ can be thought as a "weighting" function in calculating $\bar{\lambda}$ (although it should be noted that $\phi(i)$ does not necessarily sum to one). In particular, $\phi(i)$ is decreasing in W_{i0}. That is, $\bar{\lambda}$ assigns a high weight to $\tilde{W}_{i0}/\bar{W}_0$ for a consumer whose wealth was low before the policy change. This property makes $\bar{\lambda}$ favor an equalizing policy, if the policy does not alter the ranking of wealth holdings. In other words, a policy that transfers one dollar from an originally rich consumer to an originally poor consumer results in a welfare improvement

[5] Note that part of the change in wealth may (indirectly) come from the change in prices.

[6] See, for example, Young (2004) and Krusell et al. (2009).

in terms of $\bar{\lambda}$. In contrast, this policy results in no welfare change in terms of λ_R. To see this more clearly, one can calculate the marginal welfare gain from an increase in $\tilde{W}_{i0}$:

$$\frac{\partial \bar{\lambda}}{\partial \tilde{W}_{i0}} = \frac{\Omega(\mathbf{p}, \tilde{\mathbf{p}})}{\bar{W}_0}\phi(i)$$

and

$$\frac{\partial \lambda_R}{\partial \tilde{W}_{i0}} = \frac{\Omega(\mathbf{p}, \tilde{\mathbf{p}})}{\bar{W}_0}.$$

It can be seen that $\partial\bar{\lambda}/\partial\tilde{W}_{i0}$ is decreasing in W_{i0} (since it is increasing in $\phi(i)$) and $\partial\lambda_R/\partial\tilde{W}_{i0}$ is independent of i.

In a situation where the policymaker wants to use a welfare criterion which is independent of this type of transfer, λ_R may be more desirable than $\bar{\lambda}$. In order to create λ_R from the information contained in λ_i, one has to make an adjustment before integrating:

$$\lambda_R = \int \frac{1+\lambda_i}{\phi(i)} di - 1.$$

An alternative aggregate criterion to $\bar{\lambda}$ and λ_R is the $\hat{\lambda}$ that satisfies

$$\int E\left[\sum_{t=0}^{\infty} \beta^t u((1+\hat{\lambda})c_{it}(s^t))\right] di = \int E\left[\sum_{t=0}^{\infty} \beta^t u(\tilde{c}_{it}(s^t))\right] di.$$

This criterion is used by Domeij and Heathcote (2004) and Heathcote et al. (2008). Following the same steps, one can derive that $\hat{\lambda}$ can be calculated as

$$\hat{\lambda} = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \left(\frac{\int \tilde{W}_{i0}^{1-\nu} di}{\int W_{i0}^{1-\nu} di} \right)^{\frac{1}{1-\nu}} - 1. \tag{13}$$

This is different from both $\bar{\lambda}$ and λ_R. The marginal welfare gain from an increase in $\tilde{W}_{i0}$ is

$$\frac{\partial \hat{\lambda}}{\partial \tilde{W}_{i0}} = \left(\frac{\int \tilde{W}_{i0}^{1-\nu} di}{\int W_{i0}^{1-\nu} di} \right)^{\frac{1}{1-\nu}-1} \frac{\Omega(\mathbf{p}, \tilde{\mathbf{p}})}{\int W_{i0}^{1-\nu} di} \tilde{W}_{i0}^{-\nu}.$$

This is decreasing in $\tilde{W}_{i0}$. Therefore, a policy which equalizes $\tilde{W}_{i0}$ is favored by this welfare criterion. Note that what matters here is $\tilde{W}_{i0}$ rather than W_{i0}, in contrast to the case with $\bar{\lambda}$.

3.2 Log utility

A limiting case of $\nu \to 1$ is log utility:[7]

$$u(c_{it}(s^t)) = \log(c_{it}(s^t)).$$

[7] Krusell et al. (2009) calculate the cost of business cycles for each individual as in (3) using a log utility specification in a model with incomplete asset markets.

Following similar steps as in the CRRA case, the equations corresponding to (5) and (6) are

$$c_{it}(s^t) = \beta^t \frac{\pi_t(s^t)}{p_t(s^t)} c_{i0}(s_0)$$

and

$$c_{i0}(s_0) = \left(\sum_{t=0}^{\infty} \int \beta^t \pi_t(s^t) ds^t \right)^{-1} W_{i0}.$$

Therefore, the decision rule for $c_t(s^t)$ can be written in the form of (7), where

$$g_t(s^t, \mathbf{p}) \equiv \beta^t \frac{\pi_t(s^t)}{p_t(s^t)} \left(\sum_{\tau=0}^{\infty} \int \beta^\tau \pi_\tau(s^\tau) ds^\tau \right)^{-1}.$$

It is straightforward to show that the welfare effect of the policy change— the λ_i defined in (3)—can be expressed in the same form as (8), where

$$\Omega(\mathbf{p}, \tilde{\mathbf{p}}) \equiv \exp\left((1-\beta) E \left[\sum_{t=0}^{\infty} \beta^t \log \left(\frac{g_t(s^t, \tilde{\mathbf{p}})}{g_t(s^t, \mathbf{p})} \right) \right] \right). \tag{14}$$

Thus, the analysis of λ_i, $\bar{\lambda}$, and λ_R in Section 3.1 applies here in exactly the same form after replacing $\Omega(\mathbf{p}, \tilde{\mathbf{p}})$ with the one in (14). $\hat{\lambda}$ can be derived as

$$\hat{\lambda} = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \frac{\exp(\int \log(\tilde{W}_{i0}) di)}{\exp(\int \log(W_{i0}) di)} - 1$$

with $\Omega(\mathbf{p}, \tilde{\mathbf{p}})$ defined in (14). One can calculate $\partial\hat{\lambda}/\partial\tilde{W}_{i0}$ again:

$$\frac{\partial \hat{\lambda}}{\partial \tilde{W}_{i0}} = \Omega(\mathbf{p}, \tilde{\mathbf{p}}) \frac{\exp(\int \log(\tilde{W}_{i0}) di)}{\exp(\int \log(W_{i0}) di)} \frac{1}{\tilde{W}_{i0}}.$$

This is decreasing in $\tilde{W}_{i0}$, and therefore this measure also favors an equalizing policy.

4 An example

This section provides a simple example assuming that the consumer's utility follows a CRRA utility function (4). I illustrate how λ_i, $\bar{\lambda}$, λ_R, and $\hat{\lambda}$ are related to each other in different policy experiments.

4.1 Setting

Consider a small open economy. The net real interest rate is given by the constant value r. The economy is an endowment economy with one "tree." The tree produces y units of consumption goods every period, where y is a constant. The period-0 ownership of the tree (and therefore the ownership of the consumption goods produced) for the consumer i is θ_i. Because the population is 1, $\int \theta_i di = 1$. There is no other source of income. The period utility function is specified as CRRA, as in (4).

Then, it is clear that $W_{i0} = \theta_i(1+r)y/r$ and $p_t(s^t) = 1/(1+r)^t$. The optimization problem can be solved analytically:

$$c_{it} = (\beta(1+r))^{\frac{1}{\nu}t}c_{i0} = g_t(r)W_{i0}$$

(here, only the relevant price is r), where

$$g_t(r) \equiv (\beta(1+r))^{\frac{1}{\nu}t}(1 - \beta^{\frac{1}{\nu}}(1+r)^{\frac{1}{\nu}-1}). \tag{15}$$

4.2 Policy changes

Now I analyze the welfare effects of policy changes. There are two experiments. The first experiment highlights the price effect and the second experiment considers the effect through the change in wealth due to a transfer.

4.2.1 Change in the real interest rate

Consider an experiment in which r increases to $\tilde{r}$ at time 0. From (9) and (15),

$$\Omega(r, \tilde{r}) = \left(\frac{1 - \beta^{\frac{1}{\nu}}(1+\tilde{r})^{\frac{1}{\nu}-1}}{1 - \beta^{\frac{1}{\nu}}(1+r)^{\frac{1}{\nu}-1}}\right)^{-\frac{\nu}{1-\nu}}$$

is the direct price effect. Clearly, $\Omega(r, \tilde{r})$ is increasing in $\tilde{r}$ and decreasing in r. In particular, $\Omega(r, \tilde{r}) > 1$ if and only if $\tilde{r} > r$. This is because, for a given W_{i0}, a higher r means that future consumption goods are cheaper. The effect of the change in wealth is

$$\frac{\tilde{W}_{i0}}{W_{i0}} = \frac{1 + 1/\tilde{r}}{1 + 1/r}.$$

This is decreasing in $\tilde{r}$ and increasing in r. Therefore, the direct price effect and the effect through the change in wealth act in opposite directions. Note that $\tilde{W}_{i0}/W_{i0}$ does not depend on i, and thus $\lambda_i = \bar{\lambda} = \lambda_R = \hat{\lambda}$ for this policy change.

4.2.2 Asset redistribution

Suppose that the claim to the asset is distributed following the lognormal distribution with mean 1: $\log(\theta_i) \sim N(-\sigma^2/2, \sigma^2)$. Here, I evaluate the welfare effect of a policy that equalizes everyone's assets. Because the total amount of assets in the economy does not change, this policy results in a new allocation of the claim: $\tilde{\theta}_i = 1$ for all i. Because total wealth does not change, the representative consumer's consumption is unchanged and therefore $\lambda_R = 0$. Because prices are unchanged, from (8),

$$\lambda_i = \frac{\tilde{W}_{i0}}{W_{i0}} - 1.$$

Here, $\tilde{W}_{i0}/W_{i0} = 1/\theta_i$. Thus, $\lambda_i > 0$ if and only if $\theta_i < 1$. From (11),[8]

$$\bar{\lambda} = \int \theta_i^{-1} di - 1 = \exp\left(\sigma^2\right) - 1 > 0.$$

Here, as is argued earlier, $\bar{\lambda}$ favors an equalizing policy.[9] $\hat{\lambda}$ can be computed from (13):

$$\hat{\lambda} = \left[\int \theta_i^{1-\nu} di\right]^{-\frac{1}{1-\nu}} - 1 = \exp\left(\nu \frac{\sigma^2}{2}\right) - 1 > 0.$$

Again, $\hat{\lambda}$ favors an equalizing policy.

5 Conclusion

This paper analyzes the welfare effect of an unanticipated policy change in a model with complete asset markets and heterogeneous agents. The CRRA utility and the log utility cases make it clear that the welfare effect for an individual consists of two parts: the effect through the change in wealth and the direct price effect. Several aggregate welfare measures are also examined. In particular, the average of the individual welfare measure favors a policy that equalizes wealth compared to the welfare measure based on the representative agent's utility.

[8]For a lognormally distributed random variable X with $\log(X) \sim N(\mu, \omega^2)$, $E[X^n] = \exp(n\mu + n^2\omega^2/2)$ holds.

[9]The $\bar{\lambda}$ measure has one undesirable property: it is not immune to a switch of individual identity. To see this, consider an alternative scenario where there are two agents (indexed by 1 and 2) and the asset endowment switches from $(\theta_1, \theta_2) = (1/3, 2/3)$ to $(\tilde{\theta}_1, \tilde{\theta}_2) = (2/3, 1/3)$. While this is a pure transfer and the asset distribution does not change, $\bar{\lambda} = ((2-1) + (1/2-1))/2 = 1/4$ is strictly positive, which may be viewed as unreasonable.

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