Political Economy of Crop Insurance Risk Subsidies under Imperfect Information

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We consider a political economy where government cares about risk-averse farmers' loss of income and yet incurs political cost if it provides monetary support to farmers. Government evaluates three options: 1) ex-post disaster aid; 2) ex-ante insurance option with perfect information; 3) ex-ante insurance with imperfect information (farmers are over-confident about their risk). It is assumed that marginal political cost is high enough so that the possibility of monetary support to farmers in the absence of economic loss is ruled out. In comparing 1) and 2), we find that government prefers farmers manage their risks through fairly priced insurance In comparing 1) and 3), if the information problems prevent risk-averse farmers to take up full insurance under actuarially fair rates, government prefers to subsidize farmers' insurance ex-ante rather than providing disaster aid ex-post (subject to political cost) for a wide range of parameter values.

Key words: Agricultural risk, crop insurance, disaster assistance
JEL codes: D81, G22, Q12, Q18

During the 2012 Farm Bill debate, the crop insurance program has undergone an intense scrutiny, and the justification for crop insurance subsidies is being questioned in light of budget and policy issues. For example, critiques from an invited paper session on crop insurance subsidies at the 2012 annual meeting of the Agricultural and Applied Economics Association (AAEA) point out that high risk areas have received a higher portion of subsidies which in turn encourages over-production (Goodwin and Smith, 2012). In addition to efficiency concerns, budget costs are another key issue. Glauber (2012) also finds high risk areas get higher net indemnities. This paper theoretically examines the issue of crop insurance coverage and risk subsidies from the perspective of the government's preference for crop insurance support or

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disaster assistance, subject to a political cost.

Government's involvement in crop insurance markets is traditionally explained by the information asymmetries (moral hazard and adverse selection problems) or the catastrophic nature of crop insurance risks. Zulauf (2011) argues that the optimal subsidy should be equal to systemic component of risk. Nevertheless, Duncan and Myers (2000) find subsidized reinsurance as a solution to catastrophic (systemic) risk problems in crop insurance. Meanwhile, adverse selection problems (if present) may lead to market failure in the form of underinsurance. The premium cost reflecting the average risk in the market would drive lower risk farmers out of the program disproportionately, leaving a higher risk pool of insureds which over time could lead to higher loss ratios and premium rates. Subsidizing the equilibrium price of insurance is one way for government to intervene to ensure high and diverse participation.

The central presumption of adverse selection problems is that farmers are better informed about their risks compared with the insurers. However, Coble and Barnett (2012) point out that the preceding presumption may not necessarily hold, on the contrary, farmers could be over-confident. The latter point is also made in Just (2002) and confirmed in empirical studies (Sherrick, 2002; Umarov and Sherrick, 2005; and Gao et al., 2011). The information problems in the form of over-confidence could be another reason for government support for crop insurance. That issue is the central focus of this paper and will be studied within a political economy framework developed in Innes (2003). Innes (2003) points out that the ex-post urge to provide disaster relief to farmers has implications for the design of ex-ante government farm policy. Furthermore, the effects of the relationship between a farmer's perception of risk and the farmer's risk aversion (taste for insurance) for crop insurance purchases will also be explored. Menapace, Colson and Raffaelli (2012) provide some evidence that farmers are risk averse; and farmers who are more (less) risk-averse perceive greater (smaller) farm losses.

We present a theoretical model that links the modeling of the political economy in Innes (2003) with the farmer's insurance coverage choice modeling in Bulut, Collins and Zacharias (2012). In line with Innes (2003), we assume government cares about a farmer's income losses and may consider providing financial assistance at times of financial distress, yet in doing so, the government incurs some political cost. Government's interest in the farmer's income losses are revealed through persistent disaster assistance over time. Every year from fiscal years 1989 through 2012 (except for the last two years) farmers with wide-spread production or price losses received ad hoc disaster assistance (Chite, 2012). Unlike Innes (2003), we consider risk averse farmers and do not explicitly model production.[1] The farmer has a linear mean-variance utility function, pays a premium, and chooses coverage level provided that an insurance option is available. The theoretical modeling is supplemented with a numerical analysis (using MATLAB software) when no analytically tractable solution could be obtained.

Farmer's Problem

Denote the current income (wealth) of a representative farmer with M . The farmer faces the prospect of a loss (denote the loss amount with l which may refer to a production or a revenue loss) with probability p_l and no loss with probability $(1-p_l)$. The preceding random variable is denoted with $\tilde{l}$. The expected farmer's loss is $p_l l$ and the variance of the farmer's loss is $p_l(1-p_l)l^2$.

As in Duncan and Myers (2000), a "representative" farmer is assumed to have a linear

[1] Ex-ante insurance should help with the production because indemnity is certainly paid in a timely manner once a shortfall happens (provided that farmer follow good farming practices). While ex-post disaster aid would imply a great deal of uncertainty to the production (Goodwin and Vado, 2007).

mean-variance preference function specified as

$$U^0 = M - p_l l - 0.5\lambda p_l (1 - p_l) l^2 , \quad (1)$$

where U^0 denotes the utility of farmer under the assumption that farmer has perfect information regarding farmer's own risk, M is the initial income and λ is the risk aversion parameter for the farmer.[2] Denote the realized value of the random variable $\tilde{l}$ with l_h, then $l_h = l$ in case of loss and $l_h = 0$ in case of no loss. Then, we define the ratio of amount of loss (realized) to farmer's initial income with r_h, that is

$$r_h = \frac{l_h}{M} . \quad (2)$$

In case of loss, we will refer to r_h as r that is, $r_h = r = \frac{l}{M}$, otherwise $r_h = 0$.

Government's Preferences (Political Economy)

In line with Innes (2003), government is benevolent and cares about farmer's losses of income and imposes taxes/transfers (denoted with τ: where $\tau \geq 0$ indicates transfer whereas $\tau < 0$ indicates taxing). In doing so, government incurs a political cost. For the sake of simplicity, we assume that it is equally politically costly to subsidize or tax farmers. Government's preferences can be further specified as

$$G(\tau) = B + v(\Delta) - c(\tau) , \quad (3)$$

where B represents the government's utility in status quo from non-food sectors in the economy

[2] The expression in equation (1) corresponds to farmer's certainty equivalent under the assumption that farmer's income is normally distributed and farmer's utility can be represented with negative exponential utility function (Moss, 2010, p. 128). Otherwise, it is approximately equal to the certainty equivalent based on Arrow-Pratt approximation to risk-premium (Gollier, 2001, p. 22).

(which will be normalized to zero), Δ indexes the change in farmer's financial well-being, $v(\Delta)$ represents the value government receives from the changes in farmer's financial well-being, and $c(\tau)$ is the political cost of extending federal funds at the amount of $\tau > 0$ to an individual farmer. We will now focus on $v(\Delta)$ and $c(\tau)$ functions in turn.

We specify the value function $v(.)$ as

$$v(\Delta) = \psi\Delta \; . \tag{4}$$

In the preceding equation, Δ indexes the change in farmer's well-being as before, while ψ represents the government's sensitivity to the values of Δ. A simple way to think about the parameter ψ as some monetary value per farm e.g., the per-farm net-value added created in the economy.[3] The parameter Δ can be specified as [4]

$$\Delta\left(w(\tau, r_h)\right) = (\eta - e^{-w(\tau, r_h)}) \; . \tag{5}$$

In the preceding equation, $w(\tau, r_h)$ is the percent change in farmer's financial well-being depending on the amount of government's transfers (τ) and the ratio of farmer's loss to farmer's initial income (r_h).

In case of loss, farmer's ex-post income with government transfer would be $M - l + \tau$.

[3] Net value-added in 2012 is forecasted at $164.8 billion (USDA ERS, 2013) while the number of farms in 2012 is 2.2 million (USDA NASS, 2013). Per farm value added then would be $74,909 in 2012.

[4] This function is a special case of expo-power function given in Saha (1993, p. 906): $u(w) = \beta_0 - e^{-\beta_1 w^{\beta_2}}$ where $\beta_0 > 1$, $\beta_1 \neq 0$, and $\beta_2 \neq 0$. Here, we assume, w is the percent change in farmer's well-being (income), $\beta_0 = \eta > 1$, $\beta_1 = \beta_2 = 1$ to maintain simplicity and tractability. In addition, here the concavity of government objective function does not arise from risk aversion but instead from diminishing marginal political pressure as the farmer's financial well-being improves.

Then, the percent change in well-being is (ex-post calculation)

$$w(\tau,r)=\frac{(M-l+\tau)-M}{M}=1-r+\frac{\tau}{M}-1=-r+\frac{\tau}{M}. \qquad (6)$$

In case of no loss, $l=0$ and so $r_h=0$ but with government transfer τ, the farmer's ex-post income would be $M=M+\tau$. Then,

$$w(\tau,0)=\frac{(M+\tau)-M}{M}=1+\frac{\tau}{M}-1=\frac{\tau}{M}. \qquad (7)$$

In the case loss, $l>0$ and so $r>0$ but without government transfer $\tau=0$, the farmer's ex-post income would be $M-l$. Then,

$$w(0,r)=\frac{(M-l)-M}{M}=1-r-1=-r \qquad (8)$$

Finally, in case of no loss and no government transfers (that is, $l=0$ and so $r_h=0$, and $\tau=0$), which could be viewed as status quo, there would be no change in farmer's well-being

$$w(0,0)=\frac{M-M}{M}=0. \qquad (9)$$

In the preceding situation, the parameter Δ in equation (5) would reduce to

$$\Delta\left(w(0,0)\right)=(\eta-e^{-0})=(\eta-1). \qquad (10)$$

The remaining element in equation (5) is the parameter η, which may represent the politically targeted value for the farmer's financial well-being. In line with Saha (1993), $\eta>1$. One can further specify $\eta=2$. Plugging $\eta=2$ in equation (10) results in $\Delta\left(w(0,0)\right)=1$. Plugging that further in equation (4) would yield $v\left(\Delta(w(0,0)\right)=\psi\Delta(w(0,0)=\psi(\eta-1)=\psi(2-1)=\psi$. That is, when there is no change in farmer's income (status quo), the parameter ψ (farmer's net value added) shows up in the government's objective function (or some value to the government—may not be the value added).

Note that function $\Delta(w) = (\eta - e^{-w})$ is increasing and concave in w with the following critical values. $\Delta(0) = (\eta - e^{-0}) = \eta - 1$, $\lim_{w \to \infty} \Delta(w) = \eta$ and $\lim_{w \to -\infty} \Delta(w) = -\infty$. Figure 1 displays the preceding function for $\eta = 2$.

We specify the cost function $c(\tau)$ as follows:

$$c(\tau) = \begin{cases} F_d + k\tau & \text{if } \tau > 0 \\ 0 & \text{if } \tau = 0, \end{cases} \tag{11}$$

where F_d represents the fixed political cost of providing funds and $k\tau$ is the variable political cost to be incurred in extending support level $\tau > 0$. Note that the marginal political cost is k as in Innes (2013).[5] The idea of a fixed political cost of program enactment is also obtained from Innes (2013, p. 329). The fixed political costs refer to costs such as time spent in deliberations, crafting legislation language, floor time needed or costs added during the process of passing the legislation (some legislative maneuvering is needed to gather enough support).

In addition, we will assume that unless a disaster is declared, per farm fixed cost will be prohibitively high. This will ensure that government does not provide ex-post disaster aid to a single farm when the neighboring farms are faring well. If, on the other hand, a disaster is declared, per farm fixed cost will be low enough and workable. A disaster will be declared if the

[5] Innes (2003) defines the marginal political cost k as the political value of the government dollar directed to another constituency. Presumably, the marginal political cost should be related to marginal opportunity cost of government spending. Alston and Hurd (1990) find that the marginal opportunity cost of a dollar of U.S. federal spending is not one dollar per dollar of government spending but rather is likely to be in the range of $1.20 to $1.50. Innes (2003) (see footnote 18) points out that the k (per dollar political cost of funds) may refer to alternative use of funds as well as deadweight costs of raising the government revenue. Innes (2003) also mention the possibility of random political cost (see footnote 13 in p. 329). Here, both fixed and marginal political costs parameters could be random variables.

amount of area loss is sufficiently high and wide-spread, that is, the “critical mass of farm distress” will be needed (Innes, 2003). Thus, a consideration of positive value of $\tau > 0$ necessitates disaster declaration, and hence the subscript “d” in the fixed cost F_d.

Even though a disaster can be declared due to high enough area loss, the government does not provide a transfer unless the government’s value of the change in the farmer’s well being ($\psi - \psi\Delta$) exceeds the political cost of the transfer. To ensure this, government’s utility with and without any transfers should show

$$\psi(2 - e^{-\tau/M}) - F_d - k\tau < \psi \text{ for all } \tau > 0. \tag{12}$$

Re-express equation (12) as

$$\underbrace{\psi(1 - e^{-\tau/M}) - k\tau}_{=F^*} < F_d \text{ holds for all } \tau > 0. \tag{13}$$

In the preceding equation, F^* is the maximum level of fixed cost that can be accommodated given the other parameter values. When $\tau = 0$, both terms on the left-hand side of equation (13) is zero. Then, the inequality holds for any $F_d > 0$. Equating the left hand side in equation (13) to zero yields $\underline{k} = \psi(1 - e^{-\tau/M})/\tau$. Then, taking the limit of $\underline{k}$ as τ goes to zero yields a benchmark level of marginal cost as

$$\underline{k} = \frac{\psi}{M}. \tag{14}$$

Note that when $k = \underline{k}$, the following holds $\underbrace{\psi(1 - e^{-\tau/M}) - \frac{\psi}{M}\tau}_{=F^*} = \psi\left(\underbrace{1 - \underbrace{(e^{-\tau/M} + \frac{\tau}{M})}_{>1}}_{<0}\right) < F_d$ for any $F_d > 0$. Thus, for any $k \geq \underline{k}$, marginal political cost is high enough to deter ex-post disaster aid to the farmer when farmer does not show any loss (despite the event of disaster declaration due to wide-spread losses of other farmers in the same area).

Because disaster declaration requires the event of area loss, we now specify the uncertainty in this regard. Denote the event of area loss with S_a which is either 1 (area has a loss) or 0 (area does not have a loss). Use the short-hand notation A to denote the event of $S_a = 1$. We denote the probability of such an event A will happen with $P(A) = p_L$.[6] Assume that the probability that a disaster is declared without an area loss is zero. Denote whether a disaster is declared or not with the event S_d. Now, S_d is either 1 (a disaster is declared) or 0 (a disaster is not declared). Use the short-hand notation D to denote the event of $S_d = 1$. Disaster will be declared when the size of loss in the area is sufficiently large. Once the area loss happens, the conditional probability that a disaster will be declared can be denoted with $P(D \mid A)$. And the joint probability that both an area has a loss and a disaster is declared is [7]

$$P(D \cap A) = P(D \mid A) \times p_L . \tag{15}$$

Actually, the unconditional probability that a disaster is declared equal the joint probability that

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[6] Because of aggregation involved, the risk should be lower in the area compared to a typical farmer in the area. In real world, some farmers' gains would offset other farmers' losses in the area. Here and in Duncan and Myers (2000), the gains in farmers' prospects are normalized into the event of no loss to maintain simplicity and tractability. Together with the assumption of identical farmers who are identical in terms of risk profile (except perhaps risk preferences and income), the sufficient size of the area loss can be defined with the sufficient number of farmers with a loss in the area. In line with the systemic risk modeling in Duncan and Myers (2000), the probabilities for area loss can be defined as the right tail probabilities of correlated Binomial distribution. Moody's (2004) provides an approach to obtain the probabilities of the preceding distribution.

[7] Goodwin and Vado (2007) state: "in light of the consistency of agricultural disaster payments in U.S. agriculture, it is likely that farmers condition their production decisions based on an estimate of the probability that payments will be forthcoming in the event of poor production or market conditions (see p. 401)". Bulut and Collins (2012) show that the expected supplemental disaster payments and/or availability of under-priced area-insurance would dampen the crop insurance demand.

area has a loss and a disaster is declared (that is, $P(D) = P(D \cap A)$) and it is less than the unconditional probability of area has a loss (p_L) from equation (15), that is, $P(D) < p_L$. Use the following short-hand notations: $p_{d|L}$ for $P(D | A)$; $p_{d \cap L}$ for $P(D \cap A)$; and p_d for $P(D)$.

Regarding individual farmer's situation vis-a-vis the area, we denote the random outcome of whether a loss occurred for the farmer with S_i. The random outcome of whether a loss occurred for the area is denoted with S_a as defined earlier. Then, the joint events can be denoted with (S_i, S_a). The joint distribution of the individual and the area losses is as follows: both individual and area see a loss, $(1,1)$ with probability p_{lL}; individual sees a loss but area does not, $(1,0)$ with probability p_{lN}; individual does not see a loss but area does, $(0,1)$ with probability p_{nL} and neither individual nor area sees a loss, $(0,0)$ with probability p_{nN}. Furthermore, the probabilities for joint events can be written as $p_{lL} = p_l p_L + \rho r_l r_L$; $p_{lN} = p_l (1 - p_L) - \rho r_l r_L$; $p_{nL} = (1 - p_l) p_L - \rho r_l r_L$; and $p_{nN} = (1 - p_l)(1 - p_L) + \rho r_l r_L$, where ρ is the correlation coefficient from above, s_l is the standard deviation of event S_i and s_L is the standard deviation of event S_a. The standard deviations are defined as $s_l = \sqrt{p_l (1 - p_l)}$ and $s_L = \sqrt{p_L (1 - p_L)}$. In addition, the covariance term between the events (S_i, S_a) is $Cov(S_i, S_a) = \rho s_l s_L$. Note that the value of the correlation coefficient parameter must be consistent with the fact that probabilities are all non-negative. We further assume that $p_{lN} > 0$ and $p_{nL} > 0$. From these relationships, one can re-obtain the marginal probability of losses as $p_l = p_{lL} + p_{lN}$ and $p_L = p_{lL} + p_{nL}$.

Against the prospect of farmer's loss, government is evaluating two options: First option is to rely on ad-hoc disaster aid, which may happen after the farmer's loss, thus it is an ex-post instrument. Second option is having farmer covered ex-ante through insurance. The ex-ante insurance option (a much more complex form of which is currently the main risk-management program in the U.S.) will be evaluated against the ex-post disaster aid option under perfect and imperfect information environments, which are defined below in turn. The superscripts “0” and “1” henceforth indicate perfect and imperfect information environments. Finally, subscripts “EA” and “EP” henceforth indicate the “ex-ante” and “ex-post” situations, respectively.

Perfect Information

Perfect information refers to a farmer being able to accurately estimate the risk the farmer is facing. Specifically, the farmer accurately estimates the probabilities p_l, p_L, p_{lL}, p_{lN}, p_{nL}, p_{nN}, $p_{d|L}$ and the correlation coefficient ρ.

Ex-Post Disaster Aid under Perfect Information

In the absence of ex-ante insurance coverage, when loss happens, the farmer’s ex-post income with government transfer would become $M - l + \tau$. The government’s objective function is written as

$$G(\tau) = B + \psi(\eta - e^{-w(\tau,r)}) - \left(F_d + k\tau\right) \tag{16}$$

where $w(\tau, r)$ is as defined in equation (6) and $c(\tau)$ is as defined in equation (11). The government’s problem is to maximize its objective function in equation (16) by choosing a non-negative level of transfer. Solving the F.O.C. (which is necessary and sufficient) yields.

$\breve{\tau} = M\left[r - \ln\left(\frac{kM}{\psi}\right)\right]$. In addition to the lower bound defined in equation (14), we now define an upper bound for the marginal political cost as

$$\bar{k} = \frac{\psi e^{r}}{M}. \tag{17}$$

Note that $\breve{\tau} \geq 0$ so long as $k \leq \bar{k}$ and it is monotonically decreasing in k as k increases within $[\underline{k}, \bar{k}]$. Furthermore, $\breve{\tau}$ increasing in ψ, increasing in r and does not depend on p_l. Note that even though $\breve{\tau}$ becomes negative when $k > \bar{k}$, it will be set to zero because government is not interested in taxing the farmer. Recall the assumption that it is equally politically costly to subsidize or tax farmers and the variable political cost can be defined as $k|\tau|$ where $|\cdot|$ is the absolute value operator. Based on F.O.C., one then obtains

$$\breve{\tau} = \begin{cases} M\left[r - \ln\left(\frac{kM}{\psi}\right)\right] > 0 & k < \bar{k}, \\ 0 & k \geq \bar{k}. \end{cases} \tag{18}$$

In addition to the variable cost, the government should take into account the fixed cost. In the final analysis, the government's utility with a farm loss and no transfer, $G(0) = y + \psi(\eta - e^{-w(0,r)})$ should be less than should be less than its utility with a farm loss and the optimal transfer, $G(\breve{\tau} > 0) = y + \psi(\eta - e^{-w(\breve{\tau},r)}) - (F_d + k\breve{\tau})$ in order for government to extend $\breve{\tau} > 0$ to the farmer. The preceding condition can be expressed in the following:

$$F_d < \underbrace{\psi e^r (1 - e^{-\breve{\tau}/M}) - k\breve{\tau}}_{=F^*_{EP}(k)}, \tag{19}$$

where $F^*_{EP}(k)$ denotes the implied maximum level of fixed cost that can be accommodated. The right hand side of the preceding equation shows the additional value gained by extending $\hat{\tau} > 0$ to the farmer while the left hand side shows the fixed cost of doing so. For a high enough political cost $k = \bar{k}$, $\breve{\tau} = 0$, that is, marginal political cost is so high, just based on marginal analysis alone, the government does not extend any ex-post disaster aid. For $k = \bar{k}$, the right-hand side of equation (19) is zero. Given that $F_d > 0$, that would lead to contradiction. At $k = \underline{k}$, where $\underline{k}$ is defined earlier in equation (14), $F^*_{EP}(k)$ becomes $F^*_{EP}(\underline{k}) = \psi\left(e^r - (1+r)\right)$, which is positive for all $r > 0$ and the magnitude of it increases with higher values of r, suggesting that the fixed cost of ex-post disaster aid is justified for bigger losses. One can further verify that $F^*_{EP}(k)$ is a convex function of k and monotonically decreases to zero as k increases towards $\overline{k}$. Based on the foregoing, there should exist k^*_{EP} in equation (19) such that $\underline{k} < k^*_{EP} < \overline{k}$, and the following holds:

$$F^*(k^*_{EP}) = F_d \,. \tag{20}$$

Provided that $k^*_{EP} > \underline{k}$, the government can extend $\breve{\tau} > 0$ for all $k \in [\underline{k}, k^*_{EP})$, despite the presence of fixed cost F_d . We now summarize the foregoing.

Lemma 1: *Suppose that the amount of fixed political cost* F_d *is not too high so that there exists* k^*_{EP} *in equation* (20) *such that* $k^*_{EP} > \underline{k}$ *. For all marginal political cost values that are beyond* k^*_{EP} *and less than* $\overline{k}$ *, that is,* $k \in [k^*_{EP}, \overline{k})$ *, the mere presence of fixed political cost prevents the government to extend monetary support to farmers.*

Based on the preceding lemma, it follows then

$$\tau^* = \begin{cases} \breve{\tau} > 0 & k \in [\underline{k}, k^*_{EP}), \\ 0 & k \geq k^*_{EP}. \end{cases} \tag{21}$$

Now, the farmer's ex-ante calculation will take the ex-post optimal $\tau^* \geq 0$ into account. Let $\tilde{l}_{DA}$ denote the random variable of additive change in the farmer's initial income under disaster assistance. The farmer's expected loss under disaster assistance is then

$$E(\tilde{l}_{DA}) = p_{lL}(l - p_{d|L}\tau^*) + p_{lN}(l - 0) + p_{nL}0 + p_{nN}0 \,. \tag{22}$$

The preceding expression can be re-expressed as

$$E(\tilde{l}_{DA}) = (p_{lL} + p_{lN})l - p_{lL}\, p_{d|L}\tau^{*} = p_{l}l - p_{lL}\, p_{d|L}\tau^{*}\,. \tag{23}$$

As discussed earlier $\tau^{*} = 0$ when the farmer does not have a loss but the area has a loss (that event denoted with the subscript "nL") because of high enough marginal political cost. In addition, disaster aid does not protect against the basis risk (that event denoted with the subscript "nL") as disaster will not be declared in the event of no area loss. Finally, in the event of, neither the farmer nor the area has a loss, the farmer will not receive any disaster aid. A component of the farmer's variance of the loss is

$$E(\tilde{l}_{DA}{}^{2}) = p_{lL}(l - p_{d|L}\tau^{*})^{2} + p_{lN}(l-0)^{2} + p_{nL}0^{2} + p_{nN}0^{2}\,. \tag{24}$$

Because the variance of the farmer's loss is $\sigma^{2}_{\tilde{l}_{DA}} = E(\tilde{l}_{DA}{}^{2}) - \left(E(\tilde{l}_{DA})\right)^{2}$, plugging the corresponding equations yield

$$\sigma^{2}_{\tilde{l}_{DA}} = p_{lL}(1 - p_{lL})(l - p_{d|L}\tau^{*})^{2} + p_{lN}(1 - p_{lN})(l-0)^{2} - 2p_{lL}\,p_{lN}(l - p_{d|L}\tau^{*})l\,. \tag{25}$$

Let $U^{DA^{0}}$ denote the utility of farmer under the disaster aid option and perfect information. Then, $U^{DA^{0}}$ can be expressed as

$$U^{DA^{0}} = U^{0}(\tau^{*}, r) = M - E(\tilde{l}_{DA^{0}}) - 0.5\lambda\sigma^{2}_{\tilde{l}_{DA^{0}}}\,. \tag{26}$$

In the preceding equation, the farmer's ex-ante utility calculation takes into account the possibility of ex-post disaster aid in the event of loss. The government's ex-ante calculation is

$$G^{DA^{0}}(\tau^{*}) = B + \psi(\eta - e^{-w^{0}(\tau^{*}, r)}) - c_{EA}(\tau^{*})\,. \tag{27}$$

In the preceding equation $\tau^{*} \geq 0$ is the optimal solution from equation (18) (subject to area-wide loss) and

$$w_{EA}^{0}(\tau^{*},r)=\frac{U^{0}(\tau^{*},r)-M}{M}=\frac{U^{0}(\tau^{*},r)}{M}-1=\frac{U^{DA^{0}}}{M}-1\,. \tag{28}$$

where $U^{DA^{0}}$ is as obtained in equation (26). Finally, $c_{EA}(\tau^{*})$ is the expected cost of extending ex-post disaster assistance level $\tau^{*}>0$ and equal to

$$c_{EA}(\tau^{*})=p_{lL}\,p_{d|L}\left(F_{d}+k\tau^{*}\right). \tag{29}$$

We now develop the government's objective function under the ex-ante insurance option.

Ex-ante Protection through Insurance under Perfect Information

We use the insurance choice modeling developed in Bulut, Collins and Zacharias (2012). Denote the premium per unit of insurance coverage level with π. If a farmer holds x units of coverage with individual insurance, farmer's objective function in terms of decision variable x is

$$U^{Ins^{0}}=U(x^{0};\,\pi,r)=M-\pi x-p_{l}l(1-x)-0.5\lambda\left(1+(x^{2}-2x)\right)p_{l}(1-p_{l})l^{2}\,. \tag{30}$$

In the preceding equation, $U(x;\,\pi)$ denotes the utility with insurance coverage given premium rate, xpl denotes the expected indemnity from insurance and $(x^{2}-2x)\,p_{l}(1-p_{l})l^{2}$ denotes the risk reduction that can be obtained by holding coverage x and the other parameters are as defined above.

The farmer's problem is to maximize the utility function in equation (30) by choosing a non-negative level of coverage x. Solving the necessary and sufficient first-order condition

(F.O.C.) yields demand for insurance (denote with $\breve{x}$) [8] as

$$\breve{x}^0 = 1 + \frac{1}{\lambda \sigma_l^2}(-\pi + p_l l) . \tag{31}$$

If the farmer purchases full insurance, then the farmer's utility is stabilized across the states of loss or no loss as

$$U^{Ins^0} = U(\breve{x}^0 = 1; \pi^f) = M - p_l l = M(1 - p_l r) , \tag{32}$$

which is less than the farmer's initial income. [9] Note that even though r is allowed to exceed 1, there is still upper bound to it: $0 < r < \frac{1}{p_l}$. The preceding condition is equivalent to: $p_l l < M$, that is, the expected loss amount does not exceed farmer's initial income so that farmer remains solvent when such a loss occurs. Define the percentage change in farmer's financial well-being as

$$w(\breve{x}^0; r) = \frac{U(\breve{x}^0; \pi, r) - M}{M} = \frac{U^{Ins^0}}{M} - 1 . \tag{33}$$

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[8] The demand for coverage decreases with the increases in premium π and increases with increases in the expected loss pl. If the insurance is actuarially fair, that is, premium rate equals expected loss, $\pi = \pi^f = p_l l$ (so that the premium amount would equal expected indemnity), then the strictly risk averse individual will insure completely ($\breve{x} = 1$). If the premium rate is $\pi > p_l l$, that is, rates are unfair (overrated), the demand for coverage will be less than one and increasing with the risk aversion parameter λ and the variance of loss. If insurance is underrated, that is, $\pi < p_l l$, then the demand for coverage will exceed one, that is, the farmer would like to over-insure. In this case, the farmer would be willing to tolerate increased exposure to risk with increased mean income. Nevertheless, the willingness of the farmer to over insure decreases as the risk aversion parameter λ and/or the variance of loss increases.

[9] Moschini and Hennessy (2001) state that "…stating the obvious might yet be useful: risk management activities in general do not seek to increase profits per se but rather involve shifting profits from more favorable states of nature to less favorable ones, thus increasing the expected well-being [utility] of a risk averse individual."

Plugging the preceding into the government's objective function in equation (3) results

$$G^{Ins^0} = G(\breve{x}^0 = 1; \pi^f) = y + \psi(\eta - e^{-w(\breve{x}^0; \pi^f, r)}) \,. \tag{34}$$

Again, in case of loss the farmer obtains the utility given in equation (32) while the government would derive the utility given in equation (34) ex ante and ex-post from insurance for all risk aversion levels.

In order to compare the farmer's ex-ante utility from ex-post disaster assistance U^{DA^0} in equation (26) with the farmer's utility from ex-ante insurance U^{Ins^0} given in equation (32), re-express U^{DA^0} in equation (26) after substituting $E(\tilde{l}_{DA})$ from equation (23) as

$$U^{DA^0} = U^0(\tau^*, r) = \underbrace{M - p_l l}_{=U^{Ins^0}} + \left(\underbrace{p_{lL} p_{d|L} \tau^* - 0.5\lambda \sigma^2_{\tilde{l}_{DA^0}}}_{=H^0(\lambda)} \right). \tag{35}$$

In the preceding equation, the term in parenthesis $H^0(\lambda)$ represents change (gain/loss over) with respect to the insurance option under actuarially fair rates. Now, define a critical value of risk aversion as

$$\lambda^*_{EA} = \lambda^*_{EA}\left(\tau^*(k)\right) = \frac{2 p_{lL} p_{d|L} \tau^*}{\sigma^2_{\tilde{l}_{DA^0}}} \,. \tag{36}$$

For each k and F_d, τ^* is determined, which in turn determines λ^*_{EA}. Recall that $\sigma^2_{\tilde{l}_{DA^0}}$ also depends on τ^* in equation (25). From the definition of λ^*_{EA}, it follows that for all $\lambda \geq \lambda^*_{EA}$, the term $H^0 \leq 0$ in equation (35). Note that if $k \geq k^*_{EP}$, then $\tau^* = 0$. Then, λ^*_{EP} reduces to zero. In that case, any risk-averse individual is better off with the insurance option because ex-post disaster assistance does not pay due to high political cost. We summarize the foregoing.

Lemma 2. *Assume the fixed cost under a disaster declaration (* $F_d > 0$ *) and the marginal political cost are such that* $\underline{k} \le k < k_{EP}^*$ *holds so that* $\tau^* > 0$ *. Then, all farmers with risk aversion above* $\lambda_{EA}^*\left(\tau^*(k)\right)$ *prefer the fairly priced insurance option over ex-post disaster aid (recall that the latter is free to the farmer). As the marginal political cost decreases from* k_{EP}^* *towards* $\underline{k}$ *(meanwhile* τ^* *increases),* $\lambda_{EA}^*\left(\tau^*(k)\right)$ *increases, therefore the fraction of risk-averse farmers preferring fairly priced insurance tends to decrease.*

For those farmers who prefer the insurance option over disaster assistance aid, the government's choice is straightforward for insurance because ex-post disaster is politically costly while insurance under perfect information is not. For those farmers (with very low risk aversion) who prefer ex-post disaster assistance over insurance, the government has to weigh the additional value for such farmers with the cost associated with the disaster assistance option. Intuitively, government's ex-post income transfer may not efficiently reduce risk of a risk-averse farmer, favoring the ex-ante insurance option. Even though the ex-post disaster aid can increase mean income, the political cost of extending ex-post aid may not be economically justified.

So far, the analysis assumed away information problems which can prevent a farmer from taking up full insurance under actuarially fair rates. By providing premium subsidies, the government can get the farmer into insurance or encourage purchasing higher levels of coverage. The insurance option under information problems will be analyzed in the next section.

Imperfect Information: Introducing a Farmer's Over-Confidence

The previous empirical studies has indicated that farmers can be over-confident (Scherrick, 2002; Umarov and Sherrick, 2005; Gao et al. 2011).[10] We model a farmer's over-confidence as

$$q_l = \max\{p_l - \delta_l, 0\}, \quad (37)$$

where q_l denotes the farmer's assessment of risk and $\delta > 0$ represents the discrepancy with respect to true risk (p_l as defined earlier).[11] Furthermore, Menapace, Colson and Raffaelli (2012) provide some evidence that farmers are risk averse and farmers who are more (less) risk-averse perceive greater (smaller) farm losses.[12] The effects of the relationship between a farmer's perception of risk and the farmer's risk aversion (taste for insurance) for crop insurance purchases is modeled

$$\delta_l = \theta p_l A(\lambda). \quad (38)$$

In the preceding equation, $\theta \in (0,1)$ is a parameter sets the upper limit on farmer's over-confidence the degree of over-confidence and the function $A(\lambda)$ indexes the over-confidence in terms of the degree of risk-aversion. We write $A(\lambda)$ as

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[10] Based on a survey of mid-western farmers, Scherrick et al. (2004) note (see p. 113) "Our survey experience indicates that farmers can readily provide subjective probabilities (and likely use them intuitively in decision making), but how well their expectations correspond to actual yield risk is especially important to consider in the development of effective insurance markets. Providing information to help calibrate farmers' expectations about insurable risks will have high value in a continued high-risk environment."

[11] This can be viewed as a form of decision maker's errors in "probability weighting" in the language of Prospect Theory (Kahneman and Tversky, 1979). Application of Prospect Theory into farm risk-management choices can be interesting avenue of research. A review of the applications of prospect theory in other areas (risk or non-risk based) can be found in Barberis (2013).

[12] Finkelstein and McGarry (2006) find that risk-preferences and risk-types can be negatively correlated with each other in long-term care insurance markets. They mention that this may not hold in all insurance markets as there is evidence of positive correlation between the two in auto insurance markets.

$$A(\lambda) = \left(\frac{\lambda_{\max} - \lambda}{\lambda_{\max} - \lambda_{\min}} \right), \tag{39}$$

where the parameters $\lambda_{\max}$ and $\lambda_{\min}$ are the maximum and minimum risk aversion levels that can be considered (see Table 1 for more information). Thus, over-confidence is assumed to be decreasing in the farmer's risk aversion parameter. Now, substituting the expression from equation (38) in equation (37) results in

$$q_l = p_l \left(1 - \theta A(\lambda)\right). \tag{40}$$

One can verify that

$$\lim_{\lambda \to \lambda_{\min}} \delta_l = \theta p_l \text{ and so } \lim_{\lambda \to \lambda_{\min}} q_l = p_l (1 - \theta). \tag{41}$$

$$\lim_{\lambda \to \lambda_{\max}} \delta_l = 0 \text{ and so } \lim_{\lambda \to \lambda_{\max}} q_l = p_l. \tag{42}$$

That is, as risk aversion gets higher, the farmer's perception of risk approximates the true risk. Denote the random variable $\tilde{j}$ as the farmer's loss at the amount of l with the probability q_l. Then, the farmer's expected loss is $E(\tilde{j}) = q_l l$ and the variance of farmer's loss is $\sigma_{\tilde{j}}^2 = q_l (1 - q_l) l^2$. Based on $E(\tilde{j})$ and $\sigma_{\tilde{j}}^2$, farmer's preferences in equation (1) can be rewritten

$$U^1 = M - q_l l - 0.5 \lambda q_l (1 - q_l) l^2. \tag{43}$$

The same definition of area loss from the perfect information environment applies here as well. Denote the farmer's assessment of area loss under imperfect information with q_L. We will assume that the farmer holds a similar attitude towards the area risk as the farmer views one's own risk, that is,

$$q_L = \max\{p_L - \delta_L, 0\}. \tag{44}$$

In the preceding equation, the parameter δ_L represents the farmer's over-confidence towards area risk and it is defined as similar to δ_l in equation (38)

$$\delta_L = \theta p_L A(\lambda) . \tag{45}$$

Similarly, one can obtain that as the risk aversion increases towards $\lambda_{\max}$, δ_L goes to zero and the perceived area risk q_L becomes equal to true area risk p_L. In addition, as the risk aversion goes to $\lambda_{\min}$, δ_L increases towards θp_L, while q_L decreases to $p_L(1-\theta)$.

Furthermore, we will assume that the farmer will accurately estimate the correlation between area and farm yields (so ρ remains as before). The joint distribution of the individual and the area losses is re-expressed in terms of farmer's perceptions as: q_{lL} replaces p_{lL}, q_{lN} replaces p_{lN}, q_{nL} replaces p_{nL} and q_{nN} .replaces p_{nN} with the following formulations: $q_{lL} = q_l q_L + \rho z_l z_L$; $q_{lN} = q_l(1-q_L) - \rho z_l z_L$; $q_{nL} = (1-q_l)q_L - \rho z_l z_L$; and $q_{nN} = (1-q_l)(1-q_L) + \rho z_l z_L$, where ρ is the correlation coefficient, z_l is the standard deviation of event S_i and z_L is the standard deviation of event S_a under imperfect information. The standard deviations z_l and z_L are defined as $z_l = \sqrt{q_l(1-q_l)}$ and $z_L = \sqrt{q_L(1-q_L)}$ and they replace s_l and s_L, respectively. In addition, the covariance term between the events (S_i, S_a) becomes $Cov(S_i, S_a) = \rho z_l z_L$. As before, the value of the correlation coefficient parameter must be consistent with the fact that probabilities are all non-negative. The assumption that $q_{lN} > 0$ and $q_{nL} > 0$ remains. From these relationships, one can again re-obtain the marginal probability of losses as $q_l = q_{lL} + q_{lN}$ and $q_L = q_{lL} + q_{nL}$.

Comparing the joint probabilities under perfect and imperfect information environments, one can deduce that $q_{lL} \le p_{lL}$ because $q_l \le p_l$ from equation (40) and the covariance term is perceived to be lower $\rho z_l z_L \le \rho s_l s_L$**.** The latter follows from *i)* $q_l \le p_l$ from equation (40) and the assumption that $p_l < 0.5$ imply that $z_l < s_l$ and *ii)* $q_L < p_L$ from equation (44) and the assumption that $p_L < 0.5$ imply that $z_L < s_L$. Meanwhile, the direction of bias regarding the basis risk can not be determined in the formulations of q_{lN} and p_{lN} because $(1-q_L) \geq (1-p_L)$ and that counters the perception through covariance term.

Finally, we will assume that the conditional probability that a disaster will be declared will remain the same under the two information environments, that is,

$$q_{d/a} = p_{d/a}\,. \tag{46}$$

Ex-Post Disaster Aid under Imperfect Information

The farmer's utility under the disaster aid option should be revised in line with the farmer's perceptions of probability of farmer's own loss and area loss given in equations (40) and (44), respectively. Combined with the estimated value for $q_{d|L}$ above, farmer's expected loss under disaster assistance option under imperfect information is then

$$E(\tilde{j}_{DA}) = q_{lL}(l - q_{d|L}\tau^*) + q_{lN}(l-0) + q_{nL}0 + q_{nN}0\,. \tag{47}$$

Recall that τ^* in equation (21) does not depend on a farmer's perceived risk, whether that be p_l or q_l. A component of the farmer's variance of the loss is

$$E(\tilde{j}_{DA}{}^2) = q_{lL}(l - q_{d|L}\tau^*)^2 + q_{lN}(l-0)^2 + q_{nL}0^2 + q_{nN}0^2\,. \tag{48}$$

Because the variance of the farmer's loss is $\sigma^2_{\tilde{j}_{DA}} = E(\tilde{j}_{DA}{}^2) - \left(E(\tilde{j}_{DA})\right)^2$, plugging the corresponding equations yield

$$\sigma^2_{\tilde{j}_{DA}} = q_{lL}(1-q_{lL})(l - q_{d|L}\tau^*)^2 + q_{lN}(1-q_{lN})(l-0)^2 - 2q_{lL}q_{lN}(l - q_{d|L}\tau^*)l\,. \tag{49}$$

Based on $E(\tilde{j}_{DA})$ and $\sigma^2_{\tilde{j}_{DA}}$, one can then write the farmer's preference under the disaster aid option as

$$U^{DA^1} = M - E(\tilde{j}_{DA}) - 0.5\lambda\sigma^2_{\tilde{j}_{DA}} \, . \qquad (50).$$

The preceding equation represents farmer's perception of farmer's financial well-being. However, the government will continue to use farmer's utility U^{DA^0} given in equation (26) as it has the knowledge of farmer's true risk and wants to accurately evaluate the farmer's well-being. In addition, the expected cost of disaster assistance under imperfect information (denote it with $c^{DA^1}_{EA}(\tau^*)$) is equal to $c^{DA^0}_{EA}(\tau^*)$ under perfect information given in equation (29) as the government (unlike the farmer) accurately estimates p_{IL}. Denote further that the government's utility from disaster assistance under imperfect information with $G^{DA^1}_{EA}$. Then,

$$G^{DA^1}_{EA}(\tau^*) = G^{DA^0}_{EA}(\tau^*) \qquad (51)$$

where $G^{DA^0}_{EA}(\tau^*)$ is the government utility from disaster assistance under perfect information given in equation (27).

Ex-ante Protection through Insurance under Imperfect Information

In line with probability of loss q_l from equation (37), the farmer's objective function with insurance coverage (given in equation (30)) can be written as

$$U^1(x;\, \pi) = M - \pi x - q_l l(1-x) - 0.5\lambda\left(1 + (x^2 - 2x)\right) q_l (1-q_l) l^2 \, .$$

From F.O.C.s, the demand for coverage would be

$$\breve{x}^1 = 1 + \frac{-\pi + q_l l}{\lambda q_l (1-q_l) l^2} \, . \qquad (52)$$

Suppose further that the government sets the actuarially fair rates consistent with the probability of loss given in equation (37), that is [13],

$$\pi^{f} = p_l l = q_l l + \delta_l l \,. \tag{53}$$

Plugging the preceding rate in equation (31) yields

$$\breve{x}^1 = 1 - \frac{\delta_l l}{\lambda q_l (1-q_l) l^2} < 1 \,. \tag{54}$$

The equation indicates that the farmer's over-confidence results in under-insurance at the true actuarially fair rate. Note that the farmer not only under-estimates the expected loss but also the risk (variance of the loss) provided that $q_l < 0.5$). Moreover, in equation (54)

$$\breve{x}^1 = 0 \text{ when } \delta_l \geq \lambda q_l (1-q_l) l \text{ and} \tag{55}$$

$$\breve{x}^1 > 0 \text{ when } \delta_l < \lambda q_l (1-q_l) l \,.$$

Note that $\lambda \in [\lambda_{\min}, \lambda_{\max}]$ and $\lambda_{\min}$ can be a very small number. Thus, it is quite possible that the right hand side of equation (55) can indeed be lower than the left hand side. That is, if the farmer's over-confidence is sufficiently high, it can reduce the coverage demand all the way to zero.

Suppose that crop insurance premium subsidies are available. Denote the total amount of subsidy with $T \geq 0$. The amount of subsidy is modeled as a linear function of a constant subsidy rate, that is, $T = t\pi x > 0$ where $t \geq 0$ is the subsidy rate.[14] Plugging that in the farmer's objective function yields

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[13] Gao et al. 2011 (in p. 27 of their paper, which we obtained through personal communication) state that " Since it is perceived risk that governs demand and actual risk that governs supply it is no wonder that market imperfections arise and that government involvement is required to encourage participation."

[14] This is consistent with modeling the amount of premium as a linear function of premium rate.

$$U^1(x;\pi,t) = M - (1-t)\pi x - q_l l(1-x) - 0.5\lambda\left((x^2 - 2x + 1)q_l(1-q_l)l^2\right). \tag{56}$$

Maximization of the preceding utility function with respect to x yields

$$\breve{x}^1 = 1 + \frac{q_l l - (1-t)\pi}{\lambda q_l(1-q_l)l^2}, \tag{57}$$

where the constant subsidy rate creates a proportional outward shift in coverage demand.

Now, suppose that government sets the premium rate based on the true probability of loss given in equation (53). The demand becomes

$$\breve{x}^1 = 1 + \frac{q_l l - (1-t)(q_l l + \delta l)}{\lambda q_l(1-q_l)l^2} = 1 - \frac{\delta l}{\lambda q_l(1-q_l)l^2} + \frac{t p_l l}{\lambda q_l(1-q_l)l^2}. \tag{58}$$

Note that in the preceding equation, if $t = \frac{\delta}{p_l}$, then $\breve{x} = 1$; if $t < \frac{\delta}{p_l}$, then $\breve{x} < 1$; and if $t > \frac{\delta}{p_l}$, then $\breve{x} > 1$. Thus, if the subsidy rate is sufficiently low, that is, $t < \frac{\delta}{p_l}$, then the farmer under insurances. [15]

By using equation (38), one can re-express the subsidy level that induces farmer to take up full insurance in terms of parameter λ as $\frac{\delta}{p} = \theta A(\lambda)$ where $A(\lambda)$ is from equation (39). As risk aversion increases, $\frac{\delta}{p}$ goes to zero, whereas as risk aversion decreases, then $\frac{\delta}{p}$ goes to θ, the maximum level of over-confidence. [16]

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[15] We do not consider coverage restrictions, also known as "deductible". For example, the maximum coverage level available in Revenue Protection (RP) insurance plan is 85%. Furthermore, the subsidy rates in federal crop insurance are decreasing at the very high coverage levels instead of constant rate throughout coverage levels used in here.

[16] Note that this subsidy rate depends on individual farmer's risk preferences because δ does so in equation (38). In actuality, crop insurance subsidy rates are fixed for all farmers, regardless of

Ex-ante Protection through Insurance in the Presence of Ex-Post Disaster Assistance under Imperfect Information

Having shown that farmer with over-confidence can demand less than full coverage at the actuarially fair premium rates in the previous section, we now extend the insurance modeling to recognize that a sufficiently low insurance coverage can trigger disaster assistance given the political economy from equation (3). We begin with the ex-post situation where the insurance coverage is $\breve{x}^1$ from equation (58), which is a function of a subsidy rate $t \geq 0$. In case of loss, farmer's ex-post income with insurance coverage $\breve{x}^1$ would be the initial income minus the farmer paid premium minus part of the farmer's loss not covered by insurance, that is, $M-(1-t)\pi\breve{x}^1 - l(1-\breve{x}^1)$. (The preceding calculation is in line with the Supplemental Revenue Assistance (SURE) revenue calculation reported in Zulauf, Schnitkey and Langemeier, 2010, p. 502, column 2.).[17] Then, the ratio of loss with insurance coverage $\breve{x}^1$ to the initial income can be defined as

$$r(\breve{x}^1,t) = \frac{(1-t)\pi\breve{x}^1 + l(1-\breve{x}^1)}{M} = \frac{(1-t)\pi\breve{x}^1}{M} + r(1-\breve{x}^1)\,. \tag{59}$$

If government considers a transfer amount $\tau \geq 0$ in the post insurance situation, the percent change in farmer's financial well-being with τ is

$$w(\tau,\breve{x}^1,t,r) = \frac{(M-(1-t)\pi\breve{x}^1 - l(1-\breve{x}^1)+\tau)-M}{M} = -r(\breve{x}^1,t) + \frac{\tau}{M}\,, \tag{60}$$

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their risk preferences. At the same time, farmer's risk preference can be farmer's private information. Within our modeling, if government knew only up to the distribution of risk preferences in the population, it could offer a constant subsidy rate based on the expected risk preference.

[17] Even though farmer (ex-ante) enjoys some peace of mind with the risk reduction obtained from purchased coverage level, this is ignored in the ex-post situation.

where $r(\breve{x}^1, t)$ is as defined earlier. Plugging $w(\tau, \breve{x}^1, t, r)$ in the government's utility in equation (16), from F.O.C.s, one can obtain the ex-post disaster assistance in the post insurance situation as

$$\breve{\tau}(\breve{x}^1, t) = M\left[r(\breve{x}^1, t) - \ln\left(\frac{kM}{\psi}\right)\right]. \qquad (61)$$

In addition to the variable cost, the government should take into account the fixed cost in deciding whether to extend $\breve{\tau}(\breve{x}^1, t)$ to the farmer. Similar to the approach used earlier in equation (19), the amount of fixed cost (so long it is not too high) picks an upper bound for the marginal political cost (denote it with k_{EP}^{**}, which can be different than k_{EP}^{*} in equation (20)). Then,

$$\tau^*(\breve{x}^1, t) = \begin{cases} \breve{\tau}(\breve{x}^1, t) > 0 & k \in [\underline{k}, k_{EP}^{**}) \\ 0 & k \geq k_{EP}^{**}. \end{cases}. \qquad (62)$$

In case of no loss, the random variable $\tilde{l}$ takes the value of zero and so $r_h = 0$, but with the insurance coverage x in hand, the post-insurance loss would be the farmer paid premium

$$r(\breve{x}^1, t)\Big|_{r_h=0} = \frac{(1-t)\pi\breve{x}^1}{M}. \qquad (63)$$

Going back to the perfect information environment for a moment (setting δ_l in equation (38) and δ_L in equation (45) to zero at all risk aversion levels will do) and also assuming the actuarially fair premium rate $\pi = \pi^f = p_l l$ and $t = 0$, the farmer would choose full coverage level and the demands in equations (57) and (31) would coincide ($\breve{x}^1 = \breve{x}^0 = 1$). One then obtains

$$r(\breve{x}^0 = 1, t = 0)\Big|_{r_h=0, \pi=\pi^f} = \frac{p_l l}{M} = p_l r. \qquad , \qquad (64)$$

Based on preceding equation, if government considers extending transfer amount $\tau \geq 0$, the percent change in farmer's financial well-being with τ would be

$$w(\tau, \breve{x}^0 = 1, t = 0, r_h = 0) = -p_l r + \frac{\tau}{M}.$$

In order to prevent any government transfer in the preceding situation (where only loss incurred is the farmer paid premium), it is sufficient to revise the minimum level of marginal political cost in equation (14) upward to

$$\underline{k}^* = \frac{\psi e^{p_l r}}{M}. \tag{65}$$

Note that for an initial income of $M = \$50,000$, $\psi = \$74,909$ (see footnote 3), probability of farmer's loss is $p_l = 0.2$ and $r = 0.25$ (which implies that $e^{0.25} = 1.2840$), the boundary values for k ($\underline{k}^*$ in equation (65) and $\overline{k}$ in equation (17)) would reduce to $1.575 < k < 1.9237$, which is in line with the political cost numbers reported in Alston and Hurd (1990).

Having identified the benchmark level of marginal political cost $\underline{k}^*$ in equation (65), we revert back to our analysis under imperfect information. From equation (62), we identify the optimal ex-post disaster aid as function of ex-ante insurance subsidy and so ex-ante insurance coverage. We know develop government's ex-ante objective function under insurance by recognizing the political reality of potential ex-post disaster assistance. Note that even though government takes into account the farmer's perception in order to arrive at the farmer's coverage demand ($\breve{x}^1$ from equation (57)), it will continue to use farmer's true probability of loss in welfare calculations. That is because the government is interested in farmer's true financial well-being. From the government's point of view, the farmer's true expected loss under insurance plus disaster assistance option (when farmer has imperfect information) is

$$E(\tilde{l}_{Ins^1+DA^1}) = p_{lL}(l - l\breve{x}^1 - p_{d|L}\tau^*(\breve{x}^1, t)) + p_{lN}(l - l\breve{x}^1) + p_{nL}0 + p_{nN}0, \tag{66}$$

where $\breve{x}^1$ is from equation (57) and $\tau^*(\breve{x}^1,t)$ is from equation (62). Moreover, a component of the farmer's variance of the loss can be obtained as

$$E(\tilde{l}_{Ins^1+DA^1}{}^2) = p_{lL}(l - l\breve{x}^1 - p_{d|L}\tau^*(\breve{x}^1,t))^2 + p_{lN}(l - l\breve{x}^1)^2 + p_{nL}0^2 + p_{nN}0^2 . \quad (67)$$

Government then obtains the variance of the farmer's loss as

$$\sigma^2_{\tilde{l}_{Ins^1+DA^1}} = E(\tilde{l}_{Ins^1+DA^1}{}^2) - \left(E(\tilde{l}_{Ins^1+DA^1})\right)^2 . \quad (68)$$

where the expressions for $E(\tilde{l}_{Ins^1+DA^1})$ from equation (66) and $E(\tilde{l}_{Ins^1+DA^1}{}^2)$ from equation (67) are substituted. Finally, combining $E(\tilde{l}_{Ins^1+DA^1})$ and $\sigma^2_{\tilde{l}_{Ins^1+DA^1}}$ from above, government arrives at the farmer's true financial well-being under insurance plus disaster aid option as

$$U_{Ins^1+DA^1} = M - (1-t)\pi x - E(\tilde{l}_{Ins^1+DA^1}) - 0.5\lambda\sigma^2_{\tilde{l}_{Ins^1+DA^1}} . \quad (69).$$

Again, it is the government that calculates the preceding utility using the information regarding true risk while also taking into account the farmer's perceived coverage demand given in (57)..

Using $U_{Ins^1+DA^1}$ from equation (69), the government evaluates ex ante the percentage change in the farmer's financial well-being as $w(\breve{x}^1,t,r,\tau^*(\breve{x}^1,t)) = \frac{U_{Ins^1+DA^1} - M}{M} = \frac{U_{Ins^1+DA^1}}{M} - 1$. Finally, the government's ex-ante objective function when farmer has an imperfect information is

$$\begin{aligned} G_{Ins^1+DA^1} = G(\breve{x}^1;t,r,\tau^*(\breve{x}^1,t)) = B + \psi(\eta - e^{-w(\breve{x}^1;t,r,\tau^*(\breve{x}^1,t))}) \\ - ktp_l l\breve{x}^1 \\ - p_{lL}p_{d/a}(F_d + k\tau^*(\breve{x}^1,t))I(\tau^*(\breve{x}^1,t)). \end{aligned} \quad (70)$$

where insurance premium is set at the actuarially fair rate $\pi^f = p_l l$ (priced at the true risk), $\tau^*(\breve{x}^1,t)$ is from equation (62) and $I(\tau^*(\breve{x}^1,t))$ is the indicator variable which takes value of one when $\tau^*(\breve{x}^1,t) > 0$ or zero when $\tau^*(\breve{x}^1,t) = 0$. That is, the government optimally chooses a subsidy level by taking into account that the induced coverage demand may eliminate the need for some disaster assistance down the road. Note that we are not considering a fixed cost in providing subsidies with crop insurance.[18]

Denote the optimal solution to the maximization of the objective function given in equation (70) with $\breve{t}$. Now, whenever $\breve{t} \le \frac{\delta}{p}$, $\breve{x} \le 1$ would hold (the latter condition can be imposed per actuarial standards). Note that $\frac{\delta}{p}$ is monotonically increasing in δ and if the marginal political cost is sufficiently high, then government may not fully subsidize insurance coverage. The government's optimal subsidy under information problems (per requirement that the coverage level will not exceed 100%) is $t^* = \text{minimum}\left\{\breve{t}, \frac{\delta}{p}\right\}$ and so $x^{*1} = \text{minimum}\left\{\breve{x}^1, 1\right\}$.

The government's objective function in equation (70) once evaluated at (t^*, x^*) will be denoted with $G_{Ins^{*1}+DA^1}$ and is

$$\begin{aligned} G_{Ins^{*1}+DA^1} = G(x^{*1}, t^*, r, \tau^*(x^{*1}, t^*)) = B + \psi(\eta - e^{-w(x^{*1}, t^*, r, \tau^*(x^{*1}, t^*))}) \\ -kt^* p_l l x^{*1} \\ -p_{lL} p_{d/a}(F_d + k\tau^*(x^{*1}, t^*)) I(\tau^*(x^{*1}, t^*)), \end{aligned} \quad (71)$$

where again insurance premium is set at the actuarially fair rate $\pi^f = p_l l$, $I(\tau^*(x^{*1}, t^*))$ is the indicator variable which takes value of one when $\tau^*(\breve{x}^1, t^*) > 0$ or zero when $\tau^*(\breve{x}^1, t^*) = 0$.

Simulation Analysis

Numerical analysis is used to gain insights into the government choices among multiple

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[18] Crop insurance's authorization is under permanent law, the Federal Crop Insurance Act of 1980. Its legislative fixed costs are sunk. The infrastructure and labor force for the delivery of crop insurance have developed and evolved over time.

instruments to provide financial support to farmers at times of distress. Government's utility in equation (51) and that in equation (71) are simulated under perfect and imperfect information environments. For the perfect information environment, the farmer's perceived probabilities are replaced with the actual probabilities of loss (by setting δ_l in equation (38) and δ_L in equation (44) to zero for all risk aversion levels) and the government's optimization problem equation (70) is re-solved, based on which then equation (71) is re-calculated. We know from equation (51) that government objective function under sole disaster assistance option is the same under both information environments. The preceding government's utility functions are simulated based on the parameter values given in Table 1 (the necessary programs are written and run using MATLAB software). Particularly, the upper limit on the over-confidence is restricted to 75%, that is, $\theta = 0.75$ in equations (38) and (44). That means as the farmer's risk aversion decreases towards $\lambda_{\min}$, the over-confidence would approach to 75% of the farmer's probability of loss (for both individual and the area). Otherwise, the over-confidence level monotonically decreases in risk aversion with zero, which can be verified in equations (41) and (42).

The results for perfect information case are displayed in in Figures 2a, 3a and 4a under the low loss situation ($r = 0.25$); medium loss situation ($r = 0.5$); and high loss situation ($r = 1.0$), respectively. The y–axis in all figures is the farmer's risk aversion level (λ) and the x-axis in all figures is the marginal political cost (k) (see Table 1). One can verify that the government prefers the insurance option for virtually all parameter values considered. This preference holds even though some farmers may prefer ex-post disaster aid over insurance for a small range of parameters (low risk aversion levels and low marginal political cost). No insurance subsidy is needed. Farmer take up full insurance at the actuarially fair rate and ex-post disaster assistance completely deterred. Similarly, the results for the government net utility under imperfect information environment are displayed in Figures 5a, 6a and 7a (for the low, medium and high loss situations, respectively). The preceding Figures indicate that the government's net utility with subsidized insurance exceeds its utility with ex-post disaster payments over most parameter values. In addition, Tables 2 and 3 list extreme values of the government's maximum net utility from insurance and disaster assistance options under perfect and imperfect information environments, respectively. One thing that is apparent from these tables is that the insurance option provides more stable (in terms of the difference between extreme values) maximum net utility to government than that under the disaster aid option only.

Furthermore, Figures 5b, 6b, and 7b display optimal subsidy rate for low, medium and high loss situations under imperfect information. One can verify that the model generates substantial subsidy rates from low to moderate risk aversion levels, which induces farmers to participate or buy up higher crop insurance coverage. Finally, Figures 5c, 6c, and 7c report ex-post disaster assistance amounts with insurance and without insurance, as well as ex-ante subsidy amount for low, medium and high loss situations under imperfect information. By inducing higher coverage levels, ex-ante insurance subsidies accomplish: First, they reduce (in most cases they totally deter) ex-post disaster assistance. Second, they provide the only safety net when the government can not extend ex-post disaster assistance due to the fixed cost involved and high marginal political cost. Figure 5c and 6c clearly illustrate these effects. In Figure 7c, fixed cost amount is relatively small given the large amount of loss considered. As a result, in the absence of insurance, government would provide ex-post disaster assistance (displayed in green) on a large portion of marginal political cost values considered. In the presence of subsidized insurance; ex-post disaster assistance is mostly deterred with the exception of farmers who are at the lowest end of the risk aversion spectrum considered.

Summary and Conclusion

The justification for crop insurance subsidies is being questioned in light of budget and policy issues. Crop insurance has received government support for a variety of reasons. One reason for expanding government support has been to discourage ad hoc, ex-post disaster payments, which grew sharply in the 1980s and 1990s, were costly and discouraged the purchase of crop insurance. Congress restructured and further increased subsidies through legislation in the Federal Crop Insurance Reform Act of 1994 and the Agricultural Risk Protection Act of 2000 (ARPA), in a sense, buying up the farmer's participation (Coble and Barnett, 2012). Better data arising from high and diverse participation helped improve underwriting and ratemaking. Perhaps, upfront payment of subsidies credibly communicated the Federal Government's commitment to the insurance program and its preference over ex-post disaster aid. [19] In fact, after many years of Congress passing ad hoc disaster legislation to deal with weather misfortunes in agriculture, there were no calls for crop disaster legislation in 2011 and 2012.

We have focused on information problems in the form of a farmer's over-confidence as a reason that for government support for crop insurance by assuming government has an interest in farmers' welfare and considers to make transfer payments to farmers to help them deal with income losses. However, the government faces both fixed and marginal political costs in making transfer payments to farmers. In this framework, the government's objective function (which depends on the farmer's income losses) is written to evaluate three options: 1) ex-post disaster aid; 2) ex-ante insurance option with perfect information; and 3) ex-ante insurance option with

[19] House Majority Leader John Boehner told Agri-Pulse (2013) during a taped interview "Over the last 15 years, crop insurance is where we have been trying to help move farmers in terms of taking advantage of risk management tools for their crops". Mr. Boehner also noted "It is still the central focus of where we think farmers ought to be able to have easy access to insure their crops and insure some type of revenue out of it. It makes the most sense to me and always has."

imperfect information (farmers are over-confident about their risk). For option 1), an optimal level of ex-post transfer payment is derived for a given marginal political cost, fixed cost and farmer's risk. For option 2), government's utility is obtained when the farmer's risk is protected ex-ante through unsubsidized, actuarially fair crop insurance. In comparing 1) and 2), numerical analysis shows the government prefers unsubsidized crop insurance at fair premium rates.

Regarding option 3), the model is augmented by considering a farmer who underestimates the actual probability of loss for yield or revenue. The degree of over-confidence is assumed to be decreasing in the farmer's risk aversion parameter. Assuming that the government sets premium rates on the true probability of loss for the farmer, the analysis indicates the farmer will reduce insurance coverage below the level that the farmer would chose under fair rates and full information on the probability of loss. Government prefers to subsidize the premium rates to induce the over-confident farmer to take up more insurance but must balance that against a marginal political cost of providing insurance subsidies and a given level of fixed cost. When providing subsidies, government also takes into account the disaster assistance implications of induced coverage levels. The optimal subsidy level is numerically solved. Numerical analysis indicates that the government's net utility with subsidized insurance exceeds its utility with ex-post disaster payments over most parameter values (Figures 5a, 6a, and 7a). The ex-ante political cost arising from the insurance subsidy appears to be much smaller compared with the ex-post political cost arising from the optimal disaster aid whenever they are both positive (Figures 5c, 6c, and 7c).

As the 2013 Farm Bill process is underway, the debate on the degree and form of government support of agriculture will continue. The modeling framework here is fairly flexible to study (given government's preferences) the effectiveness of supplemental revenue programs as found in legislation developed during the summer of 2012. These supplemental programs, (which are typically area based plans and being offered either free or highly subsidized, under - priced in short) tend to replace crop insurance at high coverage levels (Bulut, Collins, and Zacharias, 2012; Bulut and Collins, 2012; and Bulut and Collins, 2013).

Table 1. Parameter Values Used in the Simulation

Parameters	Values
M : Farmer's initial income	\$50,000
B : Normalized value of government's utility in status quo (perhaps from non-food related sectors)	0
ψ : Net value-added to the U.S. economy, per farmer	\$74,909 [a]
η : Target (reference) level of for the farmer's financial well-being	2
$r = \frac{l}{M}$: The ratio of amount of farmer's loss to the farmer's initial income	0.25 in the small loss scenario; 0.50 in the medium loss scenario; and 1.0 in the large loss scenario.
$l = Mr$: Amount of farmer's loss	\$12,500 for the small loss scenario; \$25,000 for the medium loss scenario; \$50,000 for the large loss scenario.
θ : Maximum over-confidence	0.75
p_l : Probability of farmer's loss	0.2
$p_L = p(A)$: Probability of area loss (perfect information)	0.15
$p_{d/a} = P(D \mid A)$: The conditional probability of disaster declaration under perfect information	0.5
$q_{d/a} = Q(D \mid A)$: The conditional probability of disaster declaration under imperfect information	0.5
$p_d = P(D) = P(D \cap A) = P(D \mid A)P(A)$: The unconditional probability of disaster declaration.	$0.5 \times 0.15 = 0.075$

Table 1. Parameter Values Used in the Simulation, continued

$\underline{k}^* = \frac{\psi}{M} e^{p_l r}$: Lower bound for the marginal political cost	1.575 for the small loss scenario, 1.6558 for the medium loss scenario, 1.8299 for the large loss scenario.
$\bar{k} = \frac{\psi}{M} e^{r}$: Upper bound for the marginal political cost	1.9237 for the small loss scenario, 2.47 for the medium loss scenario, 4.0725 for the large loss scenario.
k : marginal political cost	Varies between $\underline{k}$ and $\bar{k}$ with equal increments (30 data points are used).
F_d : The amount of fixed cost (per farmer with a loss in the area in case of disaster declaration).	$1,000
ρ : Correlation between farmer's and area losses	0.5
$\lambda_{\min}$: Lower bound for the risk aversion	It corresponds to the level of risk aversion where the ratio of risk-premium (the variance component of the farmer's utility function $0.5\lambda_{\min} p_l (1-p_l) l^2$) to the size of the loss (l) is 0.01. Note that $\lambda_{\min}$ decreases as the size of loss increases.
$\lambda_{\max}$: Upper bound for the risk aversion	It corresponds to the level of risk aversion where the ratio of risk-premium (the variance component of the farmer's utility function $0.5\lambda_{\min} p_l (1-p_l) l^2$) to the size of the loss (l) is 1. Note that $\lambda_{\max}$ decreases as the size of loss increases.
λ : The risk aversion level	It varies $\lambda_{\min}$ between $\lambda_{\max}$ with equal increments (30 data points are used).

Table 2. Extreme Values of Government's Maximized Net Utility (in $) under Perfect Information

Insurance Option (No Subsidy is Needed)		
	Lowest	**Highest**
Small loss ($r = 0.25$)	$71,068	$71,068
Medium loss ($r = 0.5$)	$67,031	$67,031
Large loss ($r = 1$)	$58,324	$58,324
Disaster Assistance Option		
	Lowest	**Highest**
Small loss ($r = 0.25$)	$48,701	$70,880
Medium loss ($r = 0.5$)	$13,325	$66,685
Large loss ($r = 1$)	$-98,889	$57,595

Note. Government's utility in status-quo (when there is no change in the farmer's financial well-being is the per farmer net value added ($\psi = \$74,909$).

Lowest and highest values are of those maximized values of the government net utility function for a given option on a grid of risk aversion and marginal political cost levels (30 data points for each; see Table 1). That is, for a given option, 900 maximized values of the government net utility function are obtained, and the table reports the lowest and highest of those values for that option.

Table 3. Extreme Values of Government's Maximized Net Utility (in $) under Imperfect Information

Insurance Option with Optimal Subsidy		
	Lowest	**Highest**
Small loss ($r = 0.25$)	$70,542	$71,068
Medium loss ($r = 0.5$)	$65,052	$67,031
Large loss ($r = 1$)	$50,907	$58,324
Disaster Assistance Option		
	Lowest	**Highest**
Small loss ($r = 0.25$)	$48,701	$70,880
Medium loss ($r = 0.5$)	$13,325	$66,685
Large loss ($r = 1$)	$-98,889	$57,595

Note. Government's utility in status-quo (when there is no change in the farmer's financial well-being is the per farmer net value added ($\psi = \$74,909$).

Lowest and highest values are of those maximized values of the government net utility function in question on a grid of risk aversion and marginal political cost levels (30 data points for each; see Table 1). That is, for a given option, 900 maximized values of the government net utility function are obtained, and the table reports the lowest and highest of those values for that option.

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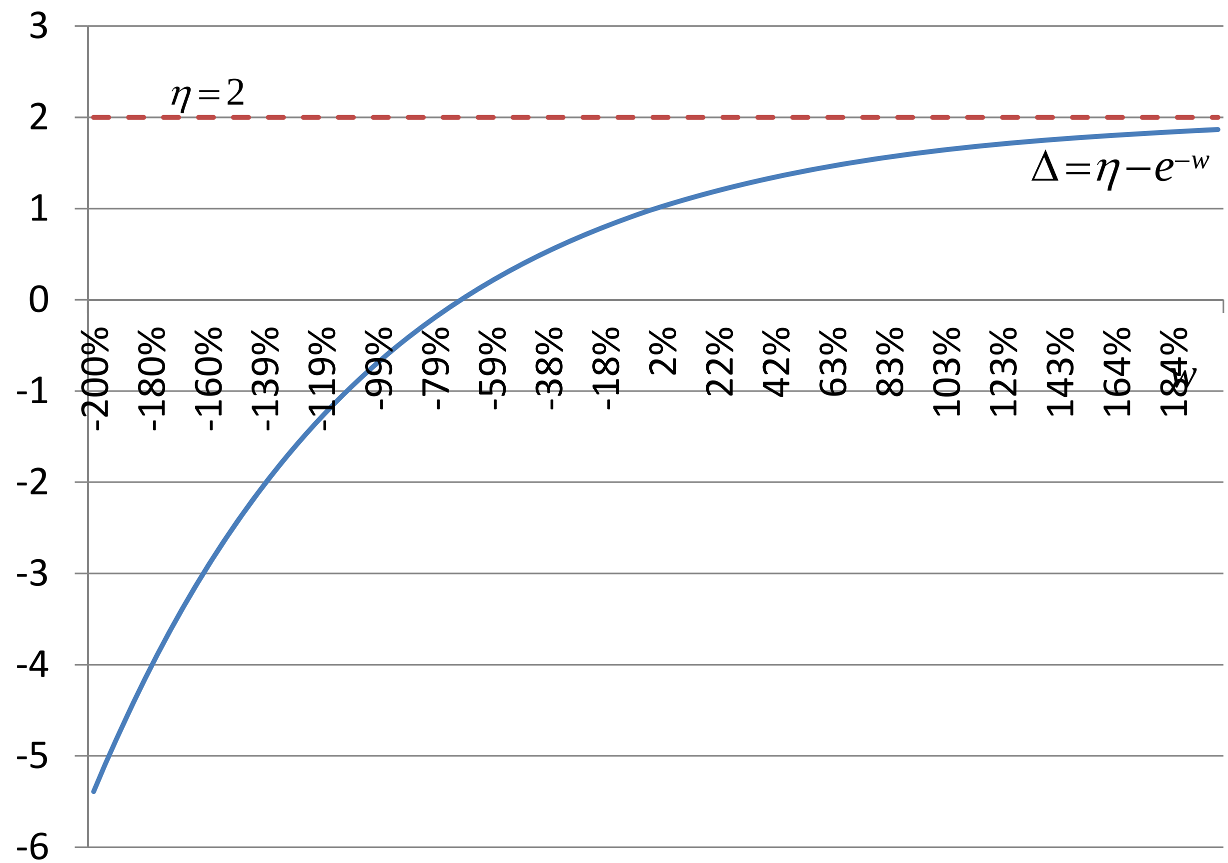

Figure 1. A plot of the function that indexes the changes in farmer's financial well-being. The x-axis displays the percent change in farmer's financial well-being (w), while y-axis displays the value of the indexing function ($\Delta = \eta - e^{-w}$ where $\eta = 2$). It can be verified in the figure that the function takes the value of one when there is no change in farmer's financial well-being.

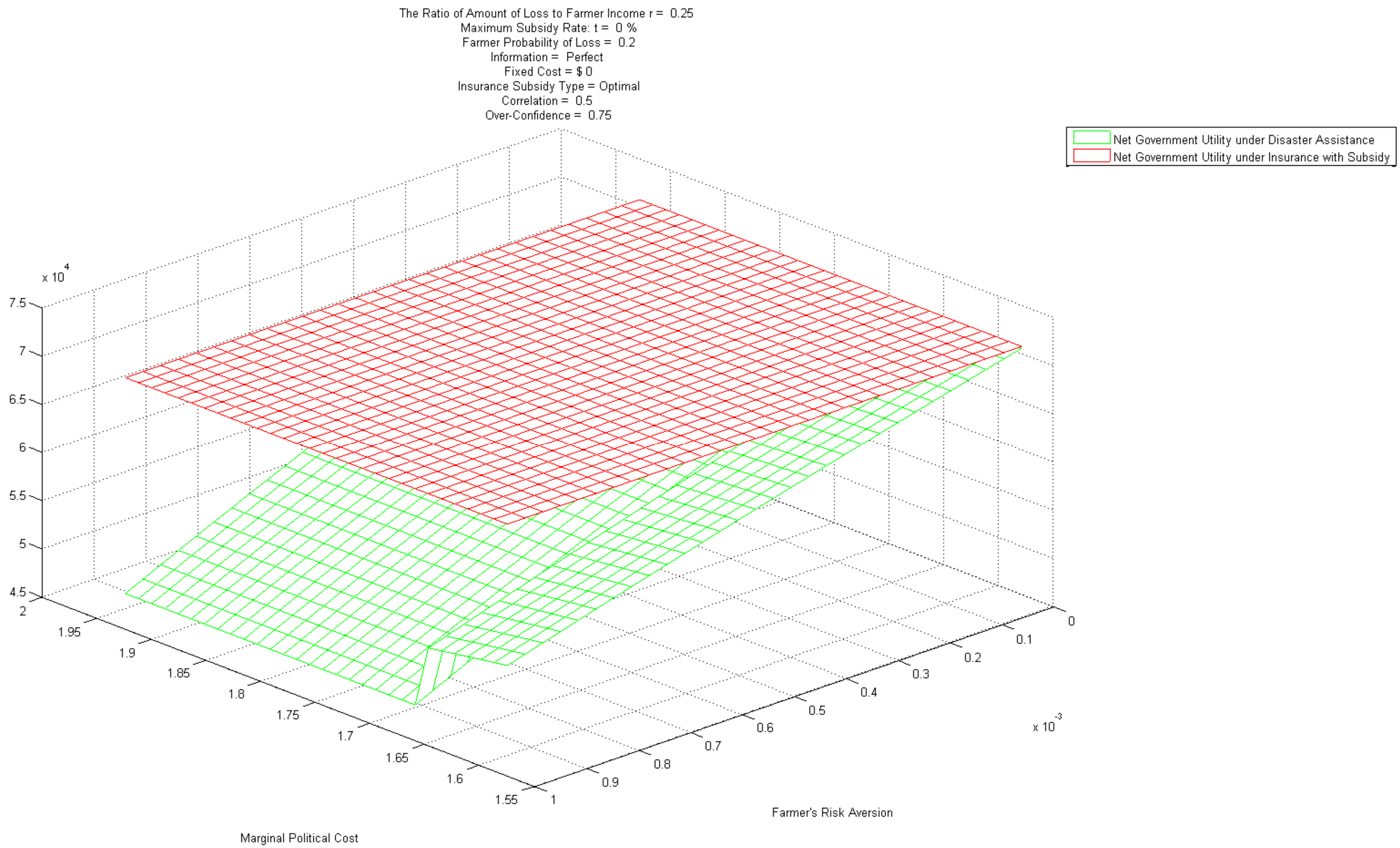

Figure 2a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.25$ and the information is perfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. No subsidy under insurance option is needed.

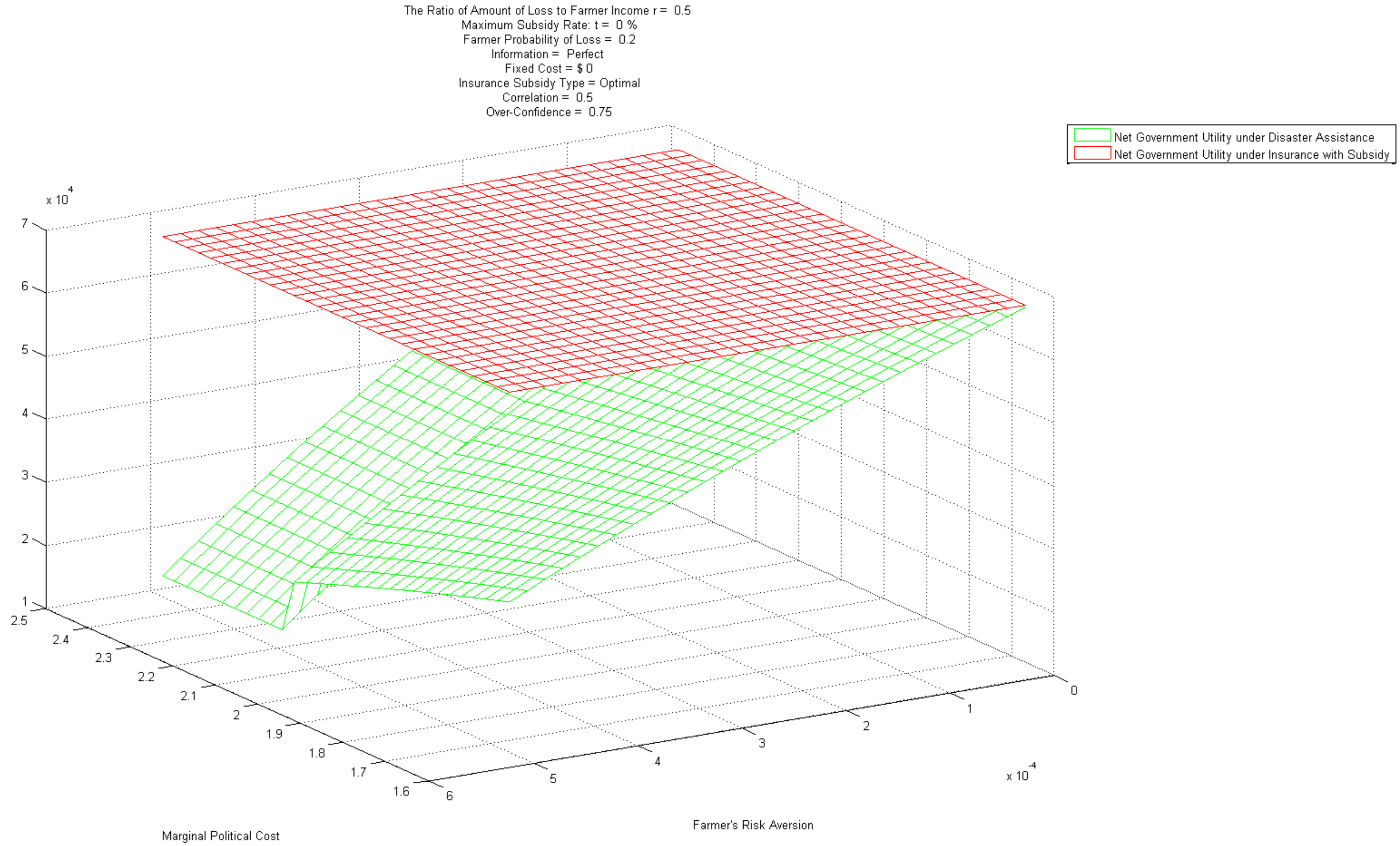

Figure 3a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.5$ and the information is perfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. No subsidy under insurance option is needed.

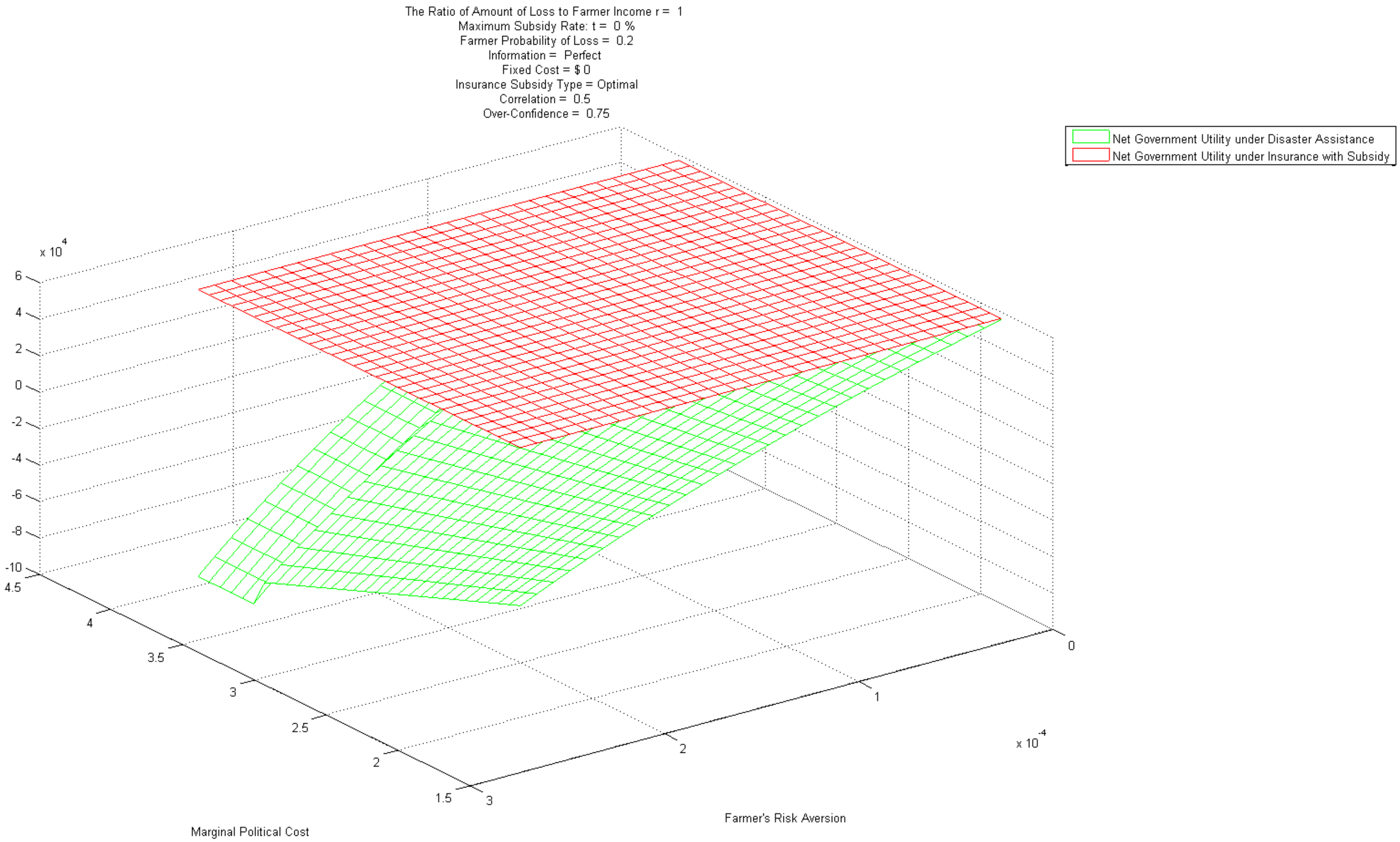

Figure 4a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 1.00$ and the information is perfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. No subsidy under insurance option is needed.

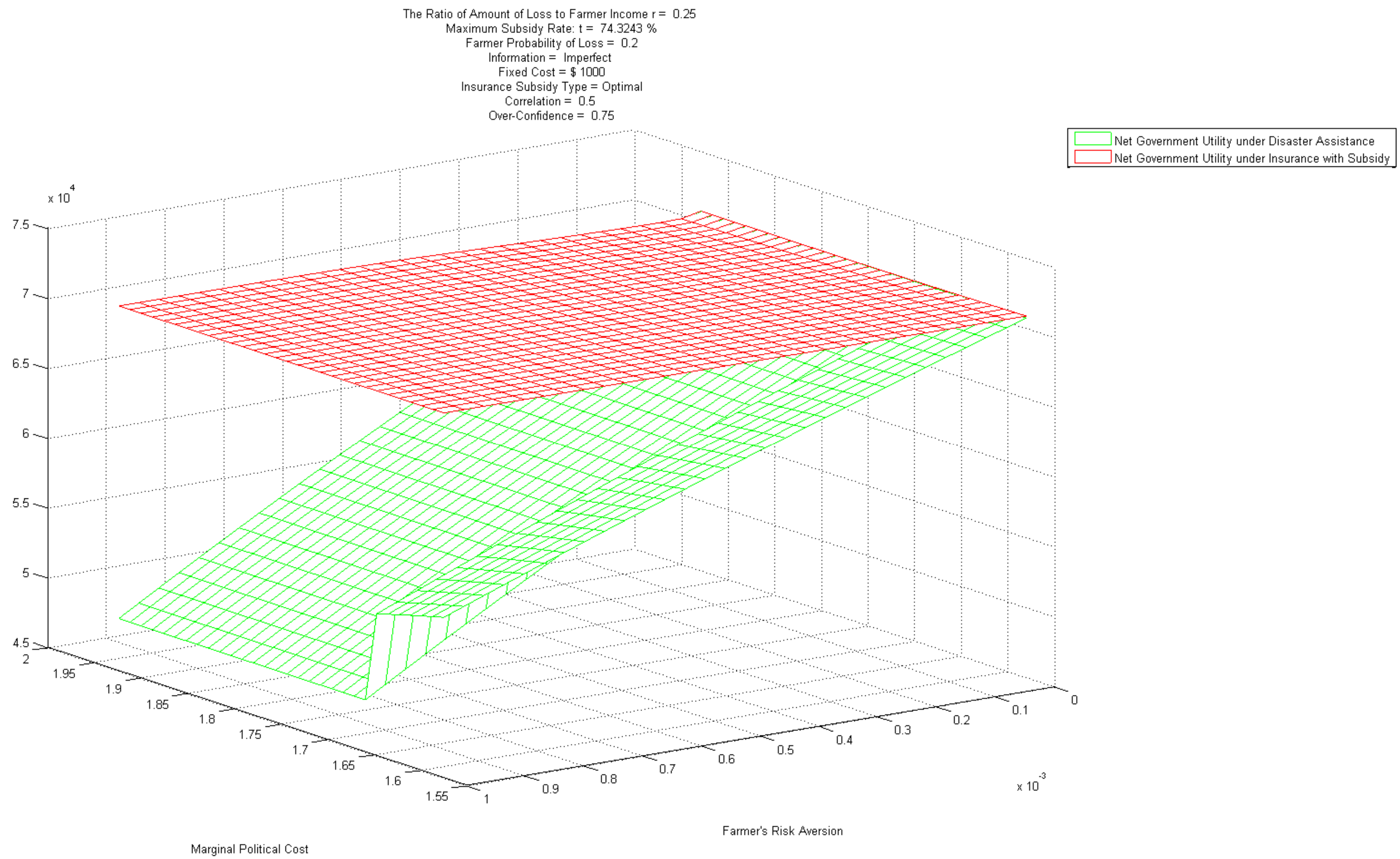

Figure 5a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.25$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. Some subsidy under insurance option is used. .

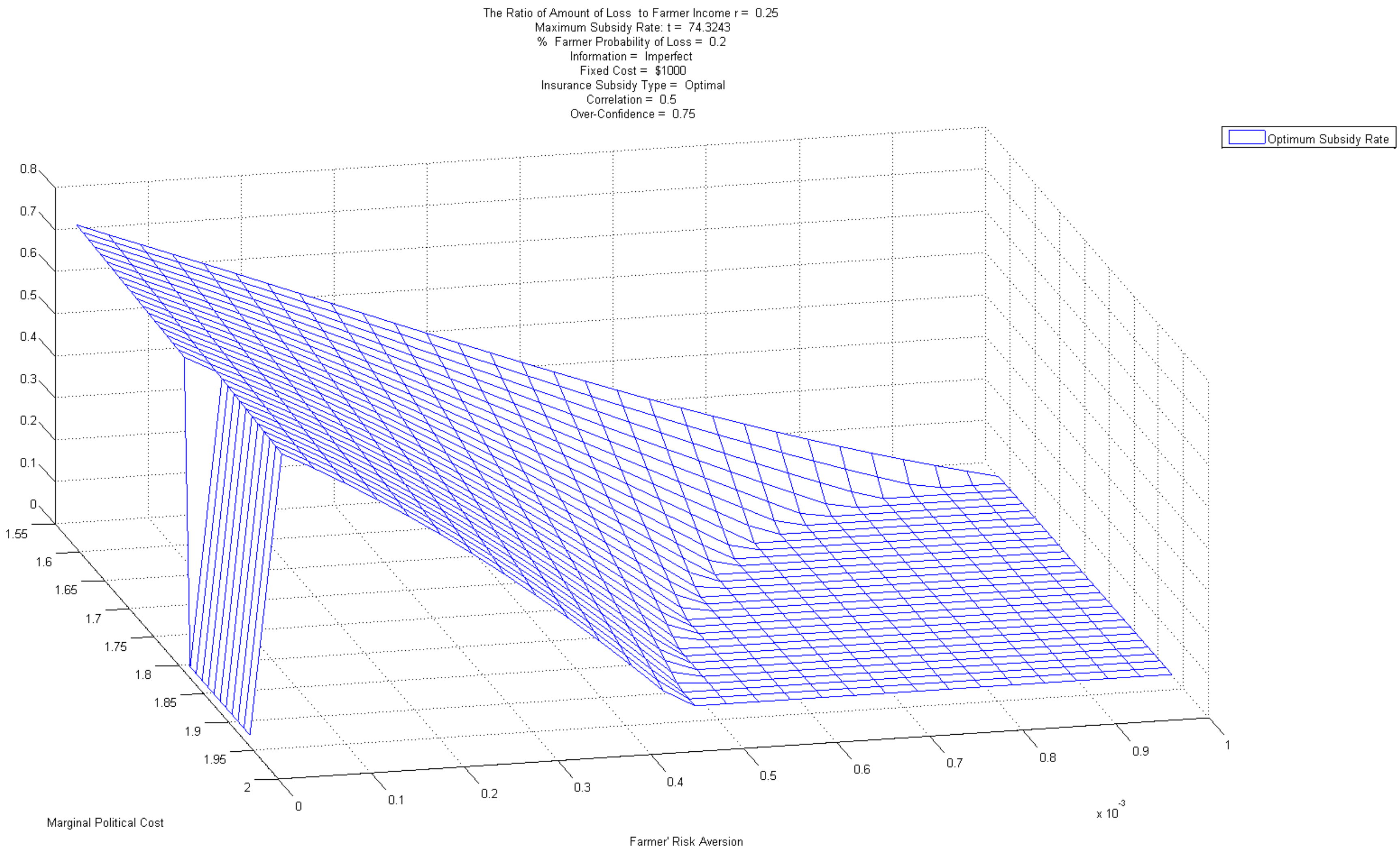

Figure 5b. Optimum subsidy rate (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.25$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.

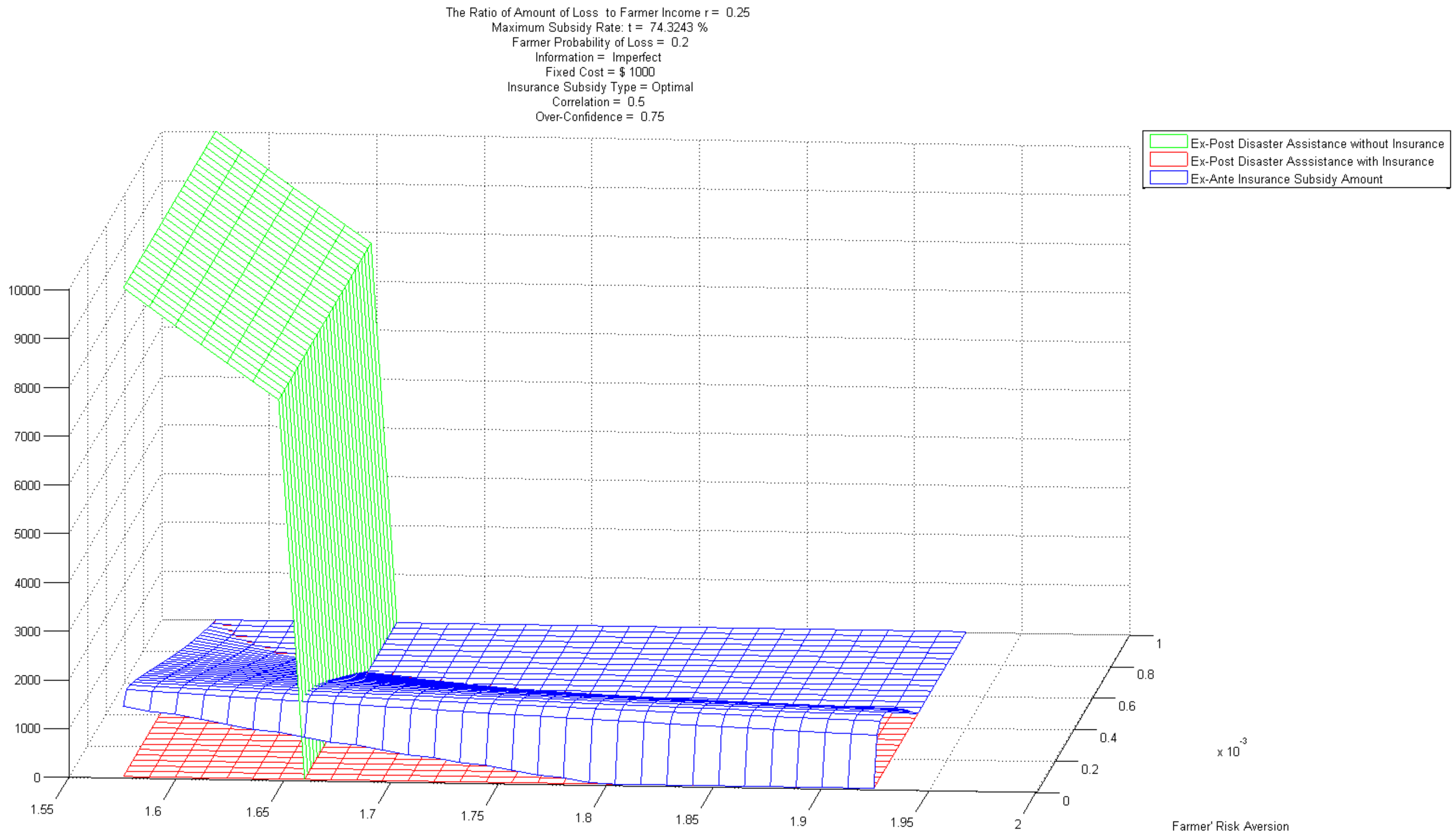

Figure 5c. Ex-post disaster assistance in case of a loss with and without insurance option (in red and in green, respectively), and the ex-ante subsidy amount under insurance option (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.25$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.

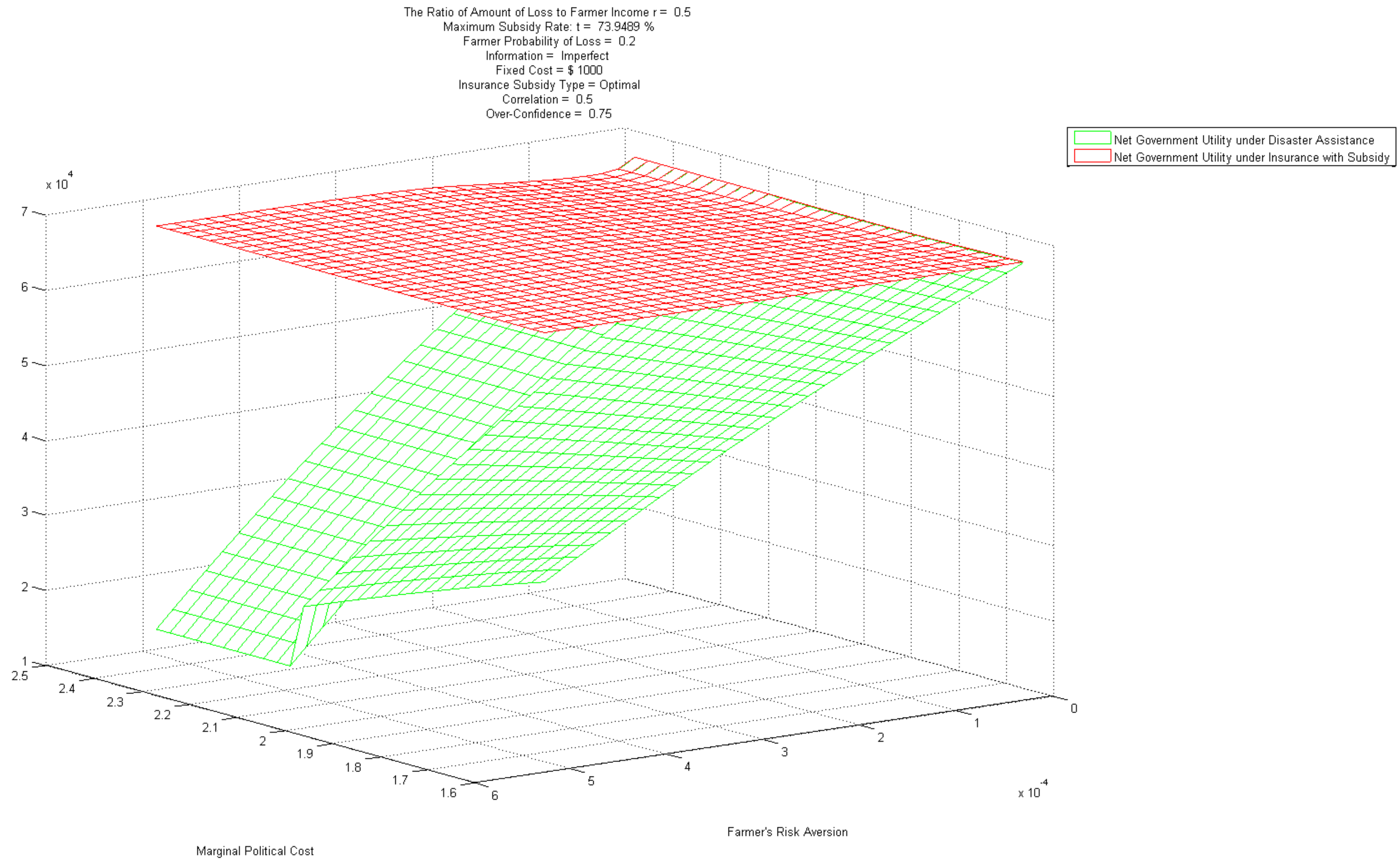

Figure 6a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.50$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. Some subsidy under insurance option is needed.

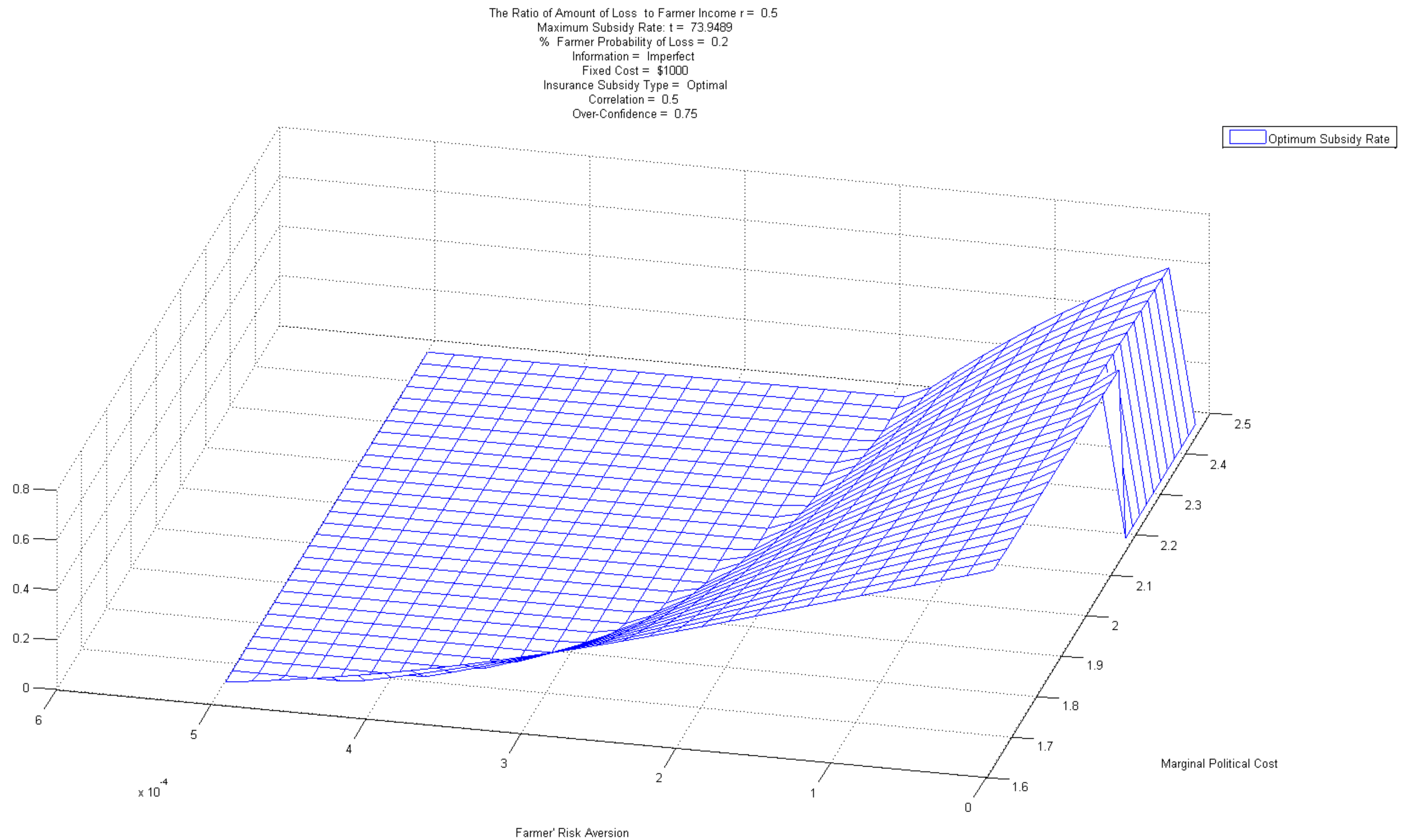

Figure 6b. Optimum subsidy rate (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.50$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.

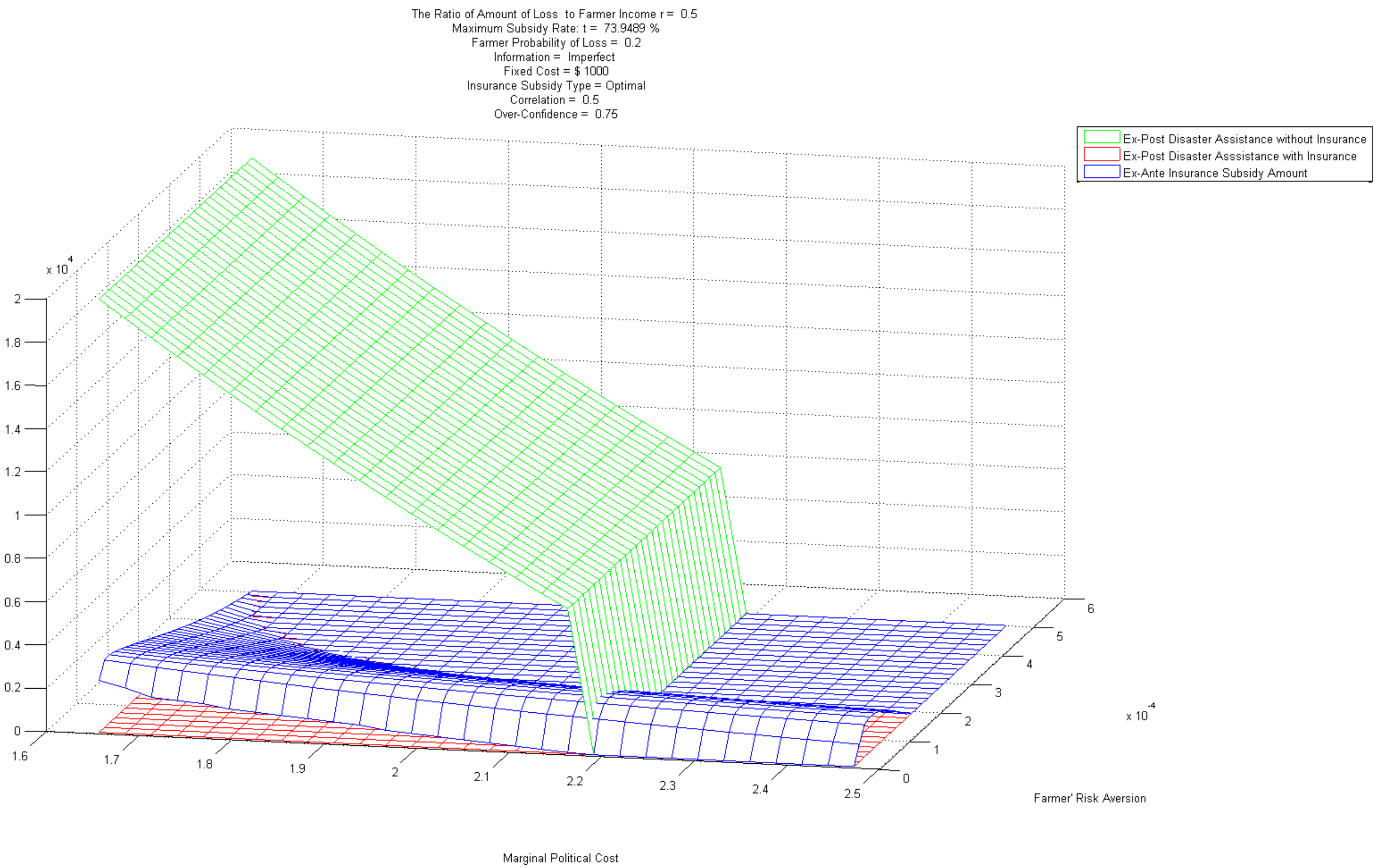

Figure 6c. Ex-post disaster assistance in case of a loss with and without insurance option (in red and in green, respectively), and the ex-ante subsidy amount under insurance option (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 0.50$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.

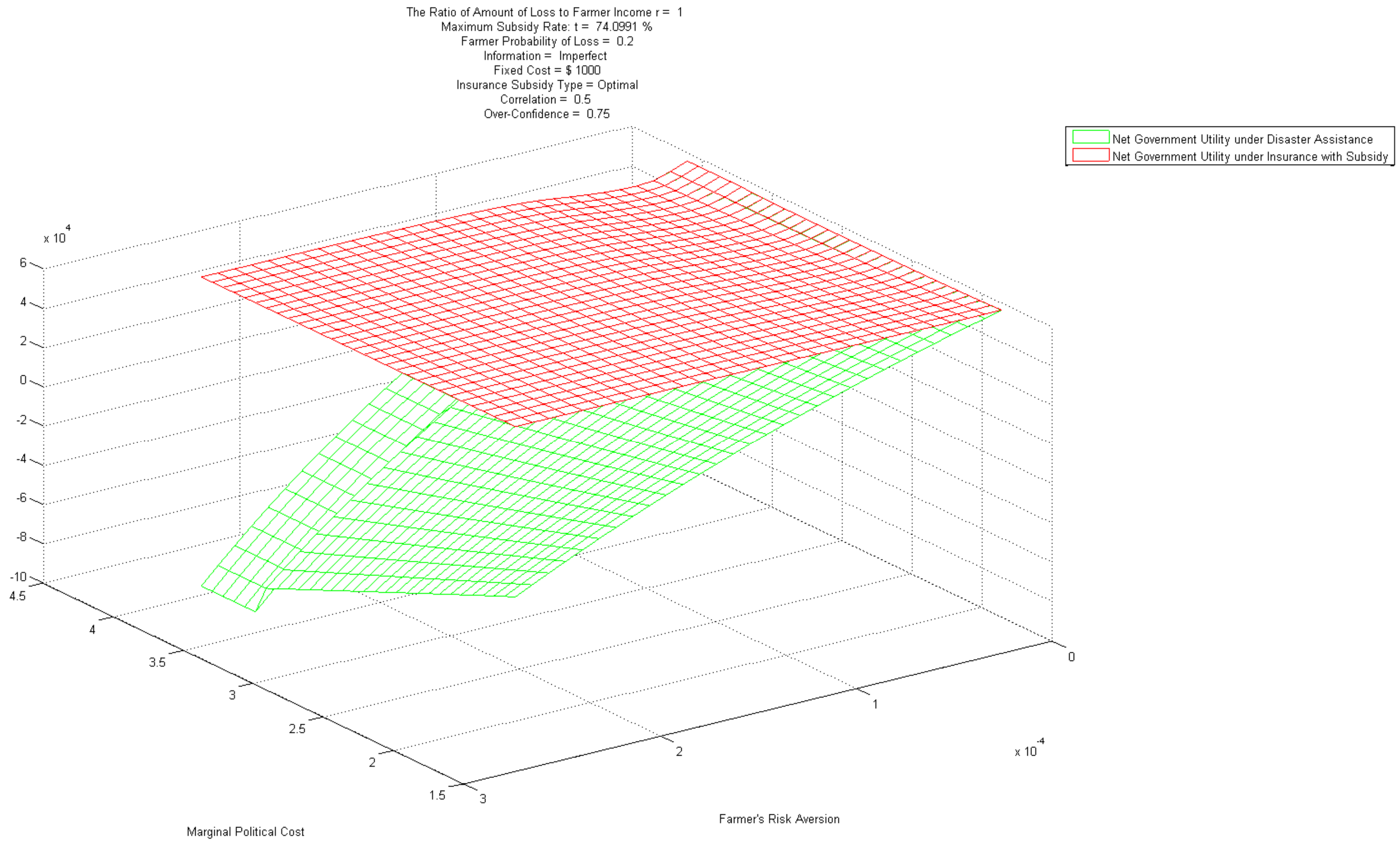

Figure 7a. Government's net utility under insurance option (in red) and that under disaster assistance option (in green) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 1.00$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications. Some subsidy under insurance option is needed.

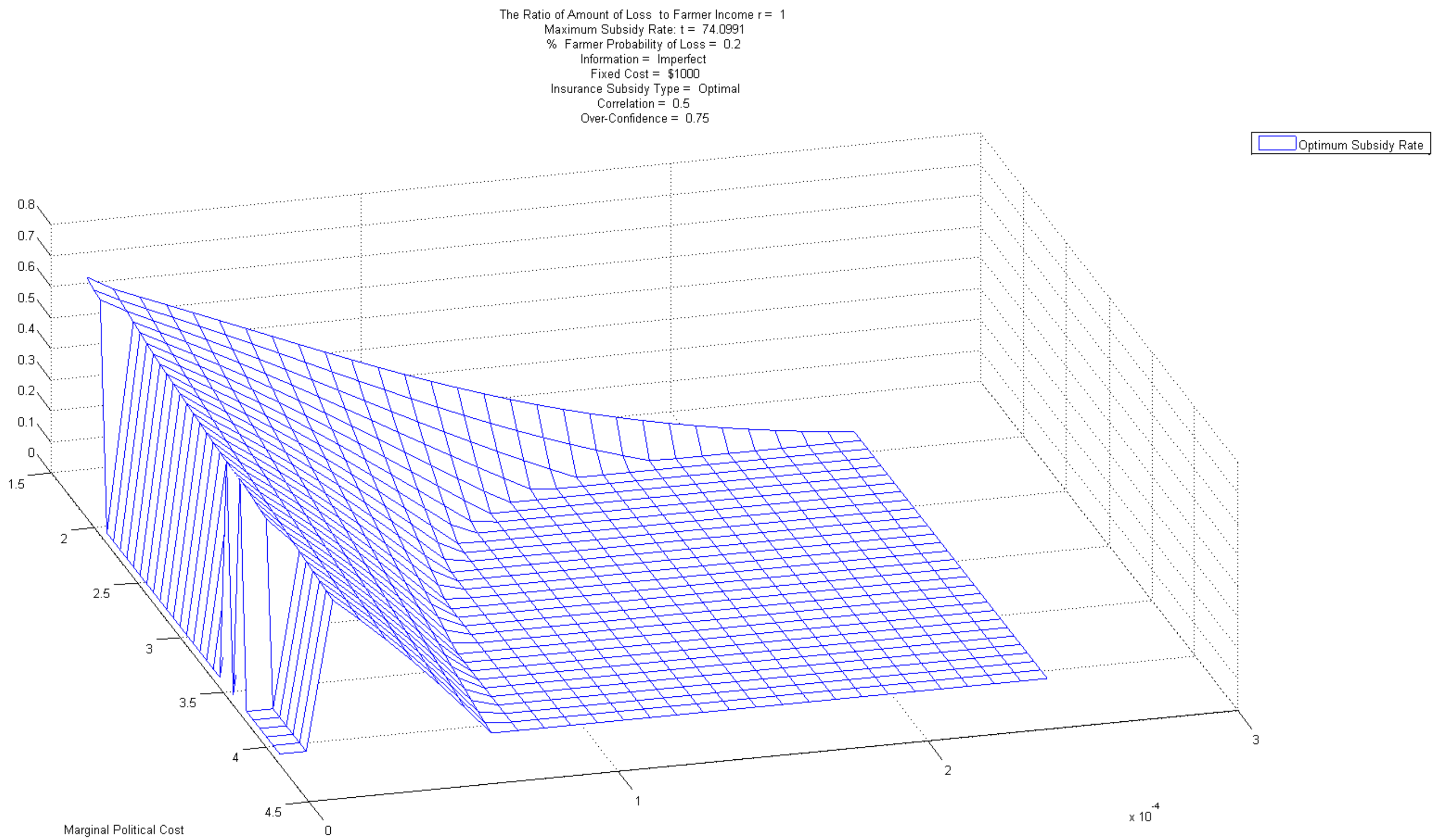

Figure 7b. Optimum subsidy rate (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 1.00$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.

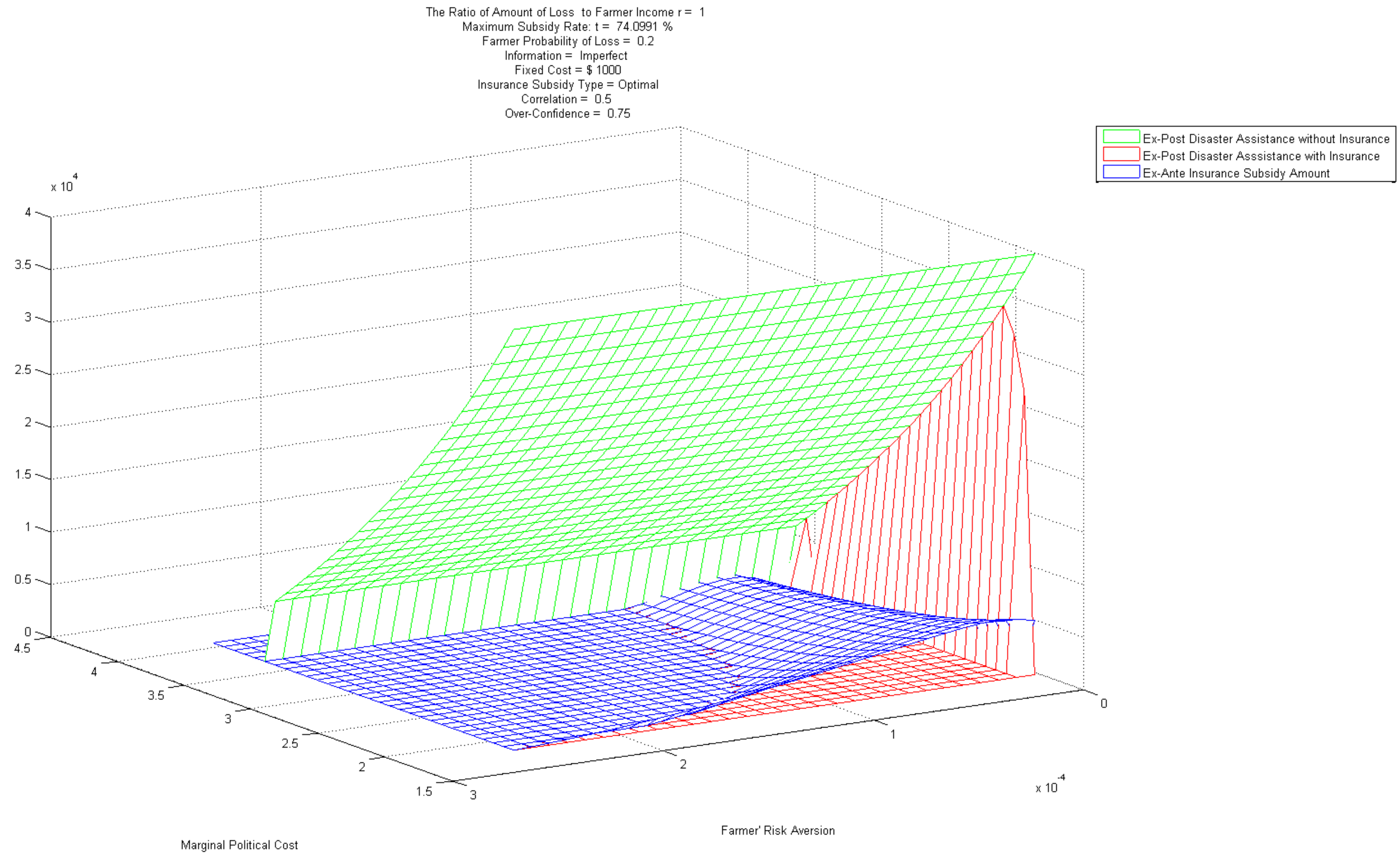

Figure 7c. Ex-post disaster assistance in case of a loss with and without insurance option (in red and in green, respectively), and the ex-ante subsidy amount under insurance option (in blue) in z-axis, marginal political cost (k) is on the x-axis and risk-aversion (λ) is on the y-axis. Note: $r = 1.00$ and the information is imperfect. Ex-ante insurance option takes into account the ex-post disaster assistance implications.