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Introduction

The National Flood Insurance Program (NFIP) was established in 1968 as a federally administered insurance program to reduce costs to the federal government for flood recovery and allocate recovery costs among potential disaster relief beneficiaries (Rumsey, 2010, pp. 56, 62). Participants purchase flood insurance through participating property insurance providers which receive a haircut of the premium for overhead costs and passes the remainder to Federal Emergency Management Agency (FEMA). This paper outlines a model to measure the net social benefits attributable to the insurance component of the NFIP. Development of this model provides the baseline for further economic and social analysis of the NFIP.

The Social Surplus Model

A benefit-cost analysis (BCA) requires a determination of whose costs and benefits count in the analysis. First is consumers, who purchase insurance through the NFIP. Second is producers, who sell flood insurance plans on behalf of the NFIP. Third is the federal government, which manages the program. Fourth is third parties affected broadly by externalities, such as environmental impacts.

A BCA methodology typically defines the net social benefit as the summed benefits minus the summed costs. This model uses an alternative approach which analyzes the change in the social surplus attributable to a program (Boardman, Greenberg, Vining, & Weimer, 2010, p. 62). The social surplus (S) is the sum of the consumer surplus (C), the producer surplus (P), government surplus (G), and the external surplus (E), each of which have their own definitional components:

$$S = C + P + G + E \tag{1}$$

In addition, the incremental shift in social benefit due to a policy change is,

$$\Delta S = \Delta C + \Delta P + \Delta G + \Delta E. \tag{2}$$

The consumer surplus measures the net benefit due to consumers from acquiring goods and services in the market. In general, the consumer surplus represents the net amount consumers are willing to spend for a given good or service minus the actual price paid (Frank, 2006, pp. 160–162). In the case of the NFIP, it is assumed that consumers would be unable to purchase flood insurance through the private market if the federal program did not exist, as was the case prior to enactment of the National Flood Insurance Act of 1968 (NFIA). The case case, where NFIP provides insurance to consumers is represented by C^* and the alternative, where the NFIP no longer provides service is represented by C'. Based on this, the total change in consumer surplus due to the NFIP is:

$$\Delta C = C^* - C'. \tag{3}$$

In the event the NFIP did not exist, it is reasonable to assume the government would make payments to those affected by flood disasters on an *ad hoc* basis. This was the stance of the Congress prior to the enactment of the NFIA (Moss, 1999). In this case, such *ad hoc* aid is represented by a. Therefore,

$$C' = a. \tag{4}$$

To calculate the consumer surplus due to the NFIP, it is necessary to find the willingness-to-pay (WTP) for insurance services (w), to estimate the premium payments consumers are likely to pay for flood insurance through the NFIP (ω), and to find the difference between the two. In a given year, this would be given by

$$C^* = w - \omega. \tag{5}$$

Combining the equations for C^* and C' with equation 3 yields a final form for ΔC:

$$\begin{aligned}\Delta C &= C^* - C' \\ &= (w - \omega) - a \\ &= w - \omega - a. \end{aligned} \tag{6}$$

This final equation, 6, shows the complete change in the consumer surplus is represented by the willingness to pay for flood insurance minus the premiums actually paid to the insurance fund and the estimated *ad hoc* disaster aid the government may sponsor.

The producer surplus measures the net benefit due to producers and their suppliers from providing goods and services to the market. In this analysis, the principal producer is the federal government. However, the surplus change due to governmental activity is better considered as part of the government surplus. Therefore, the producer surplus is limited to insurance companies providing administrative services to the NFIP.

It is assumed that consumers would be unable to purchase flood insurance if the program did not exist, because it is assumed private insurers would not provide flood insurance. The base case, where the NFIP provides insurance to consumers is represented by P^* and the alternative, where the NFIP no longer provides service is represented by P'. Based on this, the total change in producer surplus due to the NFIP is:

$$\Delta P = P^* - P'. \tag{7}$$

Because it is assumed no producer would enter a hypothetical open market for flood insurance, then $P' = 0$. In the case where the NFIP is extant and being serviced by individual insurance companies, a simple multiplier (φ) is applied to the value ω, representing the gross industry revenue from servicing NFIP programs on behalf of FEMA. However, the producer surplus is only the profit to the insurance industry for providing administrative services, which is only a portion of that revenue. Therefore, the gross revenue will be multiplied by an estimate for insurance industry profitability which is

represented by π. As a result, P^* represents the producer surplus across the entire industry due to the NFIP. The estimate for the producer surplus is:

$$P^* = \varphi\omega\pi. \tag{8}$$

Using these estimates for the producer surpluses in each case leads to an estimate for the net change in the producer surplus due to the NFIP:

$$\begin{aligned} \Delta P &= P^* - P' \\ &= \varphi\omega\pi - 0 \\ &= \varphi\omega\pi. \end{aligned} \tag{9}$$

The government surplus measures the benefits and costs due to the government as part of a policy change. The government of the United States, through the National Flood Insurance Fund (NFIF), sees inflows and outflows directly stemming from the program. Continuing the assumption program participants would be unable to purchase flood insurance if the program did not exist, The base case, where the NFIP provides insurance to consumers is represented by G^* and the alternative, where the NFIP no longer provides service is represented by G'. Based on this, the total change in the government surplus due to the NFIP is:

$$\Delta G = G^* - G'. \tag{10}$$

Prior to the NFIA, the government provided *ad hoc* disaster assistance to flood victims. Because it is assumed the government would compensate the victims of flooding, per C', the government surplus must balance this in the case where the NFIP did not exist. Therefore, $G' = -a$.

In the existing case of the NFIP, represented by G^*, government experiences inflows in the form of premium payments from program participants. It experiences outflows from claims payments made to policyholders after a flood event. Therefore, $G^* = \omega - \kappa$ and the

complete equation for the net change in the government surplus is:

$$\begin{aligned}\Delta G &= G^* - G' \\ &= \omega - \kappa + a. \end{aligned} \tag{11}$$

Finally, the external surplus is the sum of benefits and costs due to third parties caused by the actions of consumers, producers, and the government. Like the other surpluses, the change in external surplus is the difference between the external surplus with the NFIP, E^*, and the case where the NFIP did not exist, E':

$$\Delta E = E^* - E'. \tag{12}$$

In the case the NFIP did not exist, the government is likely to give disaster relief aid and this may cause some beneficiaries to rebuild in environmentally sensitive areas. Therefore, the environmental impact, β, must be accounted for. In addition, there is the externality of the impact of taxation required to pay for *ad hoc* payments in C'. This impact is a multiplier, m, against the revenue to pay for the *ad hoc* payments, a. This externality is known to be a negative externality. As a result,

$$E' = \beta - ma. \tag{13}$$

In the case where the NFIP does exist, the interactions are more complex. There are no producer nor consumer surplus, but there is an environmental impact of the NFIP funding redevelopment in environmentally sensitive areas and there is ongoing debate about whether the existence of the NFIP may create inefficient use of the floodplain. This environmental impact, B, must also be accounted for. As a result, $E^* = B$ and:

$$\begin{aligned}\Delta E &= E^* - E' \\ &= B - \beta + ma. \end{aligned} \tag{14}$$

It is possible other externalities exist, however, given the data available from FEMA regarding the NFIP, it is not currently possible to identify or estimate them in this analysis.

Using equation 2, the consumer, producer, government, and external surplus estimates are combined to provide the net social surplus given by the NFIP:

$$\begin{aligned}\Delta S &= \Delta C + \Delta P + \Delta G + \Delta E \\ &= (w - \omega - a) + (\varphi\omega\pi) + (\omega - \kappa + a) + (B - \beta + ma) \\ &= w + \varphi\omega\pi - \kappa + B - \beta + ma. \end{aligned} \tag{15}$$

Beginning with equation 15, several variables must be resolved to calculate the net social surplus for the insurance component of the NFIP. Finding the WTP is a complex matter, that differentiates between the *ex ante* and *ex post* values for the WTP. The *ex post* value represents how much an insured is willing to pay for insurance after an event and is equivalent to the expected amount received in response to an insurance claim. Because insurance policies are normally rolled over from year to year and policyholders are not likely to make a claim each year, the expected amount due to policyholders due to claims is the long run average over the lifetime of the policy.

The *ex ante* value is the amount an insured is willing to pay before a claim is made and is generally believed to be greater than the *ex post* value, based on the value of smoothing any large changes in wealth (Farrow & Scott, 2011). While the *ex post* value is simpler to find based on existing data, the *ex ante* estimate better represents the value insurance program participants place on participation.

Research by Farrow and Scott shows the expected *ex ante* estimates of WTP for flood insurance is 15 percent greater than the known *ex post* values for Baltimore, Maryland. The analysis behind this was limited to Baltimore, a city built on a major body of water. However, if this estimate reflects the national WTP for flood insurance, calculating the *ex ante* WTP is no more difficult than finding the *ex post* WTP, represented by κ here:

$$w = (1 + e)\kappa. \tag{16}$$

This estimate is, however, of limited purpose and is ripe for additional analysis through sensitivity analysis.

The estimate for the *ad hoc* disaster aid, a must also be estimated. The best estimate for it derives from the impetus behind the NFIA, to relieve pressure on the federal budget for disaster aid. As a result, it is possible to assume that the *ad hoc* disaster aid is replaced by the claims against the program following a flood event. Therefore, $a = \kappa$ is the best estimate for *ad hoc* disaster aid if the NFIP were not available.

Finally, it is necessary to estimate B and β, the environmental impacts in the external surplus. Because B and β are both the environmental damages caused by the rebuilding in sensitive areas and because the funding for those damages are presumed equal, though derived from different sources, it is reasonable to assume the environmental impacts would also be equal. Therefore, $B = \beta$ and $B - \beta = 0$.

Beginning with equation 15, this allows the value of ΔS to be further simplified:

$$\begin{aligned}\Delta S &= w + \varphi\omega\pi - \kappa + B - \beta + ma \\ &= (1 + e)\kappa + \varphi\omega\pi - \kappa + m\kappa \\ &= \kappa + e\kappa + \varphi\omega\pi - \kappa + m\kappa \\ &= \kappa(e + m) + \varphi\omega\pi \end{aligned} \tag{17}$$

Equation 17 includes six variables necessary for calculating the net change in social surplus due to the NFIP. Values for κ and ω can be estimated from historical NFIP financial data available from FEMA. Estimates for *pi* can be calculated using historical insurance industry profitability data. The variable m is provided directly by
Office of Management and Budget (1992, p. 13).

The next variable to estimate is φ, representing the percentage of the premium earned by the insurance companies participating in the Write Your Own (WYO) program for administering the NFIP. This percentage is defined in regulations governing the WYO program to be 15 percent with a potential 2 percent bonus for meeting certain targets for administration and sales. Because the value of φ is fixed within a single narrow band only 2 percent wide, this analysis will select the midpoint of the band, 16 percent, as the

baseline for analysis.

The variable e, representing the additional sum policyholders are willing to pay prior to a flood event for coverage has been researched by Farrow and Scott and estimated to be 15 percent.

Conclusion

Equation 17 provides a simple theoretical model for analyzing the net social benefits of the NFIP insurance component. On its face, it provides a single number. More broadly, this model when combined with a model for analyzing the Flood Mitigation Assistance (FMA) component, provides the net social benefits of the NFIP as a whole. This model can also be applied both prospectively and retrospectively, leading to net social benefits both historically and moving forward.

Relying on a series of assumptions, listed in table 2, the broad economic model, including some variables that cannot be estimated, is reduced to a final form using six variables with estimates readily available from NFIP financial data or the literature through benefits transfer (Desvousges, Johnson, & Banzhaf, 1998). Consequently, the reduced form model is an attempt to find a sufficient statistic for the NFIP's insurance component (Chetty, 2009), and starting point to more complex analyses of the NFIP. Because information on premiums and claims are available at the state and county level from FEMA, analytical granularity can be reduced. This encourages jurisdictional level analysis of distributional impacts of the program. In addition, by relaxing the assumptions made in the model, such as the equivalence of environmental impacts or estimates of the *ex ante* adjustment to the WTP for flood insurance, it is possible to perform break-even analysis, adapt other estimates of the values to the model, or search for optimal values through Monte Carlo simulation. Finally, this model forms the basis for analyzing proposed changes to the NFIP or new disaster insurance programs.

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Variable	Description
a	Amount of *ad hoc* disaster aid payments
B, β	Estimates of environmental impacts
C	Consumer surplus
κ	Claims made against the NFIP
E	External surplus
e	The *ex ante* adjustment for WTP
G	Government surplus
φ	WYO fees to insurers
m	the marginal excess tax burden (METB)
P	Producer surplus
ω	Premiums paid to the NFIP
π	Profit ratio for the insurance industry
S	Net social surplus
w	willingness-to-pay for flood insurance

Table 1

Variable list included in social surplus

Assumption	Explanation	Impact
$a = \kappa$	NFIP claims are equal to the expected amount of *ad hoc* aid granted in the absence of the NFIP	Limits prospective benefits of NFIP
$B = \beta$	Environmental damages caused by *ad hoc* flood recovery is the same as environmental damages caused by NFIP-funded recovery	Environmental damages are not considered
π's value	Insurers make a profit on administrative services and the profit ratio on that service is the same as the general industry profitability	Ties the producer surplus to general insurance profitability
φ's value	Property insurance provides receive administrative fees equal to mean potential fees	Reduced by the narrow band (2%) for potential fees
e's value	The estimate for *ex ante* WTP for the City of Baltimore is transferable nationwide	This may be significantly different from the nationwide WTP for flood insurance due to specific regional factors affecting local behavior

Table 2

Simplifying Assumptions Contained Within the Model