Designing public–private crop insurance in Finland

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Abstract
The Crop Damage Compensation scheme (CDC) is a combination of farm- and area-based scheme covering crop losses in Finland. The scheme is fully financed by the government. It is about to be abolished and a new risk management tool based on public–private partnership will be in place in 2016. In this study, we analysed how government expenditure will change due to the policy shift to public–private farm-based crop insurance. A stochastic simulation model using FADN and CDC data was developed to examine the risk exposure of farm based insurance. Government's risk exposure reduces when the policy is shifted towards the new type of crop insurance. Model results also indicate that the mean expenditures for the government as well as the variability of expenditure between years are expected to be lower under the new crop insurance than under the CDC scheme. Results obtained support government's decision to terminate the CDC scheme.

Keywords: government expenditures, crop insurance, stochastic simulation

1. Introduction

Adverse weather events can lead to considerable economic losses for farmers. These losses are generally compensated by governments. In Europe, the emphasis is moving from government-run programmes and disaster relief to insurances based on public–private partnership (PPP) (Meuwissen et al., 2013). In PPP, governments subsidise farmers buying yield insurance from private insurance companies. The European Union (EU) is also promoting the use of PPP in the future Common Agricultural Policy (CAP). The CAP will be reformed in 2015, and member states will be able to use premium subsidies for crop insurances based on PPP as part of rural development (EU, 2013).

Finland is situated in Scandinavia, where the harsh climate and adverse weather conditions increase the risks in crop production. The Crop Damage Compensation (CDC) scheme was designed to cover crop losses in Finland. The CDC scheme is fully financed by the government, i.e.

participation is free of charge for the farmers. However, the scheme has been widely criticized in recent years, because it does not give cover to all farmers. In the CDC scheme, compensation payments are based on area reference yields, but loss inspection is made at the farm level, and the scheme does not therefore provide cover for farms operating at high yield levels (Myyrä and Pietola, 2011). The CDC scheme is to be abolished in 2016, not only due to policy shifts to PPP on the EU level, but also because of problems related to already mentioned area reference yields and moral hazard (Myyrä and Pietola, 2011; Myyrä and Jauhiainen, 2012). New risk management tool based on PPP covering crop losses should be in place in Finland from 2016 onwards.

Changing the system into a public –private partnership based on farm level crop insurance seems interesting for the Finnish government as they no longer need to cover all expenditures from the risk management scheme. It however also raises questions, among others with regard to the type of public-private partnership (e.g. premium subsidies versus some type of reinsurance agreement), where to put retention levels for the farm sector and to which extent the overall risk exposure changes due to the switch to a farm-based scheme. The switch to a public-private scheme seems beneficial for multiple reasons including incentives for good farming practices (Meuwissen et al., 2001), the uncertainty for governments may withhold the actual implementation of the partnership.

In this context, our goal was to investigate how a crop insurance scheme based on PPP and individual farm yields would affect government expenditures compared to an area-based scheme fully financed by the government. Moreover fair premiums and the reserve loadings of the farm insurance scheme were calculated.

We developed a stochastic simulation model to study the risk exposure of crop insurance based on individual farm yields in Finland. FADN data are used as input. Historical indemnities of the CDC scheme were used to define possible losses of the current system. In section 2, the CDC scheme, the farm-based insurance scheme based on FADN data and the research methods are described. In section 3, the results from the stochastic simulation model are presented and compared to the historical indemnities of the CDC scheme. Section 4 provides discussion and conclusions.

2. Data and estimation method

In this section, the design of the CDC scheme and the farm based insurance are described and discussed. In addition, the CDC and FADN data are introduced. The stochastic simulation model is described in the final part of this section.

2.1. Crop Damage Compensation scheme design and data

The Finnish CDC scheme is fully financed by the government, which means that all farmers are automatically eligible for compensation if they experience crop loss under the condition that they follow the required guidelines for good farming practices within the EU. All the major field crops are included in the scheme. However, some high-value crops, such as strawberries, are not included. The yields of these crops cannot be insured at the moment in Finland, because private crop insurance schemes are not available in the country.

Farmers can collect CDC payments if the overall output of all crops on their farm falls below 70% of the area reference yield. Thus, even if farmers experience a total loss on a specific field, they will not be eligible for compensation if the losses for the entire farm do not exceed the 30% deductible. When the farmer applies for compensation, crop losses are inspected at the farm level. The monetary compensation is a product of the quantity lost, net of the deductible and the average producer price. The losses have to be verified on the farm before the harvest. A fixed fee is incurred to the farmer for the inspection.

The area reference yield is calculated from average yields for the past five years in that area. Reference prices, which are the average prices of a particular year, are used as a basis for calculating the compensation payment. The system is restricted to an annual aggregate budget constraint of 3.4 million Euros. When the losses are more than this amount and the overall compensation would exceed the budget constraint, the budget allocated to the scheme can be increased. The level of farmer-specific compensation can also be reduced to meet the budget constraint.

The CDC data were provided by the Information Centre of the Ministry of Agriculture and Forestry of Finland (TIKE). The data consist of payments per farm and the number of hectares lost from 1995 to 2012. Major cereal crops cultivated in Finland, i.e. barley, oats, winter and spring wheat and rye, were selected for this study. In 2012, the area cultivated with these crops represented 49% of the overall utilized agricultural area in Finland. On average, these crops account for 75% of the overall hectares lost in the CDC scheme.

2.2. Farm based insurance scheme design and data

The simulated insurance contract is based on individual farm yields. This structure is also promoted by the EU (EU, 2013). Total indemnities I for crop c in year t of yield insurance scheme are modelled as follows:

$$I_{ct}(\delta_{ct}) = \sum_{m=1}^{n} p_{ct} max[0, (\delta_{ct}\bar{y}_{ctm} - y_{ctm})], \quad (1)$$

where δ is the cover of the insurance, p is the price used for indemnity calculation, $\bar{y}$ is the average yield and y is the actual yield realized on the farm m. The cover of the simulated insurance scheme was set to 70%. The rules for subsidized crop insurance follow the World Trade Organization (WTO) agreements (WTO, 1994), where the limit of the deductible for subsidised crop insurance has to be at least 30%. Average producer prices used in the CDC scheme were used for indemnity calculations. Average farm yields were calculated as an Olympic average, i.e. the average of the five previous years yield minus the highest and lowest values. Because FADN data for this study were only available from 1998 onwards (while CDC starts from 1995), reference yields in the CDC scheme were applied in calculating the average yield in 1998–2002. This was done to expand the available dataset. FADN farm yields were compared to reference yields used in the CDC scheme, which provides farm-specific weights W for each individual farm m for each crop c:

$$W_{cm} = \frac{\sum_{t=1}^{t} y_{ctm}}{\sum_{t=1}^{t} r_{ct}}, \quad (2)$$

where r is the CDC area reference yield for crop c in year t. These farm-specific weights W were multiplied by the area reference yield for 1995–1997 in the CDC scheme. Derived weighted farm-specific reference yields were used to proxy 1995–1997 average farm yields.

The Farm Accountancy Data Network (FADN), a cross sectional dataset, was used for analysis of the farm based insurance scheme based on individual yield data. The FADN dataset is an official European Union dataset that includes detailed information on farm-specific accounts. The dataset also includes crop-specific production and cultivated hectares. The farm-specific hectare yields of winter and spring wheat, rye, oats and barley were used to calculate the average indemnity payments and fair premiums of the farm yield insurance. Our FADN dataset consisted of farm yield data for 1998–2011.

Barley is the most commonly cultivated crop in terms of the average number of farms in the dataset, and also accounts for the highest average cultivated area per year on FADN farms (Table 1). The average yield of cereal crops on the FADN farms is highest for winter wheat and lowest for rye.

Table 1. Descriptive statistics on the FADN dataset.

	Average cultivated hectares per farm	Average number of farms in the dataset	Average yield 1998–2011 kg/ha (std in parentheses)
Barley	20.0	512	3,283 (331)
Oats	12.3	482	3,212 (309)
Winter wheat	11.4	61	3,697 (426)
Spring wheat	18.6	206	3,592 (394)
Rye	7.5	81	2,378 (399)

The indemnities of individual farms per year for each crop were aggregated, and fair premiums F for each crop c were derived. The total premium TP_c for a crop c is the sum of the fair premium F_c and reserve loading L_c. In the literature, the event of an aggregate loss occurring that is so large that the collected insurance fund is exceeded is referred to as ruin (Bühlmann, 1970). In order to minimize the probability of ruin in a given period or maximize returns subject to maintaining a specified probability of ruin the insurance supplier collects a buffer fund L (Cummins, 1991):

$$L_c = k\sigma\sqrt{N}, \tag{3}$$

where k is specified from the chosen probability $1\text{-}1/k^2$ that the insurance fund avoids a ruin. Moreover, σ is the standard deviation of the indemnity payments and N is the size of the insurance pool. The insurance pool in this study was the cultivated hectares of a specific crop, because risk exposure and prices and thus fair premiums and reserve loadings differ between different crops. As the size of the insurance pool grows, the buffer fund amount allocated to each policy (reserve load per hectare) $k\sigma/N^{1/2}$ decreases.

2.3. Stochastic simulation of farm based insurance

In this section, the stochastic simulation model for farm based insurance is described. The simulation model uses inputs from the FADN and the CDC data, which are described in the previous sections. CDC data were used to estimate the tail of the loss distribution as extreme losses were not reflected in the FADN data set. Monte Carlo sampling is used as the sampling technique. In Monte Carlo sampling, random numbers are sampled from *a priori* specified distributions. Each of the obtained iterations represents a possible combination of values of the specified stochastic elements that could occur, taking into account correlations specified for the simulation model. The resulting values of output variables from iterations are computed and restored. Monte Carlo analysis in this study was based on 10,000 iterations. When the number of iterations is large enough, the distribution of each of the output variables will converge to a stable distribution (Hardaker et al., 2004). This distribution of output values reflects a realistic aspect of chance.

The overall indemnity *OI* of the crop insurance is the sum of the indemnities *I* for each crop *c* in a given year:

$$OI = \sum_{c=1}^{5} P_c \cdot I_c \cdot S_c. \tag{4}$$

The indemnities are estimated on the basis of the annual percentage of hectares experiencing a loss P_c, the average indemnity per crop I_c and the average number of cultivated hectares S_c of crop c in the period 1995–2012 in Finland. For barley, oats, winter wheat, spring wheat and rye, the average number of cultivated hectares (S) in the period 1995–2012 was 543, 368, 25, 153 and 26 thousand hectares, respectively.

Average per hectare indemnities and the number of cultivated hectares per crop were deterministic variables in the stochastic simulation model. The number of hectares lost per crop was stochastic variable and used as input in the simulation model of farm based insurance. Five cumulative distributions of crop losses were constructed (c = 5) for the simulation model.

Cumulative probability distribution describes the probability that a random variable will be a value less than or equal to some value. In the farm based insurance simulation model the random variable P is annual percentage of hectares experiencing a loss. Cumulative probability distributions of the annual percentage of hectares experiencing a loss in farm based insurance were obtained from FADN data set. The k^{th} observation was used as an estimate of the k/(n+1) fractile when the observations were arranged in ascending order (Hardaker et al., 2004). The range of the cumulative input curves was set by the observed minimum as well as the median values in the dataset. Maximum values were obtained from the two highest observations of the data in the farm based insurance model. In FADN data there were only two years in which crop losses were considerably greater than the average losses (1998 and 1999). These years were used as separate data to estimate the scale of maximum losses in crop production. The mean and standard deviation of these two values were placed in a normal distribution. The 95^{th} percentile of the normal distribution defines the maximum value in the cumulative distribution. In this way, the maximum possible loss could be estimated by considering high losses as a separate distribution compared to normal yield variation. In addition, the 80th percentile was added to the distribution functions to define the starting point for high losses.

The estimated maximum number of hectares lost per 1,000 cultivated hectares for oats, winter wheat, spring wheat, barley and rye was 306, 184, 544, 176 and 164 hectares, respectively. Respective median values in farm based insurance CDFs were 61, 50, 26, 50 and 63.

Losses in the CDC scheme are estimated based solely on past performance of the scheme, i.e. stochastic simulation model was not used for the CDC data. In the CDC data losses on field plots of individual farms are divided into total and partial losses. Total loss refers to the number of hectares for which the whole crop is destroyed. This includes 24% of the loss data. Information on losses on partially damaged sections of fields is incomplete (76% of cases). In our assessment we therefore assume that the loss in partially damaged hectares is 50% from the area reference yield. Farmers are eligible for full compensation when losses exceed the 30% deductible. The significance of the assumption that losses on partially damaged hectares amount to 50% of the area reference yield is examined with sensitivity analysis, where 40% and 60% limits are studied. Correlation coefficients between crop losses were derived also for the CDC scheme.

Cereal crops do not significantly differ in their risk exposure to adverse weather events. The stochastic nature of crop losses among different crops was taken into account in the stochastic simulation model. Stochastic dependencies between the crop-specific cumulative distributions were estimated by Pearson's correlation coefficient, and rank correlations were specified in the simulation models.

Bivariate rank correlations derived from the CDC and FADN data for the stochastic simulation model are displayed in Table 2. Correlations were used as input in the stochastic simulation model for farm based insurance. The low correlation coefficients for the farm based insurance scheme suggest that the number and spatial distribution of farms in the FADN dataset were not sufficient to give a good approximation of the systemic nature of crop losses in Finland. However, the CDC dataset includes large amount of farms that have experienced a crop loss in Finland in recent years. Therefore, we can assume that the correlation of losses in the CDC scheme is a good approximation of the systemic nature of crop losses in Finland. Consequently, the farm based insurance model was modelled with observed correlations from the FADN data and also with the correlations derived from the CDC data. All of the correlations of crop losses in the CDC scheme were found to be positive and significant. This reflects the rules of the CDC scheme, according to which the total yield of a farm must be below 30% of the reference yield before the farmer is eligible for compensation. Therefore, farmers collecting CDC payments are either seriously hit by adverse weather, when almost all their crops are damaged, or their farms are systematically producing under reference yield level. In the farm insurance model, only losses to oats and barley were correlated at the 1% confidence level.

Table 2. Bivariate rank correlations for barley, oats, winter wheat, spring wheat and rye based on CDC and FADN data.

	CDC				FARM INSURANCE			
	Oats	Winter wheat	Spring wheat	Rye	Oats	Winter wheat	Spring wheat	Rye
Barley	0.95**	0.74**	0.90**	0.82**	0.96**	0.26	0.42	0.31
Oats		0.71**	0.88**	0.83**		0.31	0.45	0.42
Winter wheat			0.90**	0.86**			0.20	0.22
Spring wheat				0.93**				-0.03

**Significant at the 0.01 level, *significant at the 0.05 level.

3. Results

In this section the results from the farm insurance stochastic simulation model and insurance premiums are described. The distribution of losses and government expenditure on the CDC scheme and the simulated farm based insurance are described in section 3.2.

3.1. Farm based insurance scheme

The average number of hectares lost derived from the FADN data was on average higher than in the current CDC scheme. This is due to the different methods for defining reference yields in the two schemes. The variability in annual hectares lost was lower in the farm insurance than in the CDC scheme. However, the standard deviation of losses between years is considerable in farm based insurance. Indemnity payments for barley, oats, winter and spring wheat and rye totalled 50.2, 48.2, 72.5, 57.3 and 50.1 Euros/hectare, respectively.

The probability of losses under the farm based insurance scheme is distributed into layers in Table 3. The probability that indemnity payments from the farm insurance scheme will be 0–5 million

Euros is 64%. The probability that payments will exceed 5 million Euros, but will be less than 10 million Euros, is 28%. Therefore, the probability that indemnity payments will exceed 10 million Euros is only 8%. When crop losses are highly correlated, i.e. correlation coefficients from the CDC scheme are used, these probabilities are 67%, 22% and 11%, respectively. Based on the simulation model, the maximum amount of indemnity payments per year will be 15–16 million Euros. Maximum possible losses from the farm based insurance scheme are much lower than in the CDC scheme. For example in 1999 CDC payments exceeded 32 million Euros.

Table 3. Annual indemnity payments from farm based insurance subdivided into layers (in parentheses, results if loss correlations from the CDC scheme are used).

Crop losses in million Euros	**Probability**	**Expected value in million Euros**	**Spread in million Euros**
0–5	0.64 (0.67)	2.5 (2.3)	0–5 (0–5)
5–10	0.28 (0.22)	7.1 (7.0)	0–10 (0–10)
>10	0.08 (0.11)	11.8 (12.7)	0–15 (0–16)

Crop losses are systemic in nature, and indemnity payments vary considerably between years. Moreover, indemnity payments vary considerably between farms within a single year. Therefore, insurance companies need to take varying losses into account when crop insurance products are developed and priced. Moreover, a reserve loading needs to be added to insurance premiums (Skees and Barnett, 1999). For the farm based insurance scheme, the reserve loading per hectare for each crop was defined as in equation 3 and divided by the average number of cultivated hectares in the FADN dataset.

The simulated fair premium for barley, oats, winter wheat, spring wheat and rye was 3.6, 4.3, 5.3, 5.0 and 4.2 Euros/hectare, respectively. These amounts are on average 8% of the average indemnity payment per hectare. If the premium subsidy covers 65% of premiums, the premium as a proportion of the expected compensation is some 3%. The simulated fair premiums do not represent a major change if crop losses are highly correlated. The percentage share of average reserve loadings from fair premiums is 5.2%, 4.2%, 40.1%, 14.8% and 27.6%, respectively, when the probability of ruin is 5%. The probability of ruin reflects the probability that aggregated yearly indemnities exceed the collected premiums.

3.2. Comparison of the CDC and farm based insurance schemes

Mean loss hectares per year are higher in the farm based insurance than in the CDC scheme (Table 4). In the CDC scheme losses are more skewed to the right than in the farm based insurance scheme. Moreover the standard deviation and maximum losses for barley, winter wheat and rye are higher in the CDC. The CDC scheme is considerably affected by moral hazard (Myyrä and Jauhiainen, 2012). Some farms have received payments from the CDC scheme very frequently, and there are no incentives for farmers to avoid yield losses if they experience crop damage. This can also be detected from the longer tail (loss distribution's are more skewed to the right) of the CDC loss distributions compared to farm based insurance.

Table 4. Distribution of historical annual hectares lost (total and partial lost hectares per 1000 cultivated ha) in the CDC scheme and estimated annual hectares lost (hectares where losses exceed 30% deductible level per 1000 cultivated ha) under the farm based insurance scheme.

	CDC scheme			**Farm insurance**		
	Mean (std)	**Skewness**	**Maximum value**	**Mean (std)**	**Skewness**	**Maximum value**
Barley	23.21 (59.07)	3.3684	240.15	71.47 (50.30)	0.6068	175.85
Oats	23.17 (54.61)	2.6436	185.66	90.21 (71.60)	1.3908	305.69
Winter wheat	33.95 (98.49)	3.2536	386.03	73.44 (58.17)	0.5346	184.39
Spring wheat	49.22 (135.96)	3.3706	545.72	86.59 (131.76)	2.0501	543.43
Rye	28.18 (69.86)	2.9747	264.20	83.42 (48.52)	0.3929	163.56

The premium subsidies of future farm based insurance scheme will be funded solely by the Finnish government i.e. EU subsidies are not used. The estimated average and median expenditure per year are presented in Table 5. The maximum rate of premium subsidy can be 65% of the crop insurance premium (EU, 2013). This share is used in the farm based insurance expenditure calculations. The simulated farm based insurance scheme is funded by the government (65% of premiums) and farmers (35% of premiums), while the current CDC scheme is fully financed by the Finnish government. Mean government expenditure is expected to be lower in the future due to the policy shift in Finland. The mean costs from farm based insurance would be 4.9 million Euros per year (without administrative costs). In the CDC scheme, the estimated government costs for barley, oats, winter and spring wheat and rye is on average some 5.6 million Euros per year in total.

Table 5. Mean and median costs of the farm based insurance and CDC scheme.

		Mean million Euros (std in parentheses)	**Median million Euros (0.05th fractile–0.95th fractile)**
CDC		5.6 (8.3)	1.3 (0.4–22.8)
Farm insurance	Government	3.2	2.1 (0.7–8.9)
	Farmers	1.7	1.1 (0.4–4.8)

4. Discussion and conclusions

In Finland the harsh climate and unpredictable weather conditions increase the risks in crop production. The government-funded CDC scheme will soon be abolished and a new risk management tool covering crop losses should be in place in Finland from 2016 onwards. This new system for Finnish agriculture will be based on a public–private partnership (PPP). EU member states can use CAP subsidies for crop insurance schemes in 2015, but this possibility is not utilised in Finland, and the future insurance scheme is funded by the Finnish government and farmers. In this study, we addressed the question of how government expenditure will change due the policy shift from a system fully financed by the government to an insurance scheme based on PPP. The risk exposure of crop insurance based on individual farm yields was compared with that of the CDC scheme.

Our research provides insight about the implications of making the change from public risk management scheme to system based on public-private partnership based on farm based insurance. The policy switch to a public-private scheme seems beneficial for multiple reasons including lower average and smaller variation of budgetary expenditure for Finnish government and increased incentives for good farming practices due to improved possibilities for risk sharing. Insurance scheme also maintains incentives for risk prevention due to retention level. Maximum possible losses from the farm based insurance scheme are also expected to be much lower than in the CDC scheme. However, lacking knowledge of these advantages for government may withhold the actual implementation of the partnership. Thus there is clear demand for results obtained with current research.

Results obtained support government's decision to terminate the CDC scheme. Results are also an important base for further development of private insurance schemes. The high variability in government expenditure will diminish, and in the future, farmers purchasing crop insurance will bear bigger part of the yield risks than under the CDC scheme.

Insurance companies are naturally aware of large liabilities related to yield insurances and also cautious in introducing new products to farmers. This is especially true in Finland, where insurance companies have experienced large losses within last few years on another natural resources related industry. Indemnity payments to forest owners were 32 million Euros as a result of storm in year 2011 which caused big financial losses for Finnish insurance companies (MT, 2013). Such financial losses suggest that sound insurance practices have not been used in forest insurance premium calculations. This paper contributes for avoiding such losses in agricultural yield insurances. In preparing for large losses, insurance companies can collect buffer funds. Our results indicate that when the probability of ruin is as low as 5%, the reserve loading should be 4–28% of the fair premium, depending on the cereal crop. The rest of the risks, as those are now clearly bounded, can be reinsured. By these procedures insurance companies have a good grip on risks and liabilities related to yield insurances.

The decision made in the EU level to promote yield insurances through rural development opens EU member states new possibilities to strengthen risk management in agriculture (Meuwissen et al. 2013). The development of yield insurances is underway in many EU member countries. Our results suggest that insurance schemes based on PPP and individual farm yields preferred to government run program with area based indemnity payment trigger. Therefore we encourage countries to develop agriculture risk management schemes that are based on PPP instead of relying on government run programs or disaster relief. The main advantage is that government expenditure is expected to be less variable under public-private insurance schemes. Moreover farm-based insurance schemes are better in dealing with asymmetric information issues. However adverse selection problem arises for the insurance companies if more risky farmers' are the first to purchase yield insurance products. Thus the insurance companies need to identify risk profiles to collect higher premiums from more risky farmers' rather than collecting average fair premiums as is assumed in this research.

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