IMPACT OF AGRO-BIODIVERSITY ON FARMERS' INCOME PROBABILITY DISTRIBUTION

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Abstract

The paper constitutes an attempt at modelling the farmers' income distribution. The main objective of the paper was to assess the impact of crop diversity on famers income probability distribution on the basis of real life data (Polish FADN), and to evaluate the size of economic incentives needed in order to encourage farmers to diversify their crop structure. Multiple linear regression and quantile regression models were developed for variance and expected value of farmers' income. It was revealed that the impact of crop diversity diminishes both variance and expected value of income. However the relation holds only for two of considered principal farming types.

Key words: agro-biodiversity, crops diversification, income risk, quantile regression

Introduction

Biodiversity of agricultural landscape is strongly related not only to typical landscape elements like: forest, rivers, ponds or clusters of trees but also to crop structure. In fact high agro-biodiversity has a positive effect on wild species survival and overall biodiversity (Laiolo et al., 2005, Robinson et al., 2001).

Crop diversification is commonly believed to be, farmers' traditional strategy of insurance against adverse environmental conditions or product price fluctuations (Baumgartner and Quaas, 2010). It is supposed to be especially important in less developed economies. Due to relatively difficult access to insurance and credit, product diversification is the main strategy of coping with income risk (MEA, 2005, Morduch, 1995).

Consequently, it is understood that crop diversification is in farmers' best interest. But as mentioned above, strong agro-biodiversity has positive influence on general biodiversity. Thus, farmers deciding to diversify their crop structure produce public goods by supporting sustainability of rich ecosystems. The "greening" reform of CAP uses this idea as justification of continued existence of subsidies in European agriculture.

However, it could be argued that if crop diversification allows farmers to obtain higher and more stable income (Di Falco and Perrings, 2005), there is no point in paying them for preserving ecosystem biodiversity.

The aim of this paper is to asses the impact of crop diversity on famers income probability distribution on the basis of real life data, and to evaluate the size of economic incentives needed in order to encourage farmers to diversify their crop structure.

Data and applied methods

This analysis uses farm level data from the Polish Farm Accountancy Data Network (FADN) (samples from years 2005 – 2011). As the purpose of this research is to determine influence of crop diversity on farmers' income, the samples were screened for farms obtaining most of their revenue from crop production. According to FADN typology (EC, 1242/2008), the type of farming is determined by relative contribution of the standard output characteristic for the holding to the total standard output. Therefore, research is limited to the following principal types of farming:

15 – Specialist cereals, oilseeds and protein crops

16 – General field cropping

61 – Mixed cropping

36 – Specialist fruit and citrus fruit

83 – Field crops - grazing livestock combined

84 – Various crops and livestock combined

Furthermore, the sample was limited to holdings present in the Polish FADN samples for the years 2005 – 2011, which significantly limited the sample size. Nevertheless, it was necessary for ensuring comparability of estimates calculated for each farm. Also, as the type of farming can change over the years, only the farms which were at least 4 years in the same type were retained in the sample. In the end, a sample consisting of 2077 farms was selected.

For each farm the following variables were observed: revenue (total output – cost of fertilizers, seeds, crop protection, contract work and hired labour; + subsidies), crop diversity and variables strongly influencing the revenue, that is, the cost of: fertilizers, seeds and crop protection, land quality index, utilised agricultural area. All variables except crop diversity and the last two were expressed in PLN/ha[1]. The crop diversity was measured by a modification of Simpson index (Simpson, 1949), that is, the Gini-Simpson index:

$$GS = 1 - \sum_{i}^{k} p_i^2 \qquad (1)$$

where k is the number of plant species and p_i is share of i-th plant species area in total utilised agricultural area.

Table 1. Descriptive characteristics of analysed variables

Variables	Mean	Standard deviation	Lower quartile	Upper quartile
Y_1 - Average revenue [PLN/ha]	4945.70	3629.97	2950.68	5494.13
Y_2 - Revenue variance	5913853.00	21902550.00	613828.80	2973487.00
X_1 - Average crop diversity	0.70	0.15	0.66	0.80
X_2 - Average cost of fertilizers [PLN/ha]	529.89	254.12	357.27	671.62
X_3 - Average cost of seeds [PLN/ha]	243.61	241.94	133.03	263.46
X_4 - Average cost of crop protection [PLN/ha]	331.83	356.39	151.16	359.83
X_5 - Average land quality index	1.03	0.34	0.79	1.29
X_6 - Average utilised agr. area	43.28	55.62	14.30	51.07

Source: own calculations, based on FADN data.

In order to assess the strength of the relation between crop diversity and the first two moments of revenue distribution, regardless of remaining variables, the Pearson correlation coefficient was used. However, the simple correlation coefficient does not take into account the possible influence of other variables. Therefore, this method is not sufficient to formulate conclusions about crop diversity impact on income distribution. Consequently multiple regression models were applied:

$$Y_{1i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 \ln(x_{6i}) + \varepsilon_i \qquad (2)$$

Since the changes in average values of income were proportional to relative rather than absolute changes of the utilised agricultural area, a logarithmic term was introduced in model (2). The same reasoning was used to justify the logarithmic transformation of income variance in model (3).

$$\ln(Y_{2i}) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 \ln(x_{6i}) + \varepsilon_i \qquad (3)$$

In order to model income variance, GLM model with gamma family, was also considered, but the improvement of model quality was negligible. Nevertheless, the discrepancies from bivariate normal distribution suggest that using additional tools for validating linear model results may be necessary. The author decided to use for that purpose one of the distribution-free methods, that is, quantile regression (Koenker, 2005).

The calculations for all models were performed in R, a statistical computing environment (R Core Team, 2013) with with help of the ‘quantreg’ package (Koenker, 2013).

Results

Pooling all considered principal farming types made it possible to examine the impact of crop diversity on the expected value and variance of income on a very broad range of income distributions. The scatterplot presented below shows the relation between the GS index and logarithm of income variance without taking into consideration the possible influence of remaining variables.

[1] The current exchange rate: 1EUR =4.25 PLN.

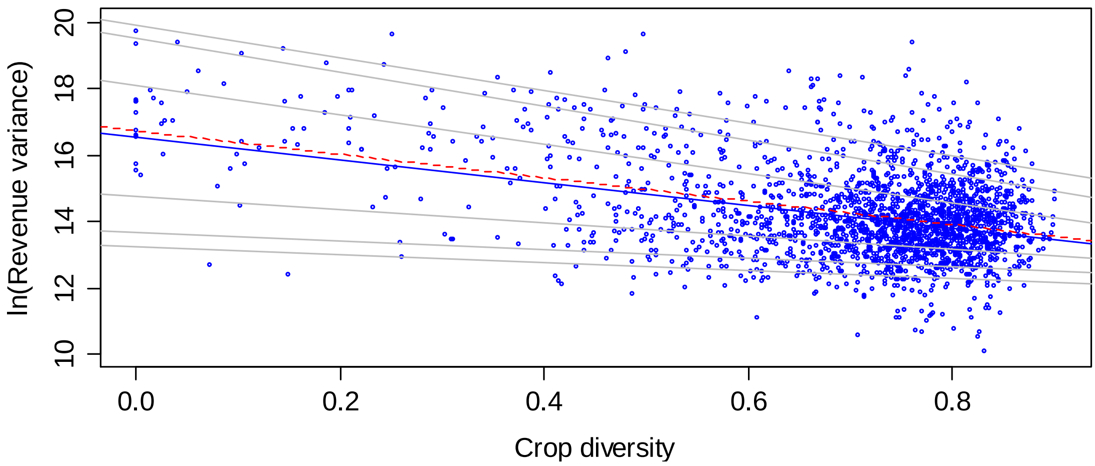

Figure 1. Relation between crop diversity and logarithm of income variance

The $\{0.05, 0.1, 0.25, 0.75, 0.9, 0.95\}$ quantile regression lines in grey, the median in solid blue, and the least squares estimate of the conditional mean function as the dashed (red) line were superimposed on the scatterplots (Figures 1. and 2.) to help judge appropriateness of using linear regression models.

The closeness of the lines representing the conditional expected value of variance logarithm and conditional median, and relative parallelism of other quantile regression lines allows us to trust the results of linear regression.

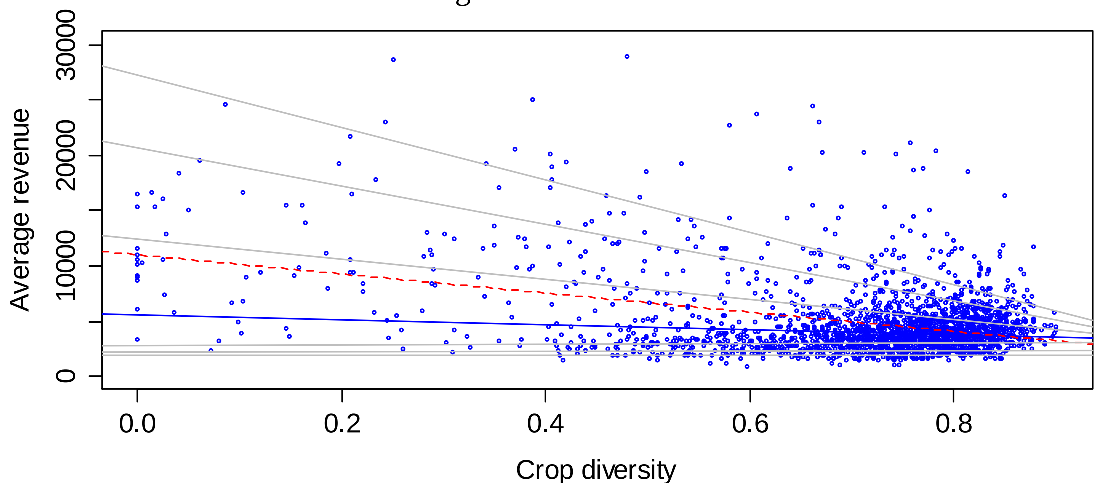

Figure 2. Relation between crop diversity and average income

In figure 2 the quantile regression lines for the median and linear model are very different, which suggests to use of linear regression results with caution. Furthermore, also the quantile regression lines for the considered set of quantiles strongly differ in terms of their directional coefficients. It means that farms with high incomes (in PLN/ha) and farms with low incomes behave completely different when crop diversity increases. Low income farms are insensitive to changes of crop diversity, while high income farms react with a significant drop of average income.

Table 2. Result of testing the hypothesis of independency $H_0: \rho = 0$.

Dependent variables	R	t	p-value
Average revenue	-0.368846	-18.0763	$< 2.2e-16$
Ln(revenue variance)	-0.3992923	-19.8387	$< 2.2e-16$

Source: own calculations, based on FADN data

Despite mentioned above reservations about bivariate normality, the large number of observations (2077) and extreme values o t statistic support using values from table 2 for verification of independence hypothesis.

In both cases, that is, for the average revenue and the logarithm of revenue variance, fairly strong negative impact of crop diversity is observed. It means the increase of crop diversity stabilizes income but at lower level. However, this relationship cold be a result of other variables influencing both crop-diversity and income distribution. To find out how crop diversity influence income distribution multiple regression models were estimated.

Table 3. Estimated parameters of models (2) and (3)

Variables	Average revenue			Ln(Revenue variance)		
	Estimate	Std. Error	p-value	Estimate	Std. Error	p-value
(Intercept)	8291.379	407.828	< 2e-16	15.44000	0.16480	< 2e-16
X_1 – Avg. crop diversity	-1531.149	0.313	0.000577	-1.15900	0.00013	0.000345
X_2 – Avg. cost of fert.	1.081	435.040	0.000442	0.00045	0.17570	5.49E-11
X_3 - Avg cost of seeds	2.668	0.281	< 2e-16	0.00076	0.00011	2.43E-11
X_4 – Avg. cost of crop protection	4.457	0.211	< 2e-16	0.00160	0.00009	< 2e-16
X_5 – Avg. land quality index	-612.885	174.567	0.000456	-0.14390	0.07052	0.041357
X_6 - ln(Average utilised agr. Area)	-1309.434	66.845	< 2e-16	-0.36160	0.02700	< 2e-16
	Multiple R^2 = 0.4945, F = 337.4 on 6 and 2070 DF, p-value: < 2.2e-16			Multiple R^2 = 0.42881, F = 259 on 6 and 2070 DF, p-value: < 2.2e-16		

Source: own calculations, based on FADN data

Both models shows surprisingly high values of determination coefficient, 49% for average income model and 43% for log-variance model. All considered variables were significant, and similarly to simple regression coefficient for crop diversity are negative.

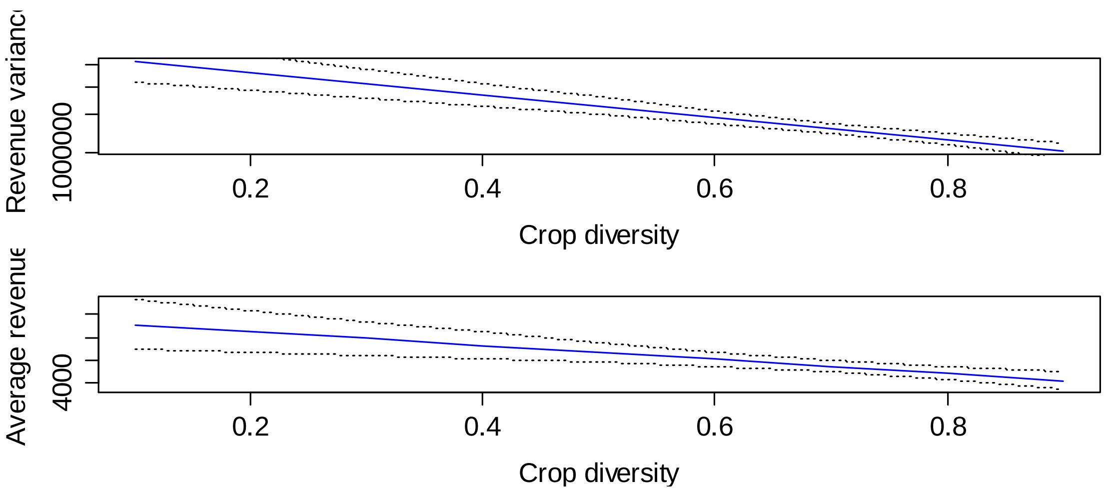

Figure 3. Relation between crop diversity and income distribution first two moments.

In figure 3 prediction of revenue variance and expected value for the whole range of GS index values are given. Those prediction clearly depends on values of remaining descriptive variables, to make it comparable their values were set to sample averages.

To show how would look the whole distribution of income (with assumption of normal distribution) density and distribution functions were plotted in figure 4. The increase of the GS index value from 0.1 to 0.8 would result in significant sliming of income distribution but the whole distribution would be shifted to left. The distribution functions prove that such income stabilization is pointless because it gives similar chance of income lower than 2000 in bad years but greatly diminishes chances of chances of extreme income in good years.

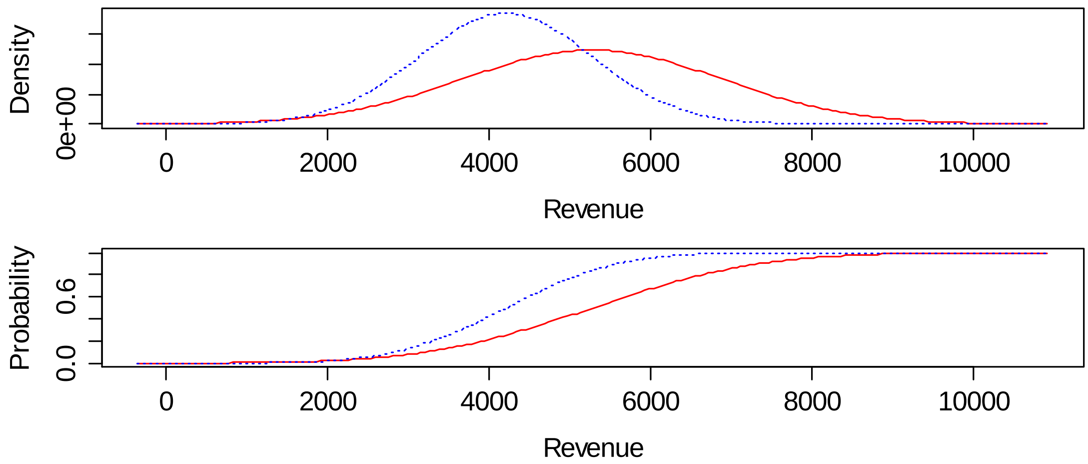

Figure 4. Assuming normal distribution of income effect of crop diversity index change from 0.1 (solid line) to 0.8 (dashed line).

On average change of the GS index value from 0 (monoculture) to 0.5 (slightly above the "greening" requirements) results in change of the income expected value by $0.5\beta_1 = 0.5*(-1531) \approx -765$ PLN/ha.

Although, it seems that analysis of income distribution relation crop diversity is finished there is still remaining discarded evidence of different reaction to crop diversity of low and high income farms (see figure 1 and 2). The values of mean crop diversity index and first 2 moments of income distribution given in table 4. support thesis that much of confirmed dependence may be a result of mixing all types of farming together.

Table 4. Characteristic of crop diversity and income for principal types of farming

Principal types of farming	Mean average crop diversity	Mean average income	Mean income variance
15 – Specialist cereals, oilseeds and protein crops	0.654	2673	1297235
16 – General field cropping	0.718	5098	5732905
61 – Mixed cropping	0.449	9800	27330490
36 – Specialist fruit and citrus fruit	0.743	5803	5061254
83 – Field crops - grazing livestock combined	0.791	4240	2589953
84 – Various crops and livestock combined	0.757	4908	3918371

Source: own calculations, based on FADN data

Therefore, it is very interesting how would crop diversity impact income distribution when assessed separately for each farming type.

Table 5. Result of testing the hypothesis $H_0 : \rho = 0$ for each principal types of farming separately

Principal types of farming	N	average income		income variance	
		R	p-value	R	p-value
15 – Specialist cereals, oilseeds and protein crops	387	-0.085	0.09446	-0.102	0.044
16 – General field cropping	368	-0.116	0.02543	-0.171	0.000972
61 – Mixed cropping	79	-0.159	0.1608	-0.242	0.03161
36 – Specialist fruit and citrus fruit	205	-0.281	0.00004	-0.360	1.16E-07
83 – Field crops - grazing livestock combined	300	-0.034	0.5576	-0.016	0.7774
84 – Various crops and livestock combined	738	-0.444	< 2.2e-16	-0.219	1.74E-09

Source: own calculations, based on FADN data

The Pearson correlation coefficient values from table 5 confirm negative relation of crop diversity on variance of income distribution, for all types except type 83. In case of expected value all correlations are also negative, but is significant only for types: 16, 36 and 84.

Since it was not possible to present full multiple regression model estimates for all types in table 6 only values of estimates corresponding to crop diversity are presented. Contrary to result based of simple correlations this time The impact of crop diversity on income distributions moments is significant only for two farming types, that is, type 36 (specialist fruit and citrus fruit) and 84 (various crops and livestock combined).

Table 6. Result of testing the hypothesis $H_0 : \beta_1 = 0$ for each principal types of farming separately

Principal types of farming	average income		income variance	
	$\hat{\beta}_1$	p-value	$\hat{\beta}_1$	p-value
15 – Specialist cereals, oilseeds and protein crops	-124.0	0.660	-0.3940	0.2914
16 – General field cropping	2417.4	0.058	0.0813	0.8748
61 – Mixed cropping	-2419.3	0.345	-1.7244	0.1700
36 – Specialist fruit and citrus fruit	-2832.3	0.029	-0.9637	0.0039
83 – Field crops - grazing livestock combined	709.7	0.631	-1.1125	0.2368
84 – Various crops and livestock combined	-11220.0	< 2e-16	-2.3815	3.18E-09

Source: own calculations, based on FADN data

Those result confirm that assessing impact of crop diversity on income distribution should be carried out separately for each principal farming type. It may arise from the different choice of crops for each farming types and suggest that number of crop species and shares of their area do not tell whole story. It indicates father direction for research on crop diversity impact on income distribution. It is necessary to include some measure of distance between species in agro-biodiversity index.

Conclusions

The income stabilizing effect of crop diversity can be confirmed on the basis of joint sample of all the principal types of farming, but it is strongly connected with the differences between farming types. When each farming type is analysed separately, income stabilizing effect of crop diversity exists only in 2 out of 6 types.

Including different types of farming in one pooled sample can lead to the false belief that increasing crop diversity always results in diminishing farmers' income risk.

Interestingly, even in case of significant reducing impact of crop diversity on income variability, the trade-off between the decrease of variability and the decrease of expected value means that distribution of income for higher crop diversity dominates only for very low values of income.

Taking the above conclusions into account, increasing crop diversity results in lowering farmers' income, therefore if policymakers want to preserve biodiversity by encouraging farmers to maintain crop diversity, they should also provide financial incentives of considerable magnitude, linked to the farming type.

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