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POTATOES YIELD VARIABILITY IN POLAND AT NUTS 2 LEVEL

ZMIENNOŚĆ PLONOWANIA ZIEMNIAKÓW W POLSCE NA POZIOMIE NUTS 2

Key words: potatoes yield, variability, production risk
Słowa kluczowe: plony ziemniaków, zmienność, ryzyko produkcji

Abstract. The paper presents an analysis of potatoes yields variability in provinces of Poland. The data used comes from Central Statistical Office for the period 1990-2009. The aim of this paper is to compare the average level and variability of potatoes yield and production of Polish provinces. Particular attention is paid to the following question: how does variability of potatoes yield change with decreasing production area?

Introduction

One of the most specific risks to agriculture sector, particularly to plant cultivation is the production risk. The yields are influenced by factors like weather conditions, pest and diseases. While the size of Poland is moderate, the weather patterns and soil conditions are quite diverse. For this reason aggregating yields across whole country when assessing production risk in plant cultivation may lead to serious inaccuracy and should be avoided.

In previous work of the author [Kobus 2009] it was shown that variation coefficient for wheat yield (after trend elimination) takes values from 5.6% in Warmińsko-Mazurskie to 16.5% in Lubuskie. It suggests that Poland cannot be treated as a uniform entity in the case of plant production risk.

In [Kobus 2010] it was shown that on a country level there was positive relationship between yield level and its variability in the case of wheat. Another conclusion from that paper was that small production area goes in pair with high variability of yield. If such relationships exists on lower level of aggregation and are universal to other plants one would expected that in case of potatoes production in Polish provinces the production risk should grow. The reason for such an expectation is reduced production area and higher yields.

The main aim of this paper is to compare changes of average level and variability of potatoes yields in Polish provinces. Particular attention is paid to the following question: what is the relationships between the average level of yield and its variability?

Apart of that author want to check influence of reduced production area on yields variability.

Data and research methods

The statistical data used in these analysis concern the average yields and production area of potatoes in Polish provinces in years 1990-2009 and are taken from the official statistics of Central Statistical Office of Poland (CSO). One of the simplest ways of measuring crop variability is to use the standard deviation estimator (1):

$$S_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{1}$$

where:

S_x – *estimator of the standard deviation* σ_x *of variable X,*

$\bar{x}$ – *sample mean,*

n – *sample size,*

x_i – i^{th} *observation of variable X.*

Contrary to standard deviation, which is expressed in the same units as the variable considered, coefficient of variation (2), expressed in percents, is a relative measure with the average value as the reference point:

$$V_x = \frac{S_x}{\bar{x}} \tag{2}$$

In the case of yield trend, the variability measured without taking this trend into consideration is overestimated [Kobus 2009]. The amount of the bias is proportional to the strength of the trend. Let us define the trend as a function of time which explains the conditional expected value:

$$E(X \mid T = t) = f(t) \tag{3}$$

where:

t – *time moment,*

$E(X \mid T = t)$ – *expected yield in time moment t.*

The function $f(t)$ could take any form but in short time series it is usually safe to use for its approximation the simplest linear form:

$$f(t) = \beta_0 + \beta_1 t \tag{4}$$

The formula for calculation of the standard deviation estimator becomes:

$$S_x = \sqrt{\frac{1}{n-2}\sum_{t=1}^{n}(x_t - \hat{x}_{(t)})^2} \tag{5}$$

where:

x_t – *observation of yield in time moment t,*

$\hat{x}_{(t)}$ – *estimate of f(t).*

To check the significance of regression coefficient β_1 test F was used with statistic defined as follow:

$$F = \frac{\hat{\beta}_1^2}{S_x^2}\sum_{t=1}^{n}(t - \bar{t})^2 \tag{6}$$

As the sample size in analysis was 20 the critical value for testing the hypothesis:

$$H_0 : \beta_1 = 0 \tag{7}$$

was 95% quantile from distribution F(1, 18) namely 4.414.

For testing the hypothesis:

$$H_0 : \sigma_1^2 = \sigma_2^2 \tag{8}$$

the F statistic was defined as follows:

$$F = \frac{S_1^2}{S_2^2} \tag{9}$$

where:

S_1^2 and S_2^2 were estimators of variation for two time periods 1990-1999 and 2000-2009 respectively, the critical value was 95% quantile from distribution F(9, 9) namely 3.179.

Results

During years 1990-2009 area of potatoes production changed dramatically. In year 1990 the total area of potatoes production in Poland was 1.835 million hectares while in 2009 it was only 0.508 million hectares. It was reduction to 27.7% of previous size, but the changes of production size were noticeably different in particular provinces.

The smallest reduction of production area was observed in three provinces in the north-western part of Poland: Pomorskie, Zachodniopomorskie, Lubuskie and two provinces from the opposite side of Poland namely Podkarpackie and Małopolskie.

Table 1. Average production area of potatoes in Polish provinces (1990-2009)

Province	Average production area [th.ha]		Index of change [%]
	1990-1994	2005-2009	
Dolnośląskie	70.8	27.9	39
Kujawsko-Pomorskie	85.1	25.8	30
Lubelskie	197.3	46.9	24
Lubuskie	26.5	12.2	46
Łódzkie	186.9	59.7	32
Małopolskie	105.4	46.6	44
Mazowieckie	314.3	85.5	27
Opolskie	43.2	12.5	29
Podkarpackie	104.3	52.1	50
Podlaskie	117.7	27.2	23
Pomorskie	57.9	29.5	51
Śląskie	77.4	17.5	23
Świętokrzyskie	94.6	29.2	31
Warmińsko-Mazurskie	57.8	13.7	24
Wielkopolskie	163.0	50.8	31
Zachodnio-pomorskie	54.1	25.2	47

Source: own study.

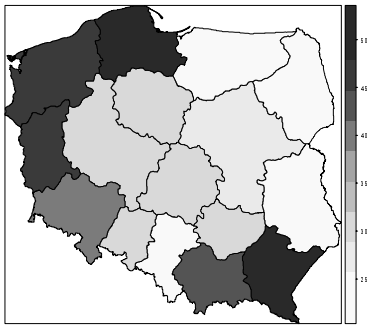

Figure 1. Index of change for Potatoes production area in percents (1990-2009)
Source: own study.

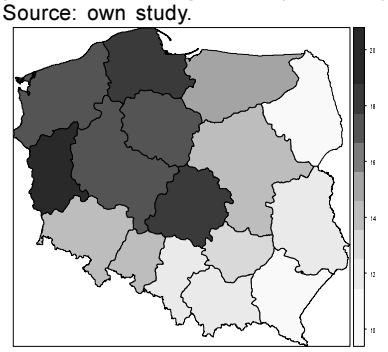

Figure 2. Variation coefficient of yield in percents (1990-2009).
Source: own study.

Table 2. Estimates of basic measures of potatoes yield variability in Polish provincess (1990-2009)

Province	Average yield [dt]	Standard deviation [dt]	Coefficient of variation [%]
Dolnośląskie	195.0	28.0	14.4
Kujawsko-pomorskie	185.5	32.4	17.5
Lubelskie	178.7	21.5	12.0
Lubuskie	178.9	35.4	19.8
Łódzkie	174.1	32.0	18.4
Małopolskie	163.6	20.4	12.5
Mazowieckie	170.8	24.3	14.2
Opolskie	196.8	27.9	14.2
Podkarpackie	175.1	18.4	10.5
Podlaskie	179.9	18.8	10.4
Pomorskie	188.6	34.3	18.2
Śląskie	186.7	22.3	12.0
Świętokrzyskie	162.1	21.5	13.3
Warmińsko-Mazurskie	180.0	26.7	14.8
Wielkopolskie	188.4	32.1	17.1
Zachodnio-pomorskie	191.4	33.4	17.5

Source: own study.

Values of standard deviations and coefficients of variation of potatoes yields in Poland's provinces are presented in Table 2. For the sake of comparison the average yields are also given, though they are not measures of variability.

The highest standard deviation (35.4 dt) is observed for Lubuskie province and Pomorskie province (34.3 dt). The highest coefficient of variation (19.8%) is also observed for Lubuskie province. It does result in almost the same ranking given by standard deviation as variation coefficient (Spearman rank correlation is equal 0.93). It may be noted that contrary to wheat yields [Kobus 2009, 2010] potatoes average yields are quite similar across provinces.

The average variation coefficient of potatoes yields equals 14.8 % while average variation coefficient for wheat equals 9.7 % [Kobus 2009] and is higher by 5.1 percent points.

One of the conclusions from the analysis of Figure 2 is that provinces in the north-western part of Poland show the highest yield variability measured by coefficient of variation, while the provinces in the Eastern part of Poland show the lowest yield variability.

When one think about reliability of estimates presented in table 2 and figure 2 the question may arise: aren't these numbers affected by neglecting possible trends? The answer is negative, in almost all provinces trends are not significant and average value of determination coefficients is below 10%. There are only two exceptions: Pomorskie and Zachodniopomorskie with values of F statistic 9.16 and 5.30 respectively. For all other provinces values of F statistic were

Table 3. Average yields of potatoes in Polish provinces (1990-2009)

Province	Average yield [dt/ha]		Index of change [%]
	1990-1999	2000-2009	
Dolnośląskie	184.0	206.0	112.0
Kujawsko-Pomorskie	176.6	194.5	110.1
Lubelskie	174.8	182.6	104.4
Lubuskie	172.7	185.1	107.2
Łódzkie	170.3	178.0	104.5
Małopolskie	159.8	167.4	104.8
Mazowieckie	166.4	175.3	105.3
Opolskie	185.0	208.6	112.8
Podkarpackie	170.4	179.7	105.5
Podlaskie	182.2	177.7	97.6
Pomorskie	170.6	206.6	121.1
Śląskie	180.8	192.6	106.5
Świętokrzyskie	156.9	167.3	106.6
Warmińsko-Mazurskie	171.8	188.3	109.6
Wielkopolskie	181.7	195.3	107.5
Zachodnio-pomorskie	177.9	205.0	115.3

Source: own study.

Table 4. Standard deviations of potatoes yields in Polish provinces (1990-2009)

Province	Yields standard deviations [dt/ha]		Index of change [%]
	1990-1999	2000-2009	
Dolnośląskie	29.3	22.9	78.1
Kujawsko Pomorskie	39.4	22.0	55.9
Lubelskie	26.7	15.1	56.7
Lubuskie	40.7	30.2	74.1
Łódzkie	36.0	28.8	80.0
Małopolskie	22.6	18.2	80.6
Mazowieckie	28.9	19.2	66.4
Opolskie	30.0	20.9	69.9
Podkarpackie	20.0	16.4	81.8
Podlaskie	22.1	15.6	70.8
Pomorskie	33.3	25.7	77.3
Śląskie	22.1	22.1	100.0
Świętokrzyskie	26.8	14.0	52.2
Warmińsko-Mazurskie	32.5	17.1	52.6
Wielkopolskie	38.1	25.1	65.8
Zachodnio-pomorskie	38.0	22.3	58.7

Source: own study.

lower then 2 while critical value was 4.414. In author opinion it confirms validity of results shown in table 2 and figure 2.

But as was mentioned in the introduction one of the aims of this paper is to find out how is changing variability in the analysed time period. For that purpose estimates of variability measures were calculated separately for two time periods: years 1990-1999 and 2000-2009. In table 3 average yields for those two periods are presented. While differences between average yields are not significant for all provinces separately it must be noted that only for Podlaskie an index of change was below 100. It suggests this increase of average yields cannot be effect of randomness.

The highest increase of yield was observed in two provinces Pomorskie and Zachodniopomorskie. It agrees with significance of trends in those two provinces. What's more those two provinces were among provinces with smallest reduction of production area.

In tables 4 and 5 estimates of variability measures are presented. When using test F for testing hypothesis $H_0 : \sigma_1 = \sigma_2$ only in two provinces significant values of test statistic were observed namely in Świetokrzyskie and Warmińsko-Mazurskie respectively 3.67 and 3.62, for all other provinces statistic values were below critical value 3.18.

Table 5. Variation coefficients of potatoes yields in Polish provinces (1990-2009)

Province	Yields variation coefficients [%]		Index of change [%]
	1990-1999	2000-2009	
Dolnośląskie	15.9	11.1	69.8
Kujawsko-Pomorskie	22.3	11.3	50.7
Lubelskie	15.3	8.3	54.3
Lubuskie	23.5	16.3	69.2
Łódzkie	21.2	16.2	76.6
Małopolskie	14.2	10.9	76.9
Mazowieckie	17.3	10.9	63.0
Opolskie	16.2	10.0	62.0
Podkarpackie	11.8	9.1	77.5
Podlaskie	12.1	8.8	72.5
Pomorskie	19.5	12.5	63.8
Śląskie	12.2	11.5	93.8
Świętokrzyskie	17.1	8.4	49.0
Warmińsko-Mazurskie	18.9	9.1	47.9
Wielkopolskie	21.0	12.8	61.2
Zachodnio-pomorskie	21.4	10.9	50.9

Source: own study.

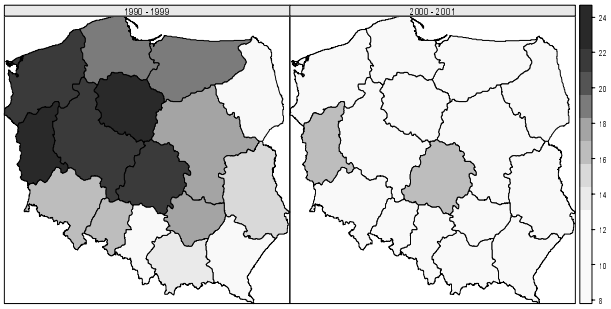

Figure 3. Variation coefficients of yield in percents (1990-2009)
Source: own study.

But one should remember that even for those 14 provinces for which there was not significant difference the probability of observing 13 or more values lower in the second period is lower then 0.001 in case equal probability of higher value of standard deviation for each period.

The variation coefficients presented in table 5 show that reduction of relative measure of variability is greater then for absolute measures. It is a result of higher average yields in years 2000-2009 then in 1900-1999.

Figure 3 shows that strength of variation coefficients in period 1990-1999 is similar to calculated for 20 years period (Fig. 2). The highest variability was in the north-western part of Poland. But in period 2000-2009 not only the values of variation coefficient are lower but also the highest risk area change to the centre of Poland.

Conclusions

During years 1990-2009 area of potatoes production was reduced to 27.7% of initial size i.e. from 1.835 million hectares to 0.508 million hectares. The smallest reduction of production area was observed in the north-west and south-eastern parts of Poland.

Although yield trends were for almost all provinces not significant the average yields were higher in years 2000-2009 then in years 1990-1999 in all provinces with one exception of Podlaskie province.

Contrary to expectations variability of potatoes yields decreased in the years 2000-2009. The variability was reduced by one third when measured by variation coefficients.

There was also a change of provinces with the highest production risk. In years 1990-1999 the most risky were provinces in north-western part of Poland while in years 2000-2009 it were four centre provinces with addition of Lubuskie.

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Streszczenie

Artykuł poświęcono analizie zmienności plonów ziemniaka w Polsce na poziomie województw. Wykorzystano dane Głównego Urzędu Statystycznego za okres 1990-2009. Celem pracy było porównanie średnich plonów oraz zmienności plonów ziemniaka w poszczególnych województwach. Szczególną uwagę zwrócono na wpływ zmniejszenia powierzchni uprawy ziemniaka na poziom plonów?

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