Climate change impact on viticulture in Poland

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Abstract

Purpose – The purpose of this paper is to identify factors resulting from climate change that could impact the cost-effectiveness and development of viticulture in Poland. Climate change is a crucial challenge for the global wine industry. It has the potential to shift the centre of gravity of viticulture from well-developed regions to new ones, including Poland.

Design/methodology/approach – Two main methods of data collection were applied: computer assisted telephone interviewing and computer assisted personal interview. A structured questionnaire was drafted, piloted and sent to farms randomly selected to represent wine producers from different wine regions of Poland. The linear probability model was used to determine the factors influencing cost-effectiveness in viticulture production. Data were calculated by using SAS software.

Findings – Current and future climate change factors could influence the cost-effectiveness and growth of viticulture in Poland. The exploitation of these opportunities will require the development and implementation of new policies and practices at the farm level, which could also promote innovation in the sector. Furthermore, wine growers according to the increased risk of the unfavourable abiotic and biotic production conditions would be forced to undertake the adaptation strategies to limit the risk of lowering the cost-effectiveness.

Originality/value – This study identifies viticulture and winemaking opportunities for new regions such as Poland. The challenges involved in managing this transition are discussed.

Keywords Poland, Cost-effectiveness, Winegrowing, Abiotic stress, Biotic stress, Climate warming

Paper type Research paper

1. Introduction

Poland is not perceived as a country with suitable climatic conditions for wine production. Although it had a great tradition of winegrowing in medieval times, industrial production was abandoned from the eighteenth to the twentieth century and is still of little economic importance. Today, however, Polish viticulture has become one of the most dynamically

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growing sectors in Europe, as has domestic wine production. As stressed by Kunicka-Styczyńska *et al.* (2016) the revival of viticulture in Poland is favoured primarily by climatic change, accompanied by some social phenomena such as consumer preferences, increasing wealth, ecotourism and value added food. It also contributes to growth in off-farm activities and to regional development (Jesiotr and Szymanska, 2016). Examples from central and eastern European countries show that wine manufacturing might be an opportunity for diversification of economic activities and for regional development. This is the case in the South Moravian Region of the Czech Republic, where grape growing and wine-production have been successfully integrated with regional development (Tomšík and Chládková, 2005) and have contributed to increased internationalisation of regional food products (Kubíčková and Peprný, 2011). The Slovak region of Banska Bystrica (Elexa *et al.*, 2016) and Hungarian region of Tokay (Tóth and Török, 2014) are also good examples of how the wine sector could contribute to entrepreneurship and innovation among small- and medium-sized companies in rural areas.

Grapevine production in Poland is difficult and more risky at present, due to climatic conditions that are not always conducive to viticulture. Jóźwiak, (2015) highlighted that progressive global climate changes and their particular impact on agriculture in Poland will have a strong influence on the cultivation of many crop plants, leading to circumstances more favourable for viticulture. Climate changes are also expected to improve the viability of winegrowing in other European regions such as southern Finland (Karvonen, 2015). Thus, it is important to understand how weather and climate changes might impact the development of the winegrowing sector, especially in the Polish context. This should have significance for further directions of development. As indicated by results of a recent literature review (Smith and Bentzen, 2011; Sacchelli *et al.*, 2016) the detailed and in-depth examination of climate change impacts on viticulture is quite recent, and the analysis of impacts on the sustainability of wine production is primarily focussed on the environmental aspects and not on the socio-economic factors.

Climate change is a crucial challenge for the wine sector. It might shift the centre of gravity of viticulture from well-developed regions to new ones, including Poland. Therefore, the objective of this paper is threefold. First, the current environmental conditions for viticulture production in Poland will be presented. Second, the state of the art of winegrowing in Poland will be characterised. Finally, based on primary data applied to an econometric model, climate change factors which could influence the operations and cost-effectiveness of Polish vineyards in the short and medium term will be described. However, the factors such as consumers' habits or international wine market changes were not addressed.

2. Materials and methods

The literature review identified factors that influence viticulture production in Poland. For this project, 50 farms were selected out of 155 that were officially registered as wine producers in 2016. Respondents were randomly selected to represent wine producers from different wine regions of Poland. A structured questionnaire containing 26 questions was drafted and piloted. Two main methods of data collection were then applied: computer-assisted telephone interview and computer-assisted personal interview. Open and closed questions were used. The category others was included in case something important was missed in the original design. The response was 54 full questionnaires, which represents 35 per cent of all officially registered wine farms in Poland. Interviews were conducted in February and May 2017 with the farms that produce and market wine.

Due to the dichotomous nature of results obtained using models of binary choices, as suggested by Long (1997), the linear probability model (LPM) was used to determine the factors influencing cost-effectiveness in viticulture production. The LPM is an application of ordinary least squares to binary outcomes instead of continuous outcomes. The dependent variable explained in the model is a qualitative variable of binary nature. The independent variables can be both qualitative and quantitative. The form of the dependency can be different. In particular, it can be non-linear. The empirical values of the dependent variable are equal to 0 or 1, but the theoretical values of independent variables (resulting from the model) do not have such limitations. Interpretation of structural parameters of LPM refers to the change in probability in response to a unitary change of the independent variable, with other factors unchanged. For calculation, the SAS software was used and the GENMODE procedure was applied SAS, (2015). The model was validated using procedures proposed by Debertin *et al.* (1980). The error term in the model is heteroskedastic as the variance is not constant and depends on the value of the independent variables. The functional form of the applied LMP is that used by Heckman and Snyder (1997):

$$p_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_k x_{ki}$$

The dependent variable was the farmers and experts' opinion about rationality and cost-effectiveness of viticulture. Initially, 13 independent variables were selected, which after estimations were reduced to 8. These variables described today's farm situation and future possible impact due to climate change. They characterised location, main cultivated varieties, soil quality, landform, impact of biotic factors (plant diseases and pests) and impact of abiotic factors (overheating, cooling). The future impact of climate change was characterised using an approach proposed by Berkhout and Van Drunen (2007). Variables included possible fluctuations of weather conditions during the cultivation period, possible impact of biotic factors (plant diseases and pests) and possible impact of abiotic factors (solar radiation, overheating, cooling, extreme phenomena).

3. Results and discussion

3.1 Winegrowing under climate change

Understanding of the impacts of climate change on natural systems has become increasingly relevant as changing levels of greenhouse gases and shifts in the earth's surface modify the hydrological cycle, earth's radiation budget and atmospheric circulation (Houghton *et al.*, 2001; Vink *et al.*, 2012; Abbott and Wilson, 2014). These observed trends and future changes will impact agricultural production through changes in the length of growing seasons. Changeability in winter hardening could have a considerable affect upon productivity and viability of diverse agricultural production (Moonen *et al.*, 2002). A good understanding of weather and climate change impacts is particularly important with viticulture and grapevine cultivation. Historical records and present observations have already shown a significant impact of climate variability on grape production. To date, research has mainly concentrated on perception of weather extremes and adaptive changes in the context of severe events such as drought, heat waves and floods (Keller, 2010; Shanmuganathan *et al.*, 2012; Tate, 2001). However, these evaluations of impacts on viticulture principally rely on worldwide climate models (White *et al.*, 2006). In contrast, there is empirical evidence that temperature-based indices have a crucial impact on grape production (Schultz, 2000; Stock *et al.*, 2005; Nesbitt *et al.*, 2016). There is a strong correlation between good vintage and annual weather conditions. According to Becker (2003), climate change can improve the quality of various varieties due to favourable thermal conditions

that can be expected in numerous growing regions. On the other hand, varieties that are adapted to cooler conditions can suffer imbalances in flavor components with rising temperature. According to Webb *et al.* (2007), grapevine phenology is highly sensitive to the various greenhouse gas emission scenarios. Moreover, climate change affects phenology, as well as pathogens and insects life cycles, which may bring new risks for the timing of phytosanitary treatments (Battaglini *et al.*, 2009). A change in climatic zones will create potential for spread of thermophile pests and diseases. Furthermore, climate change will lead to shifts in the suitability of wine-growing regions for the production of unique types of wine and could upset the competitive balance between diverse regions (Kenny and Harrison, 1992; Tóth and Végvári, 2015). According to Hannah *et al.* (2013), as a result of climate warming in the next decades (up to 2050), the most important European wine regions such as Tuscany and Bordeaux will lose between 19 and 73 per cent of production capacity. Rising temperatures will make grape growing viable in places that are currently considered to be uneconomical, including mountain slopes and river valleys in central China, Canada, central Europe and most of Poland.

The mid-term scenarios of climate change in Poland during the twenty-first century in the framework of the Klimada project were prepared using climate models (Sadowski, 2012). The results of scenario analysis show an increasing temperature across the country, varying regionally and seasonally, but strongest in the past three decades of the twenty-first century. Using climate scenarios for the years 2021-2050 and 2071-2100, it has been calculated that a grape growing season in Poland (determined by number of days with daily air temperature higher than 5°C) will be 16 days longer between 2021 and 2050, compared to the years 1971-2000, and 41 days longer for years 2071-2100. This will significantly accelerate the growth of plants. The analysis of the impact of agro-meteorological conditions on the yield of crops in Poland has shown a trend toward loss of yield as a result of drought risk. An increase in the frequency of yield losses is expected, with relatively small changes in average yields. Thus, the observed changes in thermal conditions and the impact of these changes on the phenology of crops will initially require changes in field work periods. In the longer term, adaptation of cultivation structures will be required.

In summary, changes in climate will create a strong element of uncertainty in grape production. The wine industry is very often recognised as vulnerable to climate change, due to its specific dependence on particular terroirs that are significantly climate related. Accordingly, the wine grape industry is perceived as an early warning indicator for agricultural industries in different countries.

3.2 Winegrowing in Poland under climate change

In the European Union's classification of climate for viticulture (Council Regulation No 479/2008), Poland was classified in the coldest winegrowing region and officially acknowledged as a wine-producing country, together with Germany (except for Baden), the Czech Republic (except for Moravia), Belgium and Great Britain. Polish territory was divided into three regions based on temperature: Region I (the west and southwest of the country, namely, provinces of Lubusz, Lower Silesia, Opole and Silesian and southern parts of the provinces of Wielkopolska and Lodz); Region II (threatened with more frequent cold winters, covers the south and southeast of the country, i.e. the provinces of Małopolska, Podkarpackie, Świętokrzyskie and southern parts of the provinces of Lublin and Warsaw); and Region III (the other areas, where viticulture is impossible or very difficult) (Figure 1). According to Lisek (2008), the current climate changes are conducive to the development of Polish winemaking. The average annual temperature has shown an upward trend (about 0.5°C per decade), transitional periods have been shortened, warm periods have been prolonged and

winters have become milder, allowing the cultivation of early and very early varieties or varieties sensitive to chilled temperatures. Lisek (2008) stressed that out of all the climatic changes noticed in the past several dozen years, the most favourable for grapevine growing is increased annual air temperature during the growing season, expressed as the so-called sum of active temperatures. This consists of the daily temperature averages above 10°C. His research showed that, on average, the beginning of the phenological stages of bud swelling, blooming and fruit ripening of grapevine cultivars in the years 2005-2007 occurred 12 days earlier than in the period 1987-1989. In recent years, however, climate fluctuations, especially increase of temperature during the growing season, have led to new issues concerning plant protection against pests and diseases. Some of the most important problems are more and more frequent grapevine infections with fungus. Additional threats include solar injuries to grapevine leaves and fruits caused by thermal (infrared) and ultraviolet (UV-B) radiation.

3.3 Wine production in Poland

Wine production in Poland is linked to the obligation to report to the Agricultural Market Agency (AMA) on production volumes and stocks of wine. Under the Common Agricultural Policy, AMA implements measures to determine the production potential of vines and wine in Poland. The purpose of these activities is to assess the volume of grape harvest and the production of wines and vine crops and to monitor the market. However, some vineyards do not produce wine for market purposes and are not obliged to register with AMA. At present, there are about 500 vineyards, with estimated area of 700 ha (Figure 2). Out of this number, 155 farms registered with AMA in 2016, representing a total area of 238.2 ha. There is clear dynamic growth in the number of registered farms and the registered area of vineyards for wine production in Poland. From 2009/2010 to 2016/2017, the industry has grown more than 20-fold, but starting from a low base of only 26 farms. During the same period, the production of wine increased 17-fold, from 41,249 to 699,382 dm^3, with average 50 per cent annual growth in the analysed period. The size of already existing vineyards, which are included in the records, ranges from less than 1 ha (about 75 per cent) to over 12 ha (AMA, 2017).

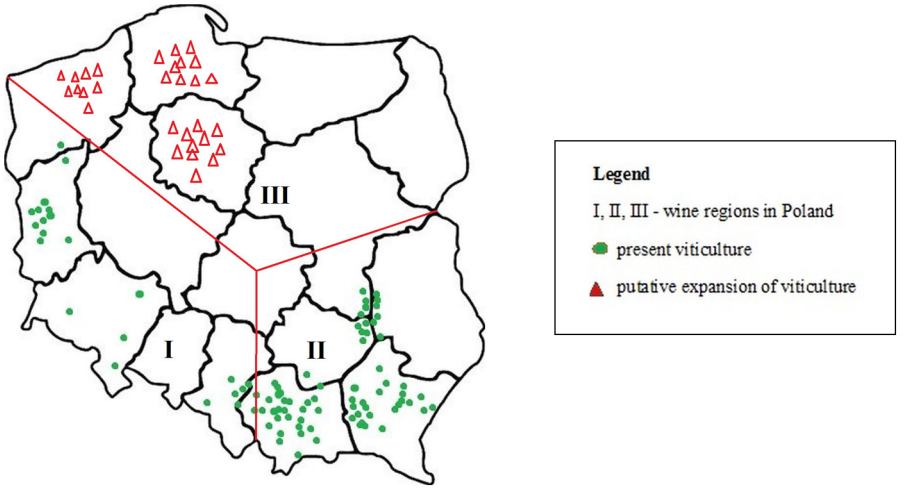


Figure 1.
Vineyards in Poland divided into three regions based on temperature

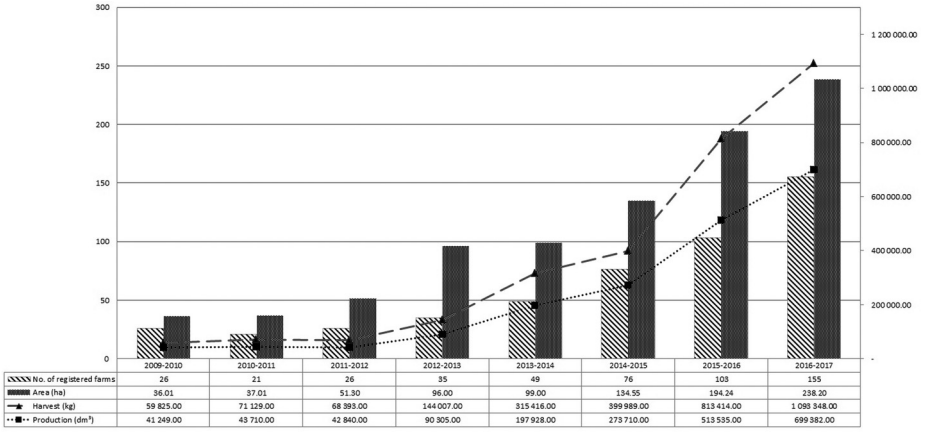
Most of the vineyards could be found in the belt of south-eastern, south-western and southern provinces, which have the most favourable climatic conditions. Listed regions are characterised by higher temperatures, optimal conditions of sunlight and longer growing seasons than the rest of the country. Moreover, natural conditions offered by these regions are optimal for cultivation of popular cold-hardy and disease-resistant hybrid grape varieties, e.g. Seyval Blanc, Solaris, Hibernal used for white wine production or Rondo and Regent used for red wine production. Vitis Vinifera species, such as Riesling, Pinot Noir, Chardonnay, Merlot and Zweigelt, are also frequently grown in these regions.

In this context, it needs to be noted that the Polish wine market has seen dynamic development over past decades. Zmarzłowski and Ochnio (2013) reported that it has developed due to the increasing share of wines in the domestic alcohol consumption. Tul-Krzyszczuk, and Kołakowska-Paszkiewicz (2008) argued that this market has a growing potential which will be stimulated by the buyer's bargaining power and growing wine culture. Polish consumers are discovering classic grape wine, looking for high-quality and healthful products, paying also the attention to their price. Smith and Mitry (2007) informed that in spite of increasing popularity of wines, the Polish wine market is rather small in contrast to the European market. A comparison with other European countries distinctly shows that it is in a state of rapid change and has some years of growth ahead before reaching maturity (Schaefer *et al.*, 2018).

3.4 Results of the model

The results of the LPM estimations show that there are important current and future climate change factors that could influence the cost-effectiveness of viticulture in Poland. The probable impact has a dichotomous character. It is expected that climate change will positively influence farm operations, but indirect effects will have a negative influence too (Table I).

It was estimated that under *ceteris paribus* conditions, the likelihood of maintaining cost-effective viticulture in Poland increases by 21 per cent due to regional location of the vineyard. It was thus confirmed that climate and weather conditions have a systemic character and are interdependent with terroir. Changing weather and climate conditions in case of Poland will impact the opportunity conditions to start the cultivation of vineyards. Such cultivation will become an alternative strategy for farmers, whom anyway will be faced with the need to adjust activities according to changeable climate conditions. These



	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
No. of registered farms	26	21	26	35	49	76	103	155
Area (ha)	36.01	37.01	51.30	96.00	99.00	134.55	194.24	238.20
Harvest (kg)	59 825.00	71 129.00	68 393.00	144 007.00	315 416.00	399 989.00	813 414.00	1 093 348.00
Production (dm³)	41 249.00	43 710.00	42 840.00	90 305.00	197 928.00	273 710.00	513 535.00	699 382.00

Figure 2.

Table I.
Results of the LPM – estimation of current and future climate change parameters influencing the cost-effectiveness of viticulture production in Poland

Parameter/Parametr	DF	Estimate	St. Error	Wald confidence limits (95%)		Wald ChiSq	Pr > ChiSq
Intercept	1	-1.5577	0.2864	−2.1191	−0.9963	29.58	<0.0001
Regional localization	1	0.2148	0.0148	0.4152	1.1654	21.45	0.0001
Variety	1	0.4918	0.1878	−0.8599	−0.1238	6.86	0.0088
Occurrence of diseases	1	−0.2731	0.2009	−0.3794	−1.1668	14.81	0.0001
Cooling stress	1	−0.4973	0.0976	−0.3059	−0.6886	25.94	<0.0001
Overheating/radiation stress	1	−0.3375	0.1771	−0.0095	−0.6846	3.63	0.0056
Future change of the weather cond. during vegetation period due to climate change	1	0.4915	0.116	0.1643	0.6188	11.4	0.0007
Future change of occurrence of diseases due to climate change	1	−0.3572	0.1182	−0.2255	−0.6888	14.96	0.0001
Future change of occurrence of pests due to climate change	1	−0.2347	0.1033	−0.9371	−0.5323	50.63	<0.0001
Scale*	1	0.1333	0.0206	0.0985	0.1804		

Note: * the scale parameter was estimated by maximum likelihood
Source: Own calculations

conditions will influence the economic tension to grow suitable plants, which will provide an economic benefit. Winegrape growing could be such strategy for Poland. A similar situation, with a higher significance level, could be observed in the case of cultivated variety. The model's results show almost 50 per cent probability that cultivated variety, under climate change, will have a positive impact on farm operation and effectiveness. This indicates that in the near future, the list of varieties might need to be revised to select those most suitable for the new conditions. This, however, will require new investment which could reduce the likelihood of implementation. Only the farmers that will be able to effort the costs of buying cuttings of new varieties, adding new field quarters and waiting for return on such investment, which will be connected also with the promotion on new wine, will build their competitive position on the market. Also, the careful calculations will be needed to investigate both trade-off effects between profiting from already growing varieties and costs of growing new one and spillover effects of growing new varieties, i.e. for enoturism.

The model estimates also suggest that the overall forecasted changes of weather conditions during the vegetation period will have an impact on the cost-effectiveness of farms. There is almost 50 per cent probability that if the forecast changes take place, much better conditions will be created for viticulture production in Poland.

Nonetheless, there are forecasted also negative effects for farm economics due to climate change. These are indirect effects related to biotic and abiotic stresses that arise from climate change. Abiotic stresses analysed in the model showed cooling and overheating jointly with radiation stresses. The results showed that in case of cooling stress, the farms' cost-effectiveness will decrease by half and in the case of overheating by one-third. Similarly, biotic stresses such as diseases could reduce farm effectiveness by 27 per cent. In the longer term, biotic stresses such diseases and pest occurrence might have negative impact on viticulture. Should climate change conditions cause an increase in the occurrence of pests such as mites or aphids, there is 23 per cent probability that the viticulture production will be less effective. Similarly, the increase of diseases such as powdery mildew, might lower farm effectiveness by 35 per cent.

Mozell and Thach (2014) showed that global warming has direct, and sometimes quite severe, implications for both vineyard management and wineries. Climate changes and their effects are remarkable, but winegrowers are not fully aware of them (Battaglini *et al.*, 2009). However, they could undertake adaptive measures to minimise the associated risk. Bernetti *et al.* (2012) have shown that adaptation actions undertaken to adjust to climate change, which can be considered as innovations at the farm, lead to a 61 per cent probability of maintaining current levels of income. The most important result of their research, however, is that farms tend to respond to climate change without stopping production. They are adopting innovations as a response to climate change. Climate change factors will impact economic performance of viticulture and could consequently also encourage innovation in the sector.

4. Conclusions

Climate change occurring today and predicted in the near future will change the centre of gravity of wine production in Europe. Poland can provide a good example and case study of this transition. The modelling presented in this paper suggests that there is a significant probability that the Polish winegrowing sector will progress and develop if appropriate strategies and practices are applied in response to climate change. Farmers should take the advantage of more suitable climate conditions. As a result the area of cultivation as well as wine production could increase in Poland. However, grape growers will be forced to address

the risks of unfavourable abiotic and biotic production conditions. New investments, practices and strategies will be required to exploit new opportunities and limit new risks.

Although viticulture in Poland is likely to remain of little economic significance in the short and medium term, due to climate change, it might become a significant branch of the agri-business sector in the long term. This might depend on other market-related factors, i.e. the development in the domestic wine consumption, wine drinking habits and the world wine market changes. These factors were not examined in this paper and require further studies, in particular in connection with the climate change issues. The study of the impacts of climate change on viticulture and wine production is a recently emerging research topic. Strategies have not yet been developed and further analysis is also needed.

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