Global warming - impact on European Agriculture and Economy

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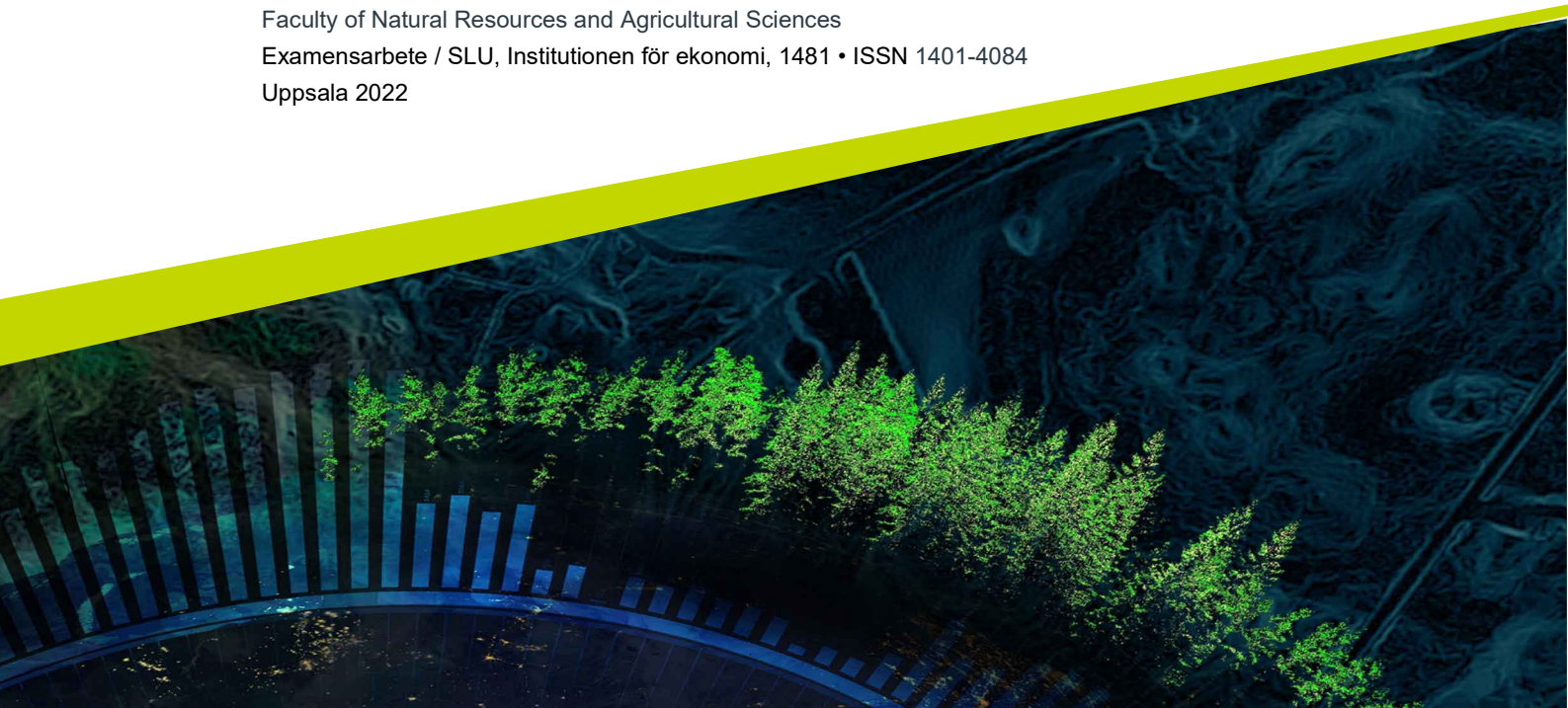

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Abstract

Global warming and its impacts are one of the most significant topics of the 21st century. The consequences of it have an impact on wide aspects of life. This thesis analyses changes in economic outcomes and agriculture by answering the following question: How will global warming affect the production of wheat in the different regions of the EU, and how will this affect prices, trade and economic welfare? This thesis studies one agriculture product – wheat. The literature suggests that wheat yield should increase in the Northern region and decrease in the Southern region of the EU by 2050., A partial equilibrium analysis suggests that these production changes will lead to exports increasing and a producer surplus increase in the North, while imports increase and producer surplus decreases in the South. Using a regression analysis, I test whether the increase in temperatures between 1980 and 2020 have already led to the changes in wheat production as predicted by the literature. Also, I find that higher temperatures are associated with higher wheat yields in both the South and North regions of the EU during the period 1980–2020.

Key words: economy, global warming, supply, wheat, price, trade, welfare, 2° C scenario

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Abbreviations

EU	European union
EDO	European drought observatory
FAO	Food and Agriculture organisation
FAOSTAT	Food and Agriculture organisation database
p	price
q	quantity
CS	consumer Surplus
PS	producer Surplus
S	supply
D	demand
I	income
pw	World price
x	independent variable
y	dependent variable

1. Introduction

This section outlines the introduction in topic, the motivation of writing this thesis and states the main objectives of thesis, its main research question, followed by brief and summary of findings.

1.1 Background

In the past few decades, humanity has witnessed global climate change. However, society still survives and adapts to the new situation every day. According to Hristov et al. (2020) and Bowen & Dietz (2016), in the future, until 2050, it is possible to record a temperature increase. In the case of this hypothetical scenario, countries of Europe will be differently economically affected. This thesis starts from analysis of the economic impact of the 2° C climate change scenario, provided by Hristov et al (2020), on the agricultural sector in the EU market. Namely, the *2 ° C scenario* predicts an increase in global temperature by 2° C until 2050, compared to the 1980s (Hristov et al. 2020). According to the mentioned *2° C scenario*, some countries will experience net benefits, and some will experience net damages to the economy (Jacobs et al., 2019). According to Hristov et al. (2020), Europe is divided into Northern and Southern regions by climate change, recognized as the central split (*Figure 1)*. The European market is vast, and in this case divided into two regions (Northern and Southern), which have different characteristics and are differently influenced by climate change. Namely, the impact can be characterized as positive in northern and negative in the southern areas.

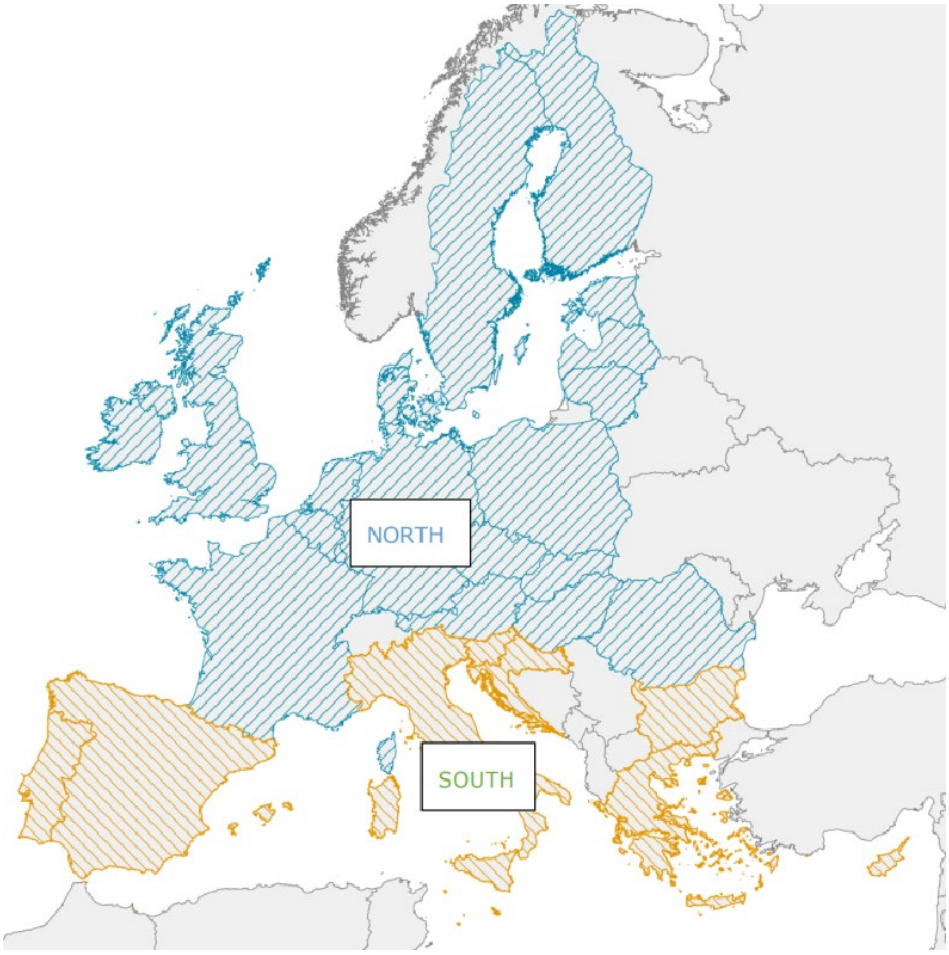

Figure 1 The division of EU on South and North (Hristov et al. 2020)
Note Northern region of EU includes: Sweden, Finland, Estonia, Latvia, Denmark, Lithuania, Ireland, Netherlands, Belgium, Luxembourg, Germany, Poland, Czechia, Slovakia, France, Austria, Hungary, Romania. Southern region of EU includes: Italy, Slovenia, Croatia, Spain, Portugal, Bulgaria, Greece, Malta, Cyprus

1.2 Motivation, aim, research question and methodology

Understanding the impact of global warming on agricultural production is important, because it, directly and indirectly, influences our everyday life. On the one side, global warming is a game-changing factor in the agriculture business, which means that conditions are changing due to climate change, while on the other side, a change in yield or total production of one good makes an impact on the market and economic outcomes.

In this thesis, the focus is to test out possible changes in supply, caused by global warming, and its connection and influence on economic outcomes. The aim of this thesis is to examine how a change in Supply influences the following economic

outcomes: price, international trading, and economic welfare in two different cases. Using a partial equilibrium approach, I studied the impact in two different cases: one of an open economy and another of a closed economy.

Recent studies suggest that climate change is already affecting Europe (IPCC, 2022). Thus, it might be already possible to see the effects of warmer temperatures on agricultural output in Europe. Therefore, this thesis will also examine changes in wheat yield due to temperature changes in the period between 1980 and 2020. According to the above, the main research question of this thesis is as follows:

How will global warming affect the production of wheat in the different regions of the EU, and how will this affect prices, trade and economic welfare?

The theoretical framework for this thesis stems from Mendelsohn et al. (1994) and Hristov et al. (2020). Mendelsohn et al. (1994), which represent the Ricardian approach and show the impact of climate on agriculture yields. However, it doesn't show what is happening with connected economic outcomes. On the other hand, Hristov et al. (2020) show significant changes in Northern and Southern regions of EU economic outcomes due to climate change.

The methodology used for this thesis is based on the following three methods to answer the research question: **Partial equilibrium** modelling (Feenstra 2010), based on the framework of supply and demand. In this case, the change in supply is analysed. Its models consider only one market at a time, ignoring potential interactions across markets. **The Ricardian approach** by Mendelsohn et al. (1994) is used to represent an analysis of economic activity. Also, to explain and test the relationship between the yield of wheat across the EU and temperature in the period from 1980 to 2020, **The Linear Regression** method (Freund 2006) is used.

1.3 Structure

The rest of the thesis is structured as follows: section 2 gives an outline of the existing literature on climate change and its impact on economics. Subsequently, the theory, method and data used in this thesis will be discussed in section 3. In section 4 theoretical analysis will be shown by using the partial equilibrium method and Ricardian approach. Next, section 5 will show a regression analysis of wheat yield and temperature by using FAO and EDO data. Finally, section 6 will show a discussion about findings, limitations and potential improvement, and suggestion for future research, while section 7 will provide the authors' briefly conclusion about the topic and results.

2. Literature review

This section offers a thorough overview of the literature, which provides the theory behind global warming, the *2° C scenario* and its impact on the economic outcomes.

In the past few years, the topic of climate change has become one of the most significant in everyday life. Hristov et al. (2020) provide *the 2° C scenario* concept and idea. This paper represents one of the most significant drivers for this thesis. Namely, global temperature in this scenario will increase by *2° C* until 2050 compared to the level from the 1980s. According to Hristov et al. (2020), the EU can be divided into two main regions when analysing the impact of climate change: Northern and Southern, which will be both analysed in this thesis. Also, Hristov et al. (2020) provide information about future European wheat production in different climate change scenarios until 2050, which is analysed in this thesis through changes in supply, price, trade and economic welfare. This study shows that careful management of agricultural producer practices under climate change conditions may also give rise to new export-demand opportunities for farmers. These benefits are combined with targeted breeding programmes.

According to Boliko (2019), global warming can increase problems due to pathogens, insects, heat stress, floods, and droughts. Moreover, this will have a negative impact on the yield, which is directly influencing supply in the market. This negative effect, according to Boliko (2019), can be much lower if there are investments in R&D, which can be implemented. Also, new crops, which are more resistant to pathogens and other factors, can be solutions. However, all these extra measures influence on price forming of the market.

According to Aydinalp & Cresser (2008), the main impact of global warming on agriculture can be described as geographical shifts and yield changes. The geographical shifts of yield are changing the export and import of many countries in the EU, which is directly connected to the economic outcomes, which are the focus of this thesis. This means that Southern countries will be confronted with decreasing production due to higher temperatures. On the other side, Northern countries will notice a higher yield level.

Shrestha et al. (2013) provide additional supportive information to understand the differences between regions in northern and southern Europe. In northern areas, climate change may produce positive effects on agriculture through the introduction of new crop varieties, higher yields, and expansion of suitable areas for crop cultivation. In southern areas, the disadvantages will likely predominate. The expected increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability, and a reduction in suitable areas for cultivation (Shrestha et al 2013).

According to Jacobs et al. (2019), climate change has already negatively affected the agriculture sector in Europe, and this will continue in the future. Future climate change might also have some positive effects on the sector due to longer growing seasons and more suitable crop conditions. This paper discusses how climate change influences change in production in agriculture, but also provides a macroeconomic point of view of climate change in the EU. Jacobs et al. (2019) find that crop productivity will decrease in parts of southern Europe and the length of growing seasons (due to higher temperatures) will increase in northern Europe, which will improve the suitability for growing crops in this region. Also, reasons for a reduction in crop productivity in the south according to Jacobs et al. (2019) are based on a longer warm period, which provides a longer time period for pathogen development and causes possible droughts. On the other hand, a warmer climate will provide a friendly environment in the Northern region for longer crop activity, which means that the length of growing seasons is increased (due to higher temperatures) and it will improve the suitability for growing crops in the North.

To understand potential damage to the social environment, a paper from Bowen & Dietz (2016) is used. During the climate change transition many problems can affect a country, and according to Bowen & Dietz (2016), the most vulnerable are the undeveloped and developing countries. Namely, countries with developed agriculture and agricultural science can solve the problem faster and they will be less damaged, but on the other hand, undeveloped and developing countries will solve this process slower and will feel more consequences. Northern Europe is less vulnerable to climate change than other parts of the world, according to Bowen & Dietz (2016). That means that countries from this region can adapt easily because most of them are highly developed countries, and agriculture is not an important part of their economies. Secondly, increases in the length of growing seasons (due to higher temperatures) will improve the suitability for growing crops in the North (Jacobs 2019).

Batten (2018) provides potential risks and consequences of the impact of global warming on agriculture. This paper defines physical risks as “those risks that arise from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of exposure of human and natural systems, including

their ability to adapt". Two main sources of physical risks can be identified: gradual global warming and an increase in extreme weather events. Transition risks, on the other hand, are defined as those risks that might arise from the transition to a low-carbon economy. This paper will take its role in the discussion section.

According to Costinot et al. (2016), a country may stop producing a crop whose yields have fallen and import it in exchange for another crop whose yields have remained constant at home. In short, the macro-consequences of climate change in a global economy are inherently related to how it affects comparative advantage across regions of the world. Yet, whether climate change will affect comparative advantage, both within and between countries, remains an open question. This paper provided a wider understanding of the consequences of change in the trade component.

For a better understanding of climate change impact, the IPCC sixth assessment report (H.-O. Pörtner et al. 2022) provides information about the impact on the everyday life of humanity, starting with a direct effect on human health and ending with indirect consequences of damaging the wildlife environment. Also, Gates (2021) provides a point of view on what will happen to the economy if humankind does not take control of climate change.

The theoretical framework draws on several sources. First, the Ricardian approach stems from Mendelson et al (1994). I describe the Ricardian approach in more detail in the next section. Feenstra (2010) describes partial equilibrium modelling approaches, which are also used in the theoretical framework. To expand the base of theoretical economic knowledge Mankiw (2014) and Nicholson & Snyder (2017) textbooks are used. On the other hand, to find a connection between wheat production and value, a well-known Regression model is used, which is described in this case by Freund (2006).

3. Theory and method

This section will describe in detail what theory and method are used to answer the research question. Also, this section will describe in detail the theoretical framework of the thesis and the methods. Theoretical framework contains an explanation of implementation of Mendelsohn's (1994) Ricardian approach theory and partial equilibrium theory to this thesis. This is followed by an explanation of the Linear Regression analysis model, and a data description.

3.1 Theoretical framework

Theoretical framework of this thesis is based on two main segments, the first one being the Ricardian approach by Mendelsohn et al. (1994) and the second being the Partial equilibrium modelling by Feenstra (2010). Both of which will be explained in the next two subsections.

3.1.1 Ricardian approach

According to Mendelsohn et al. (1994), the Ricardian approach shows the impact of climate on agriculture yields. The Ricardian system allows measuring the economic value of different activities and, therefore, verifying whether the production function implies the economic impacts. Basically, with the help of this paper is possible to find reasons and understand why farmers are switching to crops that tolerate higher temperatures and drought during climate change. This switching produces influences on mentioned economic outcomes. The results of the Ricardian approach can be seen in *Figure 2*. It assumes that the "value" measured along the vertical axis is the net yield per acre of land; more precisely, it is the value of output less the value of all inputs (excluding land rents). Under competitive markets, the land rent will be equal to the net yield of the highest and best use of the land. This rent will in fact be equal to the heavy solid line in *Figure 2* (Mendelsohn et al. 1994). Mendelsohn et al. (1994) provide a picture from a microeconomic perspective, i.e., the possibility to understand farmers' decision to transition to other types of crops or to adapt to new conditions, as well as what the consequences are

if they don't do it. According to the results of the Ricardian approach by Mendelsohn et al. (1994) climate has complicated effects on agriculture, highly nonlinear and varying by season. An important application of this analysis is to project the impact of global warming on agriculture. If markets are functioning properly, the Ricardian approach will allow us to measure the economic value of different activities and therefore verify whether the economic impacts implied by the production-function approach are reproduced in the field (Mendelsohn et al., 1994). Mendelsohn et al. (1994) showed how temperature rises to impact the choice of crops. According to *Figure 2, when* the temperature increases, wheat productivity will fall (point C), which leads to a switch to corn, which has a higher tolerance to high temperatures. Points D and F, which have the same place on the horizontal axis, show that different crops (wheat and corn) have different activity values due to different temperatures. According to this, this part of the thesis should show it is possible to compare where are mentioned regions in wheat production. This part of the research should show the wheat production in regions between A and B or B and C.

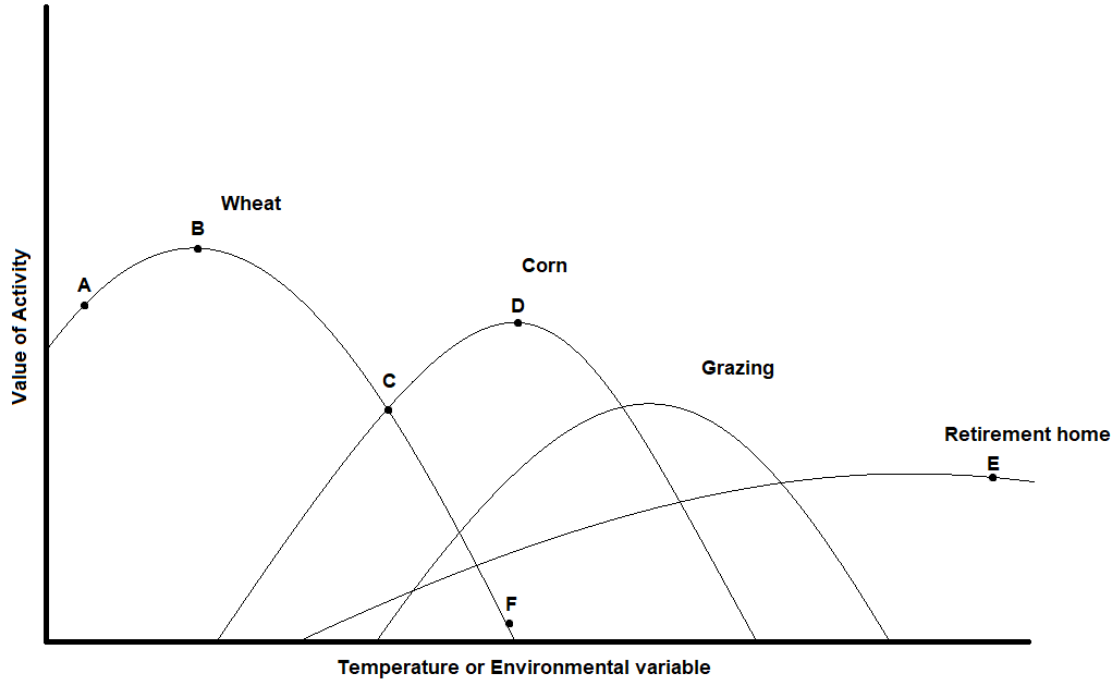

Figure 2 Bias in Production Studies (Mendelsohn et al. 1994)

To test findings of Theoretical analysis, linear regression model is used by compering yields of regions and changes in temperature. *Note that I do not test the hypothesis that farmers switch to different crops, only that the value of an activity can either increase or decrease with higher temperatures*.

3.1.2 Partial equilibrium

This thesis closely follows the partial equilibrium modelling by Feenstra (2010), Partial equilibrium modelling is a term for demand and supply analysis for a single good or set of goods. In this case, only changes in supply are followed and the demand component is fixed, because the *2° C scenario* by Hristov et al. (2020) predicts only changes in Supply, increasing in the Northern and decreasing in the Southern region of the EU. According to that, three outcomes are examined in this thesis: ***price, trading, and economic welfare.*** In this thesis mentioned outcomes will be examined for two regions of the EU (Northern and Southern) in two cases: closed economy and open economy. To provide more sources of knowledge about the impact of supply shifting, Mankiw (2014) and Nicholson & Snyder (2017) are used.

According to Mankiw (2014), when supply increases and demand stays the same, the price will decrease, but when Supply decreases and Demand stays the same, the price will increase. This statement was followed during analyzing of price change. Therefore, the change in price is directly connected to the change in economic welfare, which specifically refers to utility gained through the achievement of material goods and services and in this case possibility to buy particular agricultural goods.

On the other side to explain the findings of Regression analysis of wheat production, descriptive and comparative methods are used. The idea is based on Mendelsohn et al. (1994) Ricardian approach findings to demonstrate at which point the current production of the region is.

3.2 Linear Regression analysis model

Linear Regression analysis for this thesis is provided by Freund (2006). Regression is a statistical method used in many disciplines that attempts to determine the strength and character of the relationship between one dependent variable and a series of other variables, also known as independent variables. Regression analysis is a reliable method of identifying which variables have an impact on a topic of interest. The process of performing a regression allows you to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other. Used data for these analyses are provided by FAO and EDO database.

The linear regression model, which is used in this thesis, is written here:

$$\boldsymbol{y = \beta_0 + \beta_1 * x + \varepsilon}$$

Following the usual notation for the general expression for a straight line, the parameter $\boldsymbol{\beta_0}$, the intercept, is the value of the mean of the dependent variable when *x* is zero, and the parameter $\boldsymbol{\beta_1}$, the slope, is the change in the mean of the dependent variable associated with a unit change in *x*. In the equation *ε* represents error term. These outcomes are often referred to as the regression coefficients. Note that the intercept may not have a practical interpretation in cases where *x* cannot take a zero value (Freund 2006).

In the case of this thesis, two separate regression analyses were done, one for Northern region and one for Southern region. In both regressions for independent variable (x) is taken yield (measured in tons) and for dependent variable (y) is taken average max temperature of region (measured in Celsius degrees) . The value of produced wheat represents amount of money for which wheat was sold, on another side this value can be recognized as total income by wheat selling in one of the regions. Also, trends over time (in period of 1985-2015) for both variables are done, which are used to test predictions of *2° C scenario* and compere with Mendelsohn et al. (1994) findings.

3.3 Data description

Data on wheat yields was collected from Food and Agriculture organisation database (FAO) for the period 1980-2020. And they are presented in ***Figure 3 and Figure 4*****.** Yield **is** measured in tonnes per hectare. Data about average max temperature is collected from the EDO database, which is presented in ***Figure 5 and Figure 6*****.** for both regions. The temperature is measured in Celsius degrees year by year from 1980 to 2020. Average wheat yield is measured in tonnes per hectare, also this data represents the average yield of the Northern and Southern regions separately. Average max temperature represents the average value of all daily maximum temperatures during one year for both regions separately and is measured in Celsius degrees. Data for the Northern region are constructed on average data from all northern members of the EU, listed in ***Figure 1***, also Data for the Southern region are constructed on average data from all southern members of the EU.

Both *Figures*, *3* and *4*, present yield of wheat over the observed period (1980 – 2020). Trend lines shows increasing of yield over the time for both regions. Also, *Figures, 5* and *6* present data of average max temperature, where trend lines present increasing over the period for both periods. Note that datasets for Northern and Southern region yields can be found in Appendix in Table 1 and Table 2.

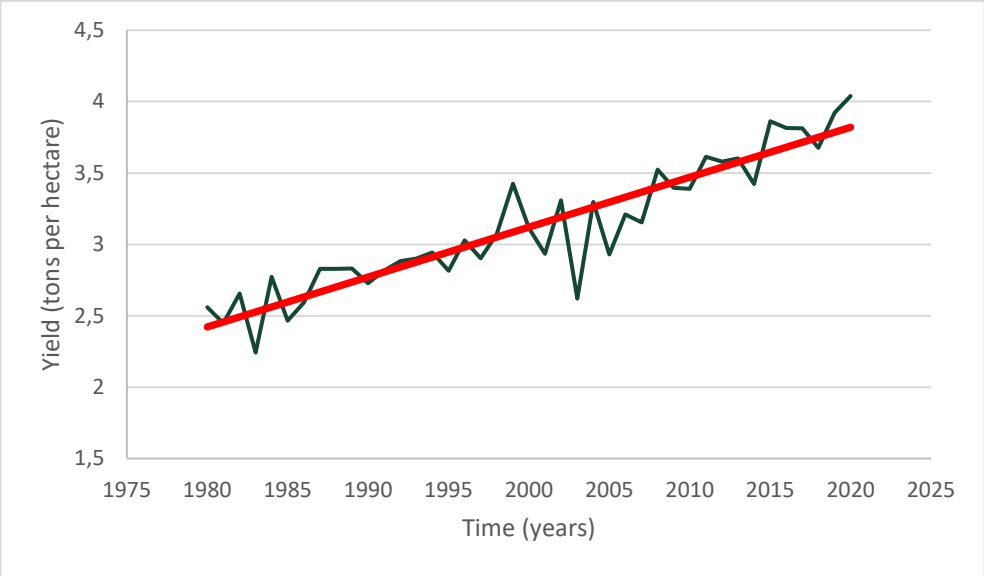

Figure 3 South Europe – wheat yield over time (1980-2020) (Source: FAO)

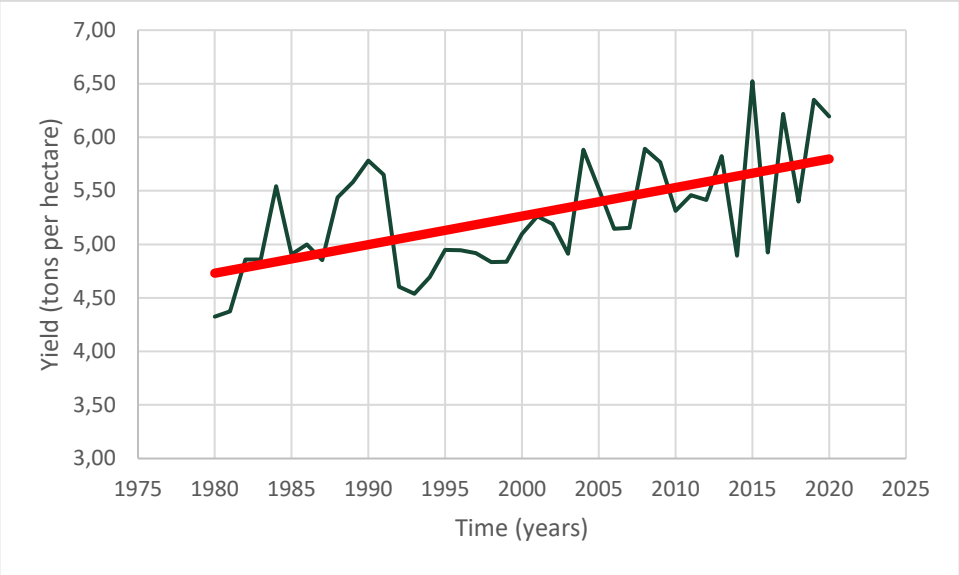

Figure 4 North Europe – wheat yield over time (1980-2020) (Source: FAO)

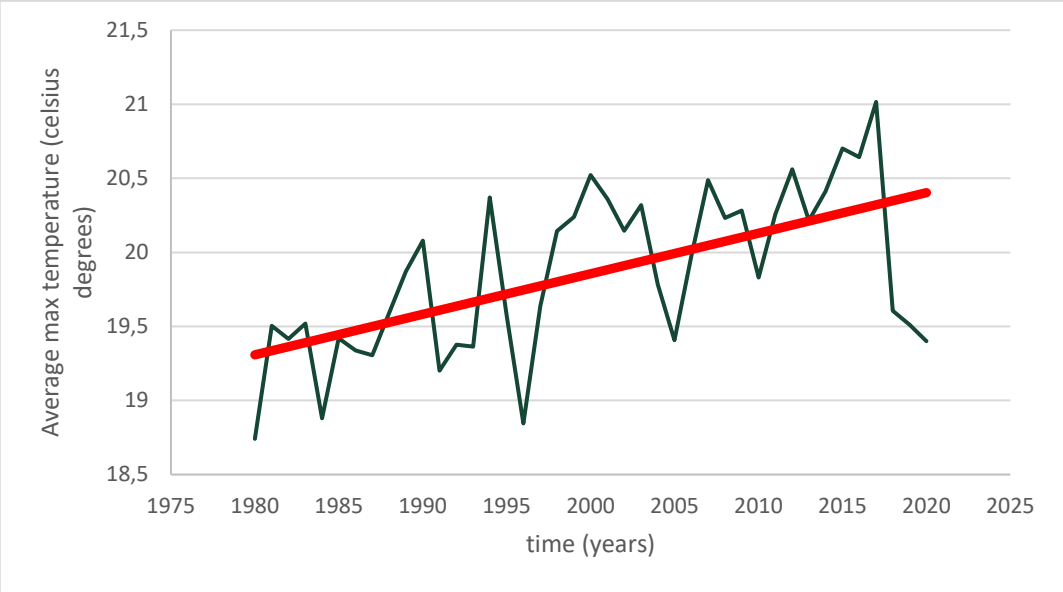

Figure 5 South Europe – Average max temperature over time (1980-2020) (Source: EDO)

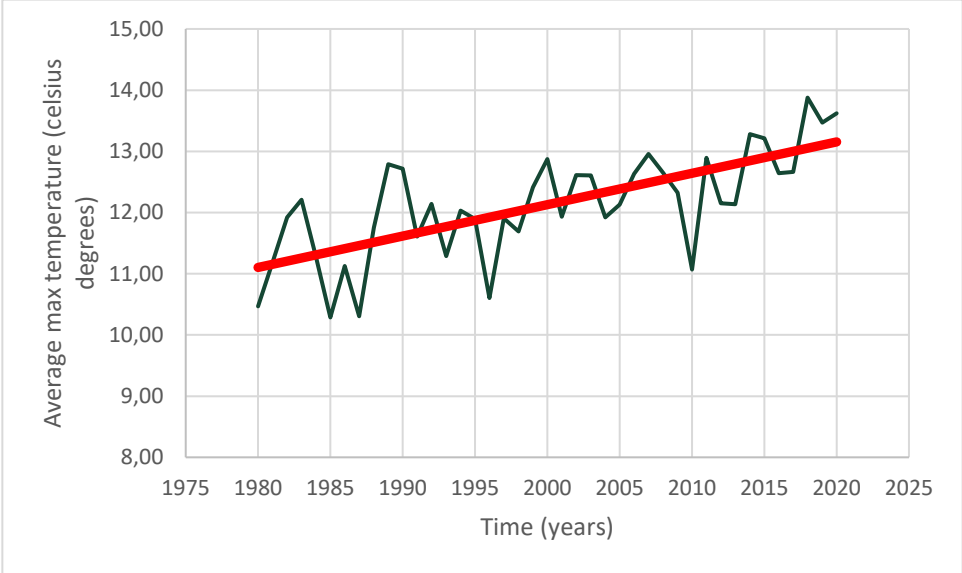

Figure 6 North Europe – Average max temperature over time (1980-2020) (Source: EDO)

4. Theoretical analysis

This section presents influence of temperature increase on plant activity and its impact on observed outcomes of EU agricultural market. This section also provides analyses of outcomes in two environments: Closed economy and Open economy case.

4.1 Impact of global warming on plant activity

According to provided theory and data by Hristov et al. (2020) and Jacobs et al. (2019), the temperature will rise in Europe, reflecting differences in the Southern and Northern regions of Europe. Climatic conditions for agriculture may change in favour of the Northern region. Also, Northern Europe, especially Scandinavia, is less vulnerable to climate change (Bowen & Dietz 2016). The southern region will be negatively influenced. Batten (2018) provides supportive statements for Hristov et al. (2020) and Jacobs et al. (2019) predictions of the *2° C scenario,* that those southern countries can be affected by more extreme weather events (droughts, floods, storms, etc…), which will produce damage, which will be presented as production decrees (decrees of Supply) followed by price increases. In the case of Northern Europe, there is no expectation of extreme weather events. Moreover, warmer weather should improve the possibilities of production, which reflects an increase in Supply.

This pattern of production response to global warming can be visualized using the theory of Mendelson, which is represented in *Figure 2*. Namely, according to Hristov et al. (2020) and Jacobs (2019), the temperature will rise by two Celsius degrees by 2050 compared to the temperature level of the 1980s, and according to Mendelsohn's (1994) findings, the Value of Activity can either increase or decrease during the temperature change. Moreover, by comparing these three findings, it is possible to conclude that the value of the activity, i.e., the yield will somewhere increase and somewhere decrease.

In the case of the Southern region, according to *Figure 2* by Mendelsohn et al. (1994) activity is going from point B, which represents the maximum activity, to

point C, which is explained by decreasing in total production of the South. Before activity comes to point C level, producers should adapt to new circumstances.

On the other side, activity in the Northern region is in an increasing process according to analysis. In this case, it should be between points A and B in *Figure 2.* The maximum production in the Northern region of the EU can be expected at the moment when activity comes to point B. Also, in the moment of maximum production level, the Northern region also might increase their exports according to analysis from subsection 5.1.2.

The *2 ° C scenario* is still in the process (prediction is based to become true until 2050). If there is no progress in preventing global warming, the Northern region will access to B point, or even pass it and go to C if it gets hot enough. On the other hand, the Southern region will access to C, even worse to F point until 2050. However, this scenario may not even happen, if global warming stops or slows down.

4.2 Economic impact of global warming in agriculture

The changes in production will lead to shifts in the supply of wheat in northern and southern Europe. This subsection describes how shifts in supply affect prices, quantities, and trade in Southern and Northern Europe. I first analyse in the partial equilibrium framework the impact of an increase in supply assuming there is no trade between regions (the closed economy case). In this analysis, I assume that the European market of agricultural goods is observed as a competitive market. Also, this analysis assumes that there are no changes in government policies – agricultural policy for import and export. Each country has its own set of policy measures, which should motivate its farmers and firms to produce and export more.

4.2.1 Closed economy case

I begin the analysis of Northern Europe, where I analyse the impact of an increase in the supply of wheat. The starting position in the case of supply is line S1 (supply) in *Figure 7*, which forms the first equilibrium with D (demand). The increase in production due to more favourable climatic conditions is shown as a supply shift from S1 to S2. The new supply (S2) is forming a new equilibrium with D, which is forming a new lower price (p2) and a new higher quantity (q2). The cause of the mentioned shift is according to references result of global warming

because a warmer climate is giving a possibility for higher yield. This scenario of supply increasing is characteristic of the Northern region of Europe.

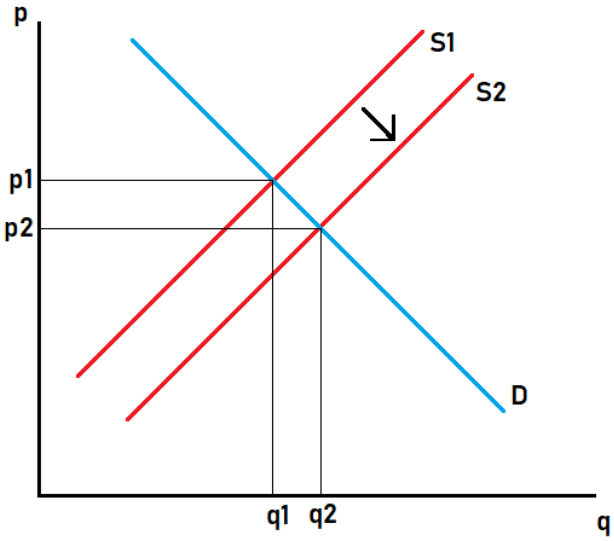

Figure 7 Change of price and quantity due to increasing of Supply in the North, no trade scenario (own source)

In the case of southern Europe, the starting equilibrium is same as in the case of Northern region, but in this case, we model the decrease in production as a leftward supply shift from S1 to S2, which is represented in *Figure 8.* In the case of Southern region of Europe, supply decreases and new price (p2) should be higher than the old price (p1) In this scenario the quantity decreases to q2. The cause of supply decreasing is based on worsened growing conditions due to the warmer climate.

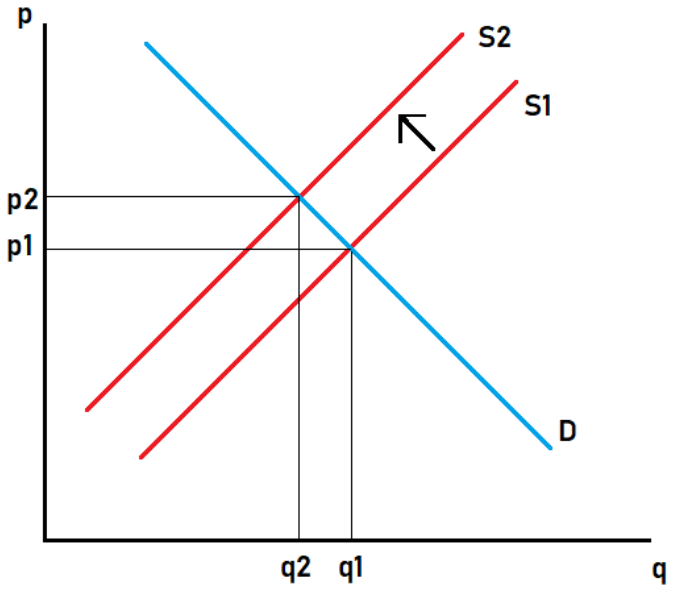

Figure 8 Change of price and quantity due to increasing of Supply in the North, no trade scenario (own source)

4.2.2 Open economy case

In reality, there is currently no closed economy[1] in the EU. The EU single market means that wheat can be freely traded between north and south Europe. It is important to include this assumption, since it can affect the results.

We begin with the analysis of an increase in supply for the open economy case, which is given in *Figure 9*. Same as in the previous analysis, the initial equilibrium is intersection of supply S1 and demand D. I assume a world price of pw. Then, due to climate change, supply shifts outward to S2. Increasing of supply opens possibility for export, which is explained by next: during the first market equilibrium production and consumption was at world price (pw), but after supply shift production is increased and consumption is still same and difference between is export. To avoid misunderstanding, in this case is started from "small country assumption", which means that that these regions only produce a small fraction of total world production, so changes in supply don't affect the world price and it can be seen on *Figures 9* and *10* that world price is constant. However, the world price (pw) is the main factor for import and export. If some country can produce some good lower than world price it will in export advantage (Figure 9), that means that it can sell that good under world price to attract more buyers or if it decides to sell it at world price, that will be represented as more profit or higher producer surplus.

[1] A closed economy is one that has no trading activity with outside economies.

In the case when forming of new price at a higher level than the world price, producer will not export that good.

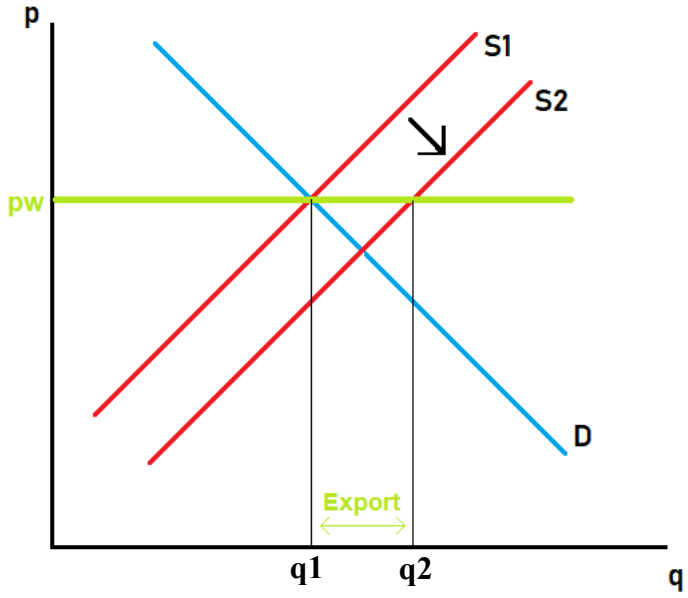

Figure 9 Opportunity for export due to increase of Supply compared to world price (pw) (own source)

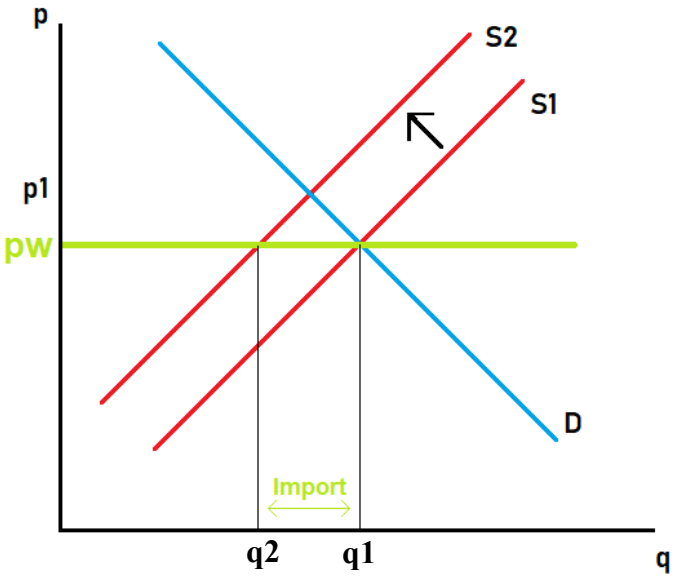

Figure 10 Opportunity for import due to decrease of Supply compared to world price (pw) (own source)

Figure 10 represents opposite scenario than *Figure* 9, the initial position of supply and demand is the same (q1 and q2), but S2 line represents new level of

supply due to climate change, which is lower than old one. In this case the first market equilibrium production and consumption were at world price, but in the second production is lower than in the first, which leads to import.

4.3 Impact on economic welfare

As previously mentioned, Supply increase is expected in Northern and decrease is expected in Southern region of Europe. I now analyse the impact of changes in supply in the north and south on economic welfare.

The primary definition of consumer surplus (CS) is the difference between the price, which represents consumer willingness to pay for that good, and the actual price of the good and producer surplus is the amount a seller is paid minus the cost of production (Mankiw 2014). On the other hand, the more significant component for this thesis is producer surplus, which primary definition is the amount a seller is paid minus the cost of production (Mankiw, 2014). Moreover, producer surplus measures the benefit sellers receive from participating in a market.

Same as in previous two subsections (4.2.1 and 4.2.2) starting position of supply is S1 line with two possibility scenarios of supply shift: increase (*Figure 11*) and decrease (*Figure 12*). In *Figures 11* and *12* triangle marked with "a" represent consumer surplus which is constant, but in the case of supply increasing during unchanged demand and world price producer surplus will increase. *Figure 11* represents increasing of producer surplus. Moreover, area "b" represents producer surplus before supply shift and area "b" plus "c" represents producer surplus after supply shift. It is possible to notice difference between CS before and after shift, which is marked as area "c".

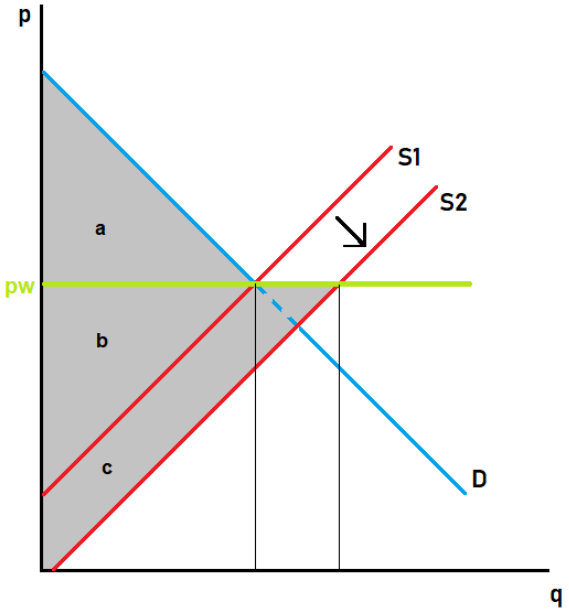

Figure 11 Increase of producer surplus due to supply increase (own source)

Figure 11 represent case of supply decreasing. Area "b" plus "c" represents producer surplus before supply shift from S1 to S2 and just area "b" represents producer surplus after shift. It is possible to notice according *Figure 11* and *12* that when supply increase and world price and demand stay same that producer surplus will increase, but when supply decrease, producer surplus will decrease, too.

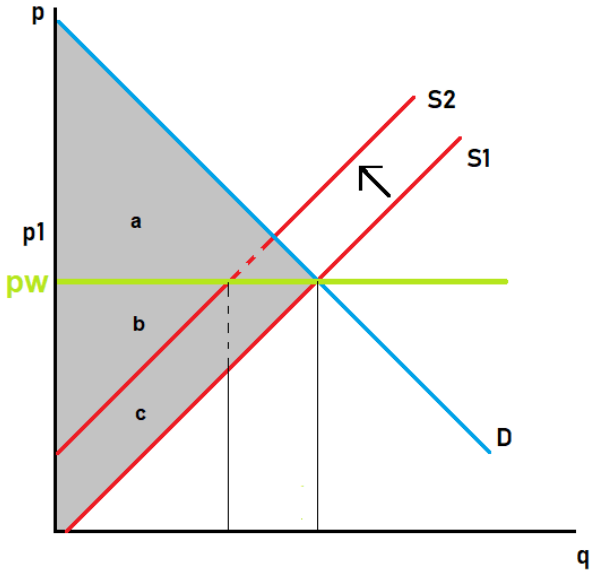

Figure 12 Decrease of producer surplus due to supply decrease (own source)

In this case of an outward shift of supply (*Figure 11)* producer surplus increases. In case of an inward shift of supply (*Figure 12*) producer surplus will decrease. These findings lead to conclusion that producers stationed in North of EU will generate more benefits, than these in South, which agrees to Hristov et al. (2020) findings.

5. Regression analysis – wheat production

This section will present changes in wheat yield due to temperature change in European union regions in period from 1980 to 2020. For analysis of these parameters, linear regression model is used.

According to Hristov et al. (2020) and Bowen & Dietz (2016) yields of agriculture goods should increase on North and decrease on South of Europe. To test these predictions, I perform a regression analysis FAO data for wheat yield EDO data for temperature change. Analysed time period is from 1980 to 2020. Two separated analyses are done, one for Southern and one for Northern region.
In this case, dependent variable is *yield*, which is measured in tons per hectare, and the value of independent variable is taken *average max temperature.*

These analyses should represent proofs for findings of this paper based on Ricardian approach and partial equilibrium analysis from previous section.

5.1 Southern region

The results of regression show positive relationship between temperature and wheat yield in the Southern region. In this case R Square (R^2) has value of 0.26, correlation coefficient (R) is 0.52 and the regression function is $\boldsymbol{y = 0.4247x - 5.3119}$. The results are showed on ***Figure 13***, and result of regression also can be found in *Table 3* (Appendix). This finding shows that a one degree Celsius increase in temperature is associated with a 0.4247 tons/ha increase in yield. They show different findings than Hristov et al. (2020) and Ricardian approach by Mendelsohn et al (1994), to them, the activity, i.e., yield should decrease in the Southern region of EU, but results show that yield is still increasing despite the temperature increase. These positive values of R and R^2 can be explain by positive trends, i.e., increasing of wheat yield and average max temperature in Southern region, which can be spotted on ***Figure 3*** and ***Figure 5***, which represent their trends over the observed period (1980-2020).

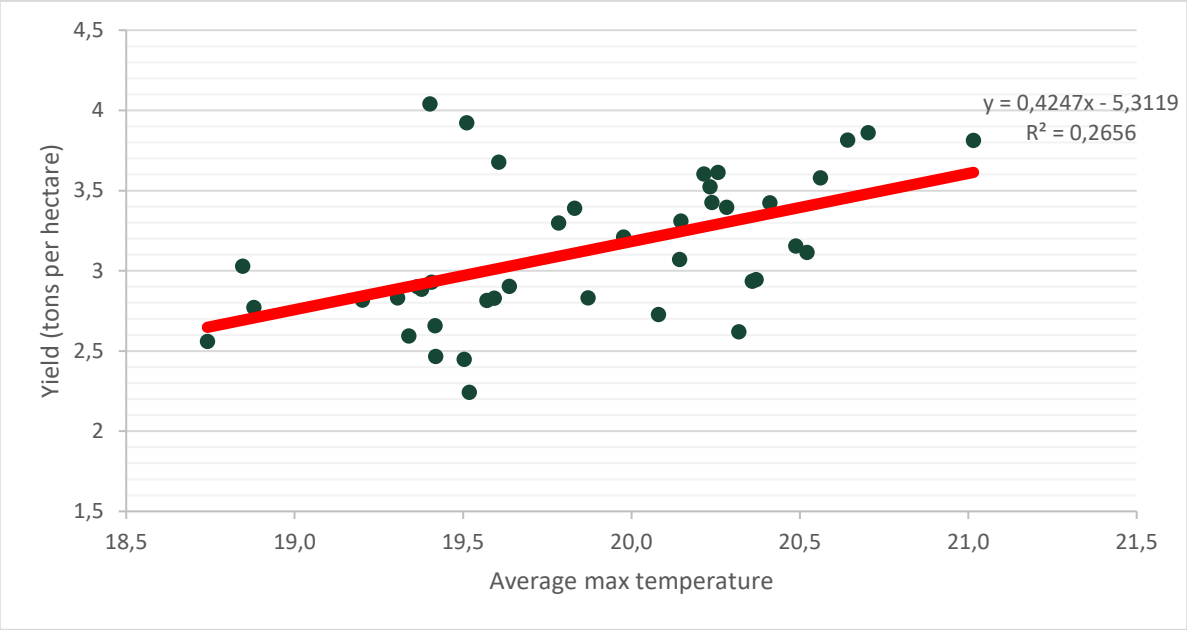

Figure 13 South Europe – Regression results (1980-2020) (own calculations)
Note: results of Southern region regression can be found in Appendix at Table 3.

5.2 Northern region

In the case of the Northern region, the results of regression also show a positive relationship between temperature and wheat yield. The R Square (R^2) has value of 0.27, correlation coefficient (R) is 0.48 and the regression function is ***y = 0.3162x + 1.429***. The results are showed on ***Figure 14*** and also shows that a one degree Celsius increase in temperature is associated with a 0.3162 tons/ha increase in yield. However, the results in this case match with findings of Hristov et al. (2020) and Ricardian approach by Mendelsohn et al (1994). Namely, the activity, i.e., yield should increase in the Northern region of EU, and results show that yield and temperature increased during observed period. The increase of both variables is possible to spot on ***Figure 4*** and ***Figure 6***, which represent their trend lines over the observed period (1980-2020).

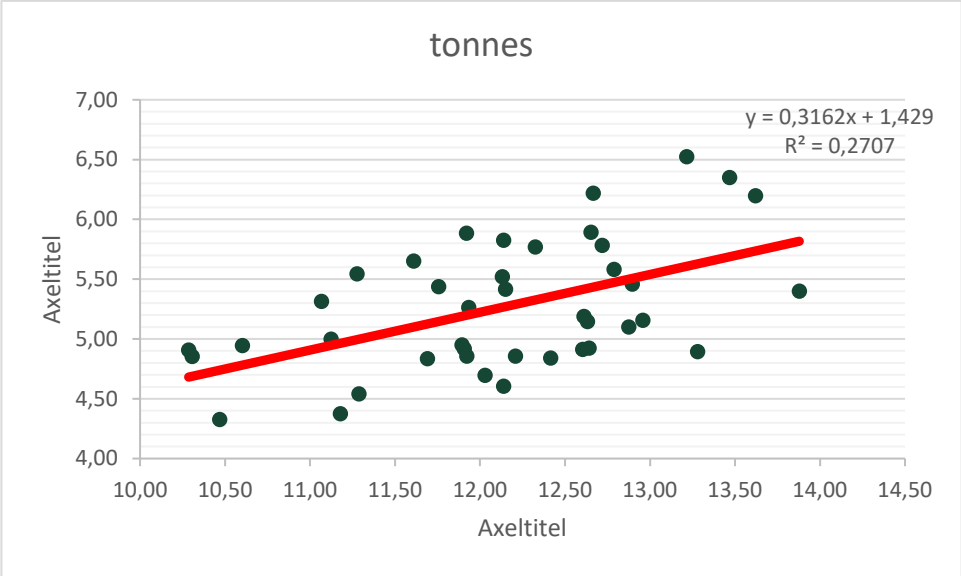

Figure 14 North Europe – Regression results (1980-2020) (own calculations)
Note: results of Northern region regression can be found in Appendix at Table 4.

6. Discussion

This section will briefly discuss key findings, implementation to future research and limitations of this study separated in two subsections: one based on theoretical analysis and one for regression analysis.

6.1 Discussion of theoretical analysis

The aim of this thesis was to answer the research question: How will a warmer climate affect the production of wheat in the different regions of the EU, and how will this affect prices, trade and economic welfare? According to that, the answer can be summarised in the follows few sentences: In theory according to theoretical analysis, until 2050 Supply will rise in the Northern region, and decrease in the Southern region, so in the closed economy case, this will lead to increasing of the of price in South, and decreasing of the price in North, which agrees with theory provided by Hristov et al. (2020). Moreover, the open economy case showed an increase of the export possibility in Northern region countries and a larger need for import in the Southern region. Producer surplus as outcomes of economic welfare will be changed. In case when supply is increasing, Producer surplus is increasing, and when Supply is decreasing, producer surplus is decreasing, too. Changes in economic welfare can be related to Bowen & Dietz (2016), which showed that more developed (Northern countries) will have more benefits and that they are less vulnerable to climate change.

This thesis focuses on the EU, but could be extended to cover different geographical areas for future research. Namely, the main research question and methodology can be adapted to one country or whole world case, which will provide complete picture of *2 ° C scenario* impact to world economy. Also, the provided results can be to improve business research about investment in agriculture in some regions and also about the stock market. This thesis provides scenario what will happen if temperature rise for 2° *C* until 2050, compering to 1980s, but in future research it can be analysed what if that change is higher or lower, and how it will influence to Value of Activity from Mendelsohn's (1994) findings.

However, *2 ° C scenario* should be fulfilled until 2050, which is a long period and there are many possible changes of many factors during the time, which can be happen. Another limitation is that only three outcomes are included in this thesis, which is not enough to represent a wider picture of how global warming will impact on economy and agriculture. Furthermore, in future research is possible to add more outcomes, for example: income and profit. Moreover, this thesis is written during the Russian-Ukraine conflict, the consequences of which are still unknown and uncalculated in total for global and EU and world economy, agriculture, and climate.

6.2 Discussion of regression analysis

To compare findings to current situation of agricultural production of wheat, two regression analyses are done, one for South and one for North. In both cases, positive connections are found. That means that increase of average max temperature is followed by yield increase during observed period (1980-2020). According to regression analyses, which were done for both regions to test current state of changes in wheat production by comparing wheat yield and average max temperature for period from 1980 to 2020, the results show agreement with theoretical analysis findings for Northern region, but disagreement with findings for Southern region of EU. Regression analysis result of Northern region shows that yield increased due temperature increasing, which agrees with Jacobs et al (2019) findings, which proclaim that warmer temperature prolong acceptable growing period in Northern region, but this result show disagreement about Jacobs et al. (2019) Southern region findings. Namely, yield should decrease, but regression analysis showed that it is still increasing.

There are multiple reasons behind this disagreement, which is based on limitations of this research. First of all, according to Mendelsohn et al. (1994) to prevent yield decreasing it is necessary to adapt to new circumstances, which means that wheat producers are maybe already adapted to global warming. Also, data do not include which type of wheat is used in each country and each region. Secondly, data control is missing, that means number of harvests per year is not considered, which can include using of winter wheat, which will increase yield average. Moreover, harvested area is not included, too. If this component is included result can represents volume of switching to other crops instead of adaptation to warmer temperature, but this thesis does not study changing to different crops, but just change in yield due temperature change and its impact to economic outputs. However, Wheat in the southern region grows usually during the winter and spring, thus is avoiding higher summer temperatures. According to that, producers avoid to grow wheat during the maximum year temperature. However, over the observed

period is expected to have productivity increase, because of technology development, which including new seeds, new growing technologies, and similar achievements. This shows that producers are potentially resolve negative effects from Boliko (2019) and Shrestha et al. (2013) papers, because there is still no yield decrease in Southern region. On the other hand, climate change effects up to 2020 have not been large enough to detect effects on wheat yield, but according to Hristov et al. (2020) if trend of temperature increasing continues, there will be significant changes in both regions. Last but not least, map of EU was changed multiple times during observed period, which means that it has not always 27 members and every new member influenced data on specific way.

However, founded results can be trigger for future research, which can include more variables, such as number of harvests per year, different wheat types, and/or period of year when sowing is done… Current results are based only on the EU, in future is possible to include whole Europe or World, which will show probably different results. Moreover including technology of wheat growing is one more variable, which leads to different results.

7. Conclusion

The aim of this thesis is to examine how a change in Supply (caused by global warming) influences the following economic outcomes: price, international trading, and economic welfare. This was done by using Partial equilibrium and Ricardian approach methods to get results, and Regression model is used to examine the relationship between yield and temperature, as two main factors. Hance, this thesis showed impact of climate change on EU agriculture. According to theoretical analysis Northern region should feel more benefits of climate change than Southern region, but regression analysis showed that impact is still not on that level, which will produce drastic benefits for Northern region and losses for Southern region.

It is possible to connect the analysed problem with two Sustainable Development Goals of the United Nations (UN Department of Economic and Social Affairs). They are No. 8 for Decent Work and Economic growth and No. 13 for Climate action. On one side, the final result can help European governments to predict changes in the economic field and adapt fastest as possible to incoming changes (No. 8). Still, on another side, it will show how climate change is an essential and inseparable factor of everyday life (No. 13).

Importance of this thesis can be spotted in showing potential economic changes, which can lead to economic and food crisis, if nothing is done. This statement is mainly focused for South of EU, because negative effects are spotted there during theoretical analysis, but Regression analysis showed us that yield is still increasing in the Southern region, which implies that this region is still not endangered. On the other hand, the yield is increasing in Northern region, which is expected by theoretical analysis and it should stay that way in near future according to Hristov et al. (2020).

To conclude, this thesis presents the great starting point from future research from the field of agricultural and environmental economics. Also, this thesis leads us to the fact that all economies, not just in EU, but in the World are connected directly or indirectly. Namely, EU has currently 27 independent members with their independent economies, but they are all connected at least by trading. To prevent possible problems, policy makers, special from environment policy sphere should think about measures and systems, which lead society to lover pollution to minimize influence to global warming.

References

Batten, S. (2018). Climate change and the macro-economy: a critical review.

Boliko, M. C. (2019). FAO and the situation of food security and nutrition in the world. Journal of nutritional science and vitaminology, 65(Supplement), S4-S8.

Bowen, A., & Dietz, S. (2016). The effects of climate change on financial stability, with particular reference to Sweden. A report for Finansinspektionen (The Swedish Financial Supervisory Authority).

Costinot, A., Donaldson, D., & Smith, C. (2016). Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. Journal of Political Economy, 124(1), 205-248.

EDO – European drought observatory (n.d.), Average max temperature. https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1059 [27th July 2022]

Feenstra, R. C. (2010). Product variety and the gains from international trade. Cambridge, MA: MIT Press.

FAO - Food and Agriculture organization - United Nations, (n.d.) FAOSTAT Database. http://www. https://www.fao.org/faostat/en/ [27th April 2022]

Freund, R. J., Wilson, W. J., & Sa, P. (2006). Regression analysis. Elsevier.

Hristov, J., Toreti, A., Pérez Domínguez, I., Dentener, F., Fellmann, T., Elleby, C., ... & Bratu, M. (2020). Analysis of climate change impacts on EU agriculture by 2050. Publications Office of the European Union, Luxembourg, Luxembourg.

H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.) (2022). IPCC, Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press.

Jacobs, C., Berglund, M., Kurnik, B., Dworak, T., Marras, S., Mereu, V., & Michetti, M. (2019). Climate change adaptation in the agriculture sector in Europe (No. 4/2019). European Environment Agency (EEA).

Mankiw, N. G. (2014). Principles of economics. Cengage Learning.

Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. The American economic review, 753-771.

Nicholson, W., & Snyder, C. M. (2017). Microeconomic theory: Basic principles and extensions. Cengage Learning.

Shrestha, S., Ciaian, P., Himics, M., & Van Doorslaer, B. (2013). Impacts of climate change on EU agriculture. Review of Agricultural and Applied Economics (RAAE), 16(395-2016-24317), 24-39.

UN Department of Economic and Social Affairs United Nations (n.d.), The 2030 Agenda for Sustainable Development. https://sdgs.un.org/goals [28th July 2022]
Williams, C. (2007). Research methods. Journal of Business & Economics Research

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In the times when we are looking for solutions to solve problems, we forgot that we are the key!
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"*The most important victory is the one which has to arrive*." – Enzo Ferrari

Appendix

Table 1 Average yield over the time of EU regions

YEAR	***AVERAGE YIELD OF SOUTHERN EU REGION***	***AVERAGE YIELD OF NORTHERN EU REGION***
	(Tons per hectare)	*(Tons per hectare)*
1980	2.6	4.3
1981	2.4	4.4
1982	2.7	4.9
1983	2.2	4.9
1984	2.8	5.5
1985	2.5	4.9
1986	2.6	5.0
1987	2.8	4.9
1988	2.8	5.4
1989	2.8	5.6
1990	2.7	5.8
1991	2.8	5.7
1992	2.9	4.6
1993	2.9	4.5
1994	2.9	4.7
1995	2.8	4.9
1996	3.0	4.9
1997	2.9	4.9
1998	3.1	4.8
1999	3.4	4.8
2000	3.1	5.1
2001	2.9	5.3
2002	3.3	5.2
2003	2.6	4.9
2004	3.3	5.9
2005	2.9	5.5
2006	3.2	5.1
2007	3.2	5.2
2008	3.5	5.9

2009	3.4	5.8
2010	3.4	5.3
2011	3.6	5.5
2012	3.6	5.4
2013	3.6	5.8
2014	3.4	4.9
2015	3.9	6.5
2016	3.8	4.9
2017	3.8	6.2
2018	3.7	5.4
2019	3.9	6.3
2020	4.0	6.2

Table 2 Average max temperature over the time of EU regions

YEAR	***AVERAGE MAX TEMPERATURE OF SOUTHERN EU REGION***	***AVERAGE MAX TEMPERATURE OF NORTHERN EU REGION***
	(Celsius degrees)	*(Celsius degrees)*
1980	18.7	10.5
1981	19.5	11.2
1982	19.4	11.9
1983	19.5	12.2
1984	18.9	11.3
1985	19.4	10.3
1986	19.3	11.1
1987	19.3	10.3
1988	19.6	11.8
1989	19.9	12.8
1990	20.1	12.7
1991	19.2	11.6
1992	19.4	12.1
1993	19.4	11.3
1994	20.4	12.0
1995	19.6	11.9
1996	18.8	10.6
1997	19.6	11.9
1998	20.1	11.7
1999	20.2	12.4
2000	20.5	12.9
2001	20.4	11.9
2002	20.1	12.6
2003	20.3	12.6

2004	19.8	11.9
2005	19.4	12.1
2006	20.0	12.6
2007	20.5	13.0
2008	20.2	12.7
2009	20.3	12.3
2010	19.8	11.1
2011	20.3	12.9
2012	20.6	12.2
2013	20.2	12.1
2014	20.4	13.3
2015	20.7	13.2
2016	20.6	12.6
2017	21.0	12.7
2018	19.6	13.9
2019	19.5	13.5
2020	19.4	13.6

Table 3 Calculation of Regression for Southern region

Regression Statistics	
Multiple R	0.515371
R Square	0.265607
Adjusted R Square	0.246777
Standard Error	0.394256
Correlation	0.52
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.192464	2.192464	14.10509	0.000564257
Residual	39	6.062075	0.155438		
Total	40	8.25454			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-5.31194	2.246192	-2.36486	0.023107
average max temperature	0.424704	0.113083	3.755674	0.000564

Table 4 Calculation of Regression for Northern region

Regression Statistics	
Multiple R	0.52031
R Square	0.270723
Adjusted R Square	0.252024
Standard Error	0.462417
Correlation	0.48
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.095747	3.095747	14.47762	0.000488
Residual	39	8.339363	0.21383		
Total	40	11.43511			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.42897	1.010451	1.41419	0.16524
acg max temperature	0.316188	0.083099	3.804947	0.000488

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