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Master Thesis International Economics

Transitioning Towards Sustainable Agriculture In The European Union Through Investment Subsidies

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Abstract

An increasing focus on climate change and sustainability impacted the agriculture sector in Europe. The Green Deal and the Paris Agreement show the intention of Europe to become more sustainable. The European Commission has set targets with regards to sustainability for the agriculture sector so that the goals from the Green Deal and Paris Agreement are met. The quantitative analysis shows that climate change impacts Northern and Southern Europe differently in both temperature and precipitation. Because different parts of Europe need different policies in their transition towards sustainable agriculture, the European Commission needs a variety of policies. Local circumstances should be considered when deciding which technologies will be subsidised. The current policies were focused on the theoretical efficiency of the policies and because of that the practical effectiveness was lower than anticipated. This thesis examines how the European Commission can improve the effectiveness of their policies and subsidies. To improve the effectiveness of their policies the European Commission can use investment subsidies and talk to farmer associations to find out which policies would be effective in each region. The investment subsidy will decrease the cost barriers in the transition towards sustainable agriculture, by decreasing the cost of the new technologies. For farmers that prefer not to work with advanced technology, the European Commission could consider using input subsidies for genetically modified organisms.

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1. Introduction

1.1. Background

The purpose of this thesis is to examine how climate change is currently impacting the farmers in Europe and how the effectiveness of the policies of the European Commission can be improved. One of the main policy options in climate change impact assessment is adaptation (Fankhauser, 1996; Smith & Lenhart, 1996; Smit et al., 1999). Adaptation to climate change is important in the agricultural sector, because the agricultural sector is sensitive to changes to climate conditions (Parry & Carter, 1989; Reilly, 1995). Studies show that climate change has a negative impact on agricultural production, but with adaptation the vulnerability of the agricultural sector can be reduced (Wheaton & Maciver 1999; Smit & Skinner, 2002).

Adaptation to climate change is possible in the form of sustainable agriculture. To determine what sustainable agriculture is this paper looks at multiple definitions. The World Commission for Environment and Development (1987) refers to sustainability as *"the needs of the present without compromising the ability of future generations to meet their own needs"*. Ikerd (1990) refers to sustainable agriculture as *"farming systems that are capable of maintaining their productivity and usefulness indefinitely"*. The American Society of Agronomy (1988) describes sustainable agriculture as *"A sustainable agriculture is one that over the long term enhances environmental quality and resource base on which agriculture depends, provides for basic human food and fibre needs, is economically viable and enhances the quality of life for farmers and society as a whole"*.

Sustainable agriculture is a policy approach that aims to maximise economic benefits without damaging the environmental quality. To reach sustainability in the agricultural sector there is a need for economic incentives to develop and adopt precision technology. An example of precision technology is drip irrigation, a technique that conserves water usage by increasing efficiency. Drip irrigation is mainly used in countries that face water scarcity and frequent droughts. The transition towards technologies like drip irrigation can improved by creating economic incentives in the form of subsidies (Zilberman et al., 1997).

A continuous problem in sustainable agriculture is the different perspectives of farmers and scientists on what would be a good solution. Scientists look at solutions that can be proven to be superior to other options, while farmers look at which farming methods that they are comfortable with. Additionally, scientists focus on theoretical solutions and focus less on practical difficulties. Farmers on the other hand focus more on the practical implications and how a specific solution would work for them and what changes it requires. The required changes and preferred farming method are different for each farmer. This difference in perspective between the scientists and the farmers leads to different preferred farming methods by scientists and farmers. Because of the heterogeneity of social, economic and physical conditions there is no general best solution, but instead the optimal solutions differs across regions. Therefore, it would be beneficial to include farmers while developing new technologies because the farmers are aware of the differences in conditions (Zilberman et al., 1997; Shiferaw et al., 2009).

Transitioning towards sustainable agriculture would improve the use of precision technologies. Precision technologies increase yield and reduce the usage of natural resources but are often expensive. When the cost of production in the agricultural sector increase, then the supply of agricultural products will decrease and/or the price of the product will increase. With certain precision technologies there are increasing returns to scale, this will lead to concentration of production. This concentration of production would mean that smaller farms will disappear and will be replaced by one or more mega farms that take over the production from the smaller farms and now have the benefits of increasing returns to scale. However, the high concentration of agricultural production is not desirable from a social and sometimes economic point of view. When the smaller farms are replaced by mega farms it will be more difficult for communities to eat locally grown products. Additionally, the mega farms would create a problem for next generation farmers. Currently the next generation of farmers can start with a small farm and increase the size in time. When there are only mega farms, then the next generation of farmers will need significantly more starting capital to join the sector. Therefore, it is important to help smaller farms in the adaptation of precision technologies where possible (Zilberman et al., 1997; Shiferaw et al., 2009). In addition to the issue of the price of the precision technologies there is the uncertainty of the changing weather conditions and EU policies. When there is uncertainty about the future benefits of precision technology investments or when there is uncertainty about future EU funding with regards to precision technologies, then farmers might choose to delay their investment and wait for additional information. The delay in investment due to uncertainty can lead to losing entire harvests in cases of extreme weather and can therefore do severe damage to farmers (Zilberman et al., 1997; Shiferaw et al., 2009).

1.1.1. Sustainable Farming in Europe

This thesis examines sustainable farming in Europe and how the sector can meet the requirements of the Common Agricultural Policies (CAP), Green Deal and Paris Agreement. The CAP helps to generalise the agricultural policies for Europe and thus makes it possible to analyse the entire European farming industry. The Green Deal and Paris agreement aim to reduce emissions and aim to transition industries towards more sustainable alternatives.

1.1.2. CAP

The Common Agricultural Policies is a set of policies that is standardised for the European agricultural sector. These policies apply to the members of the European Union (EU) and are funded by the EU. The

European Commission is tasked with managing the CAP and handing out the money that is made available for the agricultural sector.

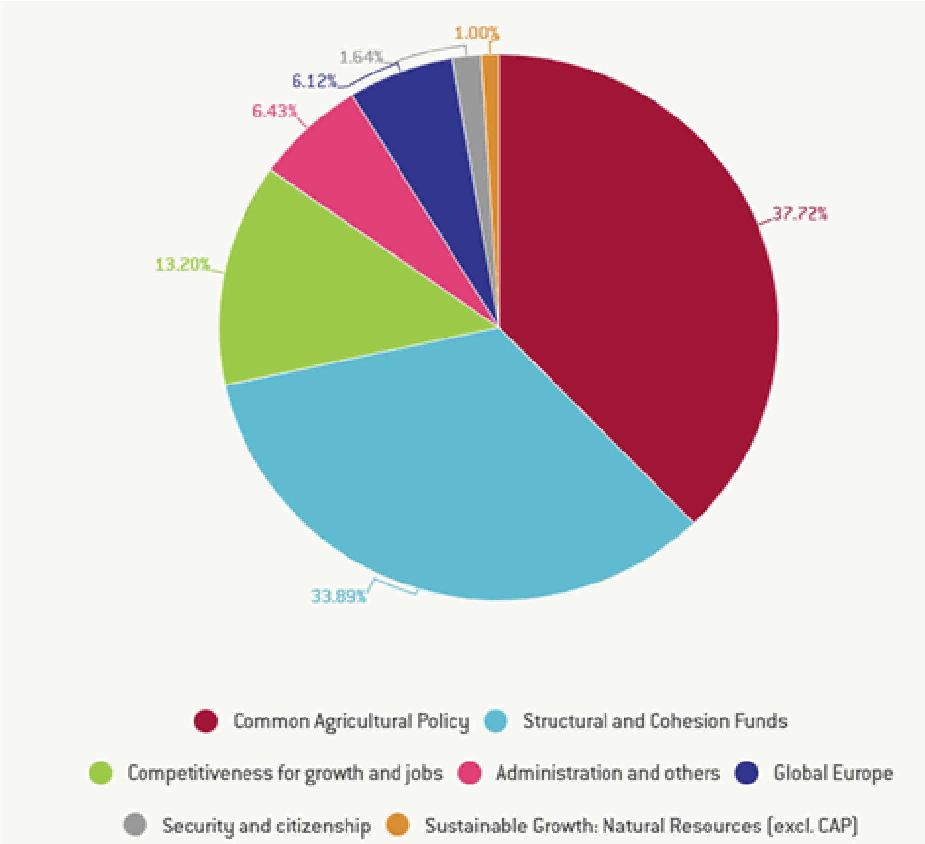


Figure 1: EU Budget Allocation; Source: Moës & Bruegel (2018)

Figure 1 shows the EU budget allocation. As can be seen in the figure, the Common Agricultural Policy (CAP) takes up the largest part of the EU budget. Figure 2 shows how the money that is allocated to CAP is spent. The largest part of the money that is allocated to the CAP is used for income support, due to the low income in the sector as was mentioned earlier. The income support is money that is used to give farmers a higher minimum wage by adding the income support to the income that farmers get from selling their crops. Even with this income support, the income of farmers is 40% lower than non-agricultural income in Europe (European Commission, 2021). In addition to the lower-income, the agricultural sector is also more sensitive to climate change. Changing weather conditions directly impact crop production. Irregular farming practises and soil exhaustion impose environmental risks for the soil and biodiversity of farmable land (Shucksmith et al., 2005). With the low income in the agricultural sector, the European farmers have to be cost-effective but at the same time maintain European food standards and preferable transition towards more sustainable practices (European Commission, 2021).

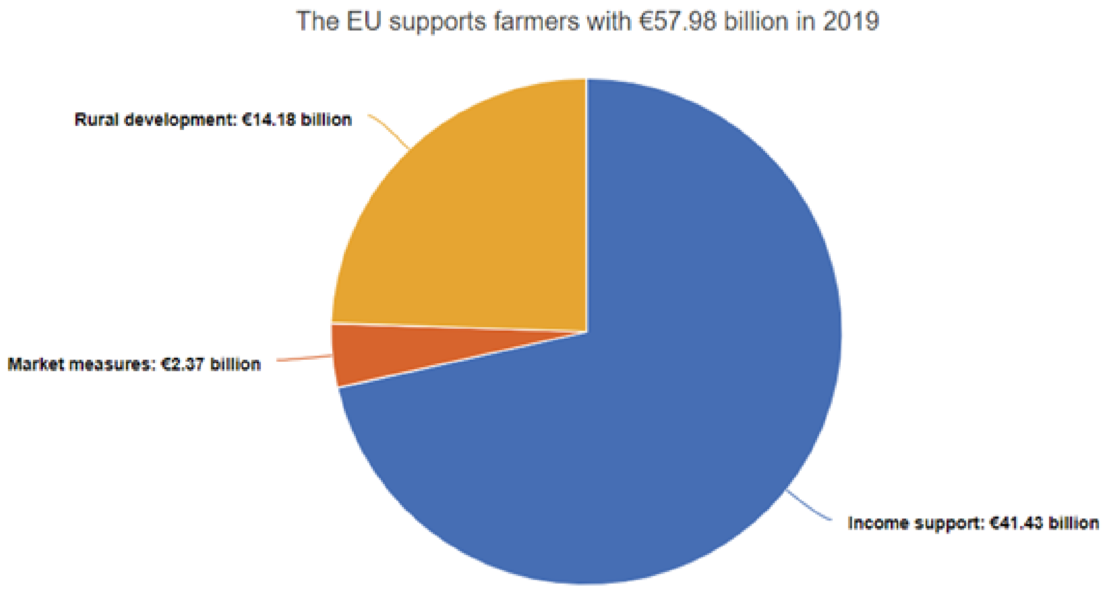


Figure 2: CAP Allocation; Source: European Commission (2021)

1.1.3. Green Deal

The Green Deal is an attempt from the European Commission to create a growth strategy that is resource-efficient while keeping a competitive economy. The goal is to adopt new and sustainable technology to reduce greenhouse gasses and emissions by 2050 (European Commission, 2021). To keep a positive trade balance in the trade of agri-food products, the production has to remain stable while reducing emissions. This means that farming has to intensify and that yield per acre has to increase.

1.1.4. Paris Agreement

The Paris conference in 2015 resulted in the first universal global climate change agreement, the 'Paris Agreement'. *"The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts"* (European Commission, 2019). The Paris Agreement aims at reducing CO2 emissions by targeting active emitters to reduce their emissions (Bodansky, 2016).

1.2. Problem Formulation

The Green Deal and the Paris Agreement are proof of the increasing focus on sustainability in Europe. This increasing focus on sustainability in Europe means that many sectors are required to make changes, one of these sectors is the agriculture sector. The European Commission has goals for 2030 and 2050 that are partly determined in the Green Deal and Paris Agreement. To achieve these goals the European

Commission has set intermediate targets to stay on track for the goals that the European Commission has to achieve as is determined in the Green Deal and Paris Agreement. In order to achieve the targets from the European Commission and the goals from the Green Deal and Paris Agreement the emissions and use of natural resources have to decrease. The agriculture sector uses a severe amount of natural resources, such as clean water, and has significant emissions, due to fertilisers and pesticides. Therefore, it is important to transition towards sustainable agriculture by changing the farming methods and technologies used in the agriculture sector. Additionally, the transition towards sustainable agriculture can be combined with improving the climate change resilience of the sector. The transition towards sustainable agriculture will be expensive for the farmer, to lower the cost for the farmers the European Commission can use subsidies. The European Commission can use subsidies to give direction to the transition by subsidising certain farming technologies that are preferred by the European Commission. In the decision on which technologies will be subsidised the European Commission focuses on the efficiency of the technologies and focuses less on the effectiveness of the policies, the difference between and the importance of the efficiency and the effectiveness will be discussed later in this thesis. The problem that this thesis examines is that the current policies and use of subsidies have not been effective enough to meet the targets that were set by the European Commission, the transition towards sustainable agriculture is not going fast enough.

1.3. Purpose

The purpose of this thesis is to examine how climate change is currently impacting the farmers and how the effectiveness of the policies of the European Commission can be improved. To examine how climate change is impacting farmers this thesis uses a quantitative analysis. To examine how the effectiveness of the policies can be improved this thesis uses a qualitative analysis, which will be based on interviews with farmer associations and the European Commission. This thesis aims to examine how these two analyses can be combined with theories on subsidising. The final purpose of this thesis is to examine whether combining all these aspects can lead to more effective policies, improved climate change resilience and a faster transition towards sustainable agriculture in Europe.

1.4. Structure

This thesis will start with a quantitative analysis of the impact of climate change on farmers. This will be done by examining how daily average temperature and precipitation changed over time and how the monthly variability changed over time. This is done through three different regression methods. The quantitative analysis is followed by a theory section where subsidies will be the main focus. This part will look into different forms of subsidising and the benefits of these different forms. After the theories section the methods section is used to explain the method and methodology that is used in this thesis.

The method section is followed by the qualitative analysis in which the results of the interviews are presented. Then there is a discussion section in which this thesis makes an attempt to combine the quantitative analysis, the theories and the qualitative analysis. The discussion section is used to advise on important aspects which should be considered when making the policies. The future research section is used to mention two potential follow-up research ideas. To conclude with the conclusion and main findings of this thesis.

2. Climate Change Impact Assessment

To understand what form of climate change adaptation is feasible and efficient it is important to determine how to measure climate change impact. A common way of analysing climate change impact is by looking at moisture and temperature (Bryant et al., 2000; Smith et al., 2000).

When analysing climate change and adaptation of the agricultural sector it is important to realise that there is short-term adaptation and long-term adaptation. The long-term adaptation focuses on the future, on the preferred farming methods in the future and on how these farming methods can be adapted to climate change. The short-run adaptation focuses on the present, on damage control by protecting the crops under the current farming methods as good as possible. These short-term adaptations often involve dealing with floods and droughts. It is important to adapt to climate change because there are variations in yearly growing seasons and crop yield. Furthermore, the extreme weather conditions are increasing in frequency and magnitude (Hulme et al., 1999; Smit & Skinner, 2002). The increasing variability of weather conditions is especially important to the agricultural sector, because the weather condition have a severe impact on crop yield. The agricultural sector is often adapting to the long-term changes, but less focused on the short-term changes and therefore negatively affected by the current extreme weather conditions (Reilly, 1995; Smith., 1996; Risbey et al., 1999).

The changing weather conditions have a severe impact on adaptation decisions. The decision-making in the agricultural sector does not only depend on weather conditions, but also on economics, politics and technology (Bryant et al., 2000). Sector wide economics and national politics have a severe impact on the decision-making process of the short-term adaptation options. National governments use government programs and insurances in short-term adaptation options, because of the importance of the short-term adaptations for the sector wide economics and national politics (Smit & Skinner, 2002).

Impact assessment increasingly focuses on farm level decision-making, especially when considering extreme weather conditions (Brklacich et al., 1997; Chiotti et al., 1997).

2.1. Regressions

This thesis examines meteoritical data to analyse how climate change impacts different geographical regions in Europe. The data is split in Northern and Southern Europe to allow for a comparison between the regions, the 49 degrees latitude line separates the North and South of Europe in this analysis. The analysis looks at temperature and precipitation for the period 2000-2020. The quantitative data is used to provide empirical evidence on structural differences in Northern and Southern Europe when it comes to climate change. This thesis will use precipitation and average temperature as proxies for climate change. The results of the quantitative analysis will be used to explain why different parts of Europe have different needs when it comes to transitioning towards sustainable agriculture and dealing with climate change.

2.1.1. OLS

The Ordinary Least Square (OLS) estimation has been used as a starting point for the estimations of temperature and precipitation changes. This thesis starts with the OLS because it is a basic regression that does not require many assumptions. The OLS is used to examine if there is a trend in the changes in temperature and precipitation for both Northern and Southern Europe. For the average temperatures the following regression is used:

$$TemperatureAverage_{gt} = \beta_0 + \beta_1 Year_t + \varepsilon$$

TemperatureAverage is the daily average temperature in group g (either North or South Europe) that is accumulated in year t. Thus the temperature variable is not based on the maximum or minimum measured temperature, but on the weighted average temperature on each day. These average temperatures have then been accumulated for each group. The constant is given by Beta zero, the coefficient of the yearly time trend by Beta one and the error term by epsilon. The monthly effects on average temperatures is given by:

$$\begin{aligned} TemperatureAverage_{gt} \\ &= \beta_0 + \beta_1 Feb_t + \beta_2 Mar_t + \beta_3 Apr_t + \beta_4 May_t + \beta_5 Jun_t + \beta_6 Jul_t + \beta_7 Aug_t \\ &+ \beta_8 Sep_t + \beta_9 Oct_t + \beta_{10} Nov_t + \beta_{11} Dec_t + \varepsilon \end{aligned}$$

In this regression Beta one to Beta 11 give the coefficients for the monthly effects, January is left out of the regression to avoid collinearity. The effect of changes in average temperatures on precipitation in Northern and Southern Europe are estimated with the following OLS regression:

$$Precipitaton_{gt} = \beta_0 + \beta_1 TemperatureAverage_{gt} + \beta_2 Year_t + \varepsilon$$

Precipitation is the dependent variable that measures precipitation in millimetres in group g in year t. TemperatureAverage is the independent variable because an increase in average temperatures at the surface leads to more evaporation. An increase in evaporation increases overall precipitation. Thus an increase in temperatures around the world is expected to increase precipitation in many areas (EPA, 2021). The following OLS regression has been used to analyse how the precipitation changes over the different months in Northern and Southern Europe:

$$Precipitation_{gt} = \beta_0 + \beta_1 Feb_t + \beta_2 Mar_t + \beta_3 Apr_t + \beta_4 May_t + \beta_5 Jun_t + \beta_6 Jul_t + \beta_7 Aug_t + \beta_8 Sep_t + \beta_9 Oct_t + \beta_{10} Nov_t + \beta_{11} Dec_t + \varepsilon$$

2.1.2. Fixed Effects

The temperature and precipitation measurements come from local weather stations. To capture possible weather station specific errors this thesis looks into a regression with fixed effects. This paper performed Hausman tests to check whether a random effects model or a fixed effects model would be appropriate. The Hausman test of the average temperature has a Chi-square of .0018, therefore, a regression with High Dimensional Fixed Effects (HDFE) has been added to analyse the average temperature changes over time. The Hausman test for Precipitation has a Chi-square of .2930, therefore, a fixed effect model would give less accurate estimations. However, because a fixed effects model controls for measurement error at the weather station level the High Dimensional Fixed Effects regression has been added to the Precipitation regressions as an additional regression. For the average temperatures, the following HDFE regression has been used:

$$TemperatureAverage_{gt} = \beta_0 + \beta_1 Year_t + \beta_2 \gamma + \varepsilon$$

This is the same regression as the OLS regression with the addition of gamma, which captures the weather station fixed effects. Additionally, the monthly changes in average temperatures is given by:

$$TemperatureAverage_{gt} = \beta_0 + \beta_1 Feb_t + \beta_2 Mar_t + \beta_3 Apr_t + \beta_4 May_t + \beta_5 Jun_t + \beta_6 Jul_t + \beta_7 Aug_t + \beta_8 Sep_t + \beta_9 Oct_t + \beta_{10} Nov_t + \beta_{11} Dec_t + \beta_{12} \gamma + \varepsilon$$

This regression is equal to the OLS, with the addition of the weather station fixed effects. For Precipitation the following regressions are used:

$$Precipitation_{gt} = \beta_0 + \beta_1 TemperatureAverage_{gt} + \beta_2 Year_t + \beta_3 \gamma + \varepsilon$$

$$Precipitation_{gt} = \beta_0 + \beta_1 Feb_t + \beta_2 Mar_t + \beta_3 Apr_t + \beta_4 May_t + \beta_5 Jun_t + \beta_6 Jul_t + \beta_7 Aug_t + \beta_8 Sep_t + \beta_9 Oct_t + \beta_{10} Nov_t + \beta_{11} Dec_t + \beta_{12}\gamma + \varepsilon$$

The OLS are HDFE regressions are both linear regressions that assume that the error term is homoskedastic. This paper used a White test to check whether this assumption is violated for the Precipitation data. The White test has a Chi-square of .0000, thus a linear regression model is not the appropriate model. The Poisson Pseudo Maximum Likelihood (PPML) estimator with High Dimensional Fixed Effects is a nonlinear regression and is instead based on the maximum likelihood. The PPML estimator works with positive values for the dependent variable and is therefore possible for Precipitation. However, the average temperature variable occasionally takes negative values and because of that it is not possible to use a PPML estimator for the average temperature.

2.1.3. Poisson

The Poisson estimator is not a linear estimator but instead a maximum likelihood estimator that stays consistent in the presence of fixed effects (Shepherd, 2013). The PPML that is used in this paper is:

$$Precipitation_{gt} = \beta_0 + \beta_1 TemperatureAverage_{gt} + \beta_2 Year_t + \beta_3\gamma + \varepsilon$$

The variables in this regression have the same meaning as the variables in the HDFE regression, however, now the regression is run by a nonlinear PPML estimator.

2.2. Data Description

The quantitative data that is used comes from the JRC MARS Meteorological Database, this is data from the research centre of the European Commission. The database uses observations from weather stations, these observations are daily observations of precipitation, daily average temperatures and wind speed. This paper uses these observations from the beginning of 2000 till the end of 2020.

Figure 3 shows the average temperature and precipitation that are accumulated on a yearly level for the complete dataset. The years are displayed on the x-axes, the average temperatures on the left y-axes and the precipitation on the right y-axes. Both the temperature averages and the precipitation have an increasing trend.

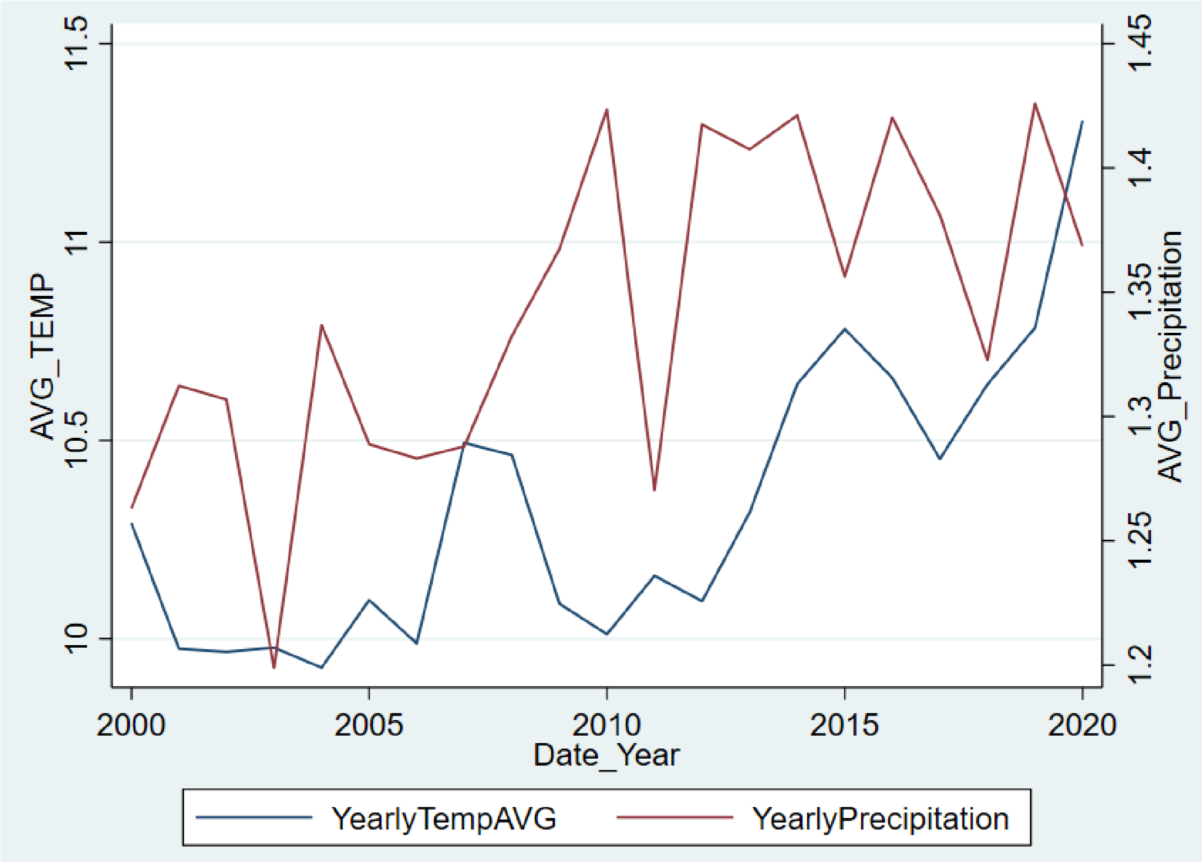
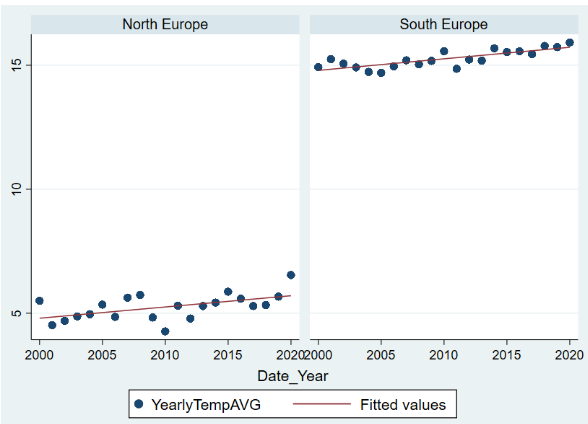


Figure 3: Temperature And Precipitation Over Time

To be able to compare Northern and Southern Europe, the sample has been split in two groups. The sample has been split at a latitude of 49 degrees, resulting in similar size groups. Figure 4 shows the difference in temperatures and figure 5 shows the difference in precipitation.



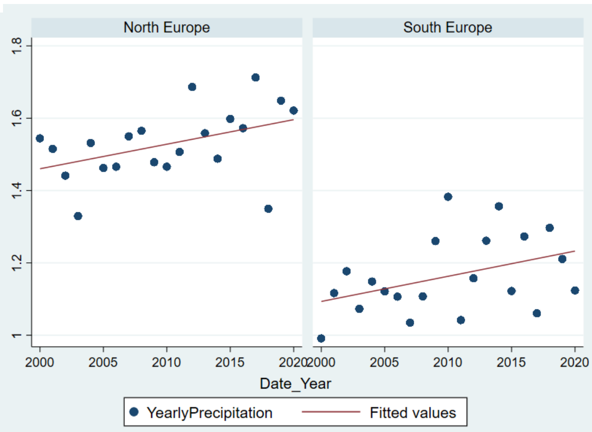


Figure 4: Temperature Over Time

Figure 5: Precipitation Over Time

Figures 4 and 5 show that there are significant difference in average temperature and precipitation in Northern and Southern Europe. These figures also show that the yearly trend in Northern and Southern Europe is similar. Appendix figure 11 and 12 show the volatility of the average temperature and precipitation. These figures show that there are monthly and seasonal differences in both Northern and Southern Europe. Thus the yearly trends are similar, but within the years there are differences. The differences are especially visible in figure 12, which shows the monthly observations of precipitation in Northern and Southern Europe. Table 1 shows the descriptive statistics.

Table 1: Descriptive Statistics Variables Included In The Model (N = 5,645,906)

Variables	Mean	SD	Minimum	Maximum
Entire Europe (N = 5,645,906)				
Monthly Temperature Average (Celsius)	10.33919	10.6533	-33.69335	39.99032
Monthly Precipitation (mm)	1.342536	1.253784	0	32.5
Yearly Temperature Average (Celsius)	10.33919	5.021988	4.267413	15.91782
Yearly Precipitation (mm)	1.342536	.2080878	.9911516	1.712593
Northern Europe (N = 2,775,780)				
Monthly Temperature Average (Celsius)	5.251792	9.878967	-33.69355	29.69677
Monthly Precipitation (mm)	1.528173	1.110268	0	21.71333
Yearly Temperature Average (Celsius)	5.251792	.5075738	4.267413	6.539178
Yearly Precipitation (mm)	1.528173	.0945644	1.329553	1.712593
Southern Europe (N = 2,870,126)				
Monthly Temperature Average (Celsius)	15.25936	8.923568	-20.96774	39.99032
Monthly Precipitation (mm)	1.163001	1.354451	0	32.5
Yearly Temperature Average (Celsius)	15.25936	.3516481	14.69354	15.91782
Yearly Precipitation (mm)	1.163001	.1047277	.9911516	1.382805

The descriptive statistics show that for both Northern and Southern Europe there are significant monthly differences. When the volatility of the precipitation increases then the farmers will need both irrigation and drainage systems.

2.3. Regression Results

2.3.1. Temperature

The descriptive statistics show significant differences between Northern and Southern Europe. Therefore, the sample has been split and the regressions have been used for both parts of the sample. Table 2 shows the results for changes in temperatures in Northern Europe, in this table Column 1 and 2 include the entire time period and columns 3 to 6 capture shorter time periods.

Table 2: Temperature Changes Northern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
Period	00-20	00-20	00-05	06-10	11-15	16-20
Weighted Yearly Trend	.045***	.045***	.021***	-.197***	.177***	.229***
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**
Adjusted R-Squared	**X**	**.1368**	**.13**	**.1213**	**.1206**	**.1360**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Column 1 in table 2 has the results for the OLS regression of the full time period for changes in average temperature in Northern Europe. Column 2 captures the results of the HDFE regression with fixed effects at the weather station level for the full time period. Column 3 captures the results of the HDFE regression for the years 2000-2005, column 4 captures the HDFE results for the period 2006-2010, column 5 captures the HDFE results for the period 2011-2015 and column 6 captures the HDFE regression results for the period 2016-2020. The results in all columns are significant at the 1% level and thus highly statistically significant. The first two columns show that there is a yearly increase in average temperatures of .045 degrees, this means that in the 21 years that is analysed the average temperatures increased with roughly 1 degree Celsius in Northern Europe. Columns 3 to 6 show that there is not just a slight increase every year, but that it differs across time periods. For instance in the period 2006-2010 the average temperature in Northern Europe decreased by roughly 1 degree Celsius and in the period 2011-2020 the average temperatures increased by 2 degrees Celsius. Thus there are still colder periods that the farmers have to be prepared for. Furthermore, this shows that determining the increase in temperature depends on the reference point.

Table 3: Temperature Changes Southern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
Period	00-20	00-20	00-05	06-10	11-15	16-20
Weighted Yearly Trend	.047***	.047***	-.081***	.12***	.181***	.098***
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**
Adjusted R-Squared	**X**	**.3122**	**.3163**	**.3061**	**.2962**	**.2973**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

The columns in table 3 have the same meaning as the columns in table 2. The results for the entire period for Northern Europe and Southern Europe are very similar, both have roughly a 1 degree Celsius increase in average temperatures. However, column 3 to 6 show different results. Just as for Northern Europe there is a period with a negative coefficient and thus a colder period for Southern Europe, however, this is in a different period than in Northern Europe. This shows that in Southern Europe, just as in Northern Europe, farmers have to prepare for cold and hot temperatures.

For farmers it is important to know if these changes are driven mainly by the extreme months or whether these results are indication changes in seasonal weather conditions and thus impact crop growing seasons. Therefore, the monthly results have been displayed in Appendix tables 7 and 8. These tables show the monthly volatility of monthly temperatures.

2.3.2. Precipitation

The tables for precipitation for both Northern and Southern Europe have 7 columns. The first three columns capture the entire time period, column 1 is the OLS regression, column 2 is the HDFE regression, column 3 is the Poisson Pseudo Maximum Likelihood High Dimensional Fixed Effects (PPMLHDFE) regression. Columns 4 to 7 capture the different time periods, just like in the table for temperature changes, but in this table the PPMLHDFE has been used. This is due to the previously explained results from the White test.

Table 4 shows that in Northern Europe the precipitation has increased in the entire time period that is analysed and also in all shorter time periods as is displayed in columns 4 to 7. The results are highly statistically significant. The results are in millimetres and thus precipitation in Northern Europe has increased by .016 * 1 degree Celsius + 21 * .004 = 0.1 millimetres. This means that on a yearly base the total the precipitation increased by 0.1 * 365 = 36.5 millimetres. This is a relatively small change, which is based on the trend from 2000 to 2020. The problem with the precipitation is the volatility, which can be seen in figure 5 and 12. Figure 5 shows that in 2017 there was 1.7 millimetres of precipitation and in 2018 there was 1.3 millimetres of precipitation. This is a roughly 25% decrease in precipitation in the next year. Figure 12 shows that this decrease in precipitation is not spread out evenly across the year, but that the majority of the precipitation occurs in a few months. Appendix table 11 shows the monthly changes in precipitation in Northern Europe.

Table 4: Precipitation Changes Northern Europe

Precipitation Average	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Period	00-20	00-20	00-20	00-05	06-10	11-15	16-20
Temperature Average	.026***	.021***	.016***	.017***	.016***	.019***	.012 ***
Weighted Yearly Trend	.006***	.006***	.004***		(omitted)		
WS Fixed Effects	NO	YES	YES	YES	YES	YES	YES
Observations (n)	**2,775,780**	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**
Pseudo R-Squared	**X**	**X**	**.0778**	**.0751**	**.0797**	**.0906**	**.0780**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Table 5 shows the changes in precipitation in Southern Europe. A clear difference with Northern Europe is that for Southern Europe most of the coefficients are negative. This means that the total amount of precipitation decreases when the temperature increases. However, for the entire dataset there is a .021 decrease in precipitation from a temperature increase of 1 degree, but at the same time there is a .007 * 21 = .147 increase from the yearly trend. Thus for the entire time period there is an increase in precipitation of .126 millimetres in Southern Europe. This means that in total the precipitation increased with .126 * 365 = 45.99 millimetres in the entire year. For farmers in Southern Europe it is not only important that there is precipitation, what is even more important for these farmers is when these changes in precipitation occur. Figure 5 shows that in 2010 there was 1 millimetres of precipitation and in 2010 there was 1.4 millimetres of precipitation, this is a 40% difference in precipitation. Thus there are high differences in yearly precipitation, but also within year. The differences in precipitation within years severely impact the growing season and crop growth. Figure 12 shows that this decrease in precipitation is not spread out evenly across the year, but that the majority of the precipitation occurs in a few months. Appendix table 12 shows the monthly changes in precipitation in Southern Europe.

Table 5: Precipitation Changes Southern Europe

Precipitation Average	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Period	00-20	00-20	00-20	00-05	06-10	11-15	16-20
Temperature Average	-.052***	-.024***	-.021***	-.019***	-.022***	-.018***	-.026 ***
Weighted Yearly Trend	.009***	.008***	.007***		(omitted)		
WS Fixed Effects	NO	YES	YES	YES	YES	YES	YES
Observations (n)	**2,870,126**	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**
Pseudo R-Squared	**X**	**X**	**.2455**	**.2443**	**.2486**	**.2431**	**.2577**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

The results show that in both Northern and Southern Europe precipitation increased. The results also show that there are different effects from increases in temperature. Increasing temperatures thus impact the different regions and farmers differently. Where in Northern Europe drainage becomes increasingly important, the Southern European farmers will focus more on irrigation systems. Because the farmers in different regions are impacted differently by climate change, they need different solutions in dealing with climate change and transitioning towards sustainable agriculture.

2.3.3. Robustness

To control for structural validity a robustness check has been performed. A control variable has been added to check whether this leads to structural differences compared to the previously shown regression results. There are no major differences when the control variable is added, but the Adjusted R-Squared and Pseudo R-Squared are slightly lower. The results of the regressions with the control variable are visible in appendix tables 9 and 10 for the temperature and tables 13 and 14 for the precipitation.

3. Theories

The previous section discussed how different geographical regions in Europe are impacted differently by climate change. The impact from climate change has to be limited for the agriculture sector to become sustainable. The impact of climate change can be limited by improving the climate change resilience of the sector. This section will discuss the main tools at the disposal of the European Commission in improving the climate change resilience and transition towards sustainable agriculture in Europe.

3.1 Subsidy

This thesis mentions the efficiency and effectiveness of subsidies throughout the thesis. With the efficiency of policies and subsidies this thesis means the cost effectiveness and the theoretical efficiency. For example, implementing drip irrigation is relatively cheap and can have a severe impact for certain farmers. So then subsidising drip irrigation would be considered efficient. When mentioning the effectiveness this thesis looks at the practical results. In the example of drip irrigation this would be the number of farmers that switch to drip irrigation and the overall result from the subsidy. Even though subsidising drip irrigation is efficient, the effectiveness of the subsidy will significantly differ in regions with high and low precipitation.

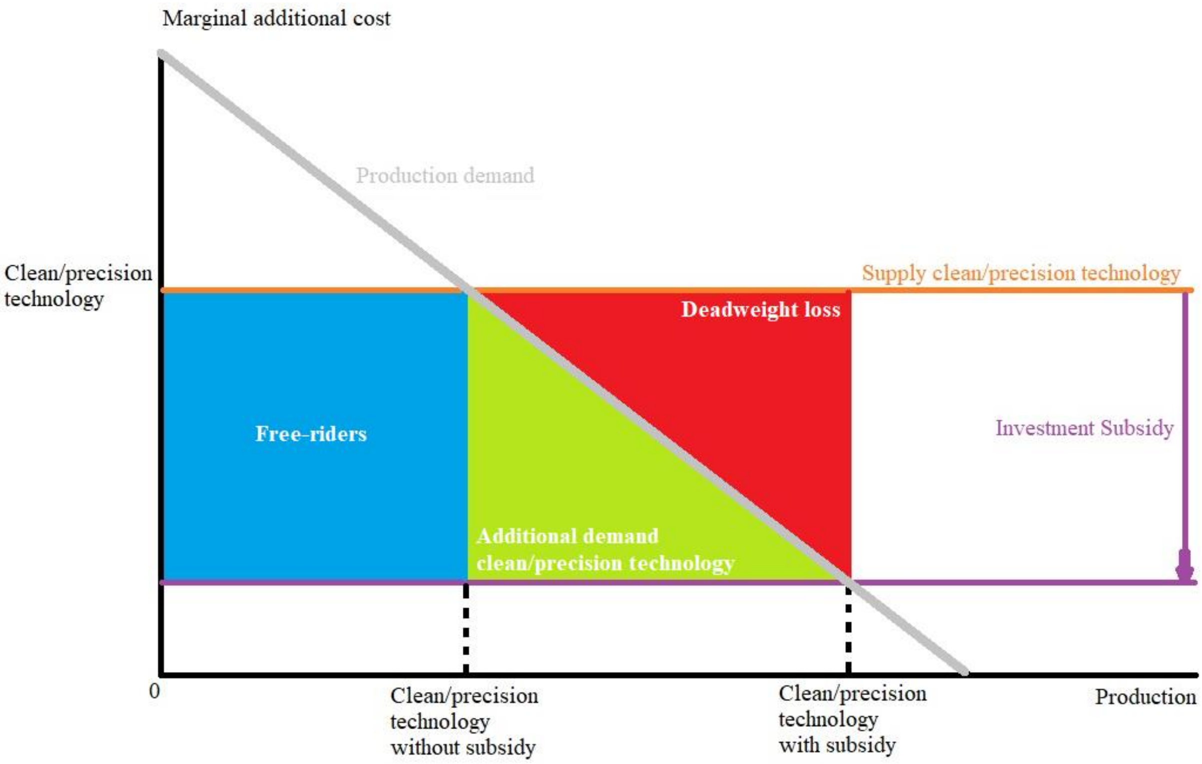


Figure 6: Free-rider problem

Figure 6 shows that investment Subsidies help to lower the cost of investment. One major concern about subsidies is the free-rider problem. Free-riders are users of a subsidy that would have made the same investment in absence of the subsidy. When there is a large number of free-riders, then the subsidy money has been used inefficiently. When the number of free-riders is limited, then the total subsidy is cheaper than when there are many free-riders. Investment subsidies are common with new technologies, especially if these new technologies have positive externalities, to speed up the adaptation of these new technologies. According to economic theory subsidising these new technologies can lead to welfare gains through environmental gains and knowledge externalities. When choosing which green technologies to subsidise it would be best to aim for technologies that do not have a short investment recovery period but instead have a longer investment recovery period. Furthermore, a subsidy becomes more effective when the investment is tax-deductible. This is because when the preferable investment is tax-deductible, then the cost of making the investment decreases (Vollebergh, 2020).

It would be important to continuously review and update the list with technologies for which subsidies apply. New technologies might replace older technologies on the list or social perspectives can change and impact the technologies that receive subsidies. Especially with the Green Deal and Paris Agreement there is a recent trend of transitioning towards technologies that are more environmentally friendly. Therefore, many technology subsidies are focused on cleaner new technologies that are currently very expensive. Using tax-deductibility of investments in such technologies helps in convincing companies to make the transition to these new technologies. The subsidies aimed at new clean technologies improve the market penetration of the technologies by decreasing the cost of the technologies. Additionally, the increase in the attention and information on such technologies increases the use of these technologies. When subsidies do not lead to higher market penetration of clean technologies, then the subsidies are inefficient (Vollebergh, 2020). Figure 7 visualises additional market penetration due to a subsidy. When the subsidy starts the line that represents the subsidy should be above the line that represents the case in which there is no subsidy. When there is no difference between the lines, there is no additional market penetration and the subsidy is inefficient. In addition to the efficiency of the subsidy it is important to realise that the money that is used for subsidies has to be collected first. When the collection of money for subsidies happens through general taxes, then the welfare effect has an additional welfare loss. If instead the money is collected through revenue from environmental taxation in the form of pollution taxes, then the welfare costs are limited (Vollebergh, 2012).

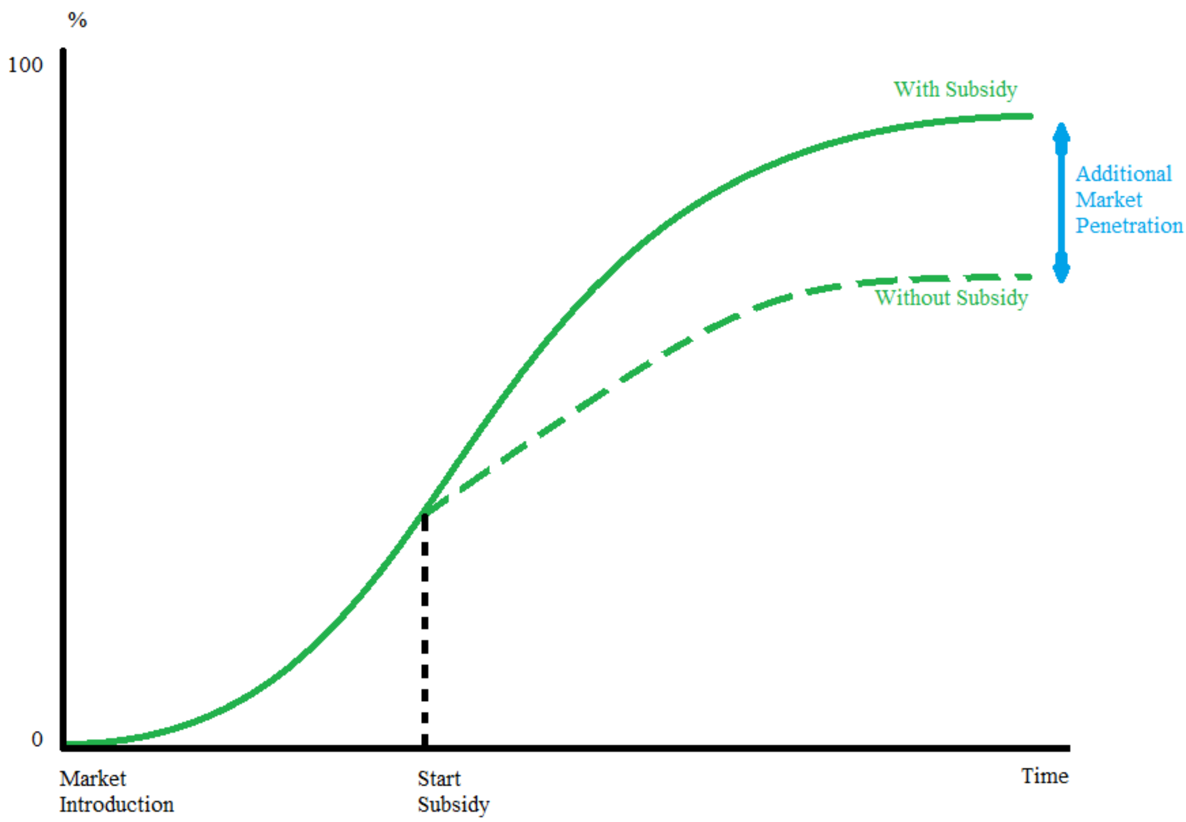


Figure 7: Additional Market Penetration

Economics examines the choices of individuals in a context of a budget constraint and relative prices. Taxes and subsidies change the budget constraint and relative prices. Just like taxes, subsidies impact the choice of individuals through the income and substitution effect. The income effect shows how individuals respond to the change in budget constraint and the substitution effect shows how individuals respond to the change in relative prices (Wolfson, 1990).

There is a trade-off between investment and production subsidies. With production subsidies the production increases, the gains from the subsidy is the extra production that keeps being produced as long as the government pays the subsidy. With investment subsidies the subsidy has to exceed a lower bound to reach marginal investments. The lower bound is a minimum amount that has to exceeded for the subsidy to have an effect. For example, when the purchase of a new technology would cost a million euros and the subsidy is a thousand euros, then this subsidy will likely have no effect. There will be a minimum amount, which will be different for each technology, that the subsidy has to cover to make a difference. When this minimum amount, or lower bound, is reached then there will be marginal investments. The marginal investments are investments that would not have been made in the absence of the subsidy. Whether it is more cost efficient to reach marginal investment through production or investment subsidies depends on the case specific parameters. Historically the preference has been production subsidies, however, in the case when significant investment is needed it is more cost effective to use investment subsidies (Yi et al., 2019). The new technologies that are used in the agriculture sector often require a significant investment. Thus in the agriculture sector it would likely be more cost effective to use investment subsidies than production subsidies.

Input subsidies are costly and are often considered inefficient but are continued due to the political interests in having a stable agricultural production. For input subsidies to be effective the subsidy should not end up with free-riders and should be used effectively and efficiently in the increase of crop production (Chirwa & Dorward, 2013).

Dorward (2009) shows that targeting a specific group of farmers would make the subsidies more efficient. Dorward (2009) shows that it would be efficient to target farmers that are capital constrained. In targeting specific groups of people it is more effective to target people based on geographical differences than to target intra-community differences. This is the case because geographical differences are often larger and require less time and effort to obtain than intra-community differences. An example of a geographical difference is the different weather conditions in Northern and Southern Europe.

3.2 Taxes

The optimal taxation theory states that the goal of a tax system should be to maximise a social welfare function, which is the same as the goal of the optimal subsidy theory. The social welfare function is often nonlinear and an accumulation of individual utilities. When constraints are absent and markets are perfect then the optimal tax is a lump-sum tax. Theoretically, the lump sum tax is the optimal tax, but this is often considered as unfair by society due to significant differences in disposable income in society. As a result, the lump-sum tax is rarely used by governments. Income depends on ability and effort, but neither ability nor effort can be observed directly. Placing the taxes on individuals with high abilities would discourage them and lower their effort to earn high wages. Governments face a trade-off between equality and efficiency (Mankiw et al., 2009). The Mirrlees (1971) framework sees the optimal tax as a game of imperfect information. To get an optimal allocation the government needs to use a policy that provides incentives for taxpayers with high abilities so that the taxpayers voluntarily reveal their ability. This framework provides the government with all the information, this information can then be used by the government to choose the most appropriate tax system. However, it is a complex framework and is also very labour intensive to keep up to date. An optimal marginal tax rate depends on the distribution of abilities and could possibly decline at the highest incomes. The marginal tax rate is often combined with a flat tax, policymakers generally prefer flatter taxes. Furthermore, policymakers seem to agree that only final products should be taxed. The big exception on this is when negative externalities come from the production of goods, then a tax is justifiable to correct for the negative externalities. These taxes are known as Pigouvian taxes or subsidies, depending on whether the externalities are negative or positive (Mankiw et al., 2009). An example is the use of pesticides and fertilisers. When there are negative externalities, the optimal output for the producer is different from the optimal output for society. Figure 8 shows an example of a case with negative externalities. This figure shows the marginal cost (MC) and marginal benefits (MB) for a producer that is polluting. The producer keeps producing to the point where MC = MB. The marginal benefits for the producer and society are decreasing when the volume increases. The marginal cost for the producer is zero and thus the producer keeps producing till MB = 0. This leads to equilibrium point x'. However, the marginal cost for society is not zero and are increasing when the volume x increases. The equilibrium for society is point x*. Due to negative externalities from pollution the equilibria of the producer and society differ, in this case it is generally accepted that the government should intervene. The government can use policies to breach the gap between the equilibria (Hanley et al., 2016).

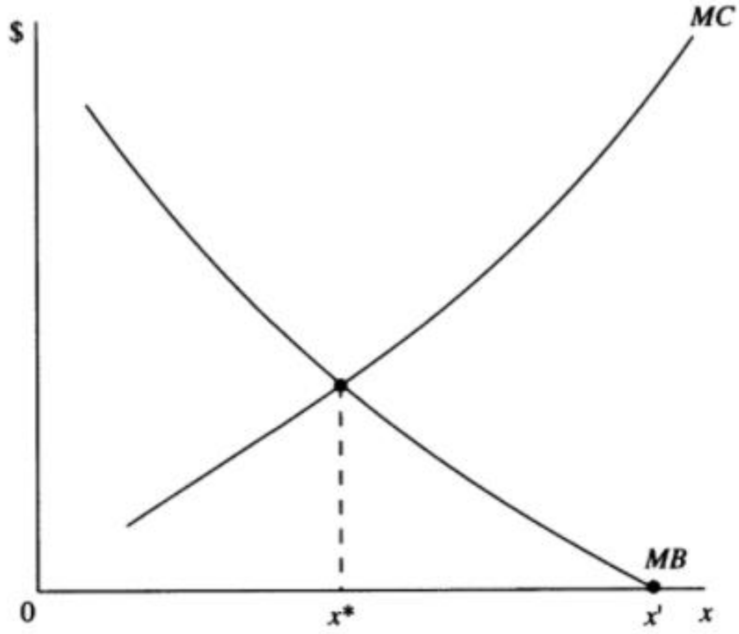


Figure 8: Negative Externalities; Source: Hanley et al. (2016)

When the government decides to put taxes on goods such as fertilisers and pesticides the government has to adjust the tax rate to the technology used when using fertilisers and pesticides due to their difference in externalities. Additionally, it is likely for the tax rates to change depending on geographical location. An alternative to the Pigouvian tax would be to base taxes on observable technologies. Imposing such taxes will be less efficient and effective than pollution taxes but will still create incentives to promote precision technology. These taxes would be less efficient and effective because they do target the polluter, but do not take the amount of pollution into consideration. Additionally, these taxes would not tax farmers when they use precision technology but at the same time use more than average amounts of fertilisers and pesticides. Furthermore, these taxes would be a form of a discriminatory tax that is aimed at farmers that use environmentally damaging technologies and will provide an incentive and reward for the use of green technologies (Zilberman et al., 1997).

4. Methods

The Green Deal and Paris Agreement aim to limit global warming and reduce emissions. To achieve these goals, the agriculture sector in Europe has to change. The subsidies that were discussed in the previous section are the main tool for the European Commission to achieve the required changes in the agriculture sector. To achieve the goals of the Green Deal and Paris Agreement the European Commission uses the CAP, in which they decide how and what they will subsidise. The CAP is updated every few years and after the CAP is updated the farmers decide whether they change their farming practices or not. To examine this setting this thesis uses a Bayesian Stackelberg game theory setting.

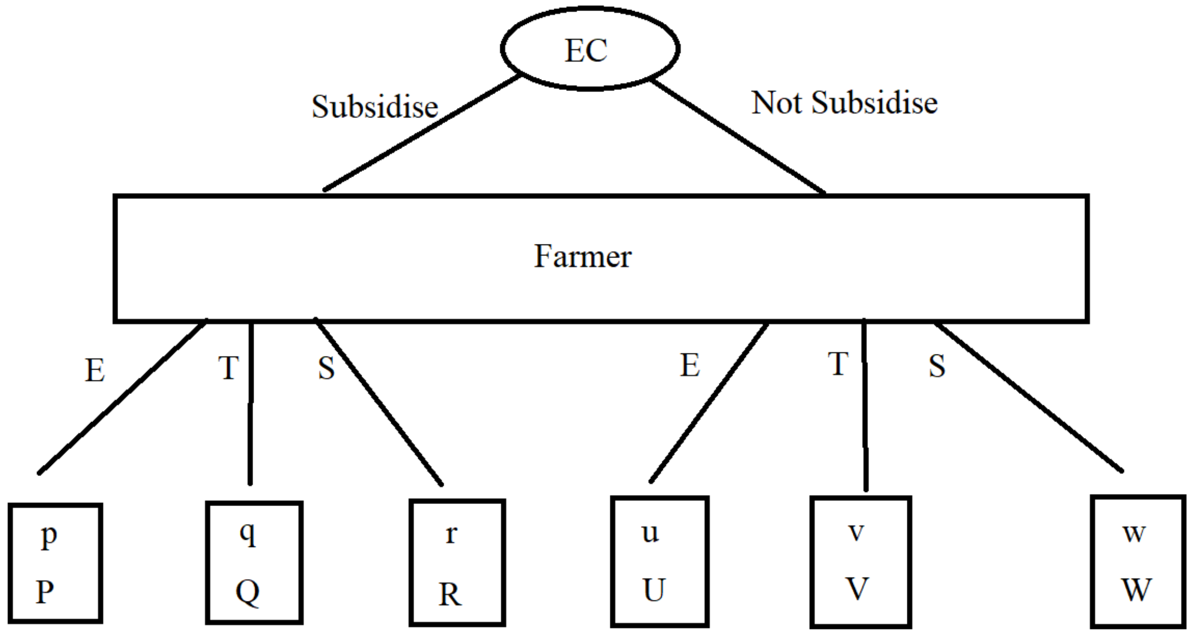


Figure 9: Bayesian Stackelberg Game With Incomplete Information

For each technology and farming method the European Commission (EC) chooses to Subsidise or Not Subsidise. After this choice is made the information becomes available to the farmers, the farmers can then choose to Exit (E), Transition (T), or Stay the same (S). The Choice of the farmer leads to payoffs for both the farmer and the European Commission, these are displayed in the boxes at the bottom of figure 9. The farmers will choose the highest payoff for themselves and the corresponding choice results in a certain payoff for the European Commission. A common technique in a Bayesian Stackelberg game is backward induction. In figure 9 there is a square with 'Farmer' inside, this is a square because there is incomplete information for the European Commission on the type of the farmer. The farmers differ in their knowledge and willingness to work with advanced technology. For simplicity this thesis divides the farmers in two groups, farmers that are willing to work with new advanced technology and farmers that are not willing to work with new advanced technology. These two groups are the different types of farmers and the European Commission does not have the information on which type a farmer is. When a farmer is of the type that is willing to work with new advanced technology, then a subsidy could convince this farmer to switch to one of the green/precision technologies that the European Commission prefers. When a farmer is of the type that is not willing to use new advanced technology, then a subsidy will be less effective. Because now the subsidy might no longer be enough to convince the farmer to transition. When the European Commission chooses not to subsidise and the majority of the farmers choose choice to Transition (T), then the European Commission does not have to subsidise. But when the majority of the farmers chooses Exit (E) or Stay (S), then a subsidy could motivate farmers to switch to choice T on the left side of the figure. This will happen when pay-off q is higher than pay-off u and w, because then the farmer profits from transitioning. However, because the European Commission does not know the type of the farmer, it is difficult to determine the size of the subsidy. Furthermore, the farmer can profit from giving false information on his type. When the farmer makes the European Commission believe that he is from the type that is not willing to use new advanced technology, then he might get a higher subsidy so that $q > w$ for that farmer and he will transition. Additionally, there are high investment cost for farmers when they switch to a new farming method or technology. This initial cost can be lowered with investment subsidies, but would stay high if the European Commission would decide to use production subsidies instead. These high initial costs could be another barrier for farmers in their choice to transition towards sustainable agriculture. To overcome this barrier, this thesis will focus on investment subsidies. To overcome the incomplete information on the type of the individual farmer this thesis uses farmer associations. The farmer associations represent large groups of farmers and are aware of the general preferences and type of the farmers in their geographical region. The farmer associations will be less likely to provide false information because the farmer associations look at the collective of farmers and not at individual farmers. To convince the European Commission to subsidise a specific farming method or technology, the farmer associations will have to reveal the collective type of the farmers. When the European Commission is aware of the type of farmer in a specific region, then the European Commission has a Stackelberg game with complete information.

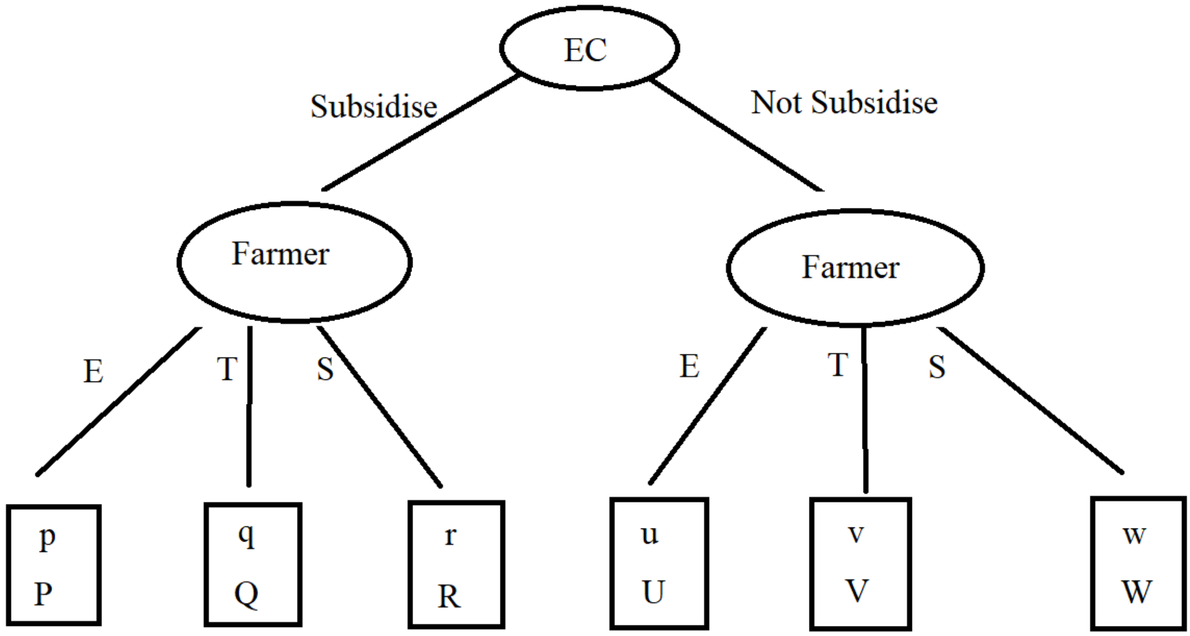


Figure 10: Bayesian Stackelberg Game With Complete Information

In this new setting there is complete information and the European Commission can use backward induction to decide which technology or farming method to subsidise to get a result that the European Commission prefers. The farmer associations benefit from revealing the collective type of the farmers because now the European Commission will use subsidies for a farming method or technology that fits the type of the farmers. In addition to the type of the farmers the farmer associations can make the European Commission aware of certain parameters that would impact the choice of the European Commission. Such parameters would be the temperature and precipitation levels that were mentioned in the quantitative analysis earlier in this thesis. Thus by revealing the collective type of the farmers the farmer associations assure that the European Commission provides subsidies for farming methods and technologies that are applicable and preferred by the local farmers. Therefore, it would be beneficial for the farmer associations to reveal the collective type of their farmers. The European Commission would also benefit from knowing the type of the farmers because now they are able to make a general assessment of the efficiency and effectiveness of their policies and subsidies. Thus by using investment subsidies and communicating with the farmer associations the European Commission can improve the efficiency and effectiveness of their subsidies and improve the transition towards sustainable agriculture in Europe.

4.1. Methodology

To gain information from the farmer associations in Europe this thesis used a qualitative analysis that is based on 10 interviews, 5 questionnaires and additional supporting documents. The majority of the data comes from farmer associations all over Europe. However, there was also an interview with the European Commission, with the Director-General of Agriculture and Rural Development, to be able to look at the data from a policy perspective. The interviews were based on semi-structured questions, so that it was possible to ask follow-up questions based on the initial answers. For the questionnaires 10 semi-structured questions were emailed to the farmer associations. The interviews were conducted through zoom. The collection of primary data through phone calls, and thus also zoom, has been researched and proven to be valid and reliable (Burke & Miller, 2001; Farooq & Villiers, 2017). To add to the reliability of the data that is collected through the interviews, questionnaires and additional documents this thesis will use data triangulation. The data triangulation will be done by comparing the data from the individual interviews and questionnaires with the other interviews, questionnaires and the quantitative analysis. This cross verification through multiple sources, where possible, will validate the information (Leech & Onwuegbuzie, 2007; Carter et al., 2014). The data collected from the farmer association will be used to examine if there are common issues and patterns in the transition towards sustainable agriculture in the European Union. This thesis uses Interpretative Phenomenological Analysis (IPA) to examine the experiences of the farmer associations. With IPA the goal is to look for reoccurring themes and not to fact-check the individual statements. The interviews are transcribed and afterwards analysed to create general themes. Once the main themes are formed the data within the themes goes through another cycle of analysis. These reoccurring topics in the second cycle are the sub-themes (Eatough & Smith, 2008). The IPA results of the different themes and sub-themes are displayed in table 6. Using IPA will make it possible to find out what the farmer associations their main issues are and how they feel about the CAP. The reoccurring topics show what the general issues are for farmer associations in Europe. The European Commission can use this information to become aware of certain barriers in the transition towards sustainable agriculture (Estrada et al., 2013).

Table 6: IPA Themes

	Climate Change	Agriculture	Sustainability	EU Policy	Financials	Transition	Technology	European Commission
Sub-theme 1	Performance	Personal Benefits	Finite Resources	Outdated	Investments	Variability	Hydroponics	Climate Change
Sub-theme 2	Precipitation	Varieties	Feasibility	Innovation	Financial Sustainable	Farmer Association	Genetics	EU Policy
Sub-theme 3	Experience	Farmers Quitting	Agriculture	Taxonomy	Research	Research		Transition
Sub-theme 4				Trust	Taxation	Technology		Technology
Sub-theme 5						EU Policy		

5. Qualitative Analysis

The qualitative analysis is structured with themes and sub-themes, displayed in table 6. The first theme is the climate change theme and how climate change impacts agriculture. This theme is followed by the agriculture theme. Then the sustainability theme will be used to address how sustainability and agriculture go together. This is followed by the EU policy theme in which the farmer associations talk about how the policies are important in becoming sustainable. Next is the financial theme in which the financial incentives that are linked to the policies are discussed. The transition theme will look into what the essentials are in transitioning towards sustainable agriculture in the European Union. The last farmer association theme is the technology theme in which examples of technologies to transition towards sustainable agriculture are discussed. The last theme of the qualitative analysis is based on the interview with the European Commission. All other themes are based on the views and experiences of the farmer associations. The European Commission theme is shorter than the farmer association themes, this is due to the amount of information. There were 9 interviews, 5 questionnaires and additional documents for the farmer associations and just one interview with the European Commission.

5.1. Climate Change

The quantitative analysis showed that there has been severe climate change impact in the past 20 years and that climate change impacts different parts of Europe differently. The climate change theme has 3 sub-themes that are used to examine how farmer associations experience climate change.

5.1.1. Performance

Climate change leads to changes in performance in the agricultural sector in Europe. The Dutch farmer association states that *"as entrepreneurs who work in and with nature, the sector is feeling the consequences of climate change"* (Website The Netherlands, 2021). The quantitative analysis at the beginning of the paper showed that the weather conditions become more extreme, the Swedish farmer association also mentioned this by stating *"You might get a very late frost, even though on average, the temperature is higher. You might get drier summer, even when on average the precipitation is higher. That makes it very difficult for performance"* (Interview Sweden, 2021). The farmer association in the Czech Republic states *"weather fluctuations associated with climate change contribute to the spread of diseases, changes in traditional production areas and disproportionate yields"* (Questionnaire Czech Republic, 2021). The quantitative analysis showed that different regions are affected differently by climate change, but these farmer associations show that there are consequences that affect all regions. That different regions are affected differently is acknowledged by the Swedish farmer association, the state *"it seems like Scandinavia is one of the parts that will be least affected by climate change. This doesn't mean that we won't be severely affected"* (Interview Sweden, 2021). The performance of farms is impacted differently across Europe due to a difference in impact from climate change, however, there are consequences from climate change that do affect all the regions.

5.1.2. Precipitation

One of the main issues from climate change for farmers is the change in precipitation. More extreme weather conditions occur all over Europe. The Danish farmer association stated *"we have had one of the most serious droughts we have had in 30 years in Denmark and then the year after that we had one of the wettest we have had"* (Interview Denmark, 2021). This shows that farmers in Denmark have to prepare for both wet and dry years if they want to have stable production. In Germany the farmers had a similar experience *"in 2018 there was a record drought in south Sweden and north Germany. It lasted almost two and a half months, no rain in the months where it usually rains every second day. I think the farmers in the region lost 70% of their crops"* (Interview Germany, 2021). When farmers are not preparing for extreme weather conditions, then large amounts of crops will continue to be lost. In Spain the farmers experience droughts more frequently, leading to water scarcity. Water scarcity impacts crop production, *"water is relative to the output of the crop that you produce"* (Interview Spain, 2021). Droughts are also a problem in Bulgaria where the farmers experience *"a lot of droughts, no rain, no moisture in the soil"* (Interview Bulgaria, 2021). The changes in precipitation that were found in the quantitative analysis are experienced in all parts of Europe and lead to changes in crop output.

5.1.3. Experience

In determining the impact of climate change and how to prepare for more extreme weather conditions the experience of farmers is essential. The European Commission could base their policy on the expectations of what will happen in the future and how this might impact farmers, but *"farmers know better than the rest of us about climate change. They see it every day"* (Interview Belgium, 2021). The practical experiences give the farmers information that the policymakers might be unaware of. Especially because different parts of Europe are impacted differently by climate change, *"climate change affects every farm differently because it's changing something different in their little ecosystem"* (Interview Belgium, 2021). The experience of how different regions are impacted differently will be valuable information for policymakers when they decide on new policies, because this information impacts the efficiency and effectiveness of the new policies and subsidies.

5.2. Agriculture

The agriculture theme has 3 sub-themes that are used to examine what the most important aspects are for agriculture in the transition towards sustainable agriculture.

5.2.1. Personal Benefits

For farmers the personal benefits from farming are important in their choices of transitioning towards different farming methods. They look at how a transition would impact them personally, *"does this work for me on my farm? Can I use this? Is it getting better? Do I feel better?"* (Interview Sweden, 2021). The farmers use the personal benefits to choose how to adjust their current farming methods to stay competitive, *"you are always developing your farm, it is essential. It's a very competitive sector. You are fighting against the world market"* (Interview Denmark, 2021). The farmers are aware that they need to keep developing, *"they are conscious of this making, managing their land effectively because of their livelihood"* (Interview Belgium, 2021). The German farmer association states that proof of concept convinces farmers, *"if they see that something is working"* (Interview Germany, 2021). When farmers know that something works they know the personal benefits of the specific farming method and might be convinced to switch to this particular farming method. The Belgium farmer association mentions that the policies should be based more on the choices of farmers based on their personal benefits if the European Commission wants change. They state *"If you're paying everybody to do what they always did, why change? Then farmers are not necessarily incentivised to want to search and fight for innovation to make a difference because they get paid"* (Interview Belgium, 2021). When farmers base their choices on personal benefits it is important that the societal preferred choices are incentivised so that the individual choices of the farmers align with the preferred societal outcome.

5.2.2. Varieties

Due to differences in geographical location and climate change impact, as is shown in the quantitative analysis, there is a large variety of farming methods used by farmers in Europe. The German farmer association points out the regional geographical impact, *"they have a completely different farming system than in a region that's completely flat"* (Interview Germany, 2021). This is in line with the view of the Danish farmer association, *"having some flexibility in terms of what makes sense for that region"* (Interview Denmark, 2021). Another aspect that increases the variety of farming methods is the difference in age of farmers, *"we will need to convince these old school farmers that the new technologies are needed and have to be applied"* (Interview Bulgaria, 2021). Lastly, there is the reason for risk diversification and crop rotation, *"we won't put all our eggs in one basket, but rather spread them out very widely"* (Interview Sweden, 2021).

5.2.3. Farmers Quitting

When farmers have a limited amount of varieties to choose from, then they look at the personal benefits of these options and choose what to do. When the personal benefits of the available options do not make sense, then farmers can choose to quit farming. The Swedish farmer association states *"I fear that we* *are losing so much knowledge and so much experience"* (Interview Sweden, 2021). This loss in knowledge and experience comes from the farmers quitting because *"they don't want to do it anymore"* (Interview Sweden, 2021). The German farmer association agrees with this view, *"I think that the farmers don't really get included in the conversation. That's what drove a lot of people out of business"* (Interview Germany, 2021). Apart from farmers quitting because they don't want to be farmers within the current policies there are farmers that quit because they are not able to make the required changes. The Bulgarian farmer association mentioned *"sharp changes in their working pattern is difficult for them"* (Interview Bulgaria, 2021).

5.3. Sustainability

The sustainability theme looks at how the agriculture sector in Europe can become sustainable and how fast the agriculture sector can become a sustainable sector.

5.3.1. Finite Resources

To reach sustainable agriculture in Europe it is important to assure that the resources that are used as input are available. Therefore, finite resources limit the sustainability of sustainable agriculture. The Swedish farmer association mentioned *"one of the things that is absolutely not sustainable is to continue overusing finite resources by fossil fuels"* (Interview Sweden, 2021). This is one of the main reasons why the Green Deal aims gradually decrease the use of finite resources.

5.3.2. Feasibility

Everyone in Europe, the farmers and policy maker, agree that the agricultural sector has to become more sustainable. The disagreement between them is in the rate of transition and the chosen policies. The Swedish farmer association thinks the changes in the budget do not align with the vision, *"farmers should do much more, but with much less money, that becomes kind of tricky"* (Interview Sweden, 2021). Apart from the changing budget the Czech farmer association states that the intensity is a problem, *"the problem is, for farmers above all, especially the intensity of sustainability and greening in of agriculture"* (Website Czech Republic, 2021). The Danish farmer association thinks the sharp changes can be avoided by making a short-term and long-term plan, *"you have to think the short and long-term"* (Interview Denmark, 2021). Where the aim of the short-term goals is to start the transition, even if these policies are not enough in the long-term. Then later *"you will probably come up with something else as you go along"* (Interview Denmark, 2021).

5.3.3. Agriculture

The agricultural sector has always been closely linked to climate change goals, *"The agricultural sector has played an important role in achieving climate goals for some time"* (Website The Netherlands, 2021). When talking about the emissions from the agricultural sector the Dutch farmer association states *"since 1990 it has reduced greenhouse gas emissions by 19%"* (Website The Netherlands, 2021). In Sweden the farmer association sees chances for the reputation of the agricultural sector, *"the green sectors, we're not there yet. But we are working to try to show Europe and the rest of the world that the green sectors are the solution, not the problem"* (Interview Sweden, 2021), here 'green' refers to the agriculture sector. The Spanish farmer association also mentions that the farmers are willing, but they think that the way through which sustainable agriculture is reached is important. They state *"we are aware that sustainable agriculture is possible, but it has to come through biotechnology"* (Questionnaire Spain, 2021), here 'sustainable agriculture' refers to meeting the current needs without damaging the environment and compromising farming in the future.

5.4. EU Policy

The EU policy theme examines what the opinions of the farmer associations are on the current EU policies. This theme highlights some of the main issues, according to the farmer associations, with the current policies and how the policies could be improved.

5.4.1. Outdated

Multiple farmer associations mentioned that the EU policies are outdated. The Swedish farmer association used the example of the Green Deal, they stated *"the things that were presented there, those are things that we have been working on in Sweden and actually in a sense written the textbooks from Swedish work for the past 40 or 30 years"* (Interview Sweden, 2021). The view in Belgium on EU policies is that *"it's always been fairly conservative"* (Interview Belgium, 2021). An important aspect of the policies is the baseline that is used in the EU. Because *"normally when we talk about the system usage, you're talking about 1990, but the EU is talking about 2005"* (Interview Denmark, 2021). That the European Commission uses a different baseline than 1990 causes frustration because the EU baseline *"makes it very difficult for countries that have already done more"* (Interview Denmark, 2021). This leads to EU policies that do not favour the frontrunners in the transition towards sustainable agriculture and because the different baselines require much more change from the countries that are ahead in the transition.

5.4.2. Innovation

The outdated policies are slowing down the innovations in the industry. The current incentives are for the farmers that have to catch up. This leads to frustration in Sweden, *"members are complaining that what happened now is that we took huge costs 40 years ago to develop these methods and now money that could have been spent on helping us continue to develop them is instead used on helping the others to catch up"* (Interview Sweden, 2021). This frustration leads to a change in farmer mindset, now farmers think *"I will not be the one stepping forward. I will not be the one trying to innovate. I will not be the one because I don't get anything for it"* (Interview Sweden, 2021). This change in mindset will severely slow down to progress of transitioning towards sustainable agriculture. The Dutch farmer association states *"sustainable government policy with appropriate legislation and regulations and additional resources are necessary to be able to invest sufficiently in climate measures"* (Website The Netherlands, 2021). In Belgium the farmer association thinks the European Commission is realising that the policies are slowing down the change, *"I think what you see is that the commission is recognising that the trend isn't happening fast enough"* (Interview Belgium, 2021).

5.4.3. Taxonomy

The taxonomy of the different farming methods and technologies is an important part of the EU policies, because the taxonomy determines who and what qualifies for subsidies and which rules apply. One problem with the current taxonomy is what the system is focused on, *"one of the challenges is that many of these systems are built to make them easy for the administrators rather than to make them work practically for the ones who are supposed to use them"* (Interview Sweden, 2021). The focus of the current system sometimes makes it difficult for farmers to understand them, *"we have difficulties following all these new requirements"* (Interview Bulgaria, 2021). The Belgium farmer association thinks that the policies should be aligned with the vision, *"you need to have a regulatory and financial framework that supports that direction"* (Interview Belgium, 2021). A part of this regulatory and financial framework could be disincentivising things that are considered to be bad by the European Commission, *"come up with some barriers, they can be regulatory barriers, they can be cost barriers"* (Interview Belgium, 2021). Most of the farmer associations agree that the current framework is too difficult to understand for the farmers and that the policies could and maybe should better fit the vision of the European Commission. Not just incentivising things that are considered to be good but also disincentivising things that are considered to be bad would be a first step in aligning the framework with the vision.

5.4.4. Trust

A reason for the policies to sometimes seem to be overcomplicated is the lack of trust. The European Commission does not seem to fully trust the farmers. The Swedish farmer association states *"I think trust is one of the key issues, because if you think that people are trying to trick you, you will think that whatever they say"* (Interview Sweden, 2021). When the policymakers do not trust the farmers and listen to the farmers when it comes to what they need to be able to meet the conditions to get a subsidy, then the farmers will not be able to be part of the transition towards sustainable agriculture. There also seems to be a lack of trust in the knowledge of farmers, *"I often take part in conversations in Brussels about farmers, on an assumption that they don't really know a great deal, which is incredible"* (Interview Belgium, 2021). There seems to be room for improvement in the trust and collaboration between the farmers and the policymakers.

5.5. Financials

The financials theme is used to examine where the farmer associations think the money that is available to the European Commission should be spent. This theme highlights three main topics that require money and how money should be spent on these topics. The last sub-theme explains how national governments can contribute to the transition towards sustainable agriculture in Europe.

5.5.1. Investments

The effects of climate change and new European policies and goals means that farmers have to change their farming methods. When farmers want or have to transition from their current farming method to farming method with green technologies then farmers have to invest to change to the new farming method. The Swedish farmer association mentioned about investments related to extreme weather that climate *change "makes it very much more costly because you would probably have to invest both in irrigation systems and an increased drainage because you need to be able to manage both types of extremes far more often, but you only get value for your investment when that happens"* (Interview Sweden, 2021). The increasing need to invest in climate change related technology mean that farmers would need more loans. The Danish farmer association noticed a change in the banking sector, they state *"since the financial crisis there were a lot of difficulties for banks to lend out money"* (Interview Denmark, 2021). However, this changed when the banks recovered from the financial crisis. Currently *"they are very willing to put money into farms"* (Interview Denmark, 2021). The farmers are currently able to get loans to invest in their farms, but many farmers choose not to. Especially with smaller farms *"farmers don't want to put themselves quite further in debt"* (Interview Belgium, 2021). This is also the reason why some farmers do not apply for funding, because to receive funding a farmer has to meet certain conditions and *"it is going to cost you more to fulfil the conditions than it is for the money you are going to get"* (Interview Belgium, 2021). These issues show that even when farmers are willing to change their farming methods to more sustainable farming methods some barriers prevent them from being able to make the change.

5.5.2. Financial Sustainable

Reaching sustainable agriculture in Europe starts with financial sustainability. This view is shared by the Swedish farmer association, they state that *"you need something in your belly as well, and something in your wallet, otherwise it's not sustainable"* (Interview Sweden, 2021). The Dutch farmer association sees the financial sustainability of farmers as one of the main obstacles in transitioning towards sustainable agriculture, *"the current earning capacity of farmers is not sufficient to achieve the desired transition"* (Website The Netherlands, 2021). The Dutch farmer association additionally mentioned *"it must be possible to earn money!"* (Website The Netherlands, 2021). The German farmer association also mentioned the financial sustainability of farmers as an important aspect in the transition towards sustainable agriculture. The German farmer association states *"they only survive by default with EU finance"* (Interview Germany, 2021). In Spain the reduced budget in combination with increasing restrictions leads to frustration, *"the budget is reduced, the restrictions have increased and they expect us to continue producing as always. We need to be subsidised for the reduction of our production or provided with a technology that can decrease our losses"* (Interview Spain, 2021).

5.5.3. Research

Research is important in developing new green technologies for the farmers that help in the transition towards sustainable agriculture in Europe. The Spanish farmer association points out the importance of investing in research, *"if we favour research and development, then this would benefit our lives, making us more healthy and immune to diseases"* (Questionnaire Spain, 2021). The Swedish farmer association agrees with the importance of research but would like to see a change in the way the research is done, *"what we see sometimes is that a lot of money has been spent on academia, which is great. Academia should be free to do all things, but I think there should be more collaboration with the actual practitioners"* (Interview Sweden, 2021).

5.5.4. Taxation

Taxation can be a tool that could contribute to the transition towards sustainable agriculture in Europe. The Swedish farmer association sees a use for taxation, because *"it costs more to use things that we know are bad"* (Interview Sweden, 2021). This view is in line with the view of the Danish farmer association which states *"the tax we have on pesticides is sent back to fund within the agricultural sector"* (Interview Denmark, 2021). With such a system the farmers that refuse to transition towards sustainable agriculture have higher costs and partly pay for the transition of other farmers. The Danish farmer association mentioned an alternative to taxation by stating *"I think that you could somehow have a crediting scheme"* (Interview Denmark, 2021). Having a crediting scheme in the form of tradeable permits or quotas would also allow farmers who pollute less than allowed to have a financial reward and create a financial incentive to use fewer pesticides and fertilisers for example.

5.6. Transition

This theme looks into the main aspects that have to be considered in the transition towards sustainable agriculture. The farmer associations explained what their role is in their opinion and what is required for a smooth transition.

5.6.1. Variability

Because climate change impacts farmers in different regions in Europe differently there is a variability of current farming methods and variability of changes that farmers have to make to transition towards sustainable agriculture. In addition to this the Swedish farmer association points out that the variability of the weather conditions within a region will increase, *"the big challenge is that the variability will increase. We will have less, we will be less able to plan because there will be real uncertainty on what will happen"* (Interview Sweden, 2021). The German farmer association points out the uncertainty for farmers in the transition process, *"the transition process takes time, it takes resources and then it's not guaranteed that the transition is successful because innovation is a lot of trial and error"* (Interview Germany, 2021). The success rate of the transition will greatly depend on a combination of the regions and policies, *"Not every country in Europe will have to do what every other country in Europe is going to do"* (Interview Denmark, 2021), *"it's different for every region"* (Interview Germany, 2021).

5.6.2. Farmer Association

The farmer association is positioned between the governments and policymakers on one side and the farmers on the other side. The Swedish farmer association states *"our job is to influence"* (Interview Sweden, 2021). One of the main focuses of the Swedish farmer association is research, *"we are trying to be part of research teams as reference groups so that the research is actually applicable"* (Interview Sweden, 2021). The reason for this is *"often one of the challenges is that people come up with great ideas, but then they haven't really thought out who should use this? Why would they use it? How should they use it?"* (Interview Sweden, 2021). The German farmer association sees their function to be a voice for the farmers, *"farmers don't get asked enough about what they need, what they require, what's possible for them"* (Interview Germany, 2021). This would make the farmer association the cumulated voice of the farmers in the region. In Bulgaria the farmer association thinks their job is to influence both groups and thus also the farmers, *"we have to educate the farmers"* (Interview Bulgaria, 2021).

5.6.3. Research

Research plays an important part in the transition towards sustainable agriculture in Europe. Due to the variability of weather conditions in Europe the research has to focus on different aspects and regions. The Swedish farmer association thinks it would beneficial to use pilots, *"these pilots we were talking about, actually check it out, see what works, how it works when it works under what circumstances and what are the challenges that come with it"* (Interview Sweden, 2021). This would make the research more focused on practicality and less theoretical. In Germany the farmer association sees a structural problem in the relationship between research and implementation, *"if you find out that in theory they could innovate, but then why do they not innovate? Maybe the systematic problem is not the farmer"* (Interview Germany, 2021).

5.6.4. Technology

The research that is done leads to technological innovations. These innovations are tools that can be used in the transition towards sustainable agriculture in the European Union. The Belgium farmer association sees this as one of the most important tools in the transition, *"the key is to ensure that you have a pipeline of different innovative options"* (Interview Belgium, 2021). Technological innovations can be difficult for old school farmers, the Bulgarian farmer association mentioned *"we have to make changes in the farmers' technologies and systems, we have to do it step-by-step, very gradually, very slow"* (Interview Bulgaria, 2021). The technological innovations are important tools but are not enough, the Swedish farmer association points out that the system around the technological innovations is just as important, *"the research community sees agriculture as mainly natural science challenges, but it's often not technical problems. It's rather finding the right governance systems so that these technological innovations can be put to use. You have to have the right incentives and legal systems"* (Interview Sweden, 2021). The technical innovations are tools that are part of the transition, but require a system that promotes the use of these technical innovations.

5.6.5. EU Policy

The policies from the European Commission determine how the budget that is available for agriculture is used. The goal of the policies is to achieve a sustainable transition towards sustainable agriculture in Europe. The farmer associations see some issues with how the policies are made. The Swedish farmer association mentioned *"I don't think that sort of trying to push sustainability down on farmers by* *enlightened bureaucrats will be the way forward. No, you need to build this from below and I think there's a huge opportunity there"* (Interview Sweden, 2021). This view is in line with the view of the Belgian farmer association who mentioned *"it is completely lost in all of this debate that farmers know better than the rest of us about climate change"* (Interview Belgium, 2021). The farmer association from Bulgaria pointed out the importance of the policies for the next years, *"if we want to involve more people in such practices that are improving the soil, making them more sustainable or make them more resilient to climate change then we have to support them mostly in this transition period that is needed to make the change"* (Interview Bulgaria, 2021). The transition period will be important in the transition of farming methods, this will mean new technology and learning about the new method by the farmers. The Spanish farmer association thinks there are too many policies that limit farmers in the choices they have, *"agriculture and farming need to be managed the same way as the rest of the business in the market. It is absurd to do it differently"* (Interview Spain, 2021).

5.7. Technology

The technology theme looks into two examples of different technologies, these two examples are based on the two types of farmers. One of the examples is focusing on advanced technology, the other example minimises the use of technology. Hydroponics is an option that requires major investments and focuses on technology. The genetics sub-theme is an example of a technology that already exists and is used outside of Europe but not yet in Europe.

5.7.1. Hydroponics

Hydroponic farming is a farming method that does not require soil, instead, the nutrients are added to water and go directly to the roots of crops. Commercial hydroponic farming often happens in climate controlled greenhouses through an automated process. In this way the crops or not impacted by extreme weather conditions, however, setting up a hydroponic farm is expensive. The Swedish farmer association sees opportunities for hydroponic farming, *"it's excellent, but I don't think that we should see that as the solution. It's one beautiful piece of a very integral puzzle and we should use it where it works"* (Interview Sweden, 2021). The Czech farmer association agrees that hydroponic farming can be useful, *"for some types of production hydroponic farming could be a good option"* (Questionnaire Czech Republic, 2021). The farmer association in Belgium stated *"I think hydroponic farming is a fantastic example of how you can evolve"* (Interview Belgium, 2021). There are also some problems with hydroponic farming, *"it's quite sensitive and requires a lot of investment, both in money and time, and technology to make it work"* (Interview Sweden, 2021). Additionally there is the problem of the electricity that is used in hydroponic farming, *"there is a problem with hydroponics, because it sucks up a ginormous amount of electricity. So the hydroponic equation is about ensuring that you have sustainable energy input into your hydroponic farm"* (Interview Belgium, 2021).

5.7.2. Genetics

There are other options than new technical innovations to make crops more resistant to the changing weather conditions. One of these options is genetically modifying the crops. The Danish farmer association mention *"I think you would see, over the next years, a more lean stance on certain parts of how you can genetically modify plants"* (Interview Denmark, 2021), meaning that the Danish farmer association expects that people will be less opposing towards genetically modifying crops. The Spanish farmer association explained the process, *"Genetically modified organisms GMOs means the introduction of an external gene in order to make the plant more resilient to new conditions"* (Interview Spain, 2021). They explained the following benefits, *"genetics linked to biotechnology is what could lead us to obtain plants that are more resistant and resilient to weather changes, plagues and water-scarcity"* (Interview Spain, 2021). The Belgian farmer association gave an example of the benefits of gene editing, *"you might get an analogy between Spain and Portugal and lack of precipitation, different to New Mexico and California in the US that could have crops growing year round because they are genetically modified to be able to grow in conditions with less precipitation"* (Interview Belgium, 2021).

5.8. European Commission

The previous themes were based on interviews with farmer associations, this theme is based on the interview with the European Commission. All quotes in this theme are quotes from the European Commission and represent their views and experiences. When the main results from the interviews with the farmer associations were presented to the European Commission, the response was: *"I think it's quite a fair assessment. The point on different options, I think that's very fair. Absolutely. The communication yes. It is probably not always ideal"*. This refers to the need for different options in different parts in Europe for the transition towards sustainable agriculture and the current issues with the communication that lead to theoretical options that are not applicable due to practical constraints.

5.8.1. Climate Change

The European Commission is putting increasing focus on the impact of climate change on farmers. The results from the quantitative analysis are in line with the results from research done by the European Commission, which stated *"clearly you see different development in different parts of Europe. More drought in one part and more rain in others"*. Climate change is creating a need for farmers to change, because *"the variability is increasing"* and *"you need to improve your resilience"*.

5.8.2. EU Policy

Climate change and sustainability are severely impacting the policies of the European Commission. They stated *"we are really trying to make sure that the productivity is sustainable"*. When they were asked about the success of the current environmental policies for the agriculture sector they responded *"the environmental policy that we put in place in 2013 for agriculture has not been successful. One of the reasons it has not been successful is that it is not very ambitious, but also that it is not well adjusted to the local circumstances"*. To change this in the future they state *"we want the strategic plans to be matching the local challenges"* and the plan to make it happens is *"we talk continuously to farmers, for all our policy proposals"*. The main instrument that the European Commission has is the common agricultural policy (CAP), *"CAP is a subsidy instrument. It's basically a big pot of money that can help address certain challenges by giving money"*. Currently *"we have about 6.8 million beneficiaries of CAP"*. When the European Commission was asked where they see room for improvement to make sure the new policies will be more successful they responded *"should we cooperate more at the local level? Yes. And does the common agricultural policy help to create this local cooperation? Yes. But that is all through the subsidy instrument"*. Furthermore they pointed out, *"we are really trying to listen and work with the farm organisation, but we're also a public administration. When a farm association comes to us, they are lobbying us, so we treat them as very serious, but we treat them according to rules for lobbying"*.

5.8.3. Transition

The European Commission has two main worries when it comes to the transition towards sustainable agriculture in the European Union. The first one is education, *"I think that education for farmers is key"*. Changing farming practices requires educating the farmers in how the new farming practices work. The second point is the investment that is necessary, *"to change the way you do your business is scary, it's uncertain. Are you going to make money by making these changes because changes often also mean investing and getting a loan from the bank. Can you pay that back? Because the return on investment in farming is extremely low"*. This large investment in combination with the uncertainty slows down the change towards sustainable agriculture.

5.8.4. Technology

The European Commission is currently looking into hydroponic farming and gene-editing. They see possibilities for hydroponic farming but also mentioned: *"we only pay subsidies for agriculture on land"*. Hydroponic farming is farming without soil and above the ground and thus *"the area based subsidies don't go to people growing on hydroponics"*. When the benefits of gene-editing were brought up the European Commission stated: *"we're going to review and change the authorization rules with the idea to facilitate access for seeds made using that technology"* and the reason for it is *"this change of policy on new breeding techniques, because we want to use the latest technology to improve seeds and varieties that are on the market"*.

6. Discussion

The goal of the European Commission is to transition towards sustainable agriculture in the European Union by meeting the targets for 2030 and 2050. The main tool the European Commission has is a big jar of money that they use to subsidise farming methods or technologies. The European Commission has been focusing on the efficiency of subsidising different technologies, however, there has been a problem with the effectiveness of the policies. This lack of effectiveness of the policies resulted in not meeting the reduction in emissions and natural resource depletion targets of the Green Deal and Paris Agreement. It is important to improve the effectiveness of the policies and subsidies, so that the end goals of the Green Deal and Paris Agreement will be met. The interviews that were done for this thesis show that some changes in the policies would increase the effectiveness of the policies. The four main aspects that came forward in the interviews were research, technology, financial sustainability for farmers and climate change resilience.

It is important to take climate change into account when making new policies. The quantitative analysis showed how different parts of Europe are impacted differently by climate change and that farmers must prepare for different forms of extreme weather conditions. Furthermore, the quantitative analysis showed how the variability and uncertainty increased in the last 20 years. These findings were confirmed by the farmer associations, which pointed out the danger of extreme weather conditions for crop yield. It is unlikely that climate change will stop tomorrow or next year and thus farmers will have to prepare for even more extreme weather conditions.

The next major aspect to focus on is the financial sustainability of the farmers. If the policies solely focus on theoretical efficient policies and do not take the financial sustainability of the farmers into account, then there will not be sustainable agriculture. The farmers must be able to make money from farming, otherwise they will go bankrupt or choose to stop farming. Another important aspect here is the current cost of investment for new technologies, the return on investment is low in agriculture. The high investment cost, low return on investment and uncertainty about the future lead to postponing of investments in new technologies.

The postponement of investment in green or precision technologies slows down the transition towards sustainable agriculture. By using investment subsidies, the European Commission can speed up the transition towards sustainable agriculture because it takes away the problems of the high investment cost and low return on investment that the farmers are facing. Because of the large variety of problems and preferences of farmers there is not one technology that will be the perfect solution for every farmer in each region. Therefore, it would be useful for the European Commission to make a list of technologies, for different geographical regions, that are efficient enough for them to consider subsidising. Currently there is a general list, but this list does not take local constraints into consideration. The conversations with the farmer associations will reveal which technologies will be effective in each region. The

European Commission can then make a final decision on which technologies they subsidise in each region while having an indication of the efficiency and effectiveness of the policies and subsidies. This would give the European Commission more information and enable them to meet the targets from the Green Deal and Paris Agreement.

All farmer associations and the European Commission agreed on the importance of research. Research can help in improving the climate change resilience and in adding new green or precision technologies to the suggested technology list for the European Commission. However, there seem to be some issues with the current form of research. Farmers are not always involved in the research or are involved in a late stage. According to the farmer associations this lack of involvement of the farmers lead to theoretical solutions coming out of the research. But these theoretical solutions do not work for farmers because of practical reasons and in the end nothing changes. The farmers are aware of the practical implications that academic researchers are often unaware of. Involving the farmers in an early stage could be seen as adding parameters in the early stage. These additional parameters can change the optimal outcome and with it the suggested policies or technologies. The farmers would not do the research or try to solve the theoretical aspects, they would instead point out the practical issues and make sure that the findings are applicable for farmers.

The theoretical part on subsidies pointed out the importance of externalities, the problem of free-riders and the importance of additional market penetration. Transitioning towards green or precision technologies has positive externalities for society. Because of the positive externalities it would be good to subsidise these technologies. The high investment cost is a reason to choose an investment subsidy, but there are more reasons. When green or precision technologies decrease the variable cost, due to a decrease in input, and improve the yield of the crops then there are more profits for the farmers. When the farmers have a higher income out of their farming practices, then the European Commission can decrease the income support. Furthermore, an investment subsidy guarantees change, because the subsidy is only paid when a farmer changes to a technology that is on the technology list of the European Commission. However, the investment subsidy will not eliminate the free-rider problem. The farmers that would have made the investment without a subsidy will be the free-riders in this case. Thus, there will still be free-riders, but here it is important to realise that the goal of the European Commission is to transition towards sustainable agriculture and not set up a perfect subsidy system. All the free-riders in the setting of investment subsidies are still part of transitioning towards sustainable agriculture and achieving the goals of the European Commission. The theoretical part of subsidies pointed out the importance of additional market penetration for the subsidy to be considered successful. Both the farmer associations and the European Commission acknowledged the postponement of investment due to high investment cost and financial risk for farmers. The investment subsidy will lead to additional market penetration because these farmers will no longer postpone the required investment.

6.1. Future Research

This thesis ends with the advice for the European Commission to create a green and precision technology list with all the technologies that they would consider subsidising. It is important that the list is adjusted to the different local constraints and that the list is continuously updated. Academia and farmer associations can both have valuable input in this list of technologies. Involving both groups will assure that the list consists of efficient and effective technologies. Because academia can examine the efficiency of technologies and farmer associations will be able to give an indication of the effectiveness of the different technologies in their specific regions. By looking at both the efficiency and effectiveness of the technologies the European Commission can decide on which technologies they subsidise in each region and have a high probability of meeting the targets and goals for 2030 and 2050.

For future research the taxation that was discussed in the theories setting of this thesis could be interesting. The problem with taxation is that the national governments decide on the taxes that apply to the local farmers. It could be interesting to examine how the European Commission can work with the national governments to change the taxation format for farmers in a way that would benefit the transition towards sustainable agriculture and how the government could re-invest this tax revenue in the sector as in done in Denmark according to the Danish farmer association.

7. Conclusion

With the Green Deal and the Paris Agreement there has been an increasing focus on becoming sustainable in Europe. Agriculture is no exception and to transition towards sustainable agriculture in the European Union, the European Commission has set targets for 2030 and 2050. The main tool that the European Commission has in achieving a sustainable agriculture sector is the ability to subsidise. Currently most of this subsidy is used as income support and not to create incentives to transition towards green technologies or precision technologies. The money that is used to create incentives for farmers to transition is based on the efficiency of the technologies. The problem here is that due to a lack of effectiveness the current measures and CAP have been unsuccessful. In a transition or change process the success of the transition or change stands or falls with the people implementing the change. Efficient policies will not lead to changes if the people who need to implement the change, the farmers, choose or are not able to implement the changes.

To improve the effectiveness of the changes the European Commission could talk to the farmer associations. As is pointed out in the quantitative analysis, climate change impacts different parts of Europe differently. Therefore, the different parts of Europe need different solutions in their transition towards sustainable agriculture. The farmer associations are aware of the common issues and wishes of farmers in their region. Because they have this information, they can inform the European Commission which policies and technologies will be effective in their region. The interviews that were done for this thesis already show some issues that are experienced by some of the farmer associations, but the interviews also found some contrasting views. In the conversation with the farmer associations, it is important that the European Commission has a list of which farming methods and technologies they are willing to subsidise. This would lower the lobbying power of the farmer associations. Furthermore, by talking to the farmer associations about which technologies would be effective in their regions would lead to more information for the European Commission. Because farmer associations will have to reveal the collective type of the farmers when they request subsidies for preferred technologies.

This thesis examined the investment subsidy option for the European Commission. Choosing an investment subsidy instead of a production subsidy has multiple benefits. By choosing for an investment subsidy the farmers that are postponing the investment due to insufficient funds will now make the required investment and thus the subsidy will lead to additional market penetration. By using investment subsidies for precision technologies, the variable costs for farmers will decrease, when farmers have more profits the income support can decrease. Decreasing the income support would mean that additional funds can be spent on research or investment subsidies. Additionally, income support creates a disincentive for change so a decrease in income support will speed up the transition process. For the type of farmers that do not like advanced technology, it would be an option to focus on genetically modifying crops. Here the European Commission could consider using input subsidies if necessary.

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Appendix

In figures 11 and 12 the smaller figures are the monthly results for each year. The first digit above the smaller figures take the value 1 for Northern and 2 for Southern Europe. Every dot in the figure represents a month in both figure 11 and 12, the months are displayed on the x-axis and the value for temperature or precipitation on the y-axis.

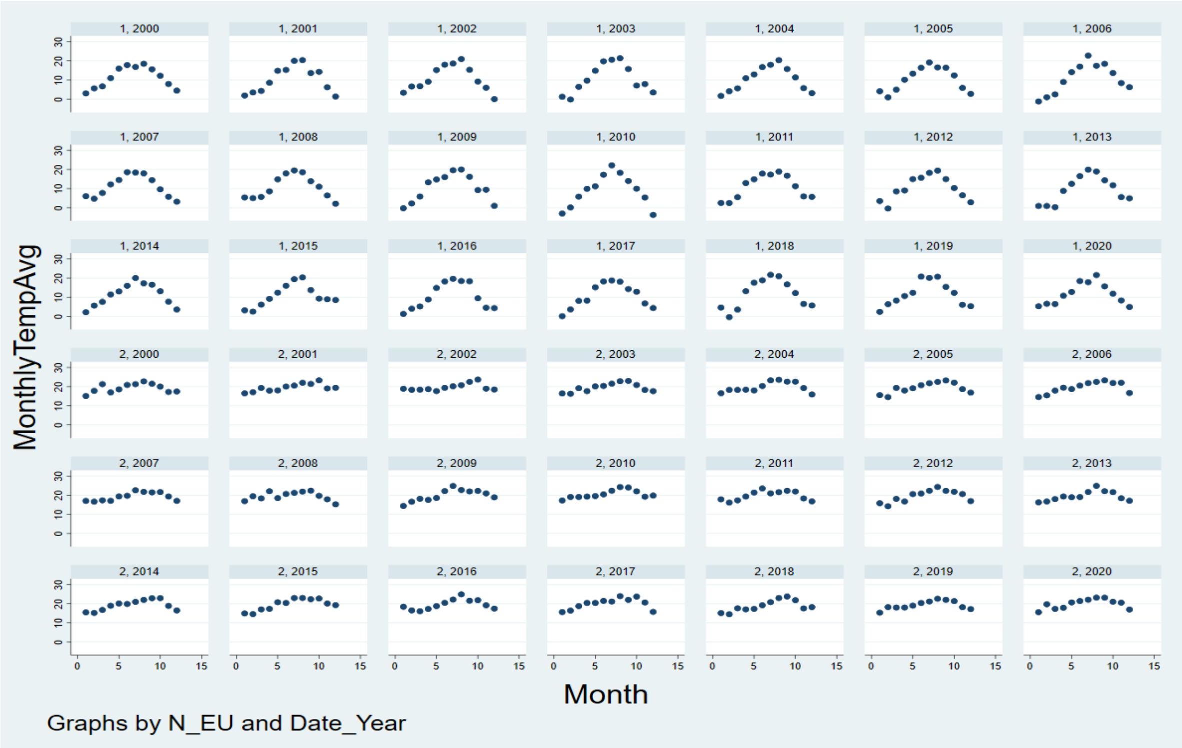

Figure 11: Temperature Monthly Variation

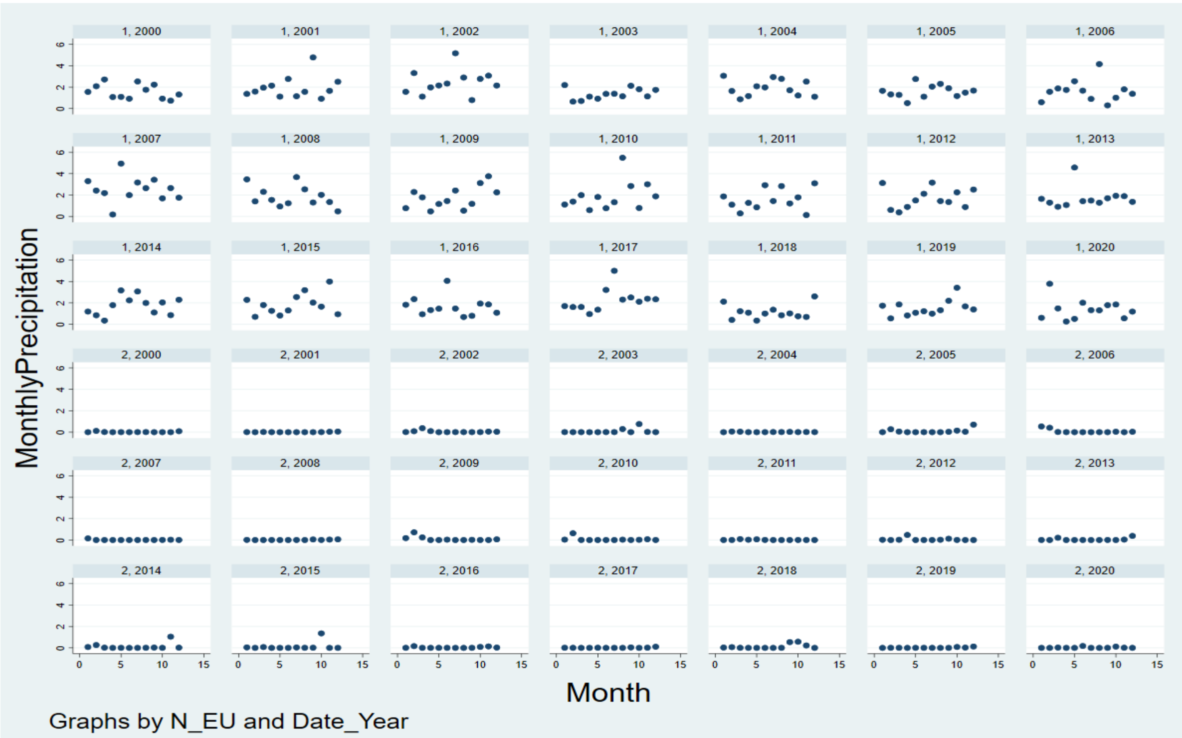

Figure 12: Precipitation Monthly Variation

Monthly Temperature Variation

Table 7: Temperature Changes Northern Europe Monthly

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
February	.798	.798	.368	-.187	.848	2.249
March	5.217	5.217	4.093	5.871	5.669	5.459
April	11.693	11.693	11.043	12.272	12.503	11.085
May	17.562	17.562	16.640	18.113	18.840	16.838
June	21.558	21.558	20.324	22.386	22.567	21.204
July	24.493	24.493	24.171	25.225	24.826	23.814
August	23.051	23.051	22.237	23.856	23.582	22.690
September	18.421	18.421	17.480	18.967	19.241	18.182
October	12.407	12.407	11.649	13.172	12.761	12.196
November	6.831	6.831	5.901	7.409	8.184	6.016
December	2.391	2.931	.424	2.782	3.937	2.814
Constant (January)	-6.783	-6.783	-6.212	-7.427	-7.412	-6.197
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**

Table 8: Temperature Changes Southern Europe Monthly

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
February	1.377	1.377	1.166	1.814	.16	2.411
March	4.995	4.995	5.093	5.276	4.25	5.341
April	8.95	8.95	8.612	9.223	8.791	9.242
May	13.257	13.257	13.115	13.411	13.109	13.42
June	17.345	17.345	17.158	17.666	16.815	17.779
July	19.936	19.936	19.839	20.211	19.574	20.14
August	19.835	19.835	19.653	20.099	19.515	20.108
September	15.969	15.969	15.666	15.947	15.917	16.406
October	11.216	11.216	11.258	11.338	10.84	11.417
November	5.645	5.645	5.547	6.004	5.463	5.586
December	1.452	1.452	1.079	1.742	1.182	1.882
Constant (January)	5.261	5.261	5.08	4.961	5.663	5.378
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**

Regressions Including Control Variable

Table 9: Temperature Changes Southern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
Weighted Yearly Trend	.063***	.043***	-.083***	.126***	.185***	.110***
Windspeed Average	1.564***	-.359***	-.299***	-.334***	-.699***	-.509***
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**
Adjusted R-Squared	**X**	**.313**	**.3168**	**.3067**	**.2986**	**.2987**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Table 10: Temperature Changes Northern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
Weighted Yearly Trend	.045***	.044***	.184***	-.369***	.232***	.440***
Windspeed Average	-.895***	-3.731***	-4.511***	-4.052***	-4.649***	-5.478***
WS Fixed Effects	NO	YES	YES	YES	YES	YES
Observations (n)	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**
Adjusted R-Squared	**X**	**.2101**	**.2348**	**.1783**	**.2179**	**.2561**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Monthly Precipitation With OLS Regression

Table 11: Precipitation Changes Northern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
February	-.177	-.135	-.157	-.177	-.381	.004
March	-.282	-.226	-.341	-.113	-.44	-.223
April	-.357	-.296	-.383	-.392	-.31	-.339
May	.016	.011	-.024	.167	.095	-.167
June	.342	.219	.344	.228	.504	.293
July	.508	.310	.469	.58	.469	.519
August	.42	.263	.3	.659	.449	.298
September	.289	.188	.19	.301	.341	.344
October	.411	.258	.349	.488	.387	.433
November	.266	.175	.193	.537	.216	.134
December	.142	.097	-.062	.105	.415	.151
Constant (January)	1.397	.397	1.398	1.306	1.422	1.46
WS Fixed Effects	NO	YES	NO	NO	NO	NO
Observations (n)	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**

Table 12: Precipitation Changes Southern Europe

Temperature Average	(1)	(2)	(3)	(4)	(5)	(6)
February	-.095	-.074	-.157	.055	-.131	.136
March	-.11	-.087	-.146	-.039	-.219	-.03
April	-.165	-.133	.039	-.225	-.235	-.28
May	-.118	-.093	-.152	-.137	-.15	-.0.28
June	-.346	-.301	-.397	-.311	-391	-.272
July	-.576	-.568	-.412	-.599	-.67	-.656
August	-.61	-.614	-.407	-.577	-.729	-.765
September	-.297	-.253	-.182	-.183	-.341	-.507
October	.049	.036	.172	.099	.013	-.111
November	.192	.135	.344	.153	.031	.211
December	.084	.061	.256	.178	-.229	.095
Constant (January)	1.329	.589	1.398	1.311	1.442	1.4
WS Fixed Effects	NO	YES	NO	NO	NO	NO
Observations (n)	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**

Regression Including Control Variable

Table 13: Precipitation Changes Northern Europe

Precipitation Average	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature Average	.029***	.028***	.021***	.023***	.022***	.026***	.020***
Weighted Yearly Trend	.006***	.006***	.003***		(omitted)		
Windspeed Average	.19***	.293***	.183***	.190***	.254***	.226***	.226***
WS Fixed Effects	NO	YES	YES	YES	YES	YES	YES
Observations (n)	**2,775,780**	**2,775,780**	**2,775,780**	**793,080**	**660,900**	**660,900**	**660,900**
Pseudo R-Squared	**X**	**X**	**.0871**	**.0843**	**.0932**	**.1029**	**.0881**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

Table 14: Precipitation Changes Southern Europe

Precipitation Average	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Temperature Average	-.048***	-.024***	-.020***	-.018***	-.021***	-.017***	-.025 ***
Weighted Yearly Trend	.008***	.009***	.008***		(omitted)		
Windspeed Average	-.16***	.093***	.072***	.100***	.094***	.082***	.106***
WS Fixed Effects	NO	YES	YES	YES	YES	YES	YES
Observations (n)	**2,870,126**	**2,870,126**	**2,870,126**	**820,286**	**683,280**	**683,280**	**683,280**
Pseudo R-Squared	**X**	**X**	**.2464**	**.2459**	**.2497**	**.2439**	**.2590**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level