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Free and green

The effect of decoupling CAP on emissions

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Abstract

The Common Agricultural Policy is one of the most important policies within the European Union. However, the support from CAP have had some unexpected consequences for the environment. Major changes were made in 2003 regarding the way payments were given to farmers, in order to reduce the environmental impact of agricultural production. The support was made decoupled, which basically meant a greater freedom for European farmers. A freedom CAP was hoping would encourage more environmentally friendly practices and reduce greenhouse gas emissions.
This study investigates whether this decoupling process managed to reduce emissions of greenhouse gases per agricultural hectare, and whether the growth of organic farming had any further influence. There are studies comparing organic versus conventional farming but there are no published studies on the link between the 2003 CAP reform and greenhouse gas emissions. This paper is an attempt to clarify the issue by doing a multiple regression analysis with data collected from FAOSTAT involving 20 European countries and 23 non-European countries during the years 2004–2010. The results point towards that the 2003 CAP reform did have a mitigating effect on emissions, whereas organic farming could not be proved to have the same impact. This suggests that a decoupled support system may have been a step towards more sustainable and less environmentally harmful agriculture within Europe.

Keywords: *Agriculture, environment, greenhouse gas emission, CAP, 2003 reform, decoupled support, organic farming*

Content

1. Introduction

The Common Agricultural Policy, namely known as CAP, arose from the ashes of 2nd World War and it is therefore one of the oldest and largest, as in budget terms, policies within the European Union. The purpose of a common policy was primarily to increase productivity and stability for European farmers, to ensure them a fair standard of living and provide affordable food for the rest of the population. Some of its strategies nonetheless accidentally led to overproduction such as food-mountains of excess supply, and environmental degradation such as increased emissions. These quite disastrous consequences were largely an outcome from intensive, excessively pollutant production techniques supported by CAP.

In the beginning of the 90's, CAP took its first steps towards a more market oriented and market sensitive support system, and less focus on output levels of production. This development from a coupled to decoupled support system was fulfilled with the 2003 CAP reform, introducing a Single Payment Scheme (SPS) and Single Farm Payment (SFP), which were somewhat fundamental changes. The reform was implemented two years later, in 2005. Also, environmental matters were emphasized to a larger extent than before, for example by imposing the criteria that supported land must be kept in 'good agricultural and environmental conditions' (Brady 2010, p 1) which lead to, among other things, that the interest in organic farming increased.

The introduction of the Single Farm Payment completely removed the linkage between support and output levels of agricultural production, hoping that this would give farmers the ability to afford the use of less intensified but more environmental-friendly production techniques. Did this change in the policy toolbox have any impact on greenhouse gas emissions per hectare agricultural area? This is one of two questions I will investigate in this thesis. I chose to zero in on greenhouse gas emissions because it captures one of the most vital aspects for climate change, and therefore for future generations, and because there seems to be no earlier studies on this specific topic, which is surprising considering its relevance. A fundamental assumption for this paper is that reduced emissions of greenhouse gases improve the prospects for the environment. The second question I will investigate is whether the share of total agricultural area committed to organic farming versus conventional farming has had any significant impact on emissions per hectare during the studied time period.

To do this analysis, I looked into data provided by the Statistical Programme of Work by the Food and Agriculture Organization of the United Nations, called FAOSTAT. I made a selection of 20 European countries and 23 non-European countries between 2004 and 2010 for making a pre-post analysis. I examined the impact of the decoupling process in Europe versus the impact of the organic share on emissions by doing a multiple linear regression analysis.

The hypothesis was that the reform would have had a mitigating effect, meaning that a more decoupled support actually did lower greenhouse gas emissions per hectare agricultural area in the European countries. Then I added the share conventional farming out of total agricultural area to investigate whether the organic aspect had any significant effect or not. The hypothesis here was that a smaller share conventional farming would not lead to lowered greenhouse gas emissions per hectare as distinctively as the reform would.

The essay is structured as follows. Firstly, a short historical background to the Common Agricultural Policy is presented. Then a brief discussion about the link between agricultural intensification and the phenomenon of greenhouse gas emissions follows. In this first section I will also explain the central elements of the 2003 CAP reform towards decoupled support and discuss organic farming, including some of the concerns associated with it. To be able to do this, I'll use a few carefully chosen articles and research studies. Naturally, this is a very complex issue and thus there are numerous factors and aspects that will not be included in this study. This theoretical section is followed by a presentation of the data and choice of sample, and also a description of the variables. I will then account for my empirical approach and the details of my method. Ultimately, I will demonstrate my results from the regression analysis and discuss the outcome in a conclusion.

2. CAP and emissions

This section firstly gives a background to CAP, which will be followed by an explanation of agricultural intensification. Secondly, I will describe the decoupling reform that was formed in 2003. Thirdly, this section is ended with a short discussion about organic farming and a table of content summary.

2.1. Short history of CAP

The Common Agricultural Policy, usually known as CAP, celebrated its 50th anniversary in 2012 and it is therefore one of the oldest policies within the European Union. The outlines of the policy were initially drawn in 1957 at the Treaty of Rome. However, it was not until five years later that the very first version of the common agricultural policy was settled and signed (European Commission 2012, p 3). There were many reasons behind the creation of a common agricultural policy and they were outlined in the five objectives of the CAP. The first objective was basically to increase agricultural productivity, which was very low after the war. The second objective was to provide a minimum standard of living for farmers. The last three objectives were about reducing fluctuations in prices of agricultural goods, to ensure farmers self-sufficiency and to offer affordable food for all European citizens (Massot 2015).

Rural areas in most European countries suffered from deep poverty after the 2nd World War. One could say that the European Union itself arose from the ashes of the wars in the 20th century and that CAP was one big step closer to the mutual goal: that the people of Europe would not have to starve ever again. Moreover, this was an approach that wished to diminish reasons for new conflicts (European Commission 2012, p 4).

In the beginning, CAP was used as a market-control instrument. Through market interventions, trade barriers and tariffs, farm income and profit rose thanks to high internal prices. The linkage between the prices of agricultural products led to a domino effect and a biased pattern of production. The reduced risk of falling prices along with higher land rents increased the incentives to invest in agriculture and to have more specialized farms (Baldwin and Wyplosz 2009, ch.12).

Simultaneously, technology and farming methods were improved to such a large extent that the EU went from being a net importer to being a net exporter, ironically known as the 'green revolution' (Baldwin and Wyplosz 2009, p 360). This went on and on, and eventually European countries were over-exploiting natural resources, resources they themselves were strongly dependent on (Schmid et al. 2005, p 598).

Since the support from CAP depended on production levels, the increased productivity led to higher support. The idea of supporting small, poor farmers did therefore not occur as intended. Instead, money was given to farms that were already wealthy and had potential to grow. Eventually, European farmers produced too much, creating so-called "food mountains" in the 1980's, which CAP tried to solve through intervention buying and export subsidies (ibid). Nowadays, however, we know that subsidies correlated to production often generate even more spillovers and decrease overall welfare, and the OECD (Organization for Economic Co-operation and Development) even classified production subsidies as environmentally harmful (Schmid et al. 2005, p 596). Research has shown that subsidies increase agricultural intensification (Keys and J. McConnell 2005, p 329), which we will discuss further in the next section.

2.2. Agricultural intensification

Before we move on to the 2003 CAP reform, it is appropriate to discuss the agricultural intensification that eventually led to the reform. Agricultural intensification is a compound process but it basically refers to increased inputs per unit area and increased output per input, and/or reduced time of natural processes. Due to progress in science and technology, agricultural outcome has shifted from being dependent on biological and natural conditions, to being more managed by human force (Keys and J. McConnell 2005, p 321-322).

During the last third of the 20th century, the total agricultural production in the world doubled and the trend does not show any signs of turning. This is mainly due to a larger part of the land devoted to agriculture. It is even claimed by some that our actions have changed the surface of the Earth to such a large extent that it is nowadays completely distorted by us humans (Keys and J. McConnell 2005, p 320). Indeed, there is a proven link between changes in the surface of the Earth and climate change. But there is more to it: increased food production per land area due to higher efficiency has had a huge impact on emissions as well. This could for example involve cultivating the land multiple times a year with different crops, which leads to further agricultural intensification (Keys and J. McConnell 2005, p 325).

Potential dangers from this agricultural intensification are erosion, nutrient depletion and carbon loss in soils, agro-chemicals and more emissions of greenhouse gases per hectare agricultural area, partly due to increased used of fossil fuels for machines and enlarged industries (Keys and J. McConnell 2005, p 321). Other threatened areas are for example water and air quality, conservation, biodiversity, wildlife habitats and landscape values (Schmid et al. 2005, p 599). Highly polluted water supplies are a severe problem for European countries, because not only does it reduce aquatic biodiversity; it can also be very dangerous to human health (Baldwin and Wyplosz 2009, p 365).

Obviously there are many important environmental concerns strongly linked to agriculture and the intensification of it. In this essay, however, I have chosen to focus on emissions of greenhouse gases (GHG) caused by agriculture, expressed as CO_2-equivalent, since it is one of our main concerns when coping with environmental sustainability and climate change, nonetheless when considering the focus of the recent global climate meeting in Paris 2015. To give an example of its importance, the World Meteorological Organization posted in a press release in November 2015 (WMO 9/11-15) that "*the amount of greenhouse gases in the atmosphere reached yet another new record high in 2014, continuing a relentless rise which is fuelling climate change and will make the planet more dangerous and inhospitable for future generations*." Additionally, the Secretary-General of the organization, Michel

Jarraud, in the same press release said that: "*Every year we say that time is running out. We have to act NOW to slash greenhouse gas emissions if we are to have a chance to keep the increase in temperatures to manageable levels.*" (ibid). Moreover, reports have shown that "*agriculture is the single largest contributor to greenhouse-gas-pollution on the planet*" (Gilbert 2011, p 7).

The details about the consequences of greenhouse gas pollution such as global warming are beyond the scoop of this paper and left to other researchers. Therefore, a fundamental assumption for this paper is that reduced GHG emission improves the prospects for the environment. The purpose of this study is rather, as mentioned earlier, to investigate whether the 2003 CAP reform did or did not affect the amount of emissions per hectare agricultural area and if the organic versus conventional share had any further impact. I shall, nevertheless, explain what signifies GHG emission since this is the content of the data material used in the study.

From the agricultural sector, the largest contributors to greenhouse gases are methane (CH_4) and nitrous oxide (N_2O). These emissions primarily come from biological processes in livestock and crop production, mainly through enteric fermentation, manure management and agricultural soils. Emissions connected to the agricultural sector can also come from manufacturing industries, energy use and input production such as mineral nitrogen and fodder. Emissions from land-use-changes, mostly carbon dioxide (CO_2) from forestry and clearing for new farmland, are usually not included when reporting and discussing emissions caused by agriculture (Jordbruksverket 2012, p 3-4), which also applies to the data on emissions used in this essay. The reason is that it often becomes too complicated to perform calculations that include changes in use of land (Kirchmann et al. 2014, p 123). When we speak of GHG emissions from agriculture, it is therefore quite common to exclude carbon dioxide. Emissions from methane and nitrous oxide are however most of the time expressed as CO_2-equivalent in order to facilitate comparison and comprehension. A fully description of how this conversion is made can be found in 3.1. Variables.

2.3. The 2003 reform: Decoupled support

We shall now move on to how CAP concretely tried to solve its problems in the end of the 20th century, and how a more sustainable development in Europe was to be encouraged. The movement towards a support system that was decoupled from production output started with the McSharry reform in 1992. Payments were made directly and partly decoupled, dependent on the quantity of cattle or hectares of land, based on the farm's historical average production rather than the outcome for that specific year. The decoupling process continued with the Agenda 2000 reform, which also introduced 'cross-compliance conditions', an improvement of the environmental standards required to receive payments from CAP (Schmid et al. 2005, p 597). Yet, it was not until the summer of 2003 that the decoupling process was completed. CAP came to an arrangement of an additional reform, containing the introduction of the 'Single Payment Scheme' (SPS), sometimes known as 'Single Farm Payment' (SFP), that would replace previous direct payments. The reform came to power on the 1st of January 2005 (ibid) and is considered to be one of the most radical reforms in the history of CAP (Brady 2010, p 1).

Presently, the SPS is also paid per hectare agricultural land but in contrast to previous system, the support money does not vary with the production intensity or use of land. The size of the SPS is based on either what was averagely given to the farm through direct payments during the period of 2000-2002, so-called historical payments, or it could also be based on the number of hectares the year the reform was implemented and the average payment for that particular region that same year (Baldwin and Wyplosz 2009, p 372).

The SPS is given no matter the farmer's individual choices, on one condition; the land must be kept in 'Good Agricultural and Environmental Condition' (GAEC) (Brady 2010, p 2). This means that farmers from 2005 and onward have much larger freedom to individually choose what to produce and, perhaps more importantly, how. In practice, the SPS gives farmers the opportunity to stop producing on their least productive land and merely maintain it according to GAEC (Brady 2010, p 9). GAEC involves aspects such as soil protection, post-harvest land management and excessive animal feeding. Moreover, to receive the SPS, the farmer must fulfil so-called 'statutory management requirement', which embraces for example wildlife, groundwater, vulnerable zones, control of animal diseases and animal welfare (Baldwin and Wyplosz 2009, p 372).

Due to enormous protests against the reform, large exceptions were made for big industries such as sugar, wine, olive groves and milk products, to mention a few. Today though, most of them are integrated in the changes (ibid).

The expected benefits from the 2003 CAP reform were basically that the opportunity cost of using more environmentally friendly farm practices would become lower (Schmid et al. 2005, p 602). Farmers were then expected to implement less intensive agriculture and use less harmful inputs, since they no longer had to strive for great output levels as before the reform. This was hoped to lead to changes such as more grassland, less arable land and smaller cattle herds, which in turn would lead to less agricultural intensification, reduced pressure on the environment and reduced greenhouse gas emissions. Moving from conventional to organic farming might be more appealing than before. This will be discussed further in the next section. Overall, the 2003 CAP reform was expected to lower output levels and reduce surplus production within the European countries (ibid).

A large sample study made by Lobley and Butler (2010) in South West England on farmers' future plans after the implementation of the 2003 CAP reform, indicate that the policy changes only had a limited effect on farmers' decision making. Their results did nonetheless reveal unevenness in the impacts of the reform depending on different kinds of farms and farm sizes. The reform rather seems to amplify current tendencies such as the polarisation between large and small farms. This was predicted by economic models presented during the negotiations of the 2003 reform, but rather as a consequence of farmers choosing to exit the market due to the introduction of the SPS and declining returns from production (Lobley and Butler 2010).

Naturally, other factors such as differences in the returns from production and the heterogeneity of environmental, agricultural and socio-economic circumstances within the European countries influence the outcome from a reform towards a decoupled support system (Brady 2010, p 3 and 7). It is also worth to mention that the most productive, and also the most profit-making, agricultural sector is the industrial farming, which is not reliant on CAP payments. They continue to be the sector practicing the most environmentally harmful farming methods (Baldwin and Wyplosz 2009, p 374). Greenhouse gas emissions are therefore not likely to decrease in those industries merely because of a fully decoupled support system.

Since the reform was implemented not too long ago, we cannot say much about the consequences. Besides, already established environmental policies and farm support within the different member countries complicate the evaluation of the decoupling process. There are still very few studies made about the environmental impact of the 2003 CAP reform. Brady (2010, p 17) argues that the pollution risk will be fairly unaffected and that more efficient environmental policy instruments than the SPS are required in order to reduce environmental damage caused by agriculture. Brady et al. (2009, p 581) although admit that "*the decoupling reform, by breaking from production-orientated support, paves the way for a future agricultural policy that is truly committed to environmental objectives*".

2.4. Organic farming

Organic farming is thought to be one way to make today's agriculture more environmentally sustainable and improve the adjustment to climate change. A striking example of the belief in organic farming and its superiority, can be found under "Frequently Asked Questions" on the website of a working group on organic agriculture from the Food and Agriculture Organization of the United Nations (FAO) where we can read the following:

> ”***What are the environmental benefits of organic agriculture?*** *Sustainability over the long term. Many changes observed in the environment are long term, occurring slowly over time. Organic agriculture considers the medium- and long-term effect of agricultural interventions on the agro-ecosystem. It aims to*

produce food while establishing an ecological balance to prevent soil fertility or pest problems. Organic agriculture takes a proactive approach as opposed to treating problems after they emerge." (FAO 2014 Frequently Asked Questions)

Nonetheless, the opinions differ a lot regarding whether the environmental impacts of organic farming is smaller than that of conventional and there are results from research studies pointing in both directions. I will now explain and shortly discuss some of the main arguments in the debate about organic farming. It is not possible to, in this paper, additionally consider the European support system regarding payments earmarked for organic farming, and so this is left for future research.

To start with, organic farming often implicate less emission per produced product but this does not necessarily take big differences in harvest into account. One must be aware of this when choosing an appropriate measurement unit for calculating greenhouse gas emissions, so as not to favour either organic or conventional farming. Organic farming requires more land to obtain the same harvest quantity as in conventional farming, and increased land use for agriculture typically equals afforestation (Kirchmann et al. 2014, p 122). A meta-analysis of European research by Tuomisto et al. (2012, p 314) shows that, in Europe, organic farming demands about 84 % more land compared to conventional. The reasons to these astounding land requirements are principally smaller harvests and lower yielding animals (ibid). As mentioned earlier, though, calculations about emissions caused by agricultural activity that include changes in use of land are very difficult to manage and therefore quite unusual (Kirchmann et al. 2014, p 123). Nevertheless, the alternative cost of the land use is an important aspect to have in mind, since less land dedicated to farming could mean more land for example wildlife conversation or biofuel production (Tuomisto et al. 2012, p 316).

A common conception is that organic farming increase the humus content in the soil, which in turn increase the carbon sequestration, i.e. the storage of carbon in the soil. This is not proved to be completely true, though. When studies comparing organic versus conventional farming also included factors such as supplementary organic fertilizers, no intensification in carbon sequestration could be shown (Kirchmann et al. 2014, p 117).

Another wide-spread conception is that organic farming improves biodiversity and this is normally the case, although we cannot be sure organic farming is to prefer compared to conventional farming under certain regulations about biodiversity conversation (Tuomisto et al. 2012, p 316).

Regarding energy use, Tuomisto et al. (2012, p 314) discovered that organic farming had about 21 % lower energy use per unit, though this varied a lot within the sectors. They also found out that the gap between organic and conventional farming regarding greenhouse gas emission was zero. As well as for energy use, there were big variances between different sectors. For example, GHG emissions from organic milk production is usually higher than conventional because of lower milk production per animal when organic, whereas organic beef production usually is lower than conventional due to less industrial inputs (ibid). An example of a frequently used input is mineral nitrogen fertilizers, which require a lot of energy and fossil fuel to produce and which causes a lot of emissions (Tuomisto et al. 2012, p 317). This is not allowed in organic farming. Still, some argue that organic farms are relying on this kind of nutrients that were added to the soil when the area was still under conventional farming, since the nutrient level can remain for many years before going back to its natural concentration (Lee et al. 2015, p 265).

Other research also supports the argument that there are significant differences between different sectors regarding whether organic farming is preferred or not. Lee et al. (2015, p 271) consequently argue that studies comparing organic versus conventional farming's emissions of greenhouse gases should involve the type of agricultural sector and only compare the same kind of farm products.

Generally speaking, by looking into earlier research studies we can conclude that if the world would experience an extensive conversation to organic farming, this may have some positive impacts on the environment. It would nonetheless also lead to lowered production output of food, more costs and/or larger areas on the Earth devoted to agriculture. This is quite in contradiction with the increasing demand for food in the world (Tuomisto et al. 2012, p 316).

The overall conclusion seems, unfortunately one may think, to be that one's decision to choose organic agricultural products over conventionally produced ones should be due to reasons other than minimizing one's climate impact, at least according to Kirchmann et al. (2014, p 125). However, this is debatable indeed. An idyllic resolution would probably be a combination of the best from both organic and conventional farming technologies (Tuomisto et al. 2012, p 318).

A very short summary of the environmental impacts from decoupled support and organic farming can be seen more clearly in the table below.

2.5. Table of content summary

	Positive (+)	**Negative** (-)
Decoupled support	Land must be maintained in good agricultural and environmental condition. Less incentive for farmers to conduct excessive agricultural intensification.	Only limited effect due to other important factors. No published studies with empirical evidence of the effects on the environment after the implementation of the decoupling reform.
Organic farming	Increased biodiversity. Less environmentally harmful inputs. Often lower GHG emissions per agricultural area.	A lot more land required. Lower production output. Higher cost per produced unit. Often higher GHG emissions per produced unit.

3. Data

This section firstly describes the data material that constitutes the basis of the study and how the selection was made. Secondly, an explanation of the involved variables and their meanings will follow.

The data was collected from the database of Statistical Programme of Work by the Food and Agriculture Organization of the United Nations, called FAOSTAT. This database provides a wide range of statistics about most of the countries in the world during a long period of time and it is therefore a suitable choice of source for the panel data I need for my study. Other databases offer more limited datasets and besides, the Food and Agriculture Organization of the United Nations is an organization of high credibility.

The records are about each country's total agricultural area and total conventional farming area, and also two different types of greenhouse gas emission caused by agriculture, expressed as CO_2-equivalent. The first and most extensive measure is total GHG emissions from agriculture, including emissions from energy used directly in agriculture. The second kind of measure is GHG emissions from agricultural soils, which is much more narrow but nevertheless convenient to have as a complement to support the result in our analysis.

The data on emissions provided by FAOSTAT is estimated by the Food and Agriculture Organization of the United Nations itself and therefore the data does not automatically correspond to data on GHG emissions reported by member countries. As with all statistics, we must be aware of the fact that there might be estimation errors and that we should not make any definitive conclusions. The purpose of the FAOSTAT database is mainly to act as an international benchmark and to help member countries evaluate their greenhouse gas emissions (FAOSTAT Methodology 2015).

For my study, I have made a selection of 20 EU-countries and 23 non-EU countries during a period of 7 years, between 2004 and 2010 for making a pre-post analysis of the reform implemented in 2005. By having this kind of panel data we get a larger number of observations, which increases the reliability in our result.

All the information required for the 20 European countries between those years is provided by FAOSTAT. Unfortunately, for 17 out of 23 non-European countries, FAOSTAT only offers data from 2005. I decided to proceed with my analysis since these countries were not the main focus of the analysis but rather used as a reference group or a kind of benchmark, when investigating the effects of the reform on the European countries. A table of all the included countries, years and variables can be found in Appendix 8.1.

A potential problem with only having data until 2010 and no later, is that quite a few agricultural sectors not were affected by the changes in the reform until a few years after the implementation in 2005 because of large protests and powerful lobbying in those sectors, as mentioned in 2.3. Decoupled support. This might have had an influence over the data on GHG emissions used in this study, since the emissions caused by those big industries may have changed a lot since 2010 within the European countries. These aspects are not possible to consider in this thesis and are thus left for future research.

For the second part of my analysis, I will include the aspect of organic agriculture, and it is therefore important to be aware of what FAOSTAT includes versus excludes in their definition of organic area, especially since this might vary between countries and organizations. Constancy is of high importance, which motivates my decision to only use data from FAOSTAT instead of involving other databases, such as EUROSTAT. According to FAOSTAT, organic area is both agricultural area certified organic and in conversion to organic. The fully definition is as followed:

1) *"**Agricultural area certified organic**: Agricultural area exclusively dedicated to organic agriculture and managed by applying organic agriculture methods. It refers to the agricultural area fully converted to organic agriculture. It is the portion of agricultural area (including arable lands, pastures or wild areas) managed (cultivated) or wild harvested in accordance with specific organic standards or*

technical regulations and that has been inspected and approved by a certification body." (FAOSTAT Glossary 2015)

2) ***"Agricultural area in conversion to organic****: Agricultural area, which is going through the organic conversion process, usually two years period of conversion to organic land."* (ibid)

I involved the organic factor for two reasons. Firstly, it is an interesting aspect to consider since the world has experienced a shift towards a smaller share conventional production and a more positive public opinion towards organic farming. Yet, the academic opinions about the outcome of this shift differ remarkably, partly because of the complexity of the environment. Therefore, it would be of interest to see whether a smaller share conventional farming area out of total agricultural area did or did not reduce greenhouse gas emissions. Secondly, if our results regarding the impact of the 2003 CAP reform on emissions would be very different when the organic aspect was included, the link between the reform and emissions could be seen as false. The conventional share can thereby additionally be understood as a control variable in our analysis.

3.1. Variables

This study has two different measures of greenhouse gas emissions per hectare agricultural area, Y_1 and Y_2, as the dependent variable. The former one contains emissions produced by biological processes (aerobic/anaerobic decomposition) in livestock and crop production and also management activities, coming from total agricultural activity including every sub-domain. Moreover, emissions from direct energy use are included. This refers to emissions from stationary energy use, for example in buildings, and from more mobile usages such as fuel use in machines and tractors (FAOSTAT Methodology 2015). The latter one, Y_2, contains emissions directly from agricultural soils. Y_1 is, thus, covering emissions to a larger extent and stands for greater values than Y_2, which does not include total agricultural activity, nor direct energy use, but only emissions from agricultural soils.

The reason to include two different varieties of GHG emissions is that if the results point in the same direction, this will increase the trustworthiness. If the results differ a lot between these two, then the test result would be ambiguous.

Both Y_1 and Y_2 consist of methane and nitrous oxide that are expressed as CO_2-equivalent. Carbon dioxide emissions from land use changes or any other source are not included, except for CO_2-emissions from direct energy use that are included in Y_1. The conversion into CO_2-equivalent is based on the global warming potential of the gas over a 100-year time frame. 1 kilogram of methane is equivalent to 25 kilograms of carbon dioxide, while 1 kilogram of nitrous oxide corresponds to 298 kilograms of carbon dioxide (Kirchmann et al. 2014, p 112).

Then we move onto the independent variables. Firstly, there are 43 land dummies, α_{it}, that are also used as fixed effects in our regression. These are expressed as (0,1) for each country, 1 for that specific country and 0 for all other countries. Secondly, there are 7 time dummies also expressed as (0,1) for each country, 1 for that specific year and 0 for all other years.

Thirdly, I created a variable that stands for the amount of years after the 2003 CAP reform. This is called the reform trend, R_{it}, and it is supposed to capture the extent to which the reform reduced emissions over time. By using data a few years before and after the implementation of the reform, it is possible to do a pre-post analysis and investigate whether the reform had any significant impact on GHG emissions or not. R_{it} is, hence, the most important variable in our study.

The value of R_{it} can vary between 0 and 5. It is zero for all non-European countries every year and also for European countries between 2004-2005, since the 2003 CAP reform did not affect these countries and/or years – at least not directly. Then R_{it} is 1 for European countries 2006, 2 for European countries 2007, 3 for European countries 2008, 4 for European countries 2009 and 5 for European countries 2010. What is potentially problematic with this approach, though, is that when we design the reform trend to be linear (0-5), we also assume the effects of the reform on emissions to be linear as well. For future similar studies, one may consider to complement this approach with, for example, so-called recursive modelling by adding time gradually and check for changes per year, which may be appropriate when testing for this kind of regime changes.

I created a fourth and last independent variable, O_{it}, about the ratio between organic and conventional farming. The O_{it} is used in my second specification of regression where the organic aspect is taken into account. The details of the different regression specifications will be explained in the next section about the empirical approach. The O_{it} is supposed to capture whether a smaller share conventional farming area out of total agricultural area, had any significant impact on GHG emissions or not. It is calculated as $\left(\frac{total\ aea - organic\ area}{total\ area}\right)$ for each country, each year. If the result for the reform trend differs a lot when the organic aspect is included, then the credibility of the reform trend would be ambiguous.

The error term, ε_{it}, is the unobserved disturbance term and covers possible measurement errors and explanatory variables excluded in our model.

All the variables are listed with their definitions and codes in Appendix 8.2, followed by their summary statistics in Appendix 8.3.

4. Empirical approach

In this section, I will guide the reader through my methodology and empirical approach. There will be a description of the specifications made in the multiple regression analysis and also an explanation to how we shall interpret the results.

4.1. Methodology

The data and the different variables were prepared in Excel, whereas the actual analysis was made in IBM SPSS Statistics software programme, version 22. Since our task is to analyse how emissions per hectare changes due to several factors such as country, year and years passed since reform, a multiple linear regression is to prefer, as it is more compound than a simple linear regression. By choosing a multiple linear regression, it is possible to involve more than just one independent variable that we suspect have an influence over the dependent variable we are studying or examining. This means that the analysis can contain several potential causes for variation in the outcome of the dependent variable. The dependent variable is, however, still restricted to be one exclusively – in our case, emissions. Furthermore, the observations must be independent from each other and approximately normally distributed, which is generally the case when we have more than 30 observations of independent random variables due to the central limit theorem. The curious reader can find out more about assumptions and requirements when using this method on, for example, Laerd Statistics' website (link found at the end).

We assume that there are country-specific factors that are more or less constant over time and that cannot be explained within our limited model, which will generate country-specific intercepts. These time invariant characteristics may influence emissions, for instance natural comparative advantages such as soil quality, climate, and national practices and regulations. National support could be especially problematic here, since it won't matter much if payments from CAP are fully decoupled if the national support in some member countries is fully coupled to production output. Nonetheless, exactly what these country-specific variances consist of is beside the point in this paper. Still, if we do not control for these, the results would have been biased. A way to deal with this problem is by adding fixed effects to the regression. Fixed effects capture a great deal of the variance in the data material and correct for this, and they therefore typically generate high R-squares in the regression. This reduces the risk for endogenity, i.e. when an unobserved variable correlates with our observed independent variable, in this case the reform trend, and makes it look as if the reform trend stands for all the variety in the emissions, when it are actually due to the unobserved variable. In other words, by using the fixed effects model and reducing the risk of having biased results, the result from our regression becomes more reliable. If we put our land dummies (1-43) as fixed effects, we can eliminate potential differences between countries since this will allow countries to have different intercepts.

By looking at each country over a certain period of time, both before and after the implementation of the reform, we can analyse the impact of the reform by comparing with those that were not (directly) affected by it; non-European countries, that is. Hence, it is possible to make a pre-post analysis of the reform and its impact on European countries' emissions per agricultural hectare, where the values from 2004 and 2005 are seen as pre-reform and the values from 2006-2010 as post-reform.

4.2. Specification 1

In order to investigate whether the 2003 CAP reform mitigated emissions or not, I make use of the following specifications:

$$\log Y_1 = \alpha_i + \beta R_{it} + \lambda_t + \varepsilon_{it} \qquad \mathbf{(1.1)}$$

$$\log Y_2 = \alpha_i + \beta R_{it} + \lambda_t + \varepsilon_{it} \qquad \mathbf{(1.2)}$$

This specification was used twice and I named them as specification 1.1 for emission 1 and specification 1.2 for emission 2.

By using this formula for our regression, we can estimate if the reform did or did not affect the emissions of greenhouse gases (CO_2-eq) per hectare in European countries. When we run our regression, we are most interested in the estimated unstandardized coefficient B for the reform trend, because this tells us how much our dependent variable (emissions) would vary with that independent variable (reform trend) when all other independent variables remain constant. If the unstandardized coefficient for the reform trend becomes positive, this indicates more emissions per hectare, while a negative value would indicate less emissions per hectare. The hypothesis is, thus, that the reform trend would have a mitigating (negative) effect and lead to less emissions per hectare.

4.3. Specification 2

As anyone living in our part of the world probably has noticed, the interest for organic agriculture has increased considerably over the last two decades. I have not been digging deeper into the reasons behind the expanded demand for organic products. Instead, my ambition has been to investigate whether the greenhouse gas emissions per hectare changed with the 2003 CAP reform when it comes to the share of conventional versus organic area. Therefore, I've been using the value of $\left(\frac{total\ aea - organic\ area}{total\ area}\right)$ as an independent variable in my second regression. The purpose of this was to examine whether a smaller amount conventional farming had a negative impact on greenhouse gases per hectare, i.e. if emissions per hectare were reduced if a greater share of a country's total agricultural area were devoted to organic farming instead of conventional farming. In order to investigate this, I make use of the following specification:

$$\log Y_1 = \alpha_i + \beta R_{it} + \lambda_t + \delta O_{it} + \varepsilon_{it} \qquad \mathbf{(2.1)}$$

$$\log Y_2 = \alpha_i + \beta R_{it} + \lambda_t + \delta O_{it} + \varepsilon_{it} \qquad \mathbf{(2.2)}$$

$$O_{it} = \left(\frac{total\ area - organic\ area}{total\ area}\right)$$

This specification was used twice and I named them as specification 2.1 for emission 1 and specification 2.2 for emission 2.

If the estimated unstandardized coefficient B for the conventional share, δ, becomes positive, this indicates more emissions per hectare, while a negative value would indicate less emissions per hectare. The hypothesis is that a smaller share conventional farming, and thus a larger share organic farming, might decrease emissions per hectare but the trend ought not be as remarkable as the reform trend. In other words, the 2003 CAP reform ought to have a stronger, and better, impact on greenhouse gas emissions than merely an alteration towards more organic farming.

5. Results

The results from the multiple regression analysis can be found in the table below. A description of how we can understand the different values and how they correspond to our hypothesis will follow. This section also includes arguments about potential errors and misperceptions regarding the results.

Table 5.1. Results

	Specification 1.1	Specification 1.2	Specification 2.1	Specification 2.2
CAP Reform β				
Unstandardized coefficient B	-0,048***	-0,011*	-0,050***	-0,012*
Sig.	(0,000)	(0,079)	(0,000)	(0,064)
Standard error	[0,012]	[0,006]	[0,013]	[0,007]
Conventional share δ				
Unstandardized coefficient B			-0,757	-0,526
Sig.			(0,660)	(0,551)
Standard error			[1,718]	[0,881]
R^2	0,997	0,989	0,997	0,989
Adjusted R^2	0,997	0,986	0,997	0,986
Residual Sum of Squares	7,375	1,939	7,369	1,936
Residual Mean Square	0,032	0,008	0,032	0,008
Sample size	284	284	284	284
Land dummies (fixed)	43	43	43	43
Time dummies	7	7	7	7

***p<0,001; *p<0,10

Let us start with specification 1.1. The R-square for this regression is 0,997, which means that as much as 99,7 % of the variance in the dependent variable, Y_1, can be explained by the independent variables. The same stands for specification 2.1, and the other two are not far behind. One reason to why we have received such large R-squares is that we have a great amount of dummies and many predictors do, unsurprisingly, increase the R-square value. Another reason is that we have used the fixed effects (the land dummies) in our regression and these capture most of the variance in the data material, which further increases the robustness in the test.

We can also have a look at the adjusted R-square, as this might be more accurate than the non-adjusted since it modifies the value with respect to the number of independent variables in the regression. For both specifications 1.1 and 2.1, the adjusted R-square is the same as the non-adjusted, 0,997. For specifications 1.2 and 2.2, however, the adjusted R-square is marginally smaller than the non-adjusted. An explanation could be that emission 1 is covering emissions to a much greater extent than emission 2 since the former also includes energy use. Consequently, the values for emission 1 are considerably larger and constitute a better database for analysis. Therefore, when doing the regression with emission 2, both R-square and adjusted R-square is somewhat lower than for emission 1.

When it comes to the residual sum of square and mean square, these tells us how good our model fits the data by measuring the difference between the predicted values and the actual data, and so the smaller, the better. We can see that our model captures most of the variation and that our variables are highly explanatory because both the residual sum of squares and mean square are fairly low. They are lower for specification 1.2 and 2.2, probably because emission 2 is narrower and contains less variety between the different countries.

The unstandardized coefficient B for the reform trend, β, in specification 1.1 has a negative value of -0,048, which indicates that emissions decreased 4,8 % per year thanks to the reform – ceteris paribus. In specification 2.1, the unstandardized coefficient B for β is -0,050, i.e. emissions decreased 5 % per year thanks to the reform, with respect to the organic aspect. In both 1.1 and 2.1, the significance of these coefficients is close to zero (0,000), which indicates that the regressions are highly significant. We can tell by 99,9 % certainty that the coefficients are not zero, and this means that the reform trend did truly have an effect on emission 1 according to our regression analysis. Note that if the coefficient for the reform had changed a lot or decreased when the organic aspect was introduced in the regression, the relationship between the reform trend and emissions probably would have been spurious, i.e. false.

In specification 1.2 and 2.2 the significance of β is 0,079 and 0,064. This is higher than the usual standard of 0,05, i.e. 5 % significance level that equals a 95 % certainty. Hence, those two regressions are only significant at a 10 % significance level and the result is not as reliable as in regression specification 1.1 and 2.1. If we accept this, we could say that with 90 % certainty emission 2 decreased 1,1 %, or 1,2 % if we include the impact of the conventional share, due to the reform. Thus, we can see the same trend in all of the four different regressions made – a quite satisfying result indeed!

When it comes to the standard errors, these tell us how reliable the estimates are. The larger the standard error, the further away the observed values can be from the estimated regression line, and therefore the more uncertain and imprecise are the estimated coefficients. The standard errors for the reform trend are low (between 0,006 and 0,013) for all the four specifications but they are higher for the conventional share in specifications 2 (1,718 and 0,881), which further supports our conclusion about the insignificance of the organic aspect in this analysis.

Let's have a closer look at the conventional share in specification 2.1 and 2.2. We can see that the unstandardized coefficient B for δ is estimated quite excessively and we must indeed reject the results since the significance of the conventional share, δ, is 0,660 versus 0,551, i.e. highly non-significant. This forces us to accept the unreliability in the estimation of the coefficients. In other words, the results from regressions specification 2.1 and 2.2 are not accurate and we can therefore say nothing about the impact of organic farming on greenhouse gas emissions in this study.

6. Conclusion

This study has used data from FAOSTAT to investigate whether greenhouse gas emissions caused by agriculture was reduced for European countries during the first few years after a CAP reform, establishing a fully decoupled support for farmers. The reform was formed in 2003 and implemented in 2005, and so a selection of non-European countries and European countries between 2004-05 were used as references. The essay began with a description of the Common Agricultural Policy and its association with environmental damage, which eventually led to the reform. This theoretical background was followed by an explanation of data and empirical approach, before presenting the results and coming to this conclusion.

The investigation was made through multiple regression analysis and the results were in line with our hypothesis. Thanks to high values of adjusted/unadjusted R-square, we can conclude that our independent variables to a large extent can explain the variance in greenhouse gas emissions. Furthermore, when taking a closer look into the coefficients and their significance level, the 2003 CAP reform has had a high impact on emissions. This conclusion seem solid even when we include one more independent variable, the conventional share, which is incorporated in the second regression to further support our result about the effects of the reform on emissions. Thereby, the conclusion is that the decoupling of CAP payments did reduce greenhouse gas emissions per agricultural hectare. This is a noteworthy inference, especially since there haven't been done much previous research on this subject.

Economic models did predict that some farmers would exit the agricultural sector because of the introduction of the Single Payment Scheme. Our results of reduced greenhouse gas emissions do, therefore, not necessarily imply that farms have become more environmentally friendly; it might as well be due to a smaller amount of farms. But since CAP's main goal with the 2003 reform was to reduce agricultural production surplus and to reduce environmental damage, my results indicate that the policy changes were successful.

The share conventional farming of total agriculture area did not prove to have any impact on emissions. This is somewhat unsurprising since earlier research have shown that the impression of organic farming as less environmentally harmful than conventional farming is quite ambiguous. However, we should not forget that although organic farming maybe do not reduce emissions from methane and nitrous oxide, they might decrease CO_2-emssions that is not included in the data used for this study. Also keeping in mind that organic farming may have a positive impact on other environmental issues not covered in this essay.

Naturally, there are many other aspects that are excluded in this study to narrow down this specific investigation. The impact of the reform on emissions is strongly dependent on other factors such as the heterogeneity of agricultural and socio-economic conditions. The final, actual outcome is impossible to say was due to one single factor such as the 2003 CAP reform. For future studies, it would be interesting to take the member countries' variations, regulations and support into account, for instance whether these have larger impact than CAP. Other potential areas could be how socio-economic conditions and farm size control farmers' individual decisions, or how citizens in different member countries value environmental sustainability and their confidence in organic farming. A study using data for a longer period of time, both before and after the decoupling reform, would be of high relevance to further increase the reliability in these results.

The main purpose of the study has been to broaden the comprehension of whether CAP's movement towards a more decoupled support system and more organic farming, did or did not lower the emissions of greenhouse gases caused by agriculture. Despite potential limitations, we can conclude that the 2003 CAP reform most likely did reduce GHG emissions per agricultural area and that organic farming did not prove to have any significant effect. My aspiration is that this study could contribute to continuous research and that the results will increase the interest for future negotiations and modifications in agricultural and environmental policies.

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8. Appendix

8.1. Table of countries

Country	**EU/non-EU**	**Data provided**
Argentina	Non-EU	2004-2010
Australia	Non-EU	2004-2010
Austria	EU	2004-2010
Belgium	EU	2004-2010
Brazil	Non-EU	2005-2010
Cambodia	Non-EU	2005-2010
Canada	Non-EU	2004-2010
China	Non-EU	2005-2010
Colombia	Non-EU	2005-2010
Croatia	EU	2004-2010
Czech Republic	EU	2004-2010
Denmark	EU	2004-2010
Egypt	Non-EU	2005-2010
Finland	EU	2004-2010
France	EU	2004-2010
Germany	EU	2004-2010
Greece	EU	2004-2010
Hungary	EU	2004-2010
India	Non-EU	2005-2010
Indonesia	Non-EU	2005-2010
Ireland	EU	2004-2010
Italy	EU	2004-2010
Latvia	EU	2004-2010
Lebanon	Non-EU	2004-2010
Madagascar	Non-EU	2005-2010
Mexico	Non-EU	2005-2010
Morocco	Non-EU	2005-2010
Netherlands	EU	2004-2010
New Zealand	Non-EU	2005-2010
Poland	EU	2004-2010

Portugal	EU	2004-2010
Republic of Korea	Non-EU	2005-2010
Slovenia	EU	2004-2010
South Africa	Non-EU	2005-2010
Spain	EU	2004-2010
Sri Lanka	Non-EU	2005-2010
Sweden	EU	2004-2010
Thailand	Non-EU	2005-2010
Tunisia	Non-EU	2004-2010
Turkey	Non-EU	2004-2010
United Kingdom	EU	2004-2010
United States of America	Non-EU	2005-2010
Viet Nam	Non-EU	2005-2010

8.2. Table of variables

Variable type	**Variable symbol**	**Definition**	**Description**
Dependent	Y_1	Greenhouse gas emissions from agricultural total plus energy, CO2-eq kg. Logged variable.	"GHG emissions produced in the different agricultural sub-domain, produced by aerobic and anaerobic decomposition processes in crop and livestock production and management activities. Consist of non-CO_2 gases, namely methane (CH_4) and nitrous oxide (N_2O), expressed in CO_2-equivalents. Aggregated measurement also including emissions from direct energy use, consist of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) gases associated with fuel burning and generation of electricity used in agriculture (including fisheries), also expressed in CO_2-equivalents." (Source: FAOSTAT Methodology, 2015)
Dependent	Y_2	Greenhouse gas emissions from agricultural soils,	GHG emissions of CH_4 and N_2O, expressed in CO_2 equivalents, direct from agricultural soils. (Source: FAOSTAT Methodology, 2015)

		CO2-eq kg. Logged variable.	
Independent	λ_t	Time dummies	(0,1) for each year. 1 for that specific year, 0 for all others
Independent, fixed effect	α_{it}	Land dummies	(0,1) for each country. 1 for that specific country, 0 for all other countries
Independent	R_{it}	Reform trend	Years after the reform 0 for all non-European countries and for European countries year 2004 and 2005 1 for European countries 2006 2 for European countries 2007 3 for European countries 2008 4 for European countries 2009 5 for European countries 2010
Independent	O_{it}	Conventional share	$\left(\frac{\text{total area} - \text{organic area}}{\text{total area}}\right)$
Random	ε_{it}	Error term	The unobserved disturbance term

8.3. Summary statistics of variables

Variable	Number	Mean	Standard deviation
Y_1	284	3,1629	3,1182
Y_2	284	0,9785	0,7787
λ_t	284	0,15	0,359
α_{it}	284	0,2	0,155
R_{it}	284	1,06	1,663
O_{it}	284	0,9721	0,0336