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Department of Economics

Make Fallow Great Again

– A Study of the Substitution between wheat production and fallow and temporary grassland

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Abstract

Biofuels are versatile and have a big field of use. However, biofuels produced from starch crops like cereals have been claimed to threaten food security and cause higher CO_2 emissions due to other cereal producer's expansion of their enterprises. This study aims to research the economic conditions on which it is possible to produce wheat on fallow or temporary grasslands. By using this land, agricultural markets are not threatened by any food deficits and there will be no cause for additional production. Data over yield and land allocation to crops in Skåne, Sweden and the output price of crops is used to research this with a two-step model. First a Rotterdam model approach is used to capture how prices affect the land allocation to crops. Estimates for this are then used in an aggregated revenue function with temporary grasslands and fallow land as fixed factors. Out of this some simulations were made by shifting the price of wheat and changing the amount of available agricultural land by decreasing the fixed factors. The simulations made, generated an increase in the land allocation to wheat by 6.2% on the condition that the unit returns from wheat increased by 20%. In short terms it can be said that there are possibilities of producing cereals on temporary grasslands. Changing of policies to benefit biofuel production could make biofuels more available and increase the farm income.

Keywords: Land allocation, Biofuels, Rotterdam-model, Indirect land use change

Sammanfattning

Biobränslen är flexibla och har ett stort användningsområde. Biobränslen producerade av stärkelsegrödor som spannmål har påståtts att hota livsmedelssäkerhet och orsakar högre koldioxidutsläpp till följd av andra spannmålsproducenters utvidgning av deras företagande. Denna undersökning syftar till att undersöka de ekonomiska förhållanden på vilka det är möjligt att producera vete på träda eller vallmarker. Genom att använda den här typen av mark blir inte jordbruksmarknaderna hotade av ett minskat livsmedels utbud och det kommer inte förekomma någon kompensation bland andra jordbruksföretag. Data över avkastning och markallokering till grödor i Skåne, i Sverige, och priset på grödor används för att undersöka detta genom en tvåstegsmodell. För det första används en Rotterdam-modell för att fånga hur priserna påverkar markaallokeringen till grödor. Uppskattningarna från Rotterdam-modellen används sedan i en aggregerad intäktsfunktion med vallmarker och träda som fasta faktorer. Utifrån detta gjordes några simuleringar genom att ändra priset på vete och ändra mängden tillgängligt jordbruksmark genom att minska de fasta faktorerna. De simuleringar som gjordes gav upphov till en ökning av landfördelningen till vete med 6,2% med kravet att nettointäkten per hektar vete ökade med 20%. Kort sagt finns möjligheter för produktion av spannmål på vallmark. En förändring av policy till biodrivmedelsproduktionens fördel skulle kunna ökatillgängligheten av biodrivmedel samtidigt som den ökar jordbruksinkomsten.

Nyckelord: Landallokering, Biobränslen, Rotterdammodellen, indirekta förändringar av landanvändning

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1 Introduction

This study intends to research the possibilities to produce cereals on fallow and temporary grassland for biofuel refinement. Hence the research question is: What are the economic conditions required to make fallow and temporary grassland in Sweden produce cereal for bioethanol refinement? To research this a duality approach is used giving estimates for the output level of crops and the optimal land allocation. This can then be used in a simulation for the possibilities of producing cereal on fallow and temporary grass land.

1.1 Background

Biofuels are cleaner substitutes for fossil fuels and can be used for many purposes. Therefore it would be desirable from a climatic point of view to substitute fossil fuels for biofuels. Over the last few decades the biofuel sector has grown significantly around the world as a result of favourable public policies. In the European Union, EU energy policy is one of the commission's main concerns. They have set a target of 20% of energy consumption should come from renewable sources. Which was agreed upon the renewable energy directive ((RED) 2009/28/EC, 2009). Furthermore, the EU has set a target that 10% of transport should be fuelled from biofuels by 2020 ((RED) 2009/28/EC, 2009). Although while using biofuels can decrease CO_2, producing starch crops or vegetable oils for biofuel refinement, bioethanol and biodiesel, can also have a negative indirect land use change, iLUC effect. Indirect land use change risks negating the greenhouse gas savings that result from increased biofuels use because grasslands and forests typically absorb high levels of CO_2. By converting these land types to cropland, atmospheric CO_2 levels may increase. This is due to a decrease in the supply of cereal and crops on the food market, hence someone else must produce this deficit to compensate the demand for food. Therefore, producing biofuels from food and feed crops have broadly been claimed to threaten food security. Because of this the

EU has put restrictions on the production of biofuels from food and feed crops and do not allow any subsidies for production and use of such fuels ((EU)2015/1513).

In Sweden, biofuels like ethanol from cereals was until 2012 promoted by an exemption from CO_2 tax and energy tax (Energimyndigheten, 2015). This tax exemption has made ethanol competitive with fossil fuels that pay full CO_2 and energy tax. However due to EU law the tax exemption is not compatible with biofuel legislation and state aid rules ((EU)2015/1513). Thus, Sweden had to change its policy, and there is now no tax exemption which resulted in a hard time for biofuels to compete with traditional fuels. The tax for E85 is today 0.3 SEK/litre and the tax for low-blend ethanol that is mixed with petrol is 0.45 SEK/litre (Energimyndigheten, 2015).

Wheat is the dominant starch crop in production of bioethanol I Sweden. (Lantmännen agroetanol, 2017) According to Turbins (2013) Sweden has produced less cereal in favour for temporary grasslands and fallow land since it joined the EU. Furthermore, EU has decided that biofuels from crops must be phased out due to iLUC effects ((EU)2015/1513). Firms producing bioethanol are of course suffering from this, they argue that the legislation has weak scientific grounds, that it is disproportionate and that there is a lot of fallow land in the EU and in Eastern Europe, Zilberman (2017) for one argues that the early research on iLUC might have overshot the effect from iLUC.

All this fallowed land could be used for producing cereals for bioethanol refinement. If the crops produced don't affect the agricultural markets, i.e. cereal on food markets stay constant they would then not cause any iLUC effects, and hence there is no reason for a cap on crop based ethanol.Considering this the research question of this study is:

- What are the economic conditions required to make fallow and temporary grass land in Sweden produce cereal for bioethanol refinement?

To research this, it will be important to find the optimal land allocations to different crops, furthermore it will be important to know how sensitive these land allocations are to changes in output prices for crops. From these estimates, it should be possible to draw some conclusions regarding the economic conditions required for substituting temporary and fallowed land to wheat production.

It is important to realize that this is a land allocation problem, and since Sweden's joining of the EU parts of Sweden has produced less cereal in favour for temporary grasslands and fallow land (Trubins, 2013). Considering this it should be possible to reverse these conditions to produce more cereal. Another important aspect of this problem is; what are the requirements for farmers to farm additional land instead of leaving it fallow? Farmers need economic incentive for this to happen. Hence some sort of premium price must be given for cereal that is refined into biofuels. Since farmers receive single farm payments, SFP and other support dependent on how they farm their land this will decide how high the price premium will be. Producing more cereal will generally give a smaller support hence the income generated from the additional cereal must be greater than the loss of support. Furthermore there must be a distinction between the cereal that becomes food and the cereal that is refined into bioethanol. One way is to distinguish the payment for the cereals.

Then $r_{food} > r_{ethanol} > r_{support}$, this would then result in an additional use of land.
If $r_{food} < r_{ethanol}$ theoretically all cereal would become ethanol which is not reasonable on many levels
and if $r_{ethanol} < r_{support}$ then there is no economic incentive to farm additional land.

If r denotes the revenue from producing cereal for food, ethanol and revenues from the support this would solve the land use problem. This is also the main argument against iLUC effects, since cereal designated for food markets would stay constant. It is important to shed light on this due to many reasons. For one it could help make policy work easier and policies better. It could also be beneficial for firms producing biofuels as well as increasing farm incomes, but maybe most of all it could help the substitution of fossil fuels towards biofuels. Even though the impacts of this research may be small it still contributes to the field in the sense that it will attempt to show that producing bioethanol from cereal can be beneficial to many parts.

1.2 Literature Review

Essentially this is a land allocation problem. In this field there has been a quite extensive amount of research. A good way to model this is by using a normalized quadratic function which has a strong theoretical foundation in production theory. Wall and Fisher (1988) thoroughly examines the properties of the production technology set, with the aim of presenting a review of the part of the production theory which is relevant for estimating the responsiveness or elasticity of output variables to changes in supply. Diewert and Wales (1988) examines how the normalized quadratic function preforms in demand systems such as the almost ideal demand system, AIDS and the duality of the normalized quadratic. Due to duality, the production side of the same problem can be modelled with a normalized quadratic which they later did (Diewert and Wales, 1992). Chambers (1986) developed a revenue function model for land allocation for estimating input-joint technologies. Which Chambers and Just (1989) builds and modifies it into a model that is a multi-crop profit function based on the normalized quadratic function, for estimating input-non-joint technologies with allocatable fixed factors. Variable input allocations can be calculated from the estimated technology using this approach. Moore and Negri (1992) use this model to research how governmental irrigation of land affects land-use decisions. Their result show that government served irrigators' crop supply and land allocation decisions are generally inelastic with respect to the water constraint. Using the elasticities, a policy simulation of a 10% reduction in governmental water allocation indicated that production response to reduced water supply would affect the national price of three of ten major crops produced by government served farms. Fezzi and Bateman (2011) use a modified version of the model where they integrate the model into a Tobit regression to analyse drivers of land use change in the past forty years in England and Wales from an environmental and a policy perspective. Carpentier and Letort (2013) similarly uses the model developed by Chambers and Just (1989). They apply the model to empirically study farm level data to investigate the performances of the multi-crop econometric model for modelling acreage choices in France. Lacroix and Thomas (2011) propose an estimation procedure dealing with multivariate selection and dynamics in land choice and unobserved heterogeneity in structural and crop selection equations, where they also use the framework produced by Chambers and Just (1989). Bayramoglu and Chakir (2016) utilizes the framework developed by Lacroix and Thomas (2011) in their attempt to measure the effects of crop prices on demand for agro-chemical inputs and land allocation. The results from their study showed that an increase in the rapeseed price, which is the most common feedstock for the production of biodiesel in France, has a positive effect on demand for agro-chemical inputs and land allocation to producing rapeseed.

All of these studies have a similar framework based on a system of equations using the normalized quadratic function with good success. Therefore, a system of equations using a normalized quadratic function seems like a good approach to the problem. However, there are several other ways to face land allocation problems for example Gazheli and di Corato (2013) use a real options approach in order to take account for farmers' uncertainty of the farmer's decision when researching the trade-off between agricultural production and energy production in the form of installing solar PV-plant on farm land. Other ways to tackle land allocation problems could be by using a computable general equilibrium, CGE model like Perpiña Castillo *et al.* (2015) when simulating land use changes within the EU between 2010 and 2050. Many others have used CGE modelling in a successful way. Seale (2014) modified the Rotterdam model originally developed by Barten (1964) to understand how changes in output prices affected the demand for land allocated to crops. Moro and Sckokai (1999) researched the impacts of changes in the CAP, specifically changes of subsidies to farmers, using a generalized quadratic function while modelling the farm enterprise. Furthermore, this was done under subject of the changes in the different payment schemes imposed on farmers, to find how decoupling affected production. They (Moro and Sckokai, 2013) also review several different approaches of methodological framework and analysing of decoupled payment models of agricultural production. They review static models where they account for many different factors e.g. risk aversion, farm efficiency, entry and exit decisions, land rents and labour allocation. Furthermore, they review dynamic models with all of the factors above in consideration. Brady *et al.* (2017) analyses whether the single farm payment gives farmers incentive to increase their fallow land (passive farming) while receiving support for it. This is done by identifying the optimal land-use choices in Sweden. Their result showed that passive farming is not an issue within agriculture, but that it might constrain structural change, and development within the sector. This could be an issue for the development of producing wheat for biofuel refinement on fallow and temporary grassland.

1.3 Outline

This thesis will be outlined as follows; an overview of the agricultural situation of Skåne county will be given in section 2, section 3 will provide a conceptual framework and the empirical model used in the study. Section 4 will give a presentation of the results from the econometric estimations of the models used. This will be accompanied with some simulations made using the results from the estimations. Section 5 will provide a discussion of the thesis, and finally, give some concluding remarks.

2 The agricultural situation of Skåne

The region of the study was chosen to Skåne county which is the county out of all the counties in Sweden that were best suited to perform the analysis on. Mainly due to the availability on data over this region but also because it is one of the most productive county in Sweden which would argue that trade-off effects should be higher.

The dataset that is used in this study have been acquired from Jordbruksverkets annual statistical report on the Swedish agriculture, Yearbook of agricultural statistics (1981-2015). The data set consists of time series data for the period of 1980 to 2014, and is on a regional level over Skåne county. The collected data consists of land in hectares allocated to production of the crops; wheat, rye, barley, oats, rapeseed, temporary grasslands or ley and permanent grasslands for the entire time period. The average yield per hectare per crop was also collected from jordbruksverkets database. However, data points between 1993 to 2003 were missing in the data set for the yields per hectare of temporary grass lands, these were estimated by ordinary least squares in MS excel. Furthermore, some single data points in the data set for rapeseed were estimated by OLS. Data for prices were collected for all the crops both absolute prices and indexes, and also prices and indexes for inputs; fertilizers, pesticides and fuels. Farmers in Sweden did not receive subsidies until the conversion 90 policy regime before Sweden joined the EU in 1994, hence data for subsidies is only in the time period 1990 to 2014. The subsidies are divided into two different categories single farm payment schemes and environmental support. Where single farm payments can be applied for regardless of the production and environmental support can only be applied for the areas allocated to temporary grasslands.

To understand the trends of land allocations to crops it is important to plot and observe the data. Below the time trends for the chosen crops are shown in Skåne and then the trends for input and output prices.

2.1 Land allocation and yield

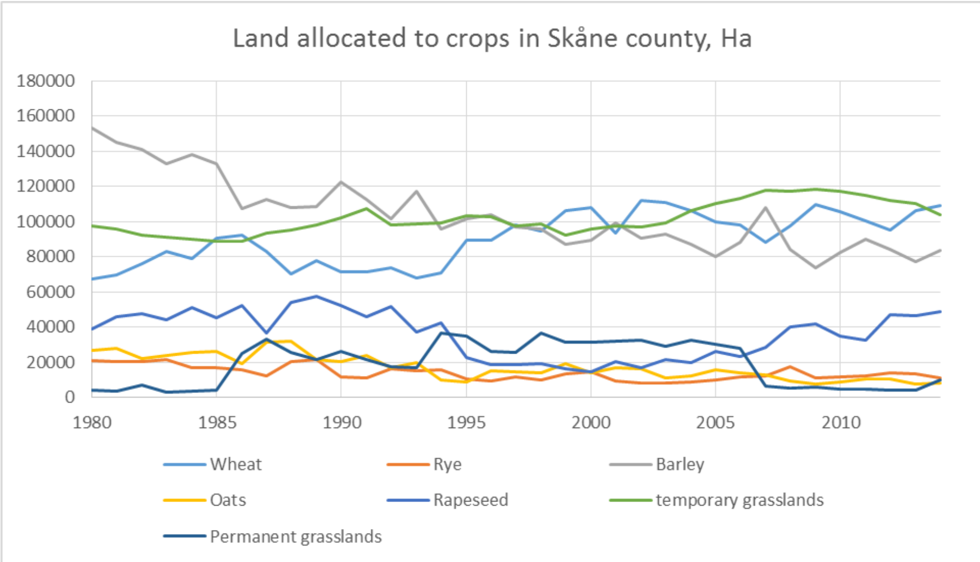

Figure 1 land allocated to crops in Skåne county in hectares.

In figure 1 the allocation of land to the different crops in Skåne county can be observed. The first thing that is noticed is that wheat, barley and temporary grasslands have a the largest land allocation. Furthermore land allocation to barley seems to have had a decrease during the period whilst land allocation to wheat seems to have had an increase. Land allocation to temporary grasslands is somewhat stable around 100,000 Ha. Rapeseed seems to be the fourth most important crop but have a clear drop in land allocation between 1994 and 2006 where permanent grasslands seems to be filling the gap. Otherwise the shares of oats, rye and permanent grasslands are quite low. Figure 2 shows the yield per hectare in Skåne county.

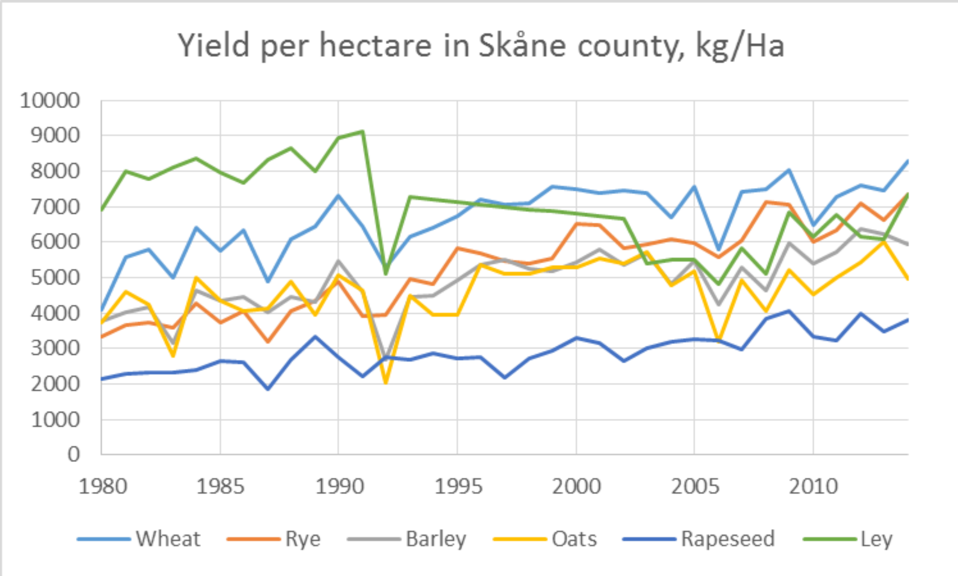

Figure 2 Yield in kilograms per hectare in Skåne county.

Considering the yield/Ha in Skåne the only observations that can be made are that all crops slowly seems to increase over the years except for ley that seems to be decreasing in yield.

What can be observed in general are that the land allocated to the production of barley have had a major decline over the years furthermore the land allocated to temporary grasslands and the production of wheat have increased. As it apears from figure 1 the crops can be divided into two categories high land allocation and low land allocation to crops. In Skåne wheat, barley and temporary grasslands have a high land allocation. The rest of the crops have a low allocation of land except for rapeseed that on it’s current increasing path is somewhere in between high and low land allocation.

2.2 Output and Input prices

Prices that farmer recive for each crop can be observed in figure 3

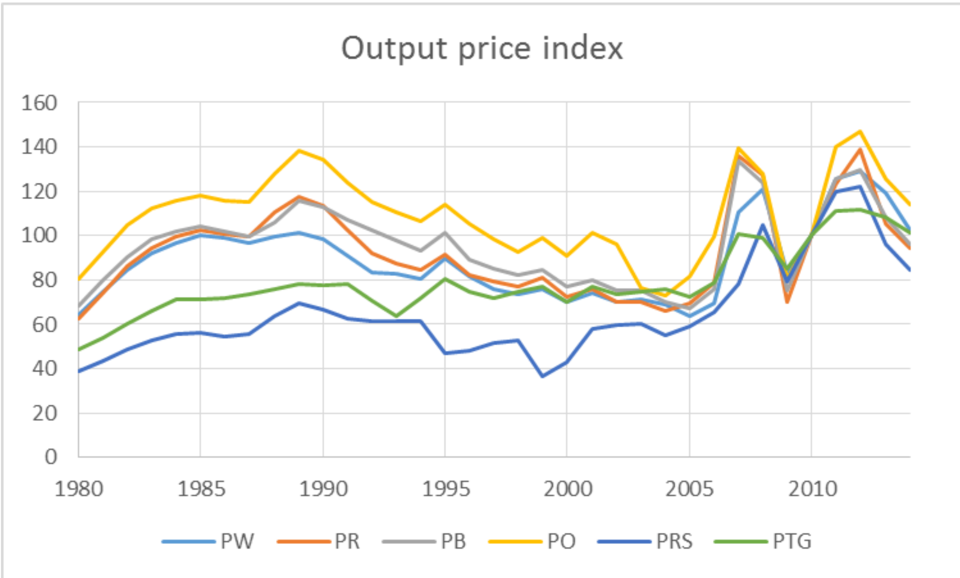

Figure 3 prices that farmers receive for each crop SEK.

Figure 3 shows the index for the output prices in SEK on the different crops with the base year 2010 where: *PW* is the index for prices of wheat, *PR* is the index for prices of rye, *PB* is the index for prices of barley, *PO* is the index for prices of oats, *PRS* is the index for prices of rapeseed, and *PTG* is the index for prices of ley (temporary grasslands). What is notable here is that all crops, except ley, follow a similar pattern, with rapeseed having a lower intercept than the others. In the beginning of the period the index is increasing, come the 90'ies index starts to decrease towards 2005 where indexes start to fluctuate and increase through the end of the period. Ley seems to have a somewhat slight increase during the whole of the period with some fluctuations towards the end.

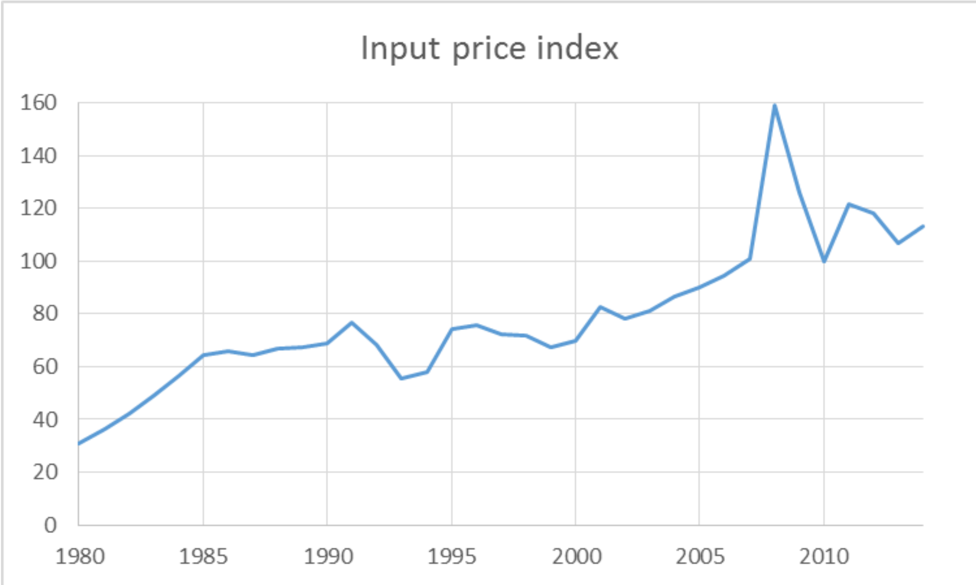

Figure 4 Price of fertilizer in SEK.

Now, if we observe figure 4 we can see the price index in SEK of fertilizers has a steady increase throughout the entire period. There are of course some correlations between the input price index and the output price index, the peak 2007-2008 is the most striking example. However, the index for input prices has a much steeper and increasing inclination, whereas it is hard to tell whether the inclination of the output price index is neutral or slightly increasing.

3 Methodology

The following chapter will present the conceptual and the empirical approach used in the study. Typical for economics is that the agents involved tries to maximize their utility under some sort of budget constraint. This is also true for agricultural economics where the farmer can be thought of as an enterprise who maximizes utility by maximizing profit from the output produced under subject to some sort of input constraint. In the case of Sweden and especially Skåne the aim is to research how changes in output prices may affect the agricultural land devoted to different crops.

Many different types of approaches can be used to research the land allocation of crops. At first a normalized quadratic function following Chambers and Just (1989) was set up for this purpose. However, this type of model failed to give any significant results due to problems with collinearity in the output prices (Gujarati, 1995, p341). Which becomes an issue once Hoteling's lemma is used to derive optimal land allocations, the output prices all become very similar due to the high correlation in-between the prices. Furthermore, finding good estimates for the properties of the input allocation of the production set was found to be difficult.

Once this approach had been disqualified, using an approach based on first differences like the Rotterdam model seemed like the way to go. This way the problem with collinearity is avoided, and the model can be backed theoretically up by a revenue function with the properties of a joint input technology like Chambers (1986) and Cahill (1997). With this sort of specification issues with input allocation over outputs is avoided, due to the joint input technology production set.

3.1 Conceptual framework

The model created for this purpose must be able to differentiate between different crops *c*, *k*, i.e. the planting decision. This is based on the on the quantity and the resources that are devoted to the crop once it has been planted, the yield decision. This can be represented by the following:

$$Q_c = Y_c A_c \qquad n = 1,2,\dots,n \tag{1}$$

Where Q_c is output level, Y_c is yield per hectare, L_c is hectares allocated to crop *c*, and n is the number of crops. By total differentiation this function can be expressed in terms of rate of change:

$$dQ_c = dL_c Y_c + dY_c L_c \tag{2a}$$

By dividing this with eq.1 the rate of change can be obtained:

$$\frac{dQ_c}{Q_c} = \frac{dL_c}{L_c} + \frac{dY_c}{Y_c} \tag{2b}$$

Expression (2b) shows that the rate of change in total output is dependent on the rate of change in area allocated to crop *c,* plus the rate of change in yield per hectare of crop *c*. In this thesis, the focus will be on targeting the changes in land allocated to crop *c*. Therefore, the construction of a component that captures the changes in the area allocated to crop *c* due to changes in the gross revenue per hectare is key.

To capture changes in the area allocated to crop *c*, a revenue function offers great representation of the farmer's land allocation decision. The revenue function gives the maximum revenue derived from the outputs with a fixed endowment of inputs in the production set, as well as the optimal land allocation to each of the crops (Chambers, 1986). In this case, a revenue function is to prefer before a profit function due to two reasons: the first, inputs are assumed to be fixed. Allowing for focus on the output markets only. The second, if fulfilling conditions according to economic theory, the laws of supply, the revenue function represents all the relevant properties of production theory. This revenue function can be represented by:

$$\mathrm{R}(P_c, \mathrm{X}) = \sum_{\mathrm{K}=1}^{\mathrm{K}} [P_c L_c | \mathrm{X} = \bar{X}; (\mathrm{L}, \bar{X})] \tag{3}$$

where P_c represents the gross unit revenue per hectare of crop *c*, in other words $P_c = p_c Yc,$ where p_c is the price of crop *c* and Y_c is the yield per hectare of crop *c*. *X* represents the fixed and allocatable inputs. L_c is the land allocated to crop *c*, and *L* is the total available agricultural land. This specification of $R(P_c, X)$ accommodates two important assumptions, input seperability and joint production of outputs. This allows the function to maximize revenue in terms of a single input and multi output technology. Implying that the production of output does not allocate inputs to the specific crops, but to the entire production of outputs (Cahill, 1997). Furthermore it allows for inputs to be fixed at an unobserved base level, without having to change these levels when the land allocated to different crops change. Meaning that inputs are equally distributed over outputs, or that outputs are equally input costly. If properties required for duality, homogeneity, symmetry, and adding up of land are imposed on $R(P_c,X)$ it is possible to assume that $R(P_c,X)$ is twice continuously differentiable, meaning that it is possible to obtain the optimal land allocation to each crop by applying Hoteling's Lemma on $R(P_c,X)$ like the following:

$$L_c(P_c, X) = \frac{\partial \mathrm{R}(P_c, X)}{\partial P_c}, c = 1, 2, .., n \tag{4}$$

by total differentiation of (4) the following is obtained:

$$dL_c(P_c, X) = \sum_{k=1}^{n} \frac{\partial \mathrm{L}_c(P_c, X)}{\partial P_k} \cdot dP_k + \frac{\partial \mathrm{L}(P_c, X)}{\partial \mathrm{X}} \cdot dX, c = 1, 2, .., n \tag{5}$$

Since inputs, X are fixed at the base level the second term in expression (5) can be set to zero for all of the crops. Leaving us with the expression:

$$dL_c(P_c, X) = \sum_{k=1}^{n} \frac{\partial \mathrm{L}(P_c, X)}{\partial P_k} \cdot dP_k\, , c = 1, 2, .., n \tag{6}$$

This gives an expression that is very similar to expression (2a).

3.2 Empirical model

Considering this land allocation problem, it is possible to divide the different types of agricultural land into different categories. The first distinction that will be made is that grazing land will not be considered in this model. This is due to that changing grazing land into cropland is costly and labour intense. Once grazing land is excluded we are left with cropland, temporary grassland and permanent grassland or fallow land. The total agricultural land can therefore be divided into these three categories of which cropland can be divided further into subcategories, i.e. land allocated to wheat barley rye and rapeseed, as shown in figure 5 below.

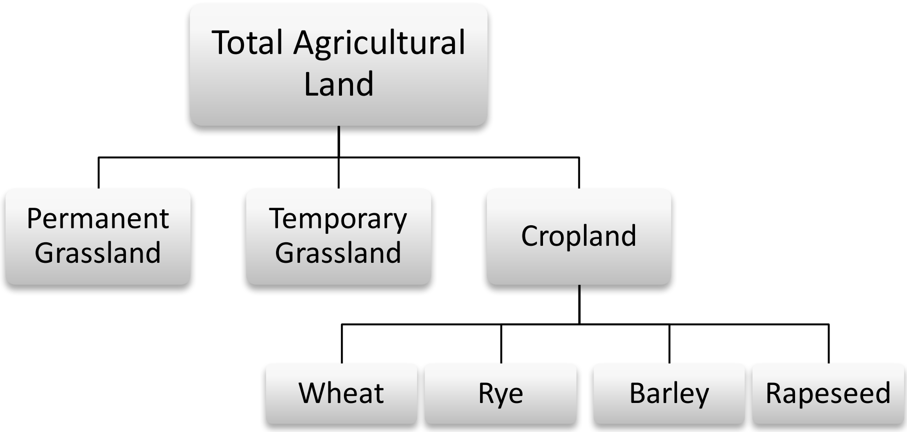

Figure 5 two-step model.

From this basic figure, it is possible to divide the modelling exercise into two. One that only considers the cropland as a function of wheat, barley, rye and rapeseed, and one aggregate model that considers the total agricultural land as a function of permanent grassland, temporary grassland and cropland.

For the allocation of cropland a land allocation model based on the Rotterdam model will be used. Originally the Rotterdam model was developed by Barten (1964), the model uses a differential approach to research changes in consumption. This model lets us apply the previous theoretical parts, by using first differentials similar to expression (6). Thiel (1977) later modified the model to account for production. Further on the model was used and modified by Seale *et al.* (2014), who linearly specified the allocation of inputs to analyse the use of agricultural land from a multi-product approach. The same model was used by Vorotnikova *et al.* (2014) when investigating whether land use decisions respond to changes in relative prices. The same model has successfully been used by DePetris *et al.* (2016), to show how relative changes in prices have affected land allocation to different crops in Argentina. Furthermore DePetris *et al.* (2016) focused on understanding how the change in land allocated to a specific crop affected the total agricultural land area. This study will adopt a similar model and focus on the Swedish agricultural sector, by researching the most relevant crops in Skåne.

If we consider agricultural land, L is the total amount of available agricultural land. Then L_c is land devoted to planting crop c. The price of crop c is denoted by p_c. By simply dividing L_c by L the share, s_c of land devoted to each crop is obtained. This lets us write the linear input allocation model (Seale *et al.* 2014) like the following:

$$s_c d(lnL_c) = \theta_c d(lnL) + \sum_{k=1}^{k} \beta_{ck}\, d(lnp_c) \tag{7}$$

where $d(lnL)=\sum s_c lnL_c$ is the "divisia index" for land. Taking the time series into account expression 7 takes finite differences i.e. $d(lnL_{ct})=lnL_{ct} - lnL_{ct-1}$, $d(lnL_t)=lnL_t - lnL_{t-1}$ and $d(lnp_{ct})=lnp_{ct} - lnp_{ct-1}$, meaning the rates of change over time. Additionally, for the shares s_c, of land devoted to crop c, in a certain period of time t, the sample mean is given by $\overline{s_{ct}}=(s_{ct}+s_{ct-1})/2$ in order to capture the land shares between periods included in the dynamics. This way the model ca be rewritten like:

$$\overline{s_{ct}} d(lnL_{ct}) = \theta_c d(lnL_t) + \sum_{k=1}^{k} \beta_{ck}\, d(lnp_{ct}) + u_{ct} \tag{8}$$

where u_{ct} represents the error term of the model. For each of the crops c, the expression (8) can be derived, yielding a system of equation for land allocation that can be estimated. This version of the Rotterdam model, in this thesis referred to as the cropland model will analyse the land use decisions, i.e. the planting decision dependent on the price of crops similarly to how the Rotterdam model usually is used to analyse consumption or input demand. To further make the model compatible with economic theory constraints had to be imposed. Adding-up constraint: $\Sigma\theta_c=1y$, $\Sigma\beta_{ck}=0$ meaning that all the coefficients for land should add up to one unit of output, and that all the price coefficients with respect to crop c should add up to zero. Furthermore, symmetry condition is required: $\beta_{ck}=\beta_{kc}$, and lastly the homogeneity constraint is imposed: $\Sigma\beta_{kc}=0$, meaning that the model is homogenous by the degree of zero.

However things are more complicated than this. During the time period of 1980-2014 Swedish agriculture have endured four different policy regimes. The first period lasting trough 1980-1990 there were no direct agricultural support. 1990-1995 the conversion 90 program was in use. Then Sweden joined the EU and during the period 1995-2005 there was a decoupled payment regime. From 2005 and throughout the period the single farm payment scheme was in action. By substituting p_c for the unit returns per hectare the model now accounts for the subsidies as well. Furthermore, s_c is modified to represent the revenue shares derived from crop to better suit the second part of the modelling exercise. Giving the expression:

$$\overline{SUR_{ct}} d(lnL_{ct}) = \theta_c d(lnL_t) + \sum_{k=1}^{k} \beta_{ck}\, d(lnUR_{ct}) + u_{ct} \tag{9}$$

Where $UR_c = p_c \cdot y_c/Ha + sub/Ha$. The different policy regimes will be divided into three dummy variables, and into a per hectare basis, and SUR_c is the share of revenue derived from crop c, $SUR_c = UR_c \cdot L_c / UR_t \cdot L_t$, where the mean, $\overline{SUR_{ct}}$ is calculated in a similar fassion as $\overline{s_{ct}}$. Note that this also affects L_t since SUR_c is a component of this variable. Expression 9 gives the final cropland allocation model.

Out of this model the parameters θ, β can be estimated. From them it is possible to calculate elasticities for the cross effect of land and output prices, and both own and cross prices like the following:

$$\widehat{\eta_c} = \frac{\hat{\theta}_c}{\bar{s_c}} \tag{10}$$

and

$$\widehat{\varepsilon_{c,k}} = \frac{\hat{\beta}_{c,k}}{\bar{s_c}} \tag{11}$$

Where η_c is the elasticity for the cross effect of land and output prices and ε_{cc}, ε_{ck} is own price and cross price elasticities respectively. Now some economic interpretations can be made from the parameters provided by the model. It must be considered that the model regresses changes in the net revenue share from crop c, on the changes of the total revenues from farming, and on the changes in price for all crops. Meaning that the estimates show the short-run average response for change in revenue shares, derived from each crop connected to the change of total revenue from farming due to changes in the cross effect of land availability and output prices θ_c, and from changes in crop prices $\beta_{c,k}$. Next, consider the elasticities. They will show to what percent, a one percent change in total revenue, i.e. the cross effect of agricultural land availability and output prices, η_c, or a one percent change in prices, $\varepsilon_{c,k}$, will impact the amount of land allocated to crop, c. Since these are dependent on the average land share, $\overline{s_{ct}}$ this means that a greater land share will give a smaller elasticity. With this in mind one has to be careful when interpreting the elasticities knowing that even tough the elasticity might be low because of a relatively high share of land the absolute change could be much greater than it first may appear.

Following this it is possible to set up the aggregate model. By using the rate of change of total agricultural land as the dependent variable it is possible to set up the aggregate model as the following:

$$\frac{dL_t}{L_t} = \frac{d\alpha TUR_c}{TUR_c} + \frac{d\gamma L_{LTG}}{L_{LTG}} + \frac{d\varphi L_{LPG}}{L_{LPG}} + \frac{d\tau SFP}{SFP} \tag{12}$$

Expression 12 shows how the rate of change of the total cropland land is affected by the rates of change in the total revenue of cropland, the amount of temporary grassland, L_{LTG}, the amount of permanent grassland, L_{LPG}, and the single farm payment, *SFP*. The dependent variable in expression 12 is the same term as the first term on the right hand side of expression 9. The first term on the right hand side of expression 12, TUR_c consists of two components. The first is the sum of the revenue shares from each crop times the rate of change in unit returns, $\overline{SUR_{ct}}$•$d(lnUR_c)$. The other component is the rate of change in the input price, W. This way the aggregate model accounts for changes in the input price. Remembering the methodology, it can be assumed that inputs are allocated equally over all outputs hence the rate of change for input price, W can simply be subtracted from the first component. Since these two variables exists in both models this is how they are linked to each other and how shifts in variables in any of the two models will affect the outcome of the other. By breaking down the first term on the right hand side into crop c revenue shares per hectare and input price W this becomes clearer. As shown by:

$$\frac{dL_t}{L_t} = \frac{d\alpha \sum \overline{SUR_{ct}} UR_{ct} - dW_c}{\sum \overline{SUR_{ct}} UR_{ct} - W_c} + \frac{d\gamma L_{LTG}}{L_{LTG}} + \frac{d\varphi L_{LPG}}{L_{LPG}} + \frac{d\tau SFP}{SFP} \tag{13}$$

Expression 13 now shows how the rate of change in total revenue from farming is affected by the rate of change in net revenue per crop per hectare, the rate of change in amount of temporary grassland and permanent grassland in hectares, which are also fixed, and the rate of change of the single farm payment.

4 Results

Before presenting the results some validation of the model and the estimations has to be made to make sure that the model is consistent with economic theory. A likelihood ratio, LR test is the usual way to go. For each of the estimated models the LR statistic was calculated, this is done as follows; $LR=-2(l^{*}-l^{U})$, where l^{*} is the log-likelihood for the restricted model and l^{U} is the log-likelihood for the unrestricted model. This is the compared to a chi^2 distribution where the number of restriction equals the degrees of freedom. For the restrictions to be accepted the critical number of the chi^2 distribution must be grater then the LR statistic. Unfortunately both homogeneity and symmetry where rejected. However, a problem with the likelihood ratio test is the size of the test. When large demand systems are estimated the LR-test it is often biased towards rejection of the restrictions (Moschini *et al,*1994). In the context of this it is possible to use a 'corrected' likelihood ratio, LR_0 where the size of the test is accounted for, adjusting the LR. This can be done as follows:

$$LR_0 = LR\left[\frac{MT - \frac{1}{2}(N_U + N_R) - \frac{1}{2}M(M+1)}{MT}\right] \tag{14}$$

Where M is the number of equations in the equation system, T is the number of time series observations, N_U and N_R is the number of parameters in the unrestricted and the restricted model (Moschini *et al,*1994). Accordingly the LR_0 static is adjusted for the size of the sample. Table 1 shows the results from both the LR-test and the 'corrected' LR-test, from which it can be observed that both homogeneity and symmetry can be accepted if the size of the sample is accounted for. In respect of this the model can be assumed to be consistent with economic theory and give a fair representation of the data.

Table 1 *LR-statistic*

	homogeneity	Homogeneity and symmetry
LR	10.196	19.92
LR_0	9.269	17.656
numer of restrictions	4	10
χ^2	9.488	18.307

4.1 Cropland model

Table 2 and 3 summarizes the estimated results from the regression of the equation system in expression 9. First consider Table 2 where the estimated coefficients for how the cross effect of changes in land availability and output prices, total revenue affects the revenue share derived from each crop can be observed. It is possible to observe significant results for wheat and barley with the coefficients of 0.38 and 0.53. The coefficients for rye and rapeseed are not significant at 0.04, respective 0.05. All of the estimates are positive which makes good theoretical sense. Regarding the values of the coefficients it also makes sense that wheat and barley are much bigger than the estimates of rye and rapeseed if we consider the total land shares occupied by wheat and barley compared to rye and rapeseed. The own price effects on the crops shown on the diagonal in Table 3 where all significant, but rapeseed, and also all positive. With the values of 0.15, 0.06, 0.21 and 0.02, respectively. Meaning that a 10% increase (decrease) in the price of wheat would give a 1.5% increase (decrease) in the revenue from wheat.

Table 2 *Total revenue coefficients*

θ_c	Wheat	Rye	Barley	Rapeseed
Land	0.38***	0.04	0.53***	0.05
	(0.17)	(0.06)	(0.16)	(0.09)
R^2	0.22	0.36	0.54	0.47
Durbin-Watson	2.07	2.24	2.4	2.57

*Note that * is significant to the 10% level, ** is significant to the 5% level, *** is significant to the 1% level*

Tablel 3 *Price coefficients*

β_c	Wheat	Rye	Barley	Rapeseed
Wheat	0.15***	-0.03	-0.13***	0.01
	(0.06)	(0.02)	(0.05)	(0.01)
Rye		0.06***	-0.04***	0.01
		(0.02)	(0.01)	(0.01)
Barley			0.21***	-0.04***
			(0.04)	(0.0)
Rapeseed				0.02
				(0.02)
R^2	0.22	0.36	0.54	0.47
Durbin-Watson	2.07	2.24	2.4	2.57

*Note that * is significant to the 10% level, ** is significant to the 5% level, *** is significant to the 1% level*

In Table 4 the elasticities for the cross effect of land and output prices, total revenue are shown. The elasticities are computed by using the estimates in Table 1 and 2 and the average land share over the entire period. The elasticities for wheat and barley show a significance at the 1% level whilst rye and rapeseed are insignificant. On average if the revenue from total cropland increased by 10% land allocation to wheat would increase by 9.4%, rye by 7.7%, barley by 12% and rapeseed would decrease by 3%, however since rye and rapeseed are insignificant they hold no interpretational value. What is important to note here is that both wheat and barley occupies much larger shares of land allocation than rye and rapeseed hence in absolute numbers the increases in land allocation to wheat and barley would be much larger than those of rye and rapeseed.

Table 3 *Total revenue elasticities on land*

η_c	Wheat	Rye	Barley	Rapeseed
Land	0.94***	0.77	1.2***	-0.03
	(0.44)	(1.05)	(0.36)	(0.0)

*Note that * is significant to the 10% level, ** is significant to the 5% level, *** is significant to the 1% level*

Table 4 *Own and cross price elasticities on land*

ε_c	Wheat	Rye	Barley	Rapeseed
Wheat	0.37***	-0.06	-0.32***	-0.12
	(0.16)	0.05	(0.12)	(0.05)
Rye	-0.47	1.1***	-0.72***	0.28
	(0.34)	(0.3)	(0.27)	(0.06)
Barley	-0.29***	-0.09***	0.46***	-0.08***
	(0.1)	(0.03)	(0.1)	(0.0)
Rapeseed	-0.49	0.15	-0.34	0.67
	(0.6)	(0.2)	(0.5)	(0.2)

*Note that * is significant to the 10% level, ** is significant to the 5% level, *** is significant to the 1% level*

Table 5 gives the estimates for own- and cross price elasticities. The diagonal shows the own price elasticities. They are all positive which is reasonable from an economic perspective and all of them are significant to the 1% level except for rapeseed which is insignificant. Wheat has the value of 0.37, rye 1.1, barley 0.46 and rapeseed 0.67, meaning if the price for wheat were to increase by 10% the land allocated to wheat would increase by 3.7%. The crops can be regarded as substitutes to each other as their cross price elasticities are negative, all except the cross price elasticity between wheat and rye and wheat are significant to the 1% level,and those of rapeseed. Observe that the substitution between crops is asymmetric, for example if the price of wheat were to increase by 10% land allocation to barley would decrease by 3.2%, however if the price of barley increased by 10% the land allocated to wheat only declines by 2.9%.

4.2 Aggregate model

The estimates from expression 13, the aggregated model are shown in table 6, in which it is possible to observe that the coefficient for cropland is 0.05 but only at the significance level 0.11. The coefficient for temporary grassland is -0.55 and significant at the 5 percent level. The coefficient for permanent grassland is -0.02 but insignificant. The coefficient for the SFP is 0.31 and significant to the one percent level. This means that if the SFP is increased this would favour the allocation of cropland over the amount of temporary grassland.

Table 6 *Showing estimated coefficients in the aggregate model*

	α	γ	ϕ	τ
Coeff	0.05	-0.55**	-0.02	0,31***
	(0.03)	0.25	(0.18)	(0.08)
R^2	0.78			

*Note that * is significant to the 10% level, ** is significant to the 5% level, *** is significant to the 1% level*

4.3 Simulations

Now, by assuming that temporary grassland was to decrease by 10% making this available for cropland this would correspond to a 4.1 increase in cropland. Furthermore if permanent grasslands decreased by 10% this would correspond to an additional 0.4% summing up to a 4.5 increase in cropland. Holding all coefficient from the cropland model fixed at their estimated levels, land allocated to wheat and barley would increase by 4.2% and 5.4% respectively, according to the estimated land elasticities. Since rye and rapeseed are not significant they will not be considered. This gives a reasonable picture of the substitution between temporary and permanent grassland to cropland farming.

Following this the estimates from the aggregate and the cropland model can be used for simulation. First, some assumptions need to be made about the revenue streams from the three different land categories. Either by increasing the single farm payment or by decreasing the environmental support which is part of the revenue stream from temporary grasslands. The land allocation to the different categories will change.

If by assumption the temporary grassland were to decrease by 10 % making this area available for cropland. The two models, (9) and (13) can be used to simulate the change in land allocated to wheat and the change in the unit returns from wheat. Holding unit returns from the other crops constant will allow the unit returns for wheat to change. This is the condition for all of the available agricultural land to be allocated to wheat. This will change the composition of the first term on the right hand side in expression 13, also causing the shares of land allocated to each crop to change and with this the unit returns follows. From this decrease in temporary grasslands, land allocated to wheat would increase by 6.2% and the unit returns per hectare of wheat would increase by 20%. Hence the economic condition for all of the land to be allocated to wheat is that the unit returns from wheat must increase by 20%. It can be argued whether this would correspond directly to a 20% increase in price or if the price must increase even more due to a decreasing yield. However temporary grassland is often part of the crop rotation on productive cropland, in that sense it seems arguable that a 10% change would have marginal effects on the yield. Furthermore this change in production would lead to an increase in total unit returns by 4.3%.

The same simulation can be made with the permanent grasslands. This would give a 3.6% increase of land allocation to wheat and a 12% increase in the unit returns. This however is a clear overshoot since 10% of the temporary grasslands in absolute numbers would be smaller than the supposed 3.6% increase in land allocated to wheat. This is much likely due to that both of the variables that is affected by the simulation are statistically insignificant therefore this gives little insights of the substitutability between permanent grasslands and wheat.

5 Summary

Researching the substitutability of fallow and temporary and grassland is not an entirely straight forward task. Many thigs has to be considered. For one, Skåne is the most productive county in Sweden (Jordbruksverket, 1981-2015) with quite small shares of fallow land. Meaning that the possibilities of producing wheat on fallow land in counties with more fallow land could be higher. In this sense, the results from this study cannot serve as a benchmark for the whole of Sweden and more research needs to be done to get more information regarding this issue in the different parts of Sweden. Although similar trade-offs to different degrees are likely in many parts of Sweden. Hence this gives farmers in Sweden opportunity to increase their revenue streams from cropland farming which in turn could increase their utility.

The model can of course not account for all thing that may affect the substitution of fallow and temporary grasslands for wheat. Especially properties of the productivity of the different types of land is difficult to account for and since the model only takes cropland farming into account, it is difficult to know what effects this might have on livestock. With a mixed model, much like the many models based on Chambers and Just (1989) accounting for both cropland farming and animal husbandry, the estimates for the substitutability between cereals and temporary would be closer to reality, since it would be possible to calculate a net revenue stream based on how much ley is required in livestock production. However, this would require massive amounts of data on both the inputs and outputs in livestock production which could be difficult to acquire.

Furthermore, the cropland model excludes some of the crops that might be considered reasonable to include. These were excluded partly due to relevance but also that these crops once estimated in the model, their economic interpretations made no sense and they had poor statistical significance. Ultimately the entire model made less sense and therefor these crops were excluded. Of course this has to be kept in mind while interpreting the estimates that the model provided, and that they don't show the entire picture but to the very least they show something that is close to what is actually going on.

Regarding the results, no interpretations could be made about the possibility to grow wheat on permanent or fallow grasslands. However, the possibilities for substituting temporary grasslands for wheat production is shown to have some good potential. This is in line with the results found by DePetris *et al.* (2016) where the crops that occupied greater land shares, the more important crops benefitted more from an increased availability of agricultural land. Vorotnikova *et al.* (2014) found that in Russia land allocation to crops is responsive to output prices, which also seems to be the case in Skåne according to the results and the simulation. Though, the results should of course be interpreted with care due to the uncertainty of the estimates used in the simulations.

With this in mind, the tax on ethanol can be considered. Lantmännen (2017) claims that they have the capacity to produce 230 000 m^3 of ethanol out of 600 000 tons of wheat. Meaning that 1 tonne of wheat produces 383.3 litres of ethanol. The tax on E85 is 0.3 SEK/litre and 0.45 on low-bled ethanol which is mixed into petrol. In addition to this 66% of the ethanol is used as low-blend ethanol, and 34% is used as E85 (SPBI, 2017). Giving an average tax = (0.3•0.34) + (0.45•0.66) = 0.3989 per litre. By multiplying the average tax with the amount of litres of bioethanol from one tonne of wheat gives the average tax/tonne of wheat, 0.3989•383,3 = 152.9 SEK/tonne of wheat, this corresponds roughly to 10% of what was payed for one tonne of wheat in 2014. There is of course nothing that indicates that by removing the energy tax on bioethanol, the price given to wheat refined into bioethanol would increase this much. Eventual increases in the price would rather be an effect from an increased demand of bioethanol due to the removal of the tax and how high the price elasticity of demand for bioethanol is. Although these are only simply calculations, it gives some insights to that the energy tax on bioethanol can affect the allocation of land to wheat production, and it gives an interesting subject for further research in this field.

Furthermore, the result shown in this study could be a cause for concern regarding iLUC effects, since this would decrease the supply of ley, similar to the results found by Bayramoglu and Chakir (2016). Where rapeseed benefitted land allocation on the expense of temporary grasslands due to an increase in the rapeseed price. Although the effects of this substitution might be smaller than iLUC-advocates would suggest. This is due to the externality that occurs when producing ethanol from wheat (Lantmännen, 2017), which is a protein feed that has potential to substitute imported soy based protein feeds. As an extension to this study research is needed on the substitutability between imported protein feed and the protein feed that is a by-product from the production of bioethanol. This could give important insights on the impacts that cereal based bioethanol has on overall CO_2 emissions. Furthermore, it could also turn out to be a possibility of depending less on imported protein feed for Sweden and in the extension Europe. Other ways of approaching the same issue would of course also give good insights to the field for example a mixed model as suggested by Chambers and Just (1989) would give better insight on how livestock production is affected by allocating more land to wheat on the cost of temporary and permanent grasslands.

Moving on, this type of study could give some interesting results for substitutability between wheat and temporary and permanent grassland if the target area would have been the same as in the study by Turbins (2013) which observed declines in the cereal production in favour for temporary and permanent grasslands, and the shares of permanent grassland is larger than in Skåne. This study aimes to start filling the gap of policy and land allocation issues in Sweden especially regarding the biofuel production. Where little studies have been made, and currant studies regarding the effect of iLUC needs to be revised.

5.1 Conclusion

This study intended to research the conditions needed to produce cereals, especially wheat on fallow or temporary grasslands. As it turns out there is some substitutability between wheat and temporary grassland. The simulations made, decreasing temporary grassland by 10%, shows that the condition for land allocated to wheat to increase by 6.2%, unit returns per hectare of wheat must increase by 20%. Hence the economic conditions for producing wheat on fallow or temporary grasslands is that the unit returns from one hectare of wheat must increase. Whether this should be done by removing taxes or by paying price premiums is outside of the scope for this study. However, it is possible to conclude that by changing biofuel policy, biofuels can be made more available while at the same time increasing the farm income. The study gives estimates on the possibilities for producing cereal for biofuel refinement, which will play an important role in the transition towards a greener society. Especially in the transport sector who could reduce their CO_2 emissions greatly if biofuel policy was changed to benefit this type of production.

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