Accounting for growth in Swedish agriculture 1961–2019

A study of productivity in Swedish agriculture

Jakob Nygårds

Degree project/Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences / Department of Economics
Agricultural programme – Economics and Management
Degree project/Department of Economics, SLU, 1444 • ISSN 1401-4084
Uppsala 2022

Accounting for growth in Swedish agriculture 1961–2019
A study on productivity in Swedish agriculture

Jakob Nygårds

Supervisor:	**Shon Ferguson, Swedish University of Agricultural Sciences, department of Economics**
Examiner:	Rob Hart, Swedish University of Agricultural Sciences, department of Economics

Credits:	30 credits
Level:	A2E
Course title:	Master thesis in Economics
Course code:	EX0907
Programme/education:	Agricultural programme – Economics and Management
Course coordinating dept:	Department of Economics
Place of publication:	Uppsala
Year of publication:	2022
Copyright:	All featured images are used with permission from the copyright owner.
Title of series:	Degree project/Department of Economics, SLU
Part number:	1444
ISSN:	1401-4084
Keywords:	Growth accounting, TFP, Agricultural productivity, USDA, Trend regression models

Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences (NJ)

Department of Economics

Abstract

This thesis analyses long-term productivity measures in Swedish agriculture between 1961-2019 based on data from USDA Economic Research Service (2021). The aim is to analyse the effects from agricultural policies on Swedish agriculture before and after the Swedish EU-entrance in 1995. Productivity is of great concern in relation to sustainability and future policy reforms should be designed to adapt and mitigate climate change.

The study contributes to existing literature on Swedish agricultural productivity through the long-term perspective of the stated time period. It adds new perspectives and enable global comparisons by using the USDA as data provider. Time series econometric methods are used to carry out the analysis. The methods include a growth accounting model with aggregated indexed output and input factors in Swedish agriculture and polynomial trend regression models of TFP, labour productivity and land productivity.

The results indicate that there has been a slowdown in productivity growth in Swedish agriculture since late 1980s. This coincides with a turbulent period of Swedish agricultural policy changes. Furthermore, this study provides evidence for a slowdown in Swedish agricultural productivity growth after Sweden became a member of the European Union in 1995.

Keywords: Growth accounting, TFP, Agricultural productivity, USDA, Trend regression models

Table of contents

List of tables

List of figures

Abbreviations

EAA	Economic Accounts for Agriculture
ERS-USDA	Economic Research Service U.S. Department of Agriculture
FADN	Farm Accountancy Data Network
FAO	Food and Agricultural Organisation
ILO	International Labour Organisation
PFP	Partial Factor Productivity
TFP	Total Factor Productivity

1. Introduction

In the introduction we present the background of this study followed by the aim and research questions as well as the limitations.

1.1 Background

Agriculture policy in Sweden has a long history of market regulations where trade barriers and price regulations have been used as powerful tools for policy makers to steer the market (Lindberg, 2012). Policy measures during the 20th century have focused on decent living standards for farmers, a structural change of the sector towards larger production units and a maintained domestic production to secure the level of self-sufficiency.

Since Sweden joined the European Union in 1995, Swedish agriculture is governed by the EU Common Agriculture Policy (CAP). CAP support farmers through the decoupled single payment scheme. It also targets sustainable agriculture as well as rural development and environmental actions through directed support payments (European Commission , 2013). It is important to analyse the effects from these support payments on all aspects of the agricultural sector to allow for adequate policies in the future.

While policy makers have governed agriculture through regulations, other factors have had a major impact on the development of the agricultural sector. Technological progress and social development with an urbanization trend has changed the conditions for agricultural business radically. This is reflected in agricultural production and productivity measures. According to statistics from Food and Agricultural Organisation (FAO) and International Labour Organization (ILO), gross value of agricultural output from crops, livestock and aquaculture has increased by 7.8% while the aggerate value of inputs decreased by 49.1%, during the period from 1961 to 2019. The average annual TFP growth during the same period is approximately 1.30% (USDA 2021, author’s calculations).

In addition, productivity growth in agriculture is of great concern in relation to the global megatrends with an increased population and constantly decreasing arable land due to climate changes, desertification and drought. This has major effects on food security and global hunger, and increased productivity is a key aspect of future solutions on how to battle these challenges. Wiréhn (2018) state that the Nordic region including Sweden, will likely achieve positive effects from climate change, such as longer crop season, potential for new crop species and greater yields. However, Wiréhn (2018) also points at an increased risk of plant diseases and nutrient leaching as well as increased risk of drought and heavy rains. A report from the European Environment Agency (2019) present worrying evidence for negative effects in southern Europe including water shortage, reduction in arable land and decreasing yields. They also conclude that these trends will likely benefit agriculture in northern Europe while the southern European regions will move towards extensive farming practices.

When the northern regions become a more important part of global and European food production the need for a greater understanding of the northern agricultural production and productivity increases. More research on Swedish agricultural productivity is thus an important contribution for future policy development.

1.2 Aim and research question

The aim of the study is to examine the effects of different input factors on agricultural productivity growth and long-term trends in agricultural productivity measures in Sweden. Furthermore, the effects from historical policy reforms on productivity will be analysed further. EU CAP's transition towards a multifunctional policy balancing between economic, environmental and social targets and needs as stated in Bindi & Olesen (2002) will be discussed in relation to the productivity trends.

The following three questions has been the main focus in this study:

How has agricultural productivity growth evolved in Sweden?

What are the effects of Swedish pre-EU agricultural policies on productivity?

What are the effects of implementing the EU CAP on productivity in Swedish agriculture?

This study uses data from USDA Economic Research Service (2021), henceforth (USDA, 2021). USDA offers a widely accepted database which is used to go further into details of productivity in Swedish agriculture, using a growth accounting approach. By computing the contribution to output from different input categories we allow for a comparison between the efficiency of inputs over time. Thus, it contributes with a long-term perspective on productivity growth in Swedish agricultural sector.

The growth accounting analysis is supplemented by a time series analysis to allow for a more detailed study of different trends in the dataset. Polynomial trend models are estimated to study productivity trends over time.

This study follows the outline in Andersen et al. (2018), which studies the evolution of productivity in U.S. agriculture, 1910–2007. They use time series econometric techniques to analyse long-term productivity growth. Their approach has been useful in the search for new perspectives of Swedish agricultural productivity measures. In addition, it contributes to a balanced comparison of Swedish and U.S long-term productivity growth.

1.3 Delimitations

This study uses data from USDA (2021) which is limited to the period from 1961 to 2019. It focuses on productivity in Swedish agriculture although it is possible to compare with other countries included in the USDA dataset. The study is limited analysing the effects from market support and transfers through Swedish and European agricultural policies. It does not consider, for instance, legislation affecting GMOs, animal welfare regulations or environmental regulations which are policy-based decisions that could be assumed to have effects on production and productivity.

1.4 Disposition

Section 1 describe the background of this study including aim and research questions. In section 2 a review of literature on productivity and productivity growth are summarized as well as a review of historical policy reforms in Swedish agriculture since 1961 until today. Section 3 present the data which has been included in the growth accounting model and the trend regression models. Further on section 4 include theories and methods used in this study. Section 5 present the results followed by an analysis and discussion of results in section 6. The thesis is summarized in section 7 together with a presentation of the conclusions and suggestions on further research.

2. Literature Review

The literature review includes a brief summary of related studies and a background to agricultural policy reforms in Sweden.

2.1 Productivity

The literature on TFP in the agricultural sector is extensive. However, TFP measures can be estimated with different methods and vary in terms of variables and time periods which in many cases will find different results. TFP is considered to explain the part of output that are not covered by inputs. In other words, TFP is a measure of how efficient inputs are used in production. Amongst economists this efficiency can be explained by technological progress which is shown as a residual in the production function. This idea has its origins from the research of Solow (1957).

This study is related to other studies that analyse the evolution of productivity in Swedish agriculture. Manevska-Tasevska and Rabinowicz (2014) presented a study of TFP in Swedish agriculture between 1990 and 2012, using aggregated Farm Accountancy Data Network Tools standard estimates (FADN). They found out that TFP in Sweden was lower than in many other EU-15 countries with an output value from production on average at 22% of total input costs between 1995–2004 and 15% between 2005–2009. However, these estimations were based on value indices and not adjusted for inflation (Manevska-Tasevska and Rabinowicz, 2014). Manevska-Tasevska and Rabinowicz conclude that TFP growth in Sweden is mainly due to a decrease in labour inputs from 1990 to 2005. This study is interesting since it focuses on the period when Sweden joined the European Union. It is good for comparisons and analysis of short-term and long-term differences as well as different data describing the same issues. FADN is a database of farm-level data based on bookkeeping principles, compared with USDA data which is based on aggregate data from FAO and ILO (European Commission, 2022). However, the study from Manevska-Tasevska and Rabinowicz (2014) covers a short time period which does not allow for a sufficient analysis of productivity before EU-entrance.

Another related study is Hansen et al. (2011), which estimates the TFP growth in Sweden from 2000 to 2009 based on quantity indices, adjusted for inflation. They show that TFP grew by 2.3% annually, compared to the average TFP growth in EU-15 of 1%. These estimations were also based on statistics from FADN, on aggregate level. During the same period capital intensity and labour productivity grew by 3.6%. The study of Hansen et al (2011) does not measure productivity during the period of the EU-entrance. Neither is the time period sufficient for a long-term analysis. However, it is still an interesting study which is useful for comparisons.

The European Commission (2016) presented a study of productivity growth in the European agriculture between 1995-2015. The study is based on detailed output and input volume indices from European Accounts for Agriculture (EAA) which are presented as a Fisher TFP index. Further on they estimate annual average TFP growth in EU-15 countries at 1.3% between 1995-2005 and 0.6% between 2005 and 2015. This is significantly lower than the estimations from Manevska-Tasevska and Rabinowics (2014). The study from the European Commission only cover the time period after Sweden entered EU and is thus not useful when analysing the EU-entrance and pre-EU policies. However, it contributes to useful comparisons of productivity measures from the Swedish EU-entrance and onwards.

Andersen et al. (2018) show that the TFP growth in the U.S. has slowed down during the period 1990-2007 compared to the period between 1910-1990. They show that TFP annually grew at a rate of 1.47% between 1910-1990 and only 1.16% from 1990-2007 and thus conclude that there is a slowdown in US farm productivity. Furthermore, when analysing TFP growth through a cubic trend regression model they find evidence of a slowdown from the inflection year 1966 and onwards. In addition, Andersen et al. (2018) analyse partial productivity measures of labour and land finding that those measures also follow a cubic trend with productivity slowdowns after the inflection years 1960 and 1978 respectively. The work of Andersen et al. (2018) provides a useful theoretical framework when studying long-term trends in productivity growth. Parts of the work of Andersen et al. (2018) are replicated in this study with Swedish data to allow for accurate comparisons between Sweden and the U.S.

Fuglie (2015) analyses global agricultural TFP and the global trends in productivity based on data from USDA (2021). However, with the global perspective Fuglie leave country-specific analysis for others. From a Swedish perspective the USDA data is highly interesting to study in more details to better understand the effects from historical policy decisions on productivity and to provide useful insights for future policy reforms. There is a great potential in the USDA-data which has not yet been exploited in research on Swedish agricultural productivity.

2.2 Growth accounting

Barro (1999) explains growth accounting as a method to break down observed economic growth into different input factors and the Solow residual g which reflects technological change. Thus, it allows us to explain growth in TFP.

The growth accounting model are developed from ideas in Solow (1957) and Jorgenson & Griliches (1967). They introduced the foundation of productivity and growth economic theory which are of great relevance yet today. Growth accounting allow for comparisons of capital, labour and intermediate inputs' share in productivity growth (Timmer, O'Mahony, & van Ark, 2007). Growth accounting is useful as long as there are available input data for a specific input and possible to estimate the corresponding cost share.

Growth accounting is a conventional method used in various sectors and on national level to account for different sectors share of an economy's total productivity growth. A large EU project which used a growth accounting approach for all sectors of the economy was the EU KLEMS project during 2003-2008 (Timmer, O'Mahony, & van Ark, 2007). EU KLEMS was an initiative to establish a database with statistics and analysis of productivity and economic growth for different sectors in EU (EU KLEMS, 2008). The EU KLEMS model has been used to build a useful framework for a specific growth accounting model in the Swedish agricultural sector.

2.3 Agricultural policies

2.3.1 The regulated agricultural market in Sweden

Lindberg (2012) wrote a historical overview of Swedish agricultural policy before the EU-entrance and the implementing of CAP. Modern agricultural policy in Sweden until 1995 has its origins in the great depression during the 1930s. At that time, Swedish export dropped and prices of cereals, dairy products and meat crashed. According to Lindberg (2012) market regulations was implemented to counter the crisis and the system continued until late 1980s. The regulations were imposed to stabilize market prices and protect Swedish production from market competition. Regulations led to an unbalanced market which resulted in additional market regulations. The economy moved towards a system based on negotiations between the government and the Federation of Swedish Farmers (LRF). Three overall objectives were defined in addition to the market regulations (Lindberg, 2012). Those were focusing on farmers income, efficiency and production output. Farmers were supposed to have a decent income that matched industrial workers. The efficiency objective focused on rationalizing farms by merging small production units. This process was facilitated when other industry sectors developed and needed more labour. Further on the production objective was defined to secure domestic production and Swedish self-sufficiency. Price regulations and trade barriers towards other countries became the most important tools during the period of market regulations.

The three objectives were established and maintained through negotiations, price regulations and trade barriers for 50 years (Lindberg, 2012). The system was generally seen as a necessity for the Swedish domestic food production with acceptable conditions for Swedish farmers and affordable prices to customers. However, in 1984 new discussions aroused when critics argued that the prevailing policy did not fulfil the objectives to fair social costs and that stakeholders had too much influence and power when forming market conditions through complex regulations (Lindberg, 2012).

According to Lindberg (2012) The criticism led to further debates and investigations during 1987-1989 and a final decision came in 1990 when the parliament accepted a reform of deregulation. Sweden implemented market prices and compensated farmers with a conversion support to those who accepted to invest in alternative crop production e.g. bioenergy or forest planting (Lindberg, 2012).

The deregulated period in Swedish agriculture was short. The Swedish government declared the same year (1990) that Sweden should join the European Union and the process began in 1991 when an application was submitted (Swedish Government, 2019). In 1995 when Sweden joined the European Union, agriculture once again was regulated, this time through the common agriculture policy (CAP).

2.3.2 Common Agricultural Policy

CAP was first agreed on in 1962 by the six founding countries of the European Communities (European Council, 2022). Back then the purpose of the policy was to increase productivity, stabilize the European markets, ensure availability of food at reasonable prices and provide decent living standards to European farmers. Those objectives are still the foundation of CAP today, only extended with additional targets. Over the years since 1962, CAP has developed together with the European Union and today CAP regulate the agriculture markets in all 27-member states. CAP has undergone several reformations, with the most significant described below.

When Sweden joined the European Union in 1995 it resulted in a transition to the EU common agriculture policy system and a return to price regulations on agricultural commodities. In 1995 the MacSharray reform from 1992 was recently implemented (Cunha & Swinbank, 2011). Back then EU supported agriculture through intervention prices on cereals, beef and dairy products, although reduced after the MacSharray reform. In addition, direct payments were used to compensate lower intervention price, those payments were coupled to area and number of animals (Cunha & Swinbank, 2011). Furthermore, EU kept milk quotas which were implemented in 1984. In the MacSharray reform EU also put focus on social and environmental issues, offering support for early retirement, extensive agriculture and environmental protection (Cunha & Swinbank, 2011).

The first CAP reform with a direct effect on Swedish agriculture was the Agenda 2000 reform. Cunha & Swinbank (2011) explain that through Agenda 2000 guarantee prices were reduced to close the gap to world market prices and increase the demand on European products. In addition, the reduced guarantee prices were compensated by increased farm support payments. The reform was expected to improve the competitiveness in EU agriculture.

In 2003 the European commission implemented a new reform of CAP with the purpose to decouple farm income support from production (Cunha & Swinbank, 2011). This is known as the Fischler reform. The change from direct payments based on production to decoupled single payments did not change the EU agriculture expenditures. However, the idea was to develop and compensate sustainable agriculture and rural development with regulations on food safety, animal health and welfare standards (Cunha & Swinbank, 2011).

In 2013 the European commission decided on a new reform valid through 2014-2020. This reform was a sequel to the previous CAP reform in 2003 and continues the movement from product support to producer support to improve competitiveness and sustainability of the agriculture sector (European Commission , 2013). New features of CAP were policy instrument focusing on greening where farmers were paid for environmental public services carried through agriculture.

The evolution of CAP expenditures is shown graphically in figure 1.

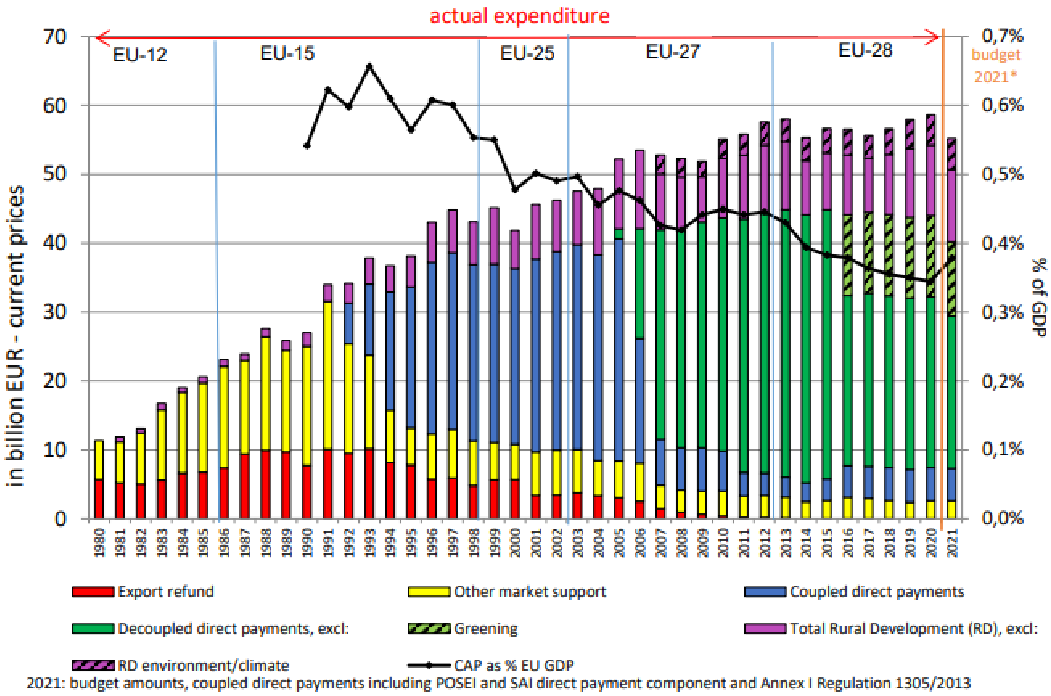

Figure 1. CAP Expenditure and CAP Reform path (current prices). Source: (European Commission, 2021) .

Bindi & Olesen (2002) discussed consequences of climate change for European agricultural productivity and the relation to future CAP reforms. They stated that agricultural policy must support the adaption of agriculture to climate change through different policy instruments. Furthermore, Bindi & Olesen (2002) argue that agriculture need to be considered having a multifunctional role affecting and balancing both social, environmental and economic values. A more recent study from Pe'er et al. (2019) state that the EU CAP is failing with its aim to address and target environmental, social and economic sustainability and that CAP should be transformed to better target environmental issues and climate change. The ideas from Bindi & Olesen (2002) and more recent statements from Pe'er et al (2019) are discussed further in section 6.

3. Data

In section 3 the choice of data is discussed followed by a presentation of the variables included in the study.

In this study a dataset processed by Fuglie (2015) and published by USDA (2021) is used. The dataset is mainly based on FAO annual time series which cover production output and input factors for the time period between 1961 to 2019 for 179 countries. Based on the data, Fuglie (2015) has produced index figures for all output and input factors. These figures are then used to compute an agriculture TFP index which we analyse further in this study. Variables in the dataset are presented in constant 2015 prices. It is important because it removes price effects and allow for comparisons between the years.

There are different sources of suitable and open data for this study. Each dataset comes with advantages and drawbacks when doing comparisons between them. Eurostat publish annual statistics of output and inputs variables on a detailed level for each member state in the European Union. This data is closer to the countries and treated to allow for comparisons between member states. However, available data would need more processing than this study can allow for. Furthermore, the processed data would limit the study in terms of available years. First available year varies between 1977 and 1990 which implies that a representative and useful dataset would be limited to the period 1990-2012. This is the same period as Manevska-Tasevska & Rabinowicz (2014) analysed in their study. Certainly, one could find interesting results from this data but it is not sufficient enough when studying long-term productivity growth and historical policy implications.

The USDA dataset processed by Fuglie (2015) is less detailed than available data from Eurostat. Fuglie mentions global average prices in output variables and not directly measured inputs as examples of limitations in the dataset. Furthermore, country specific productivity indices are based on more detailed input and output data. However, Fuglie (2015) state that the purpose of the USDA dataset was to create a consistent comparable TFP index for global agriculture. In addition, the dataset covers a longer period of time, from 1961-2019, which is positive for this study with a long-term perspective. The fact that all variables are presented as indices in the USDA dataset is useful in this study. It allows for comparisons without further processing and simplifies analysis of year-to-year changes.

3.1 Variables

In this section we present the variables used in the study. All of the variables are partly or fully compiled by Fuglie (2015)*. All variables are shown as indices where 2015=100.*

3.1.1 Productivity measures

In this study total factor productivity (TFP) and partial factor productivity (PFP) for land and labour are used as productivity measures. They are estimated as indices estimated as the ratio of total output index to total input index. The TFP index is compiled by Fuglie (2015) and based on the variables following in section 3.1. Partial Factor Productivity (PFP) for labour and land productivity are calculated as the ratio of total output index and total labour and land index respectively. They are own calculations based on USDA data.

In figure 1 TFP and PFP are shown graphically. From a visual analysis it is clear that land productivity has increased less than labour productivity. It implicates that labour has contributed to TFP to a greater extent compared with land. However, it is also shown in figure 2 that the peaks and bottoms seem to follow the same path. It could be explained by the fact that both are computed with total output and should correlate. 2019 appears to be an outlier with respect to TFP indicating a 20% increase from 2018. It could be explained by the fact that in 2018 Sweden was suffering from severe drought, which had major consequences in agriculture.

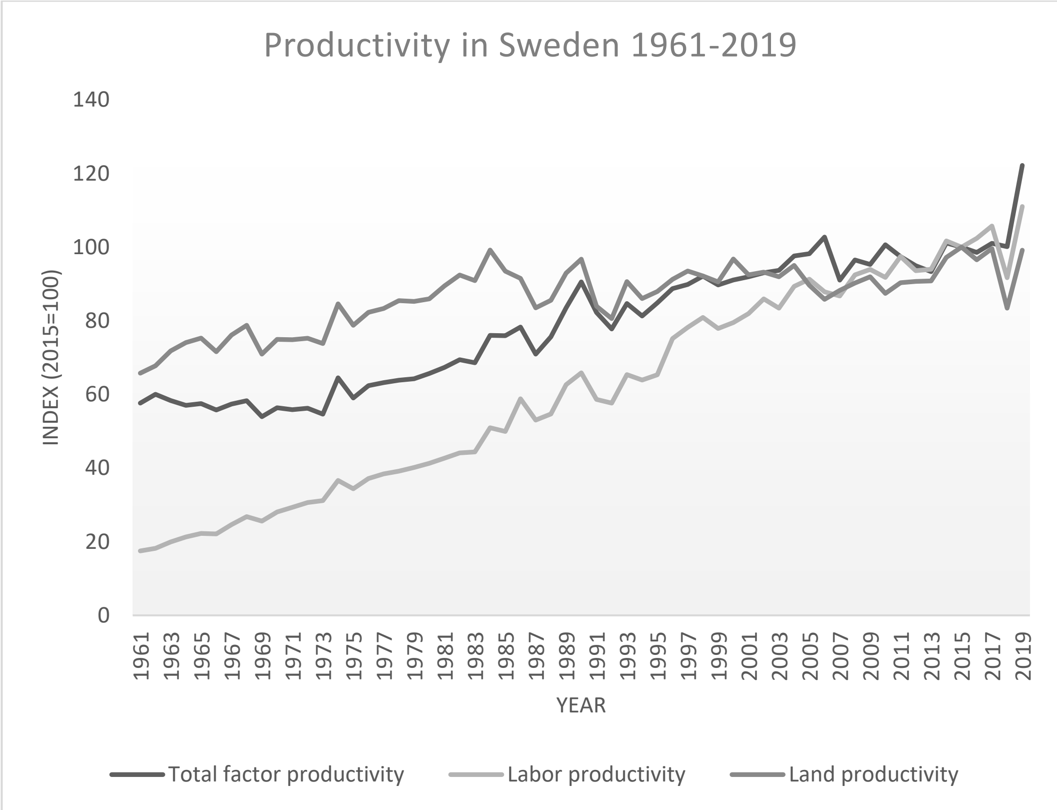

Figure 2. Productivity indices for Swedish agriculture 1961-2019. USDA (2021), author's calculations

3.1.2 Output

Total output refers to gross value of agricultural output from crops, livestock and aquaculture at constant 2015 prices (Fuglie, 2015). The variable is expressed in thousand USD and as an index where 2015 = 100.

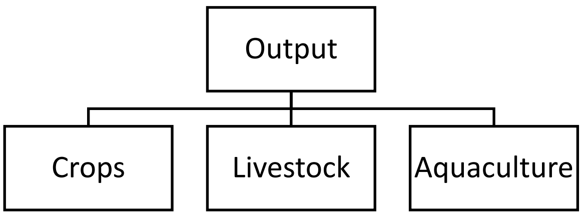

Figure 3 Output, (USDA, 2021)

3.1.3 Inputs

Available input data is structured as in figure 4. A detailed description of the input categories follows below. The descriptions of the variables are brought from USDA (2021).

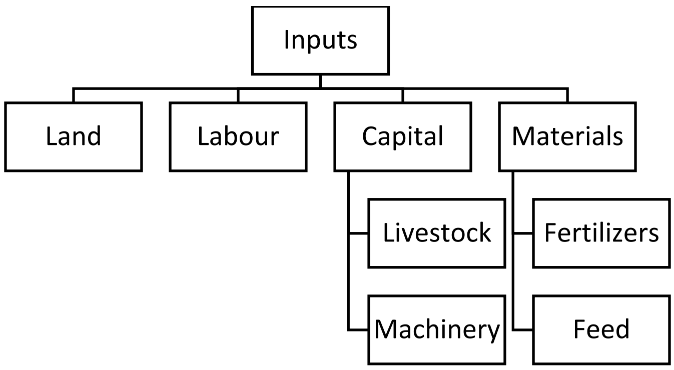

Figure 4 Input factors, USDA (2021)

Total input is an index of aggregated quantity of agricultural inputs including land, labour, capital and materials.

Land refers to quality-adjusted area, measured in thousand hectares of rainfed-equivalent cropland. The land variable is calculated from cropland and quality-adjusted irrigated area and permanent pasture expressed in rainfed cropland equivalents.

The labour variable shows the total number of persons primarily employed in agriculture, expressed in thousands.

Capital is the value of the net capital stock in thousand USD at constant 2015 prices.

Livestock refers to farm inventories of livestock and poultry measured in thousand standardized livestock units.

Machinery represents farm inventories of farm machinery measured in thousand metric horsepower in tractors, combine harvesters and milking machines.

Materials refer to an index of all intermediate inputs in crop and animal production.

Fertilizer is the total volume of nitrogen, phosphorus and potassium from chemical fertilizers and nitrogen from organic fertilizers.

Feed is the total metabolizable energy from animal feeds presented in megacalories (Mcal).

In figure 5 total output and total inputs are shown graphically. As mentioned, total output has only increased by 7.8% between 1961 and 2019, while total input has decreased by 49.1% during the same period.

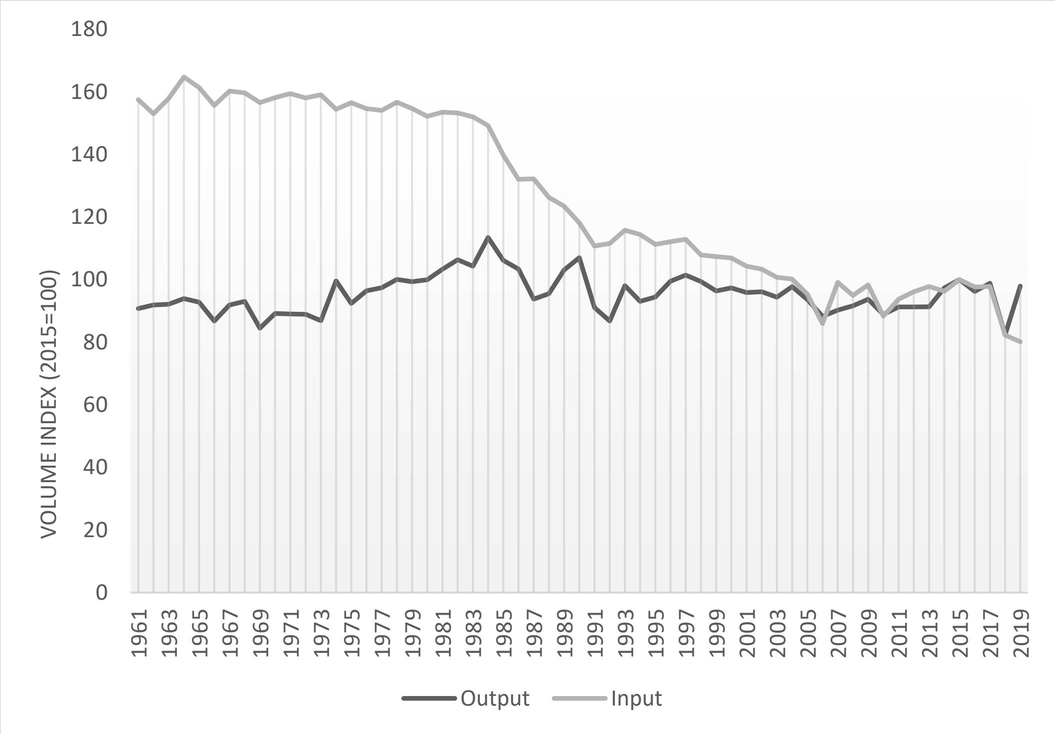

Figure 5. Index of total output and input in Swedish agriculture 1961-2019. USDA (2021), author's calculations

3.1.4 Weights

In the growth accounting model, cost shares are included as input weights. Fuglie (2015) has calculated regional cost shares which are weighted averages of national cost shares in each region. The weights are estimated as averages for 10-year periods to reduce the risk of index number bias in the TFP growth estimations (Fuglie, 2015).

In figure 6 the relative input weights for all input categories are illustrated and compared in a stacked bar chart. It provides a good overview of the contribution of each input factor to the total input volume.

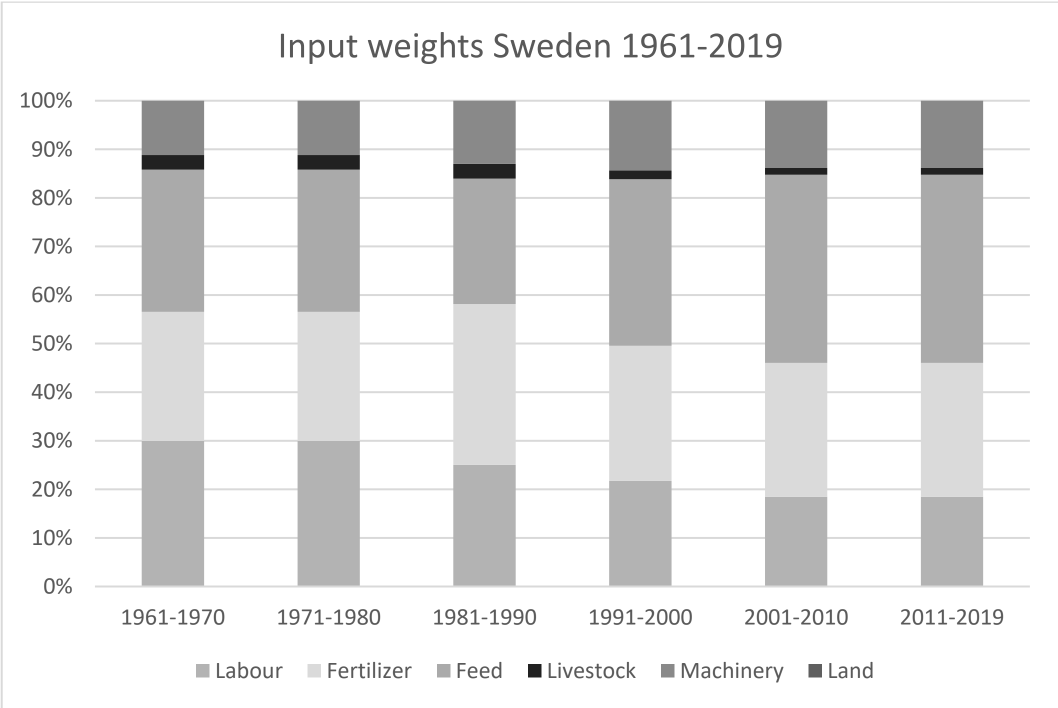

Figure 6. Inputs weights Swedish agriculture 1961-2019. USDA (2021), author's calculations.

4. Theory and Methodology

Section 4 present relevant economic and econometric theories as well as the methodology used to obtain the results.

4.1 Growth accounting model

In this study a growth accounting model is applied to allow for an accurate comparison of the different input factors.

The growth accounting method can be derived starting from a Cobb-Douglas production function.

$$Y = A * L^{S_L} * K^{S_K} * M^{S_M} \tag{1}$$

Where Y represent output and L, K, M are production inputs, labour, capital and materials. $S_{L,K,M}$ are the input weights.

By taking logs and first order derivatives with respect to time t we get equation (2) and (3)

$$ln\, Y = ln\, A + s_L\, ln\, L + s_K\, ln\, K * s_M\, ln\, M \tag{2}$$

Growth rates are calculated as time derivatives of output and input factors.

$$\frac{\mathrm{d} \ln Y}{\mathrm{dt}} = \frac{d \ln A}{dt} + s_L \frac{d \ln L}{dt} + s_K \frac{d \ln K}{dt} s_M \frac{d \ln M}{dt} \tag{3}$$

The growth accounting model shows that the growth rate in output is a weighted average of the growth rate in labour, capital, intermediate inputs and technical change. These input categories can be decomposed further in subcategories.

Year-to-year growth rates of single variables are estimated by taking $\ln\left(\frac{X_t}{X_{t+n}}\right)$.

4.2 Trend regression models

Time series data consists of a single entity i from multiple time periods t (Stock & Watson, 2020). In this study cubic and quadratic trend regression models of productivity variables have been estimated to analyse trends in the data, such as the average growth rate and inflection points etc. Andersen et al. (2018) use a similar approach when analysing the long-term trend in U.S. agricultural productivity data. They find evidence that cubic polynomial trend models of *ln(TFP), ln(PFPlabour)* and *ln(PFPland)* fits the data well.

Based on the method employed in Andersen et al (2018), the following regression models have been estimated for Sweden using the data from USDA (2021).

$$\ln Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3$$

The dependent variable Y_t represent the productivity variables. *Ln(TFP), ln(PFPland)* and *ln(PFPlabour)* are included in three different regression models. $\beta_0, \beta_1, \beta_2, \beta_3$ are regression coefficients for each explanatory variable. t, t^2 and t^3 are time variables used as explanatory variables in the trend regression models. All models are estimated with robust standard errors to account for heteroscedasticity.

5. Results

Section 5 present the results of this study. First the results from the growth accounting model followed by the results from the trend regression models.

5.1 Growth accounting

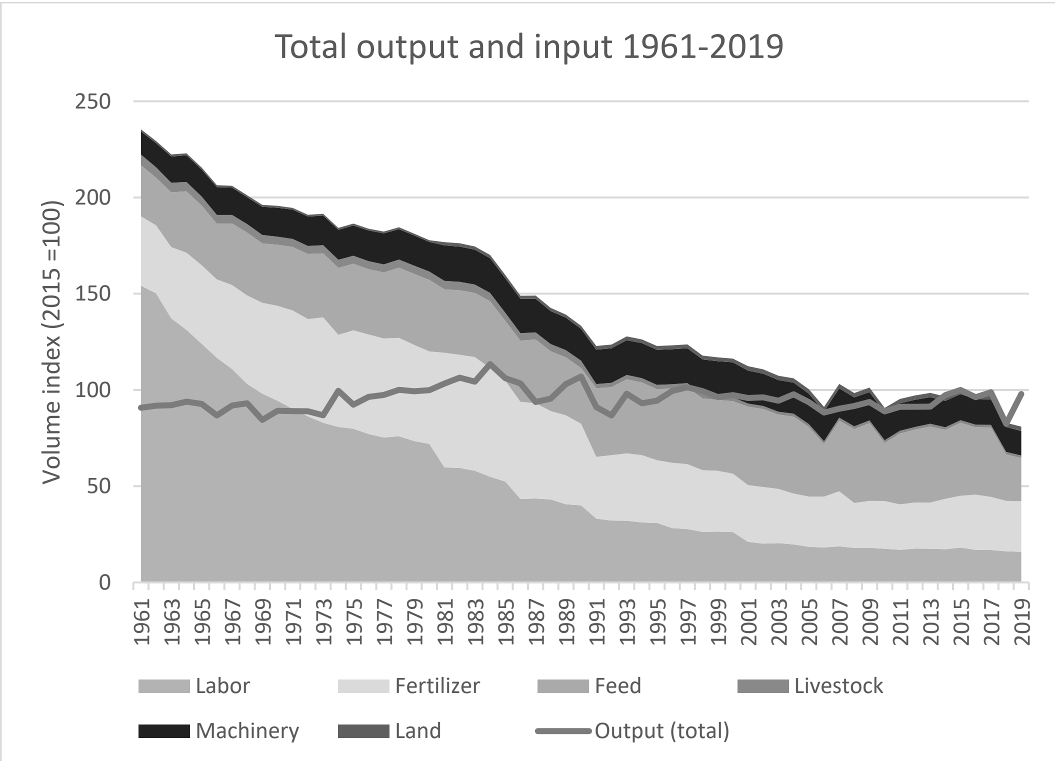

Figure 7 Total output and input 1961-2019. USDA (2021), author's calculations

Total output measured in gross value of production at constant 2015 prices has been almost unchanged during the period with a total increase of 7.8% between 1961 and 2019. It is interesting in relation to the total volume of weighted inputs which has decreased by 64.4%. This is a strong indication of productivity growth. TFP rose by 111.9 % between 1961 and 2019, with an annual average productivity growth of 1.3%.

The results from applying the growth accounting model shows that labour is the input variable with greatest contribution to TFP growth. Labour input has decreased by 89.7% during the period 1961-2019. It is also relating to a decrease in the weights for labour from 0.297 in 1961 to 0.180 in 2019. The large decrease in labour inputs should be compared with the total decrease in inputs of 64.4%. Thus, it is clear that the decrease in labour has had a large impact on productivity growth. Land is the variable with the least impact on TFP in the growth accounting model. However, even though land has decreased by 28.3% between 1961—2019 the relative impact on TFP has increased by 99.2% during the same period. This contradiction depends on the increase in land weight from 0.008 in 1961 to 0.022 in 2019.

Fertilizer and feed are subcategories of agricultural materials representing a large share of weighted total inputs. However, both fertilizers and feed has been relative stable over time, see figure 7. The volume of fertilizer inputs had a peak in early 1980s followed by a declining trend. Machinery and livestock are subcategories of agricultural capital which has a smaller impact on the total input volume when analysing the relative weights. The weight of total agricultural capital has increased slightly from 0.141 to 0.149 between 1961 and 2019. All input weights are presented in details in section 3.1.4 and can be analysed further in figure 5.

5.2 Trend regression models

Moving averages of TFP growth are calculated to better visualise the long-term TFP growth. 10-year moving averages provide a good approximation of the long-term trends while also smoothing the fluctuations of annual productivity growth. The plotted results of moving averages of annual TFP growth rates in figure 8 indicate that TFP growth grew until late 1980s and has slowed down since then. In addition, moving averages of annual labour productivity growth (figure 9) show a constant decrease since 1961. Moving averages of land productivity growth has a horizontal trend which is difficult to analyse graphically in figure 10. Thus, further analysis is needed to find evidence of potential trends.

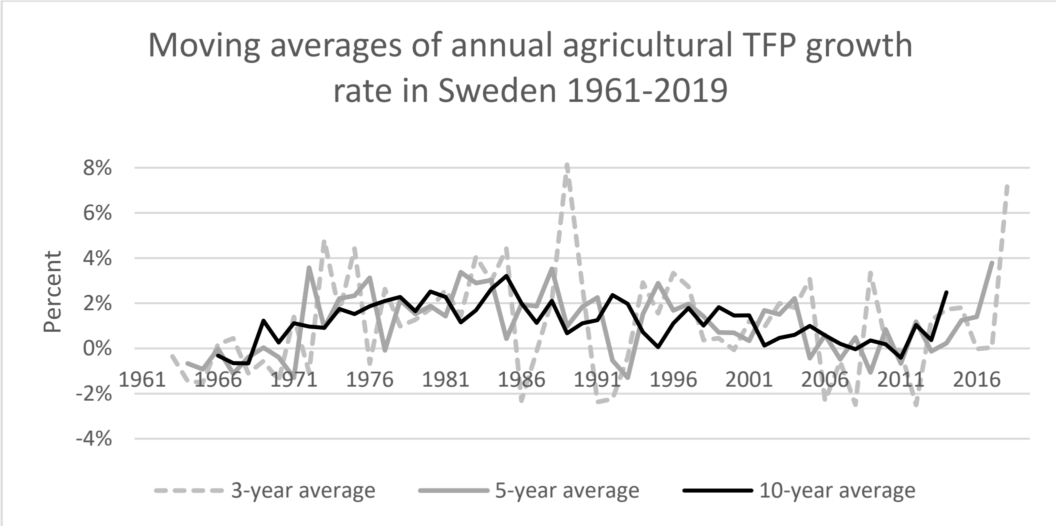

Figure 8. Moving averages of annual agricultural TFP growth rates 1961-2019 in natural logarithms. USDA (2021), author's calculations.

3-year moving average is calculated as annual TFP growth in year t-1, t, t+1. Same approach is applied for 5-year and 10-year moving averages in figure 7,8 and 9.

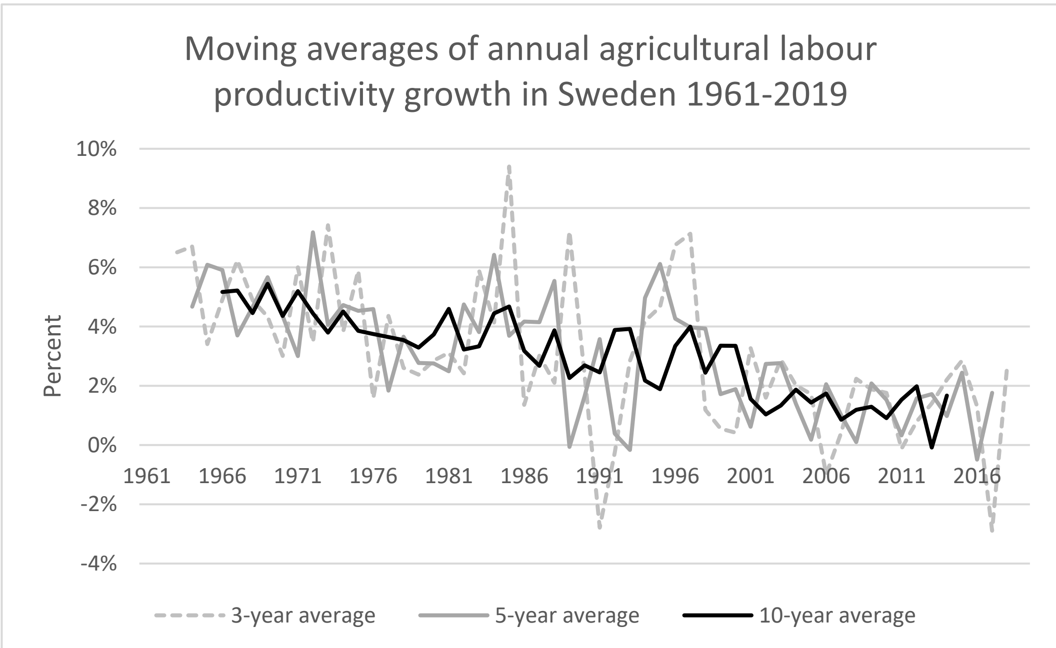

Figure 9. Moving averages of annual agricultural labour productivity growth rates 1961-2019 in natural logarithms. USDA (2021), author's calculations

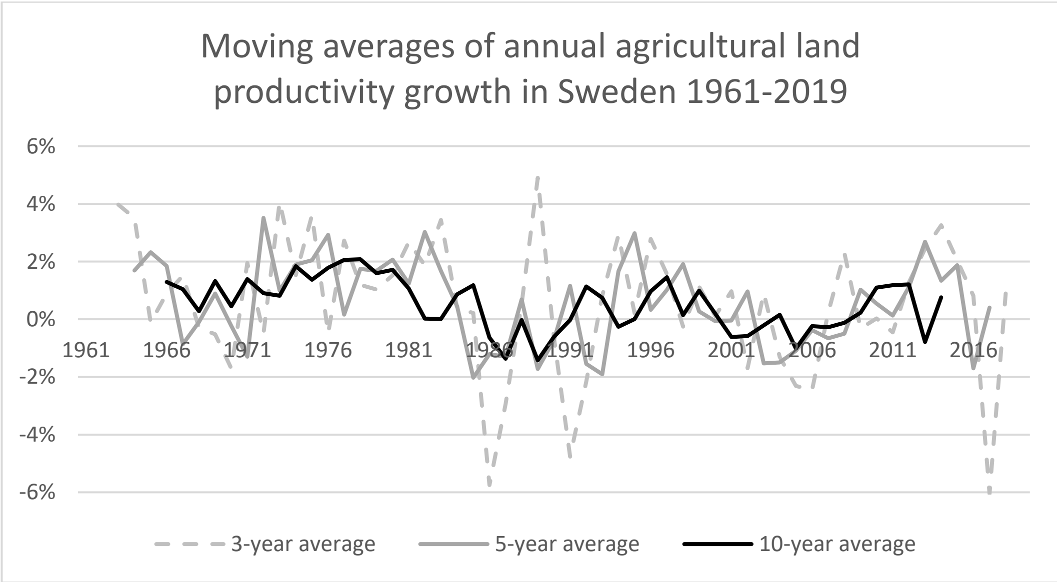

Figure 10. Moving averages of annual agricultural land productivity growth rates 1961-2019 in natural logarithms. USDA (2021), author's calculations

To go further into an analysis of productivity growth, the results from the polynomial trend models are useful. Results from the estimated trend regression models are presented in table 1.

Table 1. Trend Models of TFP and PFP in natural logarithms 1961-2019

	(1)	(2)	(3)	(4)
VARIABLES	ln(TFP)	ln(PFPlabour)	ln(PFPlabour)	ln(PFPland)
t	-0.00151	0.0554***	0.0540***	0.0224***
	(0.00466)	(0.00157)	(0.00354)	(0.00340)
t2	0.000663***	-0.000414***	-0.000355**	-0.000519***
	(0.000203)	(2.76e-05)	(0.000146)	(0.000144)
t3	-7.98e-06***		-6.52e-07	4.18e-06**
	(2.47e-06)		(1.72e-06)	(1.71e-06)
Constant	4.027***	2.812***	2.819***	4.178***
	(0.0269)	(0.0157)	(0.0211)	(0.0195)
Inflection point	1988	-	-	2001
Observations	59	59	59	59
R^2	0.948	0.992	0.992	0.777

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

F-TEST
(1) t = 0
(2) t2 =0
(3) t3 = 0

F (3, 54) = 98.30
prob> F = 0,000

Model 1, 2 and 4 are estimated as $\ln Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3$. Model 3 is estimated as a quadratic trend model, $\ln Y_t = \beta_0 + \beta_1 t + \beta_2 t^2$. All regression models are estimated with robust standard errors.

The cubic model of *ln(TFP)* (model 1) seems to fit well. R^2-value for *ln(TFP)* are 0.948 which indicate a good approximation. This is also shown in figure 11 where it is visually clear that the *ln(TFP)* values follows the fitted values of the cubic trend model. F-test indicate that the model is significant even though the linear variable *t* is not significant. Figure 11 provide further evidence that TFP growth in Sweden has slowed down since late 1980s. That is confirmed by the calculated inflection point in 1988 based on the cubic regression model.

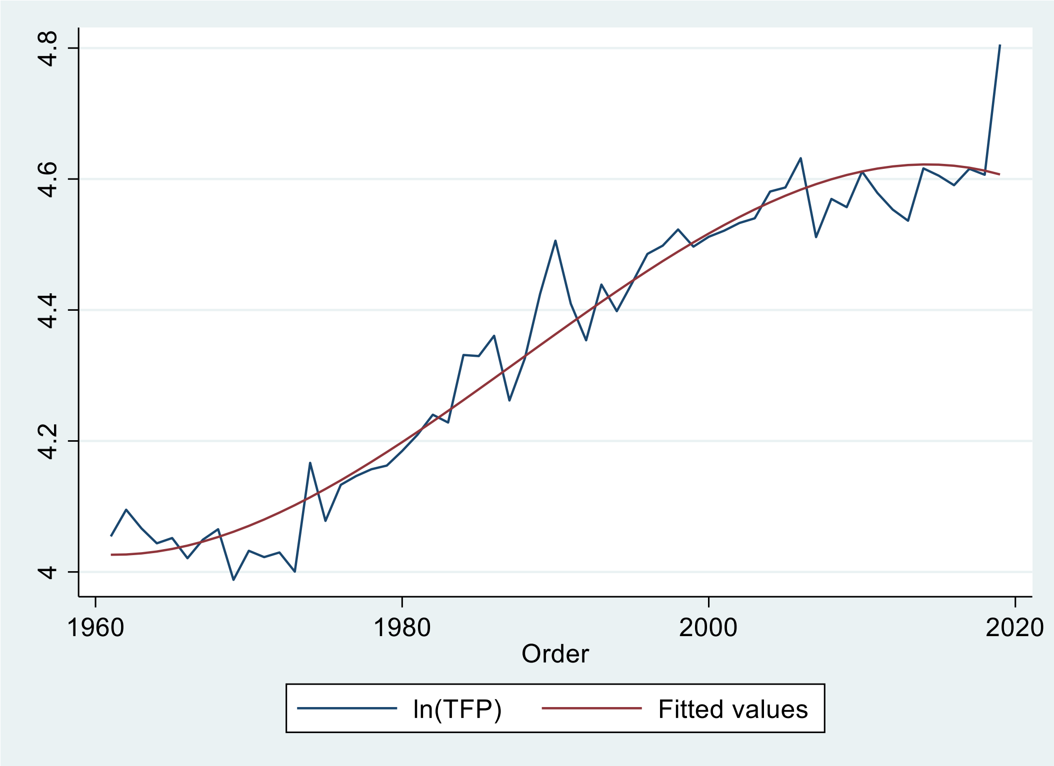

Figure 11. Cubic trend model of ln(TFP) index, 1961-2019. USDA (2021), author's calculations

The cubic model for *ln(PFPlabour)* (model 3) is not significant, however the results are interesting when estimating a quadratic model (model 2). The quadratic model is significant and a good approximation to the fitted values. It is shown graphically in figure 12. Labour productivity growth seems to have slowed down, following the concave trend line. It is a reasonable assumption since labour productivity growth has decreased continuously from high relative high levels.

Figure 12. Quadratic trend model of ln(Labour productivity) index, 1961-2019. USDA (2021), author's calculations

In addition, the cubic model of *ln(PFPland)* (model 4) have a R^2 of 0.777 which imply that the model does not explain the trend in the data to the same extend. Figure 13 shows the cubic model of *ln(PFPland),* as can be seen visually, the data fluctuate more around the fitted trend line. However, coefficients of the model are significant, see table 1. The model has an inflection point in year 2001, indicating an increased growth rate from 2001 and onwards. Estimations in model 4 must be interpreted with caution since the R-squared is lower.

Figure 13. Cubic trend model of ln(Land productivity) index, 1961–2019. USDA (2021), author's calculations

6. Analysis and Discussion

In section 6 the results from section 5 are analysed and discussed. It is followed by a discussion of agricultural policy reforms and suggestions on further research.

This is the first study of growth accounting for Swedish agriculture over the long-term period 1961-2019. The results are highly interesting since they indicate that policy reforms during the studied time period has had effects on productivity growth.

Labour is clearly the input variable with greatest contribution to TFP growth. From the growth accounting model we find that weighted labour inputs decreased by 87.9 % compared with the total decrease in inputs of 64.4%. While total output increased by only 7.8%, the combined input and output changes led to a total TFP increase of 111.9 % or a 1.3% annual average productivity growth. Further on all other input variables has been relatively stable over time and thus not contributed as much to the rising TFP. These results are in line with previous studies on TFP in Sweden. For instance, Manevska-Tasevska & Rabinowicz (2014) also found that a decrease in labour inputs was the most contributing factor to TFP growth.

In addition, Manevska-Tasevska & Rabinowicz (2014) estimated the annual TFP growth between 1995 to 2005 to 2.3%. This is significantly higher than the long-term annual TFP growth of 1.3% between 1961-2019 found in this study. Further on the European Commission (2016) calculated the EU-15 annual TFP growth to 1.3% for the period 1995-2005. This is the same annual growth rate a we have found proof of in this study. Furthermore, the study from European Commission (2016) found that the annual TFP growth was only 0,6% between 2005 and 2015. This is also in line with the results in this study indicating a continuous decline in TFP growth after 1988.

The results from this study with a longer historical perspective on TFP growth compared with other studies in Sweden add new perspectives to the research of agricultural productivity. As already stated, this study finds that TFP has a cubic trend with an inflection point in 1988 indicating that TFP growth has slowed down since then. It correlates with one of the most intense periods of agricultural policy debates in Sweden. The outcome of this period was a deregulated agricultural market in Sweden after 1990 (Lindberg, 2012).

However, many other parameters affect productivity growth and the analysis is more complex. The years from late 1970s to mid-1980s was characterised by good harvests with a top year in 1984 (USDA, 2021). This period of high output from crop production correlated with the period with highest output from animal production as well. Further on the total volume of inputs decreased significantly during these years which also had a large impact on TFP. It is an expected effect from the technological progress during the second half of the 20th century.

The cubic trend model of land productivity is reverse compared with TFP indicating that land productivity growth decreased until the inflection year which occurred in 2001. It was then followed by an increased land productivity growth from 2001 and onwards. In 2001 the Agenda 2000 reform was recently implemented in CAP and the Fischler reform in 2003 was approaching. During this period the focus shifted from guarantee prices and direct market support to decoupled farm income support. Thus, CAP shifted parts of its budget from production to strengthen other aspects such as sustainability and rural development. However, the decoupled payments were first introduced in 2006. This is shown in figure 1 of EU CAP expenditures. It is difficult to draw any conclusions from this analysis other than that land productivity growth seems to increase the last 20 years while CAP reforms have shifted focus from production and market support to sustainability and rural development. A plausible explanation is the fact that a larger part of the arable land is supported by CAP to be set aside as fallow, which decrease land inputs. Anyhow these results must be interpreted with caution due to volatile data points. It is difficult to tell from the results if land productivity growth will increase or if the long-term trend will prove to be continuously decreasing.

The decreasing labour productivity growth is obvious when analysing the results. An increased labour productivity is in line with the Swedish agricultural policy from 1930s including an efficiency objective focusing on rationalizing Swedish agriculture through mergers of small farms. Even though this policy was abandoned in 1990 agriculture has continued to be rationalized after 1990 thanks to technological progress in the agricultural sector and a continued urbanisation trend.

When comparing these results with the study of Andersen et al. (2018) we find some interesting correlating trends. Andersen et al. (2018) indicates that U.S agricultural TFP started to grew more intensely in late 1930s and the following decades after that are characterised by a high TFP growth. They show that TFP grew at a highest rate from 1940s through 1980s and the results indicate a slowdown after the inflection year 1966. This result is in line with our study. In both this study of Sweden and the U.S. study from Andersen et al (2018) the slowdown is clear. However, it is difficult to know if this trend will continue in the future or if productivity growth will start to increase again.

Further on Andersen et al. (2018) find that U.S labour productivity in agriculture have an inflection point in year 1960 with a continuously decrease since then. The results from the trend model on Swedish data from 1961-2019 indicates that the labour productivity growth trend is quadratic and decreasing. Thus, the two results match well. When comparing these two results we find that labour productivity growth in both Sweden and the U.S. has decreased the last 60 year. It would be interesting to analyse this further with Swedish data covering a larger part of the 20th century to test if labour productivity in Sweden has had a cubic trend over time. It is a reasonable assumption based on the general global shifts in production technology that has affected labour productivity, however it must be tested to find evidence.

Andersen et al. (2018) include a Bai-Perron test to analyse unknown structural breaks. There was an intention to replicate such an analysis in this study. However, it has not been done due to limited resources. Although a test for structural breaks would contribute with more knowledge of how productivity has evolved over time and what impact historical policy reforms may have had on Swedish agriculture. It is an interesting approach for further research.

Bindi & Olesen (2002) argued that EU CAP should include support payments to adapt European agriculture to climate change and mitigate the effects. Their opinions have been considered through the CAP reforms after 2002. The European Commission evaluated CAP’s impact on climate change and greenhouse gas (GHG) emissions and concluded that GHG emissions from EU agriculture were reduced by over 20% since 1990 but the reduction has slowed down after 2010 (Agriculture and Rural Development, 2021). Recent reforms have moved CAP towards a multifunctional policy as Bindi & Olesen (2002) suggested. With respect to this progress it is interesting to find that agriculture productivity in Sweden in fact has continued to increase, although with a slower pace.

In relation to the global trends with climate effects and a growing world population which cause a shift in agriculture with decreasing arable land in southern regions and an increasing need of food and nutrition, policy makers must address the slowdown in productivity growth. It is important that European agriculture continue to produce food while also contributing to a sustainable future. However increased productivity and sustainable agriculture do not contradict each other. Productivity measure how much output we can produce with a given level of inputs. Improved productivity indicate that we are more effective with the inputs which is an important part of a future sustainable production. Thus, a slowdown in productivity growth is a negative indication also for the sustainable agriculture. Though the arguments from Pe’er et al. (2019), finding CAP too weak in terms of sustainability actions are also interesting from a productivity point of view. A greater focus on sustainability through CAP could improve agricultural productivity in the future. This is an interesting area for further research.

7. Conclusion

In section 7 a summary of the study is presented together with the conclusions.

The aim of this study was to contribute with a long-term perspective on agricultural productivity in Sweden. Furthermore, it provides more knowledge of the effects on agricultural productivity from historical policy reforms.

Time-series data from USDA (2021) covering Swedish agricultural TFP, aggregated output and inputs over the period 1961—2019 are analysed with a growth accounting approach. In addition, the study is extended with polynomial trend regression models to allow for further analysis of how productivity has evolved in Swedish agriculture. Productivity measures for land and labour are computed to enable comparisons of TFP, land productivity and labour productivity.

TFP in Swedish agriculture has increased steadily since 1961. It has increased by 111.9% from 1961 to 2019. During the same period the total volume of output has increased by 7.8% while total weighted volume of inputs has decreased by 64.4%. The single most influential variable is labour with a total decrease of 89.7%. These results are in line with existing literature on agricultural productivity which all are concluding that a decrease in labour inputs explain a major part of TFP growth.

The polynomial trend regression model of log transformed productivity measures indicates that TFP has a cubic decreasing trend with an inflection point in 1988. TFP growth thus seems to slow down after 1988 until 2019. In addition, the results show that labour productivity follows a decreasing quadratic trend model. While land productivity has a cubic increasing trend with an inflection point in 2001 indicating an increased land productivity growth since then.

The results and the analysis in this study provide answers to the stated research questions in section 1. We can conclude that productivity has continued to increase after the EU-entrance in 1995. However, productivity growth has slowed down during the period of agriculture governed by the EU CAP. As discussed in section 6 there are several explanations to this progress. In addition, TFP growth was increasing during the pre-EU policies. This could be explained by Swedish policy targets of improved efficiency. However, the increasing TFP growth through 1960s to 1980s are also explained by a general technological progress.

The results from the trend regression models are in line with the study from Andersen et al. (2018) who are using a similar approach to analyse U.S long-term productivity growth during the 20th century. However, since Andersen et al. (2018)

use data from 1910–2007 while we have data covering 1961–2019 the results differ in some aspects. The reason for this is assumed to be a high average TFP growth in the U.S between 1936–1990 which was 1.81% compared with an average growth of 1.17% between 1990–2007 (Andersen et al. 2018). This indicate a slowdown in productivity growth after 1990, a result which is strengthened by this study with a slowdown after 1988. These correlations between Sweden and the U.S productivity growth implies that there are global trends affecting productivity growth and not only national and regional agricultural policies. It could be a shift in agricultural technology which affect developed economies such as Sweden and the U.S similarly.

This is the first study of growth accounting for Swedish agriculture over the long-term period 1961–2019. It adds knowledge useful in further research based on the data from USDA (2021). Together with Fuglie (2015) this study contributes with a helpful framework for additional comparisons when analysing data of other countries included in the USDA dataset. The growth accounting approach has proven to be useful when analysing the details of productivity growth. Based on the findings in this study it would be interesting to include a Bai-Perron test to analyse trends and structural breaks further. It would allow for a better comparison of the different policy reforms and how those has affected productivity growth through the history. How a single policy reform within CAP has affected agricultural productivity growth is difficult to tell from the results in this study. However, it is a highly relevant question which should be addressed in future research.

References

Agriculture and Rural Development. (2021). *Evaluation of CAP's impact on climate change and greenhouse gas emmissions*. [online] available at: https://ec.europa.eu/info/news/evaluation-caps-impact-climate-change-and-greenhouse-gas-emissions-2021-jun-01_en [2022-05-07]

Andersen, M. A., Alston, J. M., Pardey, P. G., & Smith, A. (2018). A century of U.S. farm productivity growth: a surge then a slowdown. *American Journal of Agricultural Economics, 4*, 1072-1090. doi:10.1093/ajae/aay023

Barro, R. J. (1999). Notes on Growth Accounting. *Journal of Economic Growth, 4*(2), 119-137. doi:10.1023/A:1009828704275

Bindi, M., & Olesen, J. E. (2002). Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy, 16*, 239-262. https://doi.org/10.1016/S1161-0301(02)00004-7

Cunha, A., & Swinbank, A. (2011). *An Inside View of the CAP Reform Process: Explaining the MacSharray, Agenda 2000, and Fischler Reforms.* Oxford: Oxford University Press.

European Commission . (2013). *Overview of CAP Reform 2014-2020.* Brussels: Agricultural Policy Perspectives Brief. Available at: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/agri-policy-perspectives-brief-05_en.pdf [2022-05-07]

European Commission. (2016). *Productivity in EU agriculture - slowly but steadily growing.* Brussels: European Commission. Available at: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/trade/documents/agri-market-brief-10_en.pdf [2022-05-07]

European Commission. (2021). *CAP expenditure and CAP reform path post-2013.* Available at: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/cap-expenditure-graph3_en.pdf [2022-05-16]

European Commission. (2022). *Farm accountancy data network*. [online] available at: https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/farms-farming-and-innovation/structures-and-economics/economics/fadn_en [2022-04-17]

European Council. (2022). *Common agricultural policy*. [online] available at: https://www.consilium.europa.eu/en/policies/cap-introduction/ [2022-05-08]

European Environment Agency. (2019). *Climate change adaption in the agriculture sector in Europe.* Luxembourg: Publications Office of the European Union. doi:10.2800/537176

EU KLEMS. (2008). *EU KLEMS Project*. [online] available at: http://euklems.net/project_site.html [2022-04-11]

Fuglie, K. (2015). Accounting for growth in global agriculture. *Bio-based and Applied Economics, 4*(3), 201-234. doi:10.13128/BAE-17151

Jorgenson, D. W., & Griliches, Z. (1967). The Explanation of Productivity Change. *Review of Economic Studies, 34*(3), 249-280. doi:https://doi.org/10.2307/2296675

Lindberg, H. (2012). 1980-talets avreglering - en kort paus mellan beredskapsplaner och EU. In C. Isaksson, *Maten och Makten - Hur ska den nya världen mättas?* (pp. 33-50). Stockholm: Ekerlids Förlag.

Manevska-Tasevska, G., & Rabinowicz, E. (2014). *Competitiveness of Swedish agriculture: indicators and driving forces.* Lund: AgriFood Economics Centre. available at: http://www.sou.gov.se/wp-content/uploads/2014/11/3f6346d7.pdf [2022-04-15]

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Muller, R., . . . Bonn, A. (2019). A greener path for the EU Common Agricultural Policy. *Science, 365*(6452), 449-451. doi:https://doi.org/10.1126/science.aax3146

Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics, 39*(3), 312-320. available at: https://www.jstor.org/stable/1926047

Stock, J. H., & Watson, M. W. (2020). *Introduction to econometrics* (4th ed.). Harlow: Pearson.

Swedish Government. (2019, May 17). *Sveriges väg till EU-medlemskap*. Available at: https://www.regeringen.se/sa-styrs-sverige/regeringens-arbete-pa-eu-niva/sveriges-vag-till-eu-medlemskap/ [2022-04-18]

Timmer, M. P., O'Mahony, M., & van Ark, B. (2007). EU KLEMS Growth and productivity accounts: an overview. *International Productivity Monitor, 14*, 71-85. Available at: https://www.researchgate.net/profile/Werner-Roeger/publication/46447568_An_overview_of_the_EU_KLEMS_Growth_and_Productivity_Accounts/links/004635374a307c2597000000/An-overview-of-the-EU-KLEMS-Growth-and-Productivity-Accounts.pdf

USDA Economic Research Service. (2021). *TFP indicies and components for countries, regions, countries grouped by income level and the world, 1961-2019.* Available at: https://www.ers.usda.gov/webdocs/DataFiles/51270/AgTFPInternational2019.xlsx?v=5135.6 [2022-03-02]

Wiréhn, L. (2018). Nordic agriculture under climate change: A systematic review of challenges, opportunities and adaption strategies for crop production. *Land Use Policy, 77*, 63-74. doi:https://doi.org/10.1016/j.landusepol.2018.04.059

Acknowledgements

I would like to thank my supervisor Dr. Shon Ferguson at the Swedish University of Agricultural Sciences, for the patient guidance and encouragement he has given me through the process with this master thesis.

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file. If you are more than one author, the checked box will be applied to all authors. Read about SLU's publishing agreement here:

- https://www.slu.se/en/subweb/library/publish-and-analyse/register-and-publish/agreement-for-publishing/.

☒ YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.