Tarım Ekonomisi Dergisi

Turkish Journal of Agricultural Economics

ISSN 1303-0183
http://journal.tarekoder.org

A Synthesis on Impact Assessment Models from the Perspective of Evolution of the EU Common Agricultural Policy

Selim ÇAĞATAY
Orcid no: https://orcid.org/ 0000-0002-5471-3474
Akdeniz University, Department of Economics, Antalya, Türkiye
Ahmet Ali KOÇ
Orcid no: https://orcid.org/ 0000-0001-7225-0349
Akdeniz University, Department of Economics, Antalya, Türkiye
Ahmet BAYANER
Orcid no: https://orcid.org/ 0000-0002-7629-6026
Akdeniz University, Business Administration, Antalya, Türkiye
Peyman UYSAL
Orcid no: https://orcid.org/ 0000-0001-6843-601X
Antalya Bilim University, Department of Economics, Antalya, Türkiye
Sedat ARSLAN
Orcid no: https://orcid.org/ 0000-0003-2415-4584
Akdeniz University, Institute of Social Sciences, Antalya, Türkiye

Makale Künyesi

Derleme/
Review

Sorumlu Yazar /
Corresponding Author
Peyman UYSAL
peyman.uysal@antalya.edu.tr

Geliş Tarihi / Received:
09.01.2024
Kabul Tarihi / Accepted:
26.03.2024

Tarım Ekonomisi Dergisi
Cilt:30 Sayı:1 Sayfa: 69-87

Turkish Journal of
Agricultural Economics
Volume: 30 Issue: 1
Page: 69- 87

DOI
10.24181/tarekoder.1334549
JEL Classification: D50, D58, D02, D04

Abstract

Purpose: This paper aims to provide a comprehensive analysis of the current quantitative impact assessment methodologies, examining their strengths and weaknesses in terms of data requirements, as well as their consideration of social, economic, and environmental factors. Furthermore, it aims to elucidate the necessity for new-generation agricultural impact assessment models to incorporate advancements in information technology, communication tools, and big data analytics.
Design/Methodology/Approach: In this review, the term "agricultural modelling platforms" is used to denote different equilibrium models and these models are divided into two categories according on their methodological approaches. The first category adopts a "systems approach," which includes general and partial equilibrium type models, as well as sector models. The "agent-based approach" is used by the second category. This review, thus, is primarily concerned with contrasting farm-representative models with farm-based models.
Findings: The study emphasizes the importance of methodology and criteria in modelling exercises, considering factors like analysis level, environmental impact, and relationship between agriculture and the environment. It suggests that selecting the right modelling scale and tool requires asking the right research questions in advance.
Originality/Value: In this study, general and partial equilibrium models, which allow impact analysis of policies implemented in the agricultural sector, which is increasingly faced with ecological and social problems, and Agent Based Models (ABM), which allow the problems in question to be included in the models, are compared and provided guidance to policy makers. It is aimed to reveal their advantages/disadvantages against each other. The originality of this study is that this comparison is made by taking into account the evolution of the European Common Agricultural Policy (CAP) since its establishment.

Keywords: Equilibrium Models, Agent-Based Models, Agricultural Policy Analysis, Common Agricultural Policy

AB Ortak Tarım Politikasının Evrimi Perspektifinden Etki Değerlendirme Modelleri Üzerine Bir Sentez

Özet

Amaç: Bu makale, mevcut niceliksel etki değerlendirme metodolojilerinin kapsamlı bir analizini sunmayı, veri gereklilikleri açısından güçlü ve zayıf yönlerini ve ayrıca sosyal, ekonomik ve çevresel faktörleri dikkate alma noktasındaki kapasitelerini karşılaştırmalı olarak ortaya koymayı amaçlamaktadır. Ayrıca yeni nesil tarımsal etki değerlendirme modellerinin bilgi teknolojisi, iletişim araçları ve büyük veri analitiğindeki gelişmeleri de içermelerinin gerekliliğini vurgulamaktadır.
Tasarım/Metodoloji/Yaklaşım: Bu incelemede birbirinden farklı denge modelleri "tarımsal modelleme platformları" olarak adlandırılmış olup söz konusu modeller metodolojik yaklaşımlarına göre iki kategoriye ayrılmıştır Birinci kategori, genel ve kısmi denge tipi modellerin yanı sıra sektör modellerini de içeren bir "sistem yaklaşımı"nı benimseyen modelleri içermektedir. İkici kategori ise "Ajan tabanlı yaklaşım" olarak adlandırılmıştır. Dolayısıyla bu inceleme özellikle çiftlik-temsili modellerin çiftlik-tabanlı modellerle karşılaştırılması ile ilgilidir.
Bulgular: Çalışma, analiz düzeyi, çevresel etki ve tarım ve çevre arasındaki ilişki gibi faktörleri dikkate alarak modelleme çalışmalarında metodoloji ve kriterlerin önemini vurgulamaktadır. Doğru modelleme ölçeğini ve aracını seçmenin önceden doğru araştırma sorularını sormayı gerektirdiği çalışmanın önemli bir bulgusudur.

Özgünlük/Değer: Bu çalışmada, giderek daha fazla ekolojik ve toplumsal sorunlarla karşı karşıya kalan tarım sektöründe uygulanan politikaların etki analizlerinin yapılmasına olanak sağlayan genel ve kısmi denge modelleri ile söz konusu sorunların da modellere dahil edilmesine olanak sağlayan Ajan Tabanlı Modeller (ABM), karşılaştırılması ve politika yapıcılara yol göstermek amacıyla birbirlerine karşı avantajları/ dezavantajlarının ortaya konulması amaçlanmıştır. Bu karşılaştırmanın özellikle Avrupa Ortak Tarım Politikası'nın (CAP) kuruluşundan bu yana geçirdiği evrim dikkate alınarak ortaya konuluyor olması çalışmanın özgünlüğüdür.
Anahtar kelimeler: Denge Modelleri, Ajan Temelli Modeller, Tarımsal Politika Analizi, Ortak Tarım Politikası

1. INTRODUCTION

The importance of agricultural sector in the world is increasing not only in economics sense but also due to its environmental and social impacts. This multidimensional environment of the sector necessitates the reshaping and restructuring of policies towards it, while on the other hand, it leads to the expansion of the modelling capacities of impact analysis tools for the sector. The evolution of the Common Agricultural Policy (CAP) of the European Union (EU) since the 1960s is the best example of the increasing importance and multidimensionality of the agricultural sector. This evolution has also led to diversification in the tools used for agricultural impact analysis, creating a shift from representative-type models to agent-based models.

From this perspective, this paper aims at comparatively evaluating representative-type and agent-based models with respect to various technical criteria. Thus, it tries to provide clues as to which modelling capacities can be used for impact analyses of the CAP of the EU. While fulfilling this aim, the study also provides a literature review, thus providing a broad overview of the EU's changing agricultural policies.

The CAP of the EU has undergone several reforms since its effective inception in 1962. In most cases these reforms attempted to remedy internal and external unforeseen outcomes of policies with regard to agricultural sector itself, rural livelihoods and environment. Sometimes societal demands that reflect the heterogeneity among member countries were the main factors behind modifications to the CAP.

Initial policies relied on price support, import taxes, and export subsidies to provide farmers with an appropriate environment for production; these measures also encouraged the widespread use of agricultural technologies like chemical fertilisers and mechanised harvesting, which ultimately led to higher crop yields. The 'MacSharry reform' of 1992 introduced hectare-based direct aid payments and compulsory set aside in place of price support, marking a significant change to the CAP. The MacSharry reform also encouraged sustainable farming practises. Income support is provided on the condition that farmers take care of their land and meet food safety, environmental, animal health and welfare standards as part of the CAP's "decoupling" reform of 2003. This reform followed the "Agenda 2000 reform," which acknowledged the multi-functionality of European agricultural systems (Emmerson et al., 2016). The European Agricultural Fund for Rural Development was established in 2007 to provide further support for Agri-environmental Schemes. The 'health check' of the CAP in 2008, along with the elimination of arable set aside and the introduction of additional cross-compliance requirements, finalised decoupling. Reduced direct payments to farmers as a result of the "health check" have been redirected to the Rural Development Fund. To better contribute to the goals of Europe's 2020 strategy through encouraging smart, sustainable, and equitable growth, the CAP underwent another significant overhaul in 2013 (EC, 2015).

The three main goals of the CAP 2014-2020 were stable food production, responsible climate and resource management, and equitable territorial growth. Pillar I of the CAP focuses on providing income support for farmers and implementing market-support measures; Pillar II on promoting rural development through various means. In addition, a transitional regulation will be in place to facilitate a seamless transfer to the future framework of the CAP strategic plans while also extending most of the CAP rules of the 2014–20 term.

In particular, the agricultural sector's multi-functional structure and complex interactions make policy impact assessment a challenging undertaking. Despite its importance as a source of revenue for rural communities, agriculture in many countries faces competition for the most valuable resource: land. The sector is at the centre of the bioeconomy and has strong ties to tourism, rural economies, and cultural preservation. Because of the sector's unique relationship to the environment on many levels, it is essential that these connections be taken into account when conducting impact assessments. The industry is also distinguished by its focus on organic species, which brings up concerns about the well-being of animals and plants as well as their impact on biodiversity and human health. However, it is also difficult to analyse the effects of agricultural policies because of the diversity introduced by the varying degrees of development between nations, which influences the sector's organisational structure, farm size, and farm management techniques. Institutional structure and societal demands are both influenced by the level of development. It is therefore a significant problem to simulate policies affecting the rural and agricultural sectors.

The literature provides a rich toolbox that includes various qualitative methods and quantitative models to use for policy impact assessment regarding the agricultural sector. If qualitative methods are left aside as these are not at the focus of the paper, the quantitative modelling approaches cover several methods including cost-benefit analysis, multi-criteria analysis, counterfactual analyses, life-cycle analyses, input-output models, micro-simulation models, econometric analysis, general equilibrium models, partial equilibrium models and integrated approaches. The integrated components (biophysical, environmental, and social), temporal aspects (time horizon and choice of static/dynamic settings), spatial resolution levels (plot, farm, parcel, region, and country), and other characteristics (e.g., policy instruments) distinguish these tools from one another. Others in the field put these quantitative tools into different categories. For instance, Millington et al. (2017) coined the term "tele coupling" to describe the practise of connecting agricultural markets with environmental factors and rural economies on a global scale. Partial equilibrium economic models, system dynamics modelling, and agent-based modelling are the categories they use to organise these empirical methods. From a "simulation" point of view, Rizojeva-Sileva et al. (2018) categorise the aforementioned empirical techniques as follows: system dynamics (including partial and general equilibrium models), agent-based models, hybrid models, and discrete event simulation.

While policy impact assessment regarding agricultural sector is not an easy task and embodies various challenges, reviewing the alternative methodologies is difficult as well due to its wide coverage and therefore the methodologies have to be limited accordingly with the aim of the paper. The focus of this article is not on the modelling of individual events, hence discrete event simulation techniques will not be discussed in depth. The usage of hybrid models raises novel concerns such as the need for large amounts of data, theoretical consistency, and representation issues, and the fact that every hybrid model has its own unique characteristics and framework. As a result, we won't be covering hybrid models either.

In this review, we use the term "agricultural modelling platforms" and divide the models into two categories according on their methodological approaches. The first category adopts a "systems approach," which includes general and partial equilibrium type models, as well as sector models. The "agent-based approach" is used by the second category. This review, thus, is primarily concerned with contrasting farm-representative models with farm-based models. From the above perspective, this paper reviews the existing empirical impact assessment approaches and tools with a critical eye to derive the strengths and weaknesses in terms of data requirement, created indicators, social, economic and environmental specifics and policy content. Particularly the review aims at revealing how different assessment approaches respond to evolution of the EU's common agricultural policy.

The first section of the paper after the introduction explains the evolution of the CAP and this is followed by the overview of agricultural policy impact assessment models in the second section. In the third section, a synthesis of the different modelling approaches is carried out and the paper concludes in section four. The details of the CAP evolution are also provided in an extended table in the Appendix Table A1.

2. EVOLUTION OF THE COMMON AGRICULTURAL POLICY

The EU CAP was put into place in early-1960s which was constituted on three principles of "free intra-community trade, Community preference and common financing (Zobbe, 2001). To effectively implement the CAP, European Agriculture Guidance and Guarantee Fund (FEOGA) was established to finance the agricultural policy (Folmer et al., 1995). The EU has two policy instruments: market organizations measures, so called Common Market Organizations (CMO), financed by guarantee section of FEOGA and structural measures financed by the guidance section of FEOGA (Al-Khudhairy, 2000). Four types of support mechanisms were applied between 1968 and 1984. These are minimum producer prices, import tariffs and levies, producer price support, and a flat-rate producer subsidies based on area harvested or production quantity. As a result, agricultural production growth has exceeded the demand growth, export and budgetary outlay has drastically increased. Therefore, the policies were adjusted in response to these developments. Restrictive price adjustment, co-responsibility levies, guarantee thresholds and milk quota system were introduced. The effects of these adjustments were remained limited. Additional measures, called "stabilizers", were taken. Threshold increase would result in a price decrease and a set-aside measure was put in action (Folmer et al., 1995).

The essence of the CAP had been the costly market price support system. Therefore, MacSharry launched a fundamental reform of the CAP for the period of 1993-1995 in 1992. The MacSharry reform was also prompted the GATT Uruguay Round agreement. Reduced support prices, new direct payments to farmers, more regulation of production (via set-aside and quotas), and stronger safeguards for the environment were the four key tenets of this reform. The basic policy instruments such as market prices support and variable levies and export refunds were kept, but at much lower levels. Moreover, new instruments were developed to supplement these measures. To increase the competitiveness inside the Community and on global markets, agricultural product prices were drastically cut. Payments per hectare or per head were made to compensate the price reductions. Milk production quotas were maintained, but the usage of production factors was restricted (via set-aside and stocking rate conditions). Accompanying initiatives include the implementation of environmentally friendly farming practises, afforestation, and early retirement for farmers (EC, 1992; Baltas, 2001).

Large and small farms were also distinguished. Large farms were only eligible to hectare compensation if they set aside 15% of the so-called basic area. An early retirement program was developed for the farmers over 55 years old. Agri-environmental measures developed concerns the environment protection and the maintenance of the countryside by applying relevant agricultural methods. A forestry scheme was introduced for the development of farm forestry as an alternative to agricultural land use (Folmer et al., 1995). The CAP market organization was supplemented by a so-called "structural policy". These measures focused on the factors of production. Modern farms benefited more from these funds. Therefore, a special support scheme was introduced for Less-Favoured Areas (LFA), including mountainous areas, areas under the risk of de-population, and specific handicapped areas caused by permanent natural conditions unfavourable for farming in favour of cattle and sheep farming. A "Mediterranean package" including irrigation investment program, forestry and rural infrastructure and rural information services was instituted for the Mediterranean agriculture. The program aimed at integrating agricultural development measures with rural economic activities (Folmer et al., 1995 and Al-Khudhairy,2000).

Council Regulation (EEC) No 2078/92 was reviewed in 1997. Recommendations defined in the review are: "more specific scheme objectives; greater effort to be expended on monitoring and evaluation of schemes; the promotion of training courses within agri-environment programs; increased emphasis on 'environmental services which call for an extra effort on the part of the farmer'; further integration of agri-environment and Structural Fund programs; and the possibility of establishing an observatory to monitor programs throughout the EU" (Farmer, 2012).

The Commission published draft "Agenda 2000" in March 1998. CAP was split into two pillars: Pillar I focusing on the economic aspects of agriculture and Pillar II focusing on the economic, social and environmental aspects rural development measure such as providing support for LFAs, with the forestry, early retirement and agri-environment measures (Farmer, 2012). The main objectives of the CAP reform under Agenda 2000 were to keep Community farming competitive, to reinforce the rural development, and to safeguard farm incomes. Agenda 2000 aims to ensure multi-functionality, sustainability and competitiveness of EU agriculture (Al-Khudhairy, 2000). MacSharry introduced "direct agricultural subsidies and the Agenda 2000 reforms introduced "direct income support" which is "decoupled" from production, but conditioned on "cross-compliance" measures. Rural development and environmental policies are called modulation of direct aid payments 20% of the Pillar One funds was directed to the Pillar Two budget (Farmer, 2012).

As Andrews and Nelson (2001) point out, market access concerns aren't directly addressed in the Agenda 2000 package. However, the WTO Doha Round requirements, including further cuts to domestic support and import tariffs and the elimination of export subsidies (referred to as "blue box" measure) were not addressed in the Agenda 2000. Therefore, in 2003, Commissioner Franz Fischler put up a plan for reform. Decoupling direct payments from production, modulation, cross-compliance, the fiscal plan 2007-2013, fiscal discipline, and reducing price support are all key components of this reform (Farmer, 2012).

The 2003 CAP Reforms so-called the 'mid-term review', was implemented in 2005 to respond to the budget pressure of the EU East enlargement in 2004. This reform aims to improve the market orientation and environmental sustainability of EU agriculture. Decoupling measure was the core of the reform leading to a Single Farm Payment (SFP) based on the compulsory cross-compliance requirements. The farm budget was agreed to remain stable until 2013 thanks to a financial discipline mechanism. The European Agricultural Guarantee Fund (EAGF) was replaced with the European Agricultural Fund for Rural Development (EAFRD), a unified fund for rural development expenditure. The primary objective of these newly implemented policies is to enhance the competitiveness of the agricultural and forestry sectors (Axis 1), promote sustainable land management practises to preserve the environment and rural landscapes (Axis 2), and enhance the overall quality of life in rural areas by encouraging diversification (Axis 3) (eur-lex.europa.eu).

The CAP Health Check was agreed in November 2008. The Health Check did not change Agenda 2000 or the 2003 reforms much but has a number of changes to improve the sustainability of agricultural land use. These changes include further decoupling of direct payments, transferring budget between Pillar One and Pillar Two through compulsory modulation, reinforcing the priorities and focus of the EAFRD, extending the provisions of 'national envelopes' and the introduction of new cross-compliance standards (Farmer, 2012).

The EU-2020 Strategy set out the priorities for Europe over the last decade. This was a radical move to reorient the CAP called the "The Future of the CAP post-2013" into a policy so that the needs of EU society were met and the economic, social and environmental challenges of the decade were tackled. The stated goals of the post-2013 CAP encompassed three main areas: ensuring sustainable food production, promoting sustainable management of natural resources and climate action, and fostering balanced growth of territories. According to Farmer (2012), it is recommended to maintain the two-pillar structure of the CAP when considering policy tools.

A 'green' payment for climate- and environmental-friendly farming practises and a payment for young farmers were both implemented as part of the reforms made to Pillar I, which also included a revision of direct payments and the distribution, design, and targeting of the support. Per-hectare payments for 'natural constraints' and coupled payments for'specific types of farming or specific agricultural sectors having certain difficulties and are particularly important for economic and/or social and/or environmental reasons' are discretionary and given to farmers at the discretion of the government. The rural development policy has undergone a replacement with the introduction of six key priorities. These priorities include the facilitation of knowledge transfer and innovation, the enhancement of competitiveness, the organisation of the food chain and management of associated risks, the restoration, preservation, and improvement of ecosystems, the promotion of resource efficiency and the transition to a low carbon economy, as well as the promotion of social inclusion, poverty reduction, and economic development in rural areas. (Nègre, 2021).

In essence, the CAP has undergone modifications over time to strengthen the position of European agriculture in the long term, responding to shifting economic conditions and the demands of people. The evolution of the CAP can be succinctly summarised as follows: The CAP was established in 1962 with the primary aims of ensuring equitable livelihoods for farmers and ensuring accessible food supplies for the EU citizens. The CAP demonstrated a high level of efficacy, resulting in a growth rate of food production that surpassed the growth rate of demand. Therefore, by the year 1984, there existed an excess of food supplies. The MacSharry reform, which was implemented in 1992, sought to align production levels more closely with market demands. Through the implementation of this reform, there has been a notable shift in market support, transitioning from a focus on supporting products to a focus on supporting producers. The substitution of price support with a direct form of support to farmers in the form of compensating payments occurred. The promotion of environmentally friendly practises was advocated. The reform was implemented concurrently with the 1992 Rio Earth Summit, which introduced the concept of sustainable development. The CAP underwent a division into two distinct pillars as a result of Agenda 2000 in March 1998. Pillar I was designed to address the economic dimensions of agriculture, while Pillar II aimed to encompass the economic, social, and environmental components of rural development measures. In 2003, a novel CAP reform known as the Midterm review was introduced, which severed the connection between subsidies and production. Instead, it aimed to offer income support to farmers on the condition that they effectively manage the farms and adhere to requirements pertaining to food safety, environmental preservation, as well as animal health and welfare. The CAP Health Check was established in November 2008 with the objective of enhancing the long-term viability of agricultural land utilisation. The CAP underwent reforms in 2013, with the aim of enhancing the competitiveness of the agricultural sector, fostering sustainable farming practises and innovation, bolstering employment and economic growth in rural regions, and redirecting financial aid towards the productive utilisation of land. These reforms were implemented for the period spanning from 2014 to 2020. Most of the regulations pertaining to the CAP that were implemented during the 2014-2020 timeframe had been prolonged into the subsequent period of 2021-2022. On 1 June 2018, the European Commission unveiled legislative suggestions about the future of the CAP. These proposals outlined a path forward for the CAP, with the objective of creating a more streamlined and effective policy that aligns with the sustainable goals of the European Green Deal. Upon the establishment of the new legal framework, the implementation of CAP strategic plans is scheduled to commence in all EU member states starting from 1 January 2023. The European Commission has put up a proposal for the CAP for the period 2021-2027. This proposal outlines nine primary objectives that would serve as the foundation of the CAP, with a particular emphasis on social, environmental, and economic goals. The aforementioned objectives will serve as the foundation for the development of individual strategic plans by European Union member states for the CAP. The stated objectives encompass several key aspects, including the provision of equitable incomes to farmers, the enhancement of competitiveness, the restoration of equilibrium in the food supply chain, the pursuit of climate change mitigation efforts, the promotion of environmental responsibility, the preservation of landscapes and biodiversity, the facilitation of generational renewal in agricultural activities, the cultivation of thriving rural communities, and the safeguarding of food and health standards.

A graphical illustration of the evolution of CAP was presented in Figure 1. Dark lines are the main CAP reforms conducted since 1962. Red lines give the other changes during the implementation of CAP, basically indicating the rural development policies of the EU. A summarized and detailed information regarding the evolution of the CAP is also presented in Table 1 and Appendix Table A1 respectively.

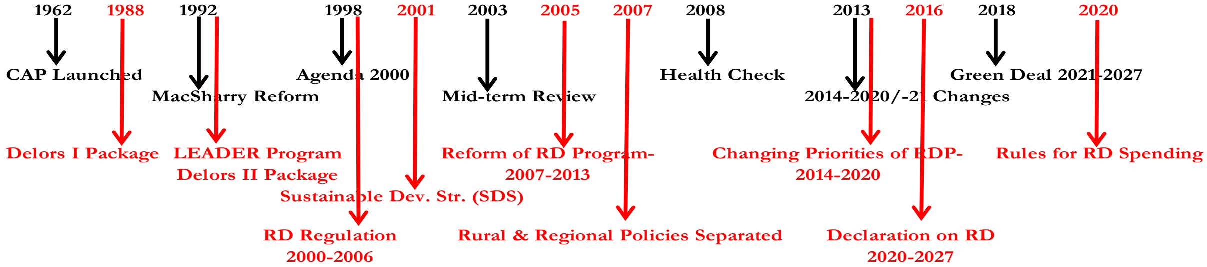

Figure 1. Evolution of the CAP

Table 1. CAP Evolution

1962	Launch of the CAP	Focus on price support.
1972	Introduction of Rural Development Funds	Introduction of limited farm restructuring measures.
1975	Creation of Regional Funds	Introduction of transfers between member states
1988	Delors I Package	Foundation of the present budget structure; introduction of multi-annual financial frameworks and fundamental principles of regional funding.
1992	Delors II Package	Large increases in regional funds.
1992	MacSharry Reforms of the CAP	Introduction of direct payment mechanisms; phasing out price support; reinforcement of rural development policies.
1998	Introduction of the CAP pillars: Agenda 2000	Deepening of the reform of the CAP. Pillar I: Economic aspects of agriculture. Pillar II: Economic, social and environmental aspects of rural development measures.
2000	Lisbon Strategy	Focus on growth and employment, through innovation.
2003	Mid-term Review of the CAP	De facto decoupling of direct income support from production in the CAP (income support to farmers), reform of agricultural markets. (Axis 1): improve the competitiveness of agriculture and forestry. Axis 2: The environment and countryside by supporting land management (Natura 2000). Axis 3: improve the quality of life in rural areas and encourage diversification.
2005	Reform of Rural Development Policies	Widening of scope of rural policies to support non-agricultural actors.
2007	New EU Financial Perspectives	Fiscal plan 2007-2013. Reform of the budget, stronger focus on employment and innovation.
2008	Health check	Keep Agenda 2000 and Mid-term review measure. Improve the sustainability of agricultural land use.
2013	The future of the CAP post-2013**:** 2014-2020	Strengthen the competitiveness of the sector, to promote sustainable farming and innovation, to support jobs and growth in rural areas and to move financial assistance towards the productive use of land.
2018	Reform for 2021-2027	European Green Deal (CAP strategic plan around 9 key objectives focusing on social, environmental and economic goals).

CAP Expenditures

The development of the CAP expenditure for the period of 1980-2020 as a share of the EU budget is given in Figure 2. The share has decreased about half over the past 25 years, from 65.5% in 1985 to 35% in 2020 despite the successive EU enlargements. This downward trend is mainly due to CAP reforms and the growing share of other EU policies (EC,

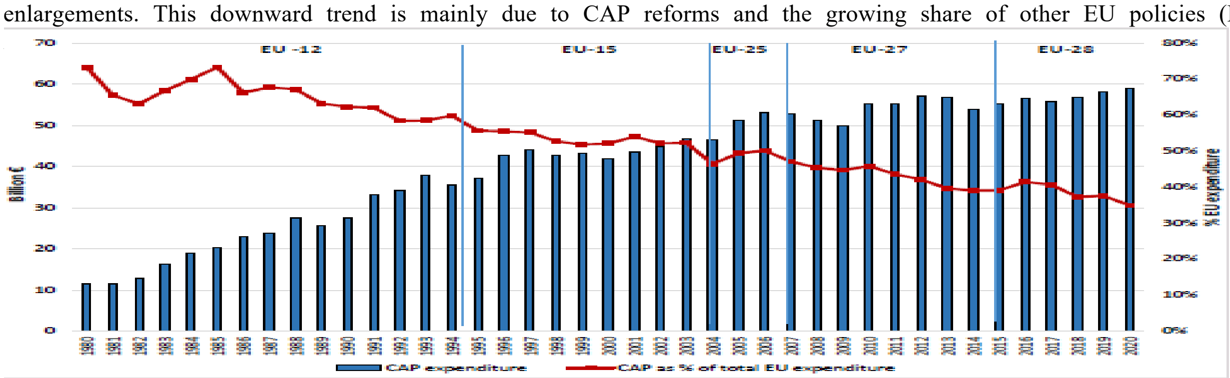

Figure 2. CAP expenditure in total EU expenditure (2011 constant prices)

Sources: Reproduced from CAP expenditure: European Commission, DG Agriculture and Rural Development (Financial Report). EU expenditure: European Commission, DG BUDG-2008 EU Budget Financial Report for 1980-1999, DG BUDG-2015 EU Budget Financial Report from 2000.

Annual expenditure in 2011 constant prices by applying a 2% yearly constant deflator/inflator.

Figure 3 demonstrates how CAP expenditure has changed over time in response to policy shifts. Due to agricultural surpluses, CAP spending in the 1980s went towards market price support mechanisms, namely intervention and export subsidies, and then grew at the outset of the 1990s. Initiating producer support, the MacSharry reform of 1992 eliminated market price support and direct payments. There was also an increase in investments in rural areas. Agenda 2000 included a new component as a second pillar, rural development policy, to its reform agenda. Most direct payments were untethered from productivity in the 2003 reform. Instead, they were calculated solely on the basis of the farmer's past income. The money put into rural revitalization projects kept rising. In keeping with the CAP reform, market support was further lowered in 2008 as part of the Health Check. The market-oriented reform approach was maintained in 2013, and a new greening system strengthened the link between decoupling direct support and environmental and climatic actions. Despite a series of expansions, CAP spending has levelled out, and as a percentage of GDP, it has fallen from 0.54 percent in the 1990s to 0.38 percent in 2019 (EC, 2021b).

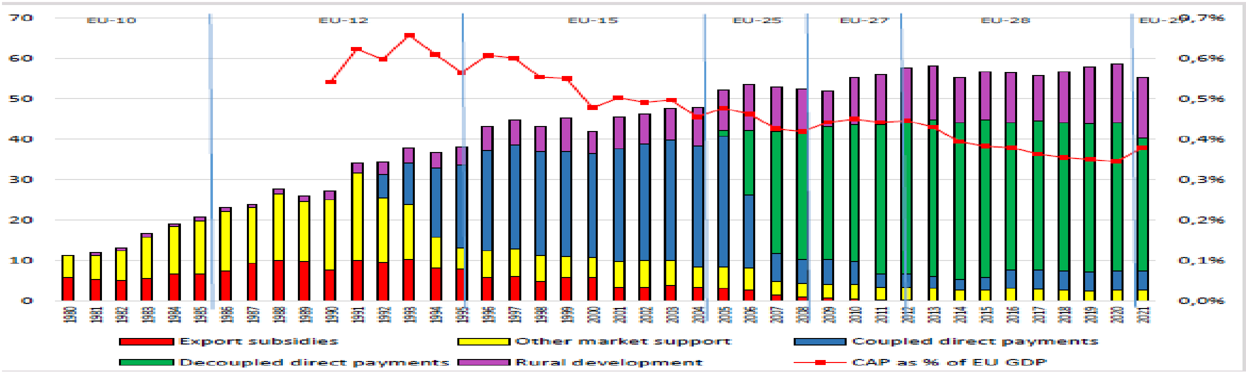

Figure 3. CAP expenditure and CAP Reform path (2011 constant prices)

Sources: Reproduced from CAP expenditure: European Commission, DG Agriculture and Rural Development (Financial Report). GDP: Eurostat. Annual expenditure in 2011 constant prices by applying a 2% yearly constant deflator/inflator.

3. A GENERAL OVERVIEW OF AGRICULTURAL POLICY IMPACT ASSESSMENT MODELS

The agricultural sector, worldwide and in the EU, has been confronted with persistent economic, social, and environmental issues in a dynamic institutional and economic environment. Inevitably the policy objectives and instruments of the CAP have shifted from one end to the other in the last 50 years or so. Together with changes in policy objectives and instruments, policy impact assessment regarding the sector became a real challenge and modelling platforms had to be modified and radical adaptations had to be made. For a long period, output, input and trade based non-market-oriented policies dominated the policy packages. Then market interventionist, distorting policies lost their importance and market-oriented policies came to the front. To protect and enhance environmental quality, food safety, and animal welfare, decoupled payments have been utilised extensively and in substantial sums. To summarize, the wide variety of used policy instruments and prioritized objectives since the beginning of the millennium can be grouped under two Pillars. 1st Pillar focusing on the economic aspects of agriculture namely direct payments and market measures together with greening payments and 2nd Pillar focusing on the economic, social and environmental aspects and more importantly on rural development. Policy impact assessment regarding 1st Pillar has been carried out mostly by partial equilibrium-sector and/or agricultural trade models, general equilibrium models and in some cases by econometric and simulation models. However, two facts have paved the road for changes in modelling platforms.

The first one being the rising concerns about environment and bioenergy; the second one is the shift in focus of the platforms towards farm/agent-based analyses. Due to the farm and policy heterogeneity farm-level analyses rather than sector/region-based representative-type analyses gained importance. Agricultural policies have shifting priorities in response to shifting social needs, and it is envisaged that greening measures will have diverse outcomes on a regional/farm scale. A critical challenge, then, is the need to advance modelling techniques capable of disaggregated analysis of the socioeconomic and environmental effects of agricultural policies. To take into consideration, the interconnected economic, environmental, and social repercussions across many time and space scales, researchers have turned to hybrid modelling methodologies just as bio-economic models or agro-economic models. Furthermore, models developed at the farm level are increasingly being used in impact assessments.

In this paper the existing empirical impact assessment approaches and tools are reviewed with a critical eye to derive the strengths and weaknesses in terms of data base, social, economic and environmental specifics and policy content. The review focuses particularly on the ones utilizing "systems approach" which covers equilibrium type models (both general and partial) and sector models and the ones utilizing "agent-based approach" (Rizojeva-Sileva et al.). A summary of the review is given in Table 2. Integrated assessment (hybrid approaches) platforms will not be included in this review as each of those platforms are tailored accordingly with the focus of the research they are used in and hence they come with their own distinguishing structural features and are not directly comparable neither with each other nor with the other methodologies mentioned above.

Systems Approach

The systems approach necessitates and seeks a more profound comprehension of the underlying factors influencing behaviour. This behaviour focuses on the agricultural sector's response to both internal and external factors' change inside the system. It aims to identify the connections between the agricultural sector and other elements of the economy. The systems approach employs feedback relations, sometimes known as cause-effect loops, to represent the interactions inside a single component and between multiple components in a hierarchical manner. Instead of modelling the behaviour of specific actors, the reaction of the sector or component as a whole is studied.

The models known as computable general equilibrium (CGE) and partial equilibrium (PE) are categorised as market/price equilibrium type models. One of the primary distinctive characteristics pertains to the extent of focus exhibited by these models. The primary focus of PE models is to examine a specific sector of the economy, such as the agricultural sector in this review. This narrow focus enables a comprehensive analysis of the chosen sector. Conversely, CGE models aim to encompass the entire economy, of which agriculture is just one component. CGE models seek to identify the interdependencies between sectors and facilitate the examination of feedback relationships among various markets and industries. PE models focusing on agriculture can be categorised into two distinct types: PE agricultural trade models and PE agricultural sector models. The primary focus of PE agricultural trade models is centred on the quantification of international commerce, either through a net or a bilateral trade perspective. The inclusion of these categories in this review is beyond its intended scope, given the bulk of these models do not consider input markets and the input-output relationships within the agricultural sector. Therefore, the focus of this review is directed towards PE agricultural sector models.

Typically, CGE models place greater emphasis on commodity groups and/or sub-sectors within the agricultural sector. CGE models are constructed upon the foundation of general equilibrium theory. To ensure analytical tractability, these models rely on a set of stringent assumptions. These assumptions include the presence of perfectly competitive markets and market clearing, the absence of transaction costs, and the assumption of homogeneous products. However, certain models deviate from these stringent assumptions and instead incorporate elements such as non-market clearing, imperfect competition, and heterogeneous products. Nevertheless, is important to note that in all CGE models, the fundamental dynamic mechanism is the adjustment of prices until the quantity supplied is equal to the quantity demanded (Millington et al., 2017). Certain CGE models that specifically incorporate the agricultural sector provide a more comprehensive framework for addressing issues related to farming. This is achieved by explicitly modelling key factors of production, namely land, labour, and capital, which contribute to the value added in the agricultural sector. The CGE modelling platforms facilitate the analysis of the interconnections, both direct and indirect, between primary and processed products, such as grains and the food industry. Additionally, these platforms enable the examination of the relationships between agricultural inputs and outputs, such as chemicals and grains, however at a rather broad level of aggregation.

The interconnection of sub-sectors is further established by their struggle for the many components that contribute to the creation of value, such as land, capital, and labour, within the respective marketplaces. The coverage of CGE models surpasses that of PE models in terms of depth. However, due to their high level of aggregation, CGE models are unable to effectively capture the implications of new policy instruments and sometimes struggle to simulate particular products. Both the PE and CGE models operate under the assumption that the economy is composed of production and consumption sectors that are collectively represented. These models aim to capture the entire economy, by simultaneously modelling the relevant aggregation of economic actors.

The utilisation of PE agriculture sector models enables more comprehensive and in-depth assessments in comparison to CGE models. The extent of the sophistication of this modelling platform is derived from its capacity to explicitly model a wide range of products at highly detailed levels, while also establishing connections with internal behavioural input marketplaces. The models also integrate land as the primary input for agricultural output. The advantage of using PE modelling platforms in the agricultural sector is in their ability to focus on the level of disaggregation, while disregarding the interlinkages with non-agricultural industries and macro balances, as compared to CGE models. The utilisation of mathematical programming and the advancement of computer capacity further reinforce the application of disaggregation level in PE models. The integration of optimisation techniques is highly compatible with the neoclassical economic theory, which posits and endorses the maximisation behaviour of farmers. This integration enables the examination of agricultural policy implications on the socioeconomic and environmental systems associated with the agricultural sector (De Muro and Salvatici, 2001). One compelling rationale for employing mathematical programming in agricultural sector modelling is the ability to effectively capture the relationship between economic factors and the biophysical and ecological components of farming. This enhances the utility of PE modelling platforms as valuable instruments for conducting agricultural policy assessments. According to Norton and Hazell (1986), mathematical programming models provide distinct advantages compared to alternative methodologies due to their capacity to analyse the intricate and interconnected characteristics of agriculture. In a more recent study, Heckelei and Britz (2005) identified three distinct advancements that have emerged in programming paradigms. In general, PE models has the capability to simulate the impacts of various policy tools, including price support, as well as their effects on quantities and areas.

Moreover, the incorporation of multi-functionality within the agriculture sector can now be more effectively internalised within the framework of PE platforms. Finally, the enhanced ability to simulate the effects of unavoidable limitations, commonly referred to as real-life constraints, has bolstered the reliability of optimisation endeavours. Arfini (2001) highlights the theoretical progression of mathematical programming and its subsequent refinement, transitioning from linear and quadratic programming to positive mathematical programming. This evolution has facilitated the integration of econometrics with mathematical programming, enabling more comprehensive analyses of the impacts of agricultural policies at regional or sectoral levels. Notably, these advancements have allowed for the utilisation of information sets that were previously deemed inadequate for earlier methodological approaches.

Agent-Based Aproach

The agent-based approach is a relatively new in academic research and is predominantly observed in the 21st century (Mohring et al., 2016). According to a comprehensive literature study on policy evaluation using agent-based modelling (ABM) conducted between 2000 and 2016, it was found that there was a notable surge in the number of publications after 2008. This increase can be largely attributed to the influence of influential early studies published in the preceding decade (Kremmydas et al., 2018). The significance of farm level policy analysis has been growing in prominence as a result of a shift in agricultural policy focus. ABMs utilise a bottom-up approach to simulate the activities of agents, which are the individual components of the system. These models aim to capture how agents respond to both internal (endogenous) and external (exogenous) changes within the system, as well as how agents interact with each other. The agents under examination are farms, hence data pertaining to these farms is used to elucidate their behaviour and analysing the macro-level response or behaviour is not the primary focus of our review and consequently falls outside its scope.

According to the study conducted by Millington et al. (2017), the ABM is a computer simulation technique that represents the attributes, behaviours, and interactions of disaggregated, individuated, and often autonomous elements. These models are employed to depict and mirror the way agents' distinct attributes influence their process of decision-making. The introduction of the ABM has brought about a level of flexibility that allows for the representation of individual subjects. As a result, this method has been widely employed in many analyses pertaining to the interactions of human-and environment, as well as land use and the change in landscape.

ABMs are utilised within the agricultural sector to investigate a range of topics, including farmers' reactions to climate change, the adoption of organic farming practises, the dynamics of structural changes, the diffusion of innovations, the simulation of water management practises, environmental modelling, and the impact of social networks on decision-making processes. The agent-based modelling approach primarily addresses two simplifying assumptions inherent in traditional models, namely the assumption of agenthomogeneity and the challenge of accurately representing interactions between agents and their environment. ABMs take into account the interactions among farms and their varying behavioural characteristics (Kremmydas et al., 2018). Thus, employing an agent-based modelling methodology will result in the incorporation of two critical characteristics inside the systems. The interaction among agents inside the system gives rise to the implementation of a bottom-up modelling technique, resulting in the presentation of both local and global features (Axelrod & Tesfatsion, 2012). However, ABMs often reflect a local level of agents, as they emphasise individual behaviours and interactions. But it is also possible to depict several levels of hierarchical organisation, including houses and communities (Kremmydas, 2012).

Billari et al. (2006) provide a concise summary of some benefits associated with the ABM approach. Firstly, the incorporation of feedback relations can be accomplished with relative ease. Secondly, the modelling of agents' risk behaviour is feasible. Thirdly, compared to conventional mathematical models, the modelling of heterogeneous agents who are not fully rational is relatively straightforward. Lastly, it is possible to formulate and solve problems that are intractable using typical analytical models, such as non-linear systems or systems involving a substantial number of interacting agents. Axtell (2020) further suggests that ABM systems have the capability to simulate time, space, and social networks, even in situations when equilibrium is not present. Nevertheless, some disadvantages are also cited. ABM exhibits a lower level of robustness in comparison to conventional mathematical models due to its reliance on the initial circumstances of the simulation for generating solutions. The concept of "black box" critique pertains to the challenge of effectively describing the underlying assumptions and algorithms associated with a model in a standardised and easily understandable manner.

Table 2. A Comparison of the Main Features of Alternative Modelling Approaches

	Partial equilibrium models			**General equilibrium models**			**Agent-based models**	
Spatial Focus	-region/country	-activity based (output focused)	-homogeneity in regions/heterogeneity among regions	-region/country	-mostly commodity based (sub-sector focused)	-homogeneity in regions/heterogeneity among regions	-farm based (land based)	-heterogeneity among producers and regions
Data Requirement/ Parametrization /Calibration	-required data increases depending on the output/input varieties and the interaction among them	-calibration can be a problem while linking inputs to production		-required data increases depending on the sectoral coverage and macroeconomic setting	-calibration can be a problem while disaggregating to sub-sectors		-required data increases depending on the heterogeneity among farms sourced by social, economic, environmental structures	-calibration can be a problem while integrating social, economic, environmental structures to output/land
Price Determination	-mostly endogenous for output and for some inputs			-endogenous for agricultural sub-sectors, endogenous/exogenous for inputs			-mostly exogenous for outputs/inputs but endogenous for land	
International Trade	-can be endogenous/exogenous to the platform	-products can be homogeneous/heterogeneous (net trade versus bilateral Armington)		-endogenous in the platform	-products can be homogeneous/heterogeneous (net trade versus bilateral Armington)		-exogenous to the platform/endogenous in the hybrid system (telecoupling)	-products are heterogeneous
Temporal Properties	-static and/or recursive dynamic (w.r.t. time dimension)			-static and/or intertemporal and recursive dynamic (w.r.t. time dimension)			-feedback loops among farms competing for land	
Policy Focus	-interventionist and coupled	-market oriented and decoupled	-region/activity based	-interventionist and coupled	-market oriented and decoupled	-region/activity based	-decoupled	-land/farm based

Source: Compiled by the authors, 2021.

4. A SYNTHESIS OF SYSTEMS AND ABM APPROACHES WITH RESPECT TO THEIR WEAKNESSES/STRENGTHS IN MODELLING CAP

In the last decade works on agricultural impact assessment present a shift towards the agent-based modelling efforts from the systems approach. We may highlight three main factors behind this shift. First, the CAP has put more emphasis on farm and rural development in Pillar II, and hence modelling heterogeneous characteristics of farms and inter-linkages among them become more important. Second, due to the changing focus of CAP, farm-based policy outcomes gained more importance and differences in economic and institutional structures of the countries do affect farm-based policy responses. Finally, as time passes the environmental and sustainability concerns regarding the policies gain importance and those concerns do vary depending on the location of the farms.

A Comparative Evaluation

The first criterion that can be used to compare different approaches will be spatial/geographical coverage. In the systems approach the maximum level of disaggregation that can be attained is either at country or at region (under country) level. Therefore, for example the production decision of the farmer in that locality/country is determined and modelled as to represent the country/region (representative models). As a natural outcome of this, different producers cannot have different production functions, but the production function is specified to use different production factors and inputs. Product/input substitution takes place at the regional level. Again, as a natural consequence of this structure, interregional relations cannot be established. Only in multi-region/country models foreign trade can be a tool of setting interregional relations. This might introduce product heterogeneity among regions, but products are homogeneous within the regions. In the ABM approach, the modelling unit is the farm and farms' heterogeneous production structures can be modelled. In ABMs, farms are differentiated within a region, and their response and behaviour with respect to policy changes can be modelled. Interactions among farms can be established on the basis of the land which is the main factor of production and for which farms compete in the land market. In systems approach it becomes a computational burden and calibration problem if the level of analyses is disaggregated from region/country to farm level. However, reaching to region level from farms in ABM approach also creates the same computational problems. In addition, these efforts in both approaches may yield in unfeasible data and theoretically inconsistent assumptions.

Another criterion to be used in the comparison is the problem of data requirement, parameterization and calibration. Typically, data requirements in the agricultural sector are limited to output, input use, land, capital, and labour statistics, as well as policy data. The inclusion of supplementary exogenous policy data and macro data may be necessary depending on the nature of the exercise and the modelling platform being utilised. Although spatial disaggregation (modelling at the smallest unit/level) is an advantage in terms of compliance with policy purposes (as in ABMs), the data requirement, the parameterization of this data and calibration of the model becomes more difficult as the level of disaggregation increases. Other than policy relevance, the other reason for using ABMs is the necessity to consider environmental and sustainability impacts of policy changes which requires significant amount of data. It is an important problem in farm level analyses to gather compatible climate, soil structure and farm structure data and in case these are not compatible, it becomes another problem to do the required modifications/adjustments. Input use in agricultural production is also related with climate and soil structure etc. which also affects data requirement. When we look at the systems approach the data need, parameterization and calibration become a problem especially in CGEs, and these problems aggravate as the sectoral disaggregation increases. The amount of data needed to run a CGE model empirically can vary greatly depending on the level of aggregation of countries, regions, and commodities as well as the model's theoretical foundations (homogeneous or heterogeneous products, bilateral or pooled markets). The need for this data could grow as the markets for agricultural inputs get more specific and as more details emerge about the components of products' value chains. Obtaining both the sector level data and the parameters used to set inter sectoral relations becomes a constraint in front of disaggregating the economy in the modelling platform. Probably the easiest way to model climate and soil structure etc. within the CGE framework is setting these as exogenous modules. Endogenizing these in the CGE would be a very demanding computational effort and would create calibration problems. In PE models, having only the agricultural sector in the analyses is an advantage in terms of the required data but still depending on how agricultural inputs are integrated (as constraints or as fully endogenized markets) the data need may increase. Although the data problem is not as big as it is in ABMs when input markets are endogenized, PEs still has the problem of being "representative". In addition, the climate and soil structure etc. are usually treated in exogenous modules.

The third comparison criterion can be price determination procedures and the way foreign trade is handled in the modelling platforms. We can also call these behavioural specifics of the platforms which mainly creates the differences among them. In the ABM approach, endogenous price determination is certainly not a top priority. The priority here is to model the distribution of land between agricultural and non-agricultural uses, between alternative agricultural uses, selling/renting behaviours, and use of agricultural land for production/investment purposes. Majority of ABM based assessment studies are related to "land use and land cover changes (LUCC) and focused to assessment of specific policy or regulation impacts on LUCC (Kremmydas et al., 2018; Ren et al., 2019). In studies that employ agent-based modelling (ABM) to examine agricultural policy, there is a primary emphasis on variables such as farm number, farm size, and farm intensification. The treatment of land as an endogenous variable is contingent upon factors such as farm profitability, farmer demographics, and social traits like age and the existence of successors. Land prices are often not taken into account in various research, either because they are seen as exogenous variables or because they are directly collected from market realisations. The rental price of parcels in the models is derived from market data. However, in recent studies, land models based on ABM have focused on analysing farm exit and investment decisions by considering profitability indicators and demographic factors such as the age of farmers and the presence of successors. Generally, ABMs are employed within the agricultural domain to examine the decision-making processes that govern agents' expansion of land, the distribution of land, and the alterations in land use that occur at local or regional levels.

In ABMs, product prices can be obtained exogenously. Endogenous modelling of these implies integration of the demand component in the modelling platform, which is not a common approach in ABM. Resource flows in ABMs are implicit in agent behavioural equations and in interactions among agents. Naturally, modelling foreign trade (foreign demand is certainly not one of the main priorities of ABMs. Since there is no export on farm basis, modelling of foreign trade in ABMs requires an aggregation from farm to product/region to a large extent. The above discussion for output prices also applies for input prices as well. Although modelling international trade is generally not the focus in ABMs, recent studies present that by "tele coupling" international trade can be endogenized in ABM modelling platforms. Tele coupling is used to connect distant systems such as climatic conditions, environmental systems, demographic conditions, socio-economic variations, human systems, foreign trade, foreign direct investments etc. (Liu *et al*., 2019. The term "distant systems" refers to differences among countries and/or regions in certain contexts. When it comes to modelling agricultural foreign trade in the ABM, tele coupling links the agent-based use of agricultural land in various countries/regions with product/country/region level aggregated production and demand (Millington *et al*., 2017. This method to model foreign trade introduces two difficulties. First is the aggregation problem from farm level land use/production to regional level and second is setting the sending/receiving/spillovers systems in the modelling platform (Dou and Liu, 2017. The latter is transforming ABM to a hybrid system and international trade here is modelled as it is in systems approach PE models. Therefore, determination of trade prices gains importance. Particularly the extensive data need and calibration problems in hybrid approaches should be kept in mind.

In the systems approach, and especially in the CGEs, the endogenous determination of the product prices is a top priority. This structure links supply and demand. The outcome of this structure is the representative prices based on product/region, and foreign trade is shaped based on whether products are treated as homogeneous or heterogeneous. In CGEs the land market is either endogenously solved to find the prices or land is treated exogenously as a constraint. Input markets are included but at aggregated levels. The structures of the PE modelling platforms are not as rigid as the CGEs. There are examples that take the price exogenously, by excluding the demand side but including only the supply side of the sector or there are examples that solve the prices by equalizing supply and demand. The primary focus in PE platforms lies in the examination of the processes involved in the production and exchange of goods and services within regional and/or global contexts. In the latter, land typically serves as a limiting component, while other elements of production may be treated as exogenous to the system or represented in a more simplified manner. The former incorporates the modelling of production decisions, but international trade necessitates the utilisation of a hybrid approach. Within the realm of PE models, agents are implicitly depicted and subject to certain stringent assumptions, including perfect rationality, homogeneity, profit maximisation, and market clearing. The fundamental premise underlying PE models is the idea that players inside the market are price-takers. In PE models, the explicit representation of resource flows is absent, as they are instead governed by the interplay of supply and demand. The exchange of pricing information between producers and customers constitutes a vital kind of feedback. One notable divergence lies in the assumption made by PE models, which posit that demand is independent from production. Conversely, CGE models acknowledge that production decisions impact demand by altering the level of income.

The temporal properties of the platforms can be the other criteria to differentiate the platforms. The dynamics in the ABM approach is introduced through the equation structure that sets the interaction between farms whereas in the systems approach the dynamics is established either in a recursive relation in the equations or with inter-temporal behaviour (particularly in CGEs. In ABMs agents are explicit, heterogeneous, and they interact with each other (explicit representation of the feedback loops. While modelling dynamics in the systems approach involves time dimension, in the ABMs interacting loops in provide the dynamics.

Policy modelling capacities of the platforms is the final criteria to compare systems and ABM approaches. The first radical modifications to CAP involved the shift from interventionist, market distorting policies towards market-oriented policies. Interventionist policies were directly related to the price and/or quantity of the outputs and inputs, and implemented either in the domestic market or border, or both. Both CGEs and PEs were commonly used to model the impact of those policies either in a single region/country or multi-region/country setting. The ABM approach was not used to model agricultural policy impact in those early years as the necessity was not felt. The first modifications introduced policies independent from prices and quantities, mostly called decoupled payments, being more competitive and market-oriented and providing less trade-distorting support to farmers. The CGEs and PEs were still used but with some modifications to their behavioural and identity equations to introduce decoupled payments to the sector. Decoupled payments were also given for preserving/improving environmental quality, higher food safety, and better animal welfare standards (modelling environment focused policies require integration of environment modules either exogenously or endogenously as mentioned above). The second modifications to CAP involved farm-based decoupled payments which also created the change in expectations towards farm-based policy responses. This was quite a challenge for existing systems approach platforms and ABMs came to the scene with their capacity to realize farm-based analyses. Further modifications to the CAP are introduced to achieve sustainable agriculture and rural development. These changes in policy objectives asked for deeper environmental analyses and for analyses considering the differences in economic, social and environmental structures surrounding the farms. With these policy developments, the ABM approach gained importance once again with their capacity to model farm-based analyses considering the various dimensions of new policies particularly the greening measures. ABMs are utilized in various policy contexts. One of their main foci is on simulating policy impacts on land use patterns by endogenizing land rental prices. Another focus point is impact of environmental regulations on land market. Farm based impacts of drought, of migration and of resource use are among the other research priorities in ABMs.

5. CONCLUDING REMARKS

Modelling exercises certainly embody a trade-off while choosing the methodology that is going to be used. There is definitely no one modelling platform that one creates answers for all the questions. Creating multi-functional hybrid approaches might be considered quite complex with regard to various criteria and each criterion can be become a challenge.

For instance, "level of analysis" might become a real challenge. While farm level economic and policy analysis might be preferred to reflect the farm heterogeneity and farm interactions, endogenizing particularly input markets at the same level could be cumbersome. Another challenge is the inclusion of environmental factors/components at farm level which the scope of the environment and its relative importance might change according to location of the farms. However, when the significance of "agricultural sustainability" in the CAP is considered, then we cannot just easily exclude the environmental factors from the models just to get rid of the problems. In addition, when it comes to environment, it is one problem to find the necessary data at the analysis level and is another problem to parameterize and calibrate the modelling platforms with these environmental modules. Finally, the inconsistency between primary and secondary social, economic and environmental data brings another challenge in terms of data adjustment as the spatial characteristic of these data differs. The "big data" tools might create solution for this adjustment problem as the availability spatial data increases.

Data and calibration problems introduce the trade-off/questions once again. Is there an optimal size for impact assessment platforms? Farm based or representative models? Should the economic and environmental impacts have modelled separately or together? The complex interdependencies between agriculture and the environment, the expected changes in farm-level responses are big challenges for conventional systems approach models and ask for agent-based impact assessment platforms however this comes with the above-mentioned problems. If we start to think about considering the relations of agriculture with the rest of the economy and multi-dimensional structure of the environment, the problem and challenge aggravates. Investigating issues connected with the production such as bioenergy from agricultural biological matter, efficient management of natural resources are other examples of significant challenges.

Probably in these days the smallest problem is the computational capacity of the modelling platforms. There have been significant developments in computer science and big modelling platforms now can simultaneously solve thousands of equations either with linear or non-linear mathematical algorithms. Therefore, size of the platform is not a computational problem.

To conclude, a few recommendations might be made for scholars studying the topic based on the information uncovered by the survey. It is essential to ascertain the end users of the research outcomes and the specific research questions. The answers to these queries will help to establish the analysis scale in terms of the affects that are going to be assessed. Hence, the necessity to use a representative systems approach or instead an agent-based modelling platform will be understood. Accurate definition of the explicit and implicit goals of the analyses is also of utmost importance. Using separate modelling platforms for different purposes and then checking for the consistency of the outcomes among the platforms might be a simple but more straightforward approach. On the contrary, building an integrated assessment platform, given the advanced computer technology of today, might be attractive, however it might turn into a black box depending on the complexity of relationships it involves. Hence it might easily become difficult to interpret findings and to identify the factors that lead to those findings.

Contribution Rate of Researchers Declaration Summary
The authors declare that they have contributed equally to the article and have not plagiarized.

Conflict of Interest Declaration
The authors of the article declare that there is no conflict of interest between them.

Additional Info
This work had been prepared under Work Packages entitled WP3 Agent Based Models and WP5 Policy Impact Assessment in the project that was funded by the H2020 AGRICORE project, grant number 816078 (2019-2024).

REFERENCES

Al-Khudhairy D. H. A. (2000), The 1992 Cap Reform: A General Analysıs of its Effect on The Environment. JRC and European Commission, January, EUR 19048 EN. https://op.europa.eu/en/publication-detail/-/publication/a6199b7d-0b4b-11ea-8c1f-01aa75ed71a1/language-en/format-PDF/source-118580645. 04.05.2021. (Accessed in May 2022)

Andrews N., Nelson R. (2001), Agenda 2000: The European Union's Reform Package for Grains. Australian Commodities, 8(2). https://www.researchgate.net/publication/296518604. (Accessed in May 2022)

Arfini F., (2001), Mathematical programming models employed in the analysis of the common agriculture policy (No. 1149-2016-92948).

Axelrod R., Tesfatsion L. (2012), On-line guide for newcomers to agent-based modelling in the social sciences. Handbook of Computational Economics, 2. http://www2.econ.iastate.edu/tesfatsi/abmread.htm. (Accessed in June 2022).

Axtell R., (2000), Why agents?: On the varied motivations for agent computing in the social sciences.https://www.researchgate.net/publication/228718823_Why_Agents_On_the_Varied_Motivations_for_Agent_Computing_in_the_Social_Sciences. (Accessed in May 2022).

Baltas N. C. (2001), The Common Agricultural Policy: Past, Present and Future. January. https://www.researchgate.net/publication/5058543_The_Common_Agricultural_Policy_Past_Present_and_Future (Accessed in May 2022)

Billari F. C., Fent T., Prskawetz A., Scheffran J.(2006), Agent-based computational modelling: an introduction. In Agent-based computational modelling. 1-16. Physica-Verlag HD.

Dou Y., Liu J.J. (2017), Modelling telecoupled systems: design for simulating telecoupled soybean trade, Unpublished manuscript, Center for Systems Integration and Sustainability, Michigan State University. https://www.gtap.agecon.purdue.edu/resources/download/8750.pdf. (Accessed in May 2022).

European Commission (EC) (1992), Council Regulation (EEC) No 2078/92 of 30 June 1992 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside. https://op.europa.eu/en/publication-detail/-/publication/4f9edd7f-dcbd-4758-be9b-d8819f4831ce/language-en (Accessed in May 2022).

European Commission (EC) (2015), The Monitoring and Evaluation Framework for the Common Agricultural Policy 2014–2020, Luxembourg: Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/00da6abf-7c75-11e5-9fae-01aa75ed71a1. (Accessed in May 2022).

European Commission (EC) (2021a), Common Agricultural Policy: Key graphs & figures: CAP expenditure in the total EU expenditure, https://agriculture.ec.europa.eu/data-and-analysis/financing/cap-expenditure_en#keygraphsonthecap (Accessed in September 2022).

European Commission (EC) (2021b), Common Agricultural Policy: Key graphs & figures: CAP expenditure and CAP reform path, https://agriculture.ec.europa.eu/data-and-analysis/financing/cap-eexpenditure_en#keygraphsonthecap (Accessed in September 2022).

Emmerson, M., M.B. Morales, J.J. Oñate, P. Batáry, F. Berendse, J. Liira, T. Aavik, I. Guerrero, Bommarco R., Eggers S., Pärt T., Tscharntke T., Weisser W., Clement L., Bengtsson J. (2016), Chapter Two: How Agricultural Intensification Affects Biodiversity and Ecosystem Services, in Editor(s): A. J. Dumbrell, R. L. Kordas, Guy Woodward, Advances in Ecological Research, 55, 43-97, Academic Press. https://www.sciencedirect.com/science/article/abs/pii/S0065250416300204. (Accessed in June 2022)

Farmer A.M. (2012), Manual of European Environmental Policy. 1043. Routledge, London. https://ieep.eu/understanding-the-eu/manual-of-european-environmental-policy/. (Accessed in May 2022)

Folmer C., Keyzer M. A., Merbis M. D., Stolwijk H. J. J., Veenendaal, P. J. J. (1995), The Common Agricultral Policy Beyond the Macsharry Reform. Elsevier. E-book. https://books.google.com.tr/books?hl=tr&lr=&id=LkwXBQAAQBAJ&oi=fnd&pg=PP1&dq=Folmer,+C.,+Keyzer,+M.+A.,+Merbis,+M.+D.,+Stolwijk,+H.+J.+J.+And+Veenendaal,+P.+J.+J.+1995.+The+Common+Agricultral+Policey+Beyond+the+Macsharry+Reform&ots=0-OG0J6kZF&sig=idIjPhtVI7BulGcoPIxNFEvvBYk&redir_esc=y#v=onepage&q=Folmer%2C%20C.%2C%20Keyzer%2C%20M.%20A.%2C%20Merbis%2C%20M.%20D.%2C%20Stolwijk%2C%20H.%20J.%20J.%20And%20Veenendaal%2C%20P.%20J.%20J.%201995.%20The%20Common%20Agricultral%20Policey%20Beyond%20the%20Macsharry%20Reform&f=false (Accessed in May 2022)

Heckelei T., Britz W. (2005), "Models based on positive mathematical programming: state of the art and further extensions", Contribution appeared in Arfini, F. (Ed.) (2005) "Modelling Agricultural Policies: State of the Art and New Challenges", proceedings of the 89th EAAE Seminar, 2: 48 - 73. https://ageconsearch.umn.edu/record/234607/ (Accessed in May 2022)

Kremmydas D., Athanasiadis I. N., Rozakis S. (2018), "A review of Agent Based Modelling for agricultural policy evaluation", *Agricultural Systems*, 164, pp.95-106.

Kremmydas D. (2012), Agent based modelling for agricultural policy evaluation: A technical report, AUA Working Paper Series. https://www.researchgate.net/profile/Dimitrios-Kremmydas/publication/261552249_Agent_based_modelling_for_agricultural_policy_evaluation_A_review/links/00b495349a4839cd48000000/Agent-based-modelling-for-agricultural-policy-evaluation-A-review.pdf (Accessed in May 2022)

Liu J., Herzberger, A. Kapsar, K. Carlson A. K., Connor T. (2019), What is telecoupling?. in Telecoupling. C. Friis, J. Ø. Nielsen (eds.). Chapter 2, 19-48. Palgrave Macmillan, Cham. https://link.springer.com/chapter/10.1007/978-3-030-11105-2_2 (Accessed in May 2022)

Millington D., Xiong H., Peterson S., Woods J.(2017), Integrating modelling approaches for understanding telecoupling: Global food trade and local land use. Land, 6(3): 56.

Möhring A., Mack G., Zimmermann A., Ferjani A., Schmidt A., Mann S. (2016), "Agent-based modelling on a national scale–experiences from SWISSland", *Agroscope Science*, 30, pp.1-56.

Nègre, F. (2021), Second Pillar of The CAP: Rural Development Policy. European Commission. https://www.europarl.europa.eu/ftu/pdf/en/FTU_3.2.6.pdf. (Accessed in May 2022)

Norton R.D., Hazell P. B. (1986), Mathematical programming for economic analysis in agriculture. Macmillan.

Paris, Q. 2001. Symmetric positive equilibrium problem: A framework for rationalizing economic behavior with limited information. American Journal of Agricultural Economics, (Agricultural and Applied Economics Association), vol. 83(4): 1049-1061.

Ren Y., Lu Y., Comber A., Fu B., Harris P., Wu L., 2019. Spatially explicit simulation of land use/land cover changes: Current coverage and future prospects. Earth-Science Reviews. 190:398-415. https://doi.org/10.1016/j.earscirev.2019.01.001

Rizojewa-Silava A., Pilvere I., Zeverte-Rivza S., 2018. Agriculture modelling in the European Union in Proceedings of the International Scientific Conference on Economic Sciences for Agribusiness and Rural Economy, 2. https://js.wne.sggw.pl/index.php/esare/article/view/1493. (Accessed in May 2022).

De Muro P., Salvatici L., 2001. The common agricultural policy in multisectoral models. Osservatorio delle Politiche Agricole dell'UE Working Paper, (11). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=313601. (Accessed in May 2022).

Witzke H., Zintl A., 2005. CAPSIM-Documentation of model structure and implementation, Agriculture and fisheries-Working papers and studies.

Zobbe H., 2001. The Economic and Historical Foundation of the Common Agricultural Policy in Europe. Fourth European Historical Economics Society Conference, September 2001. Merton College, Oxford, U.K. Unit of economics working papers 2001/12. https://ageconsearch.umn.edu/record/24212/ (Accessed in May 2022).

https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en. 05.05.2021.

https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap/key-policy-objectives-future-cap_en#nineobjectives. (Accessed in May 2022)

https://www.europarl.europa.eu/factsheets/en/sheet/110/second-pillar-of-the-cap-rural-development-policy. (Accessed in June 2022)

https://ec.europa.eu/jrc/en/research-topic/rural-development). (Accessed in June 2022)

https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/rural-development_en. (Accessed in June 2022)

https://eur-lex.europa.eu/legal-content/SK/ALL/?uri=legissum:l60032 (Accessed in May 2022)

Appendix

Table A1. Details of CAP Evolution

CAP Reforms	Policy objectives	Measures
1962 Treaty of Rome	1. To increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimal utilization of the factors of production, in particular labour 2. To ensure a fair standard of living fort the agricultural community in particular by increasing the individual earnings of persons engaged in agriculture 3. To stabilize market 4. To assure the stability of supplies 5. To ensure that supplies reach consumers at reasonable prices.	Market organizations measures (CMO) 1. Intervention purchases 2. Storage costs 3. Compensatory payments 4. Production aids 5. Export refunds Tariffs and levies, producer price support, and a flat-rate producer subsidies based on area harvested or production quantity Structural measures 1. Restructuring and modernization of farms 2. Compensatory allowances for Natural handicaps 3. Young farmers 4. Assistance for processing and marketing 1984 Dairy quotas 1988 Budgetary stabilizers
1992 MacSharry	1. To decrease the cost of CAP 2. To control large surpluses of major commodities 3. To harmonize CAP with that of GATT rules or to liberalize agricultural policy Affiliated objectives: 1. To accompany the changes to be introduced under the market organization rules 2. To contribute to the achievement of the Community's policy objectives regarding agriculture and the environment 3. To contribute to providing an appropriate income for farmers	1. Market prices support 2. Variable levies and export refunds 3. Set-aside and stocking rate criteria 4. Retention of the milk production quotas 5. Area-based payments 6. Direct (compensation) payments 7. Extensification premium for livestock 8. Agri-environment measures 9. Afforestation measures 10. Early retirement measures 11. Less-favoured areas (LFA) payments 12. Mediterranean package
2000 Agenda 2000	1. To respond the expected stricter rules of the WTO Doha Round 2. To keep Community farming competitive 3. To reinforce the rural development 4. To safeguard farm incomes 5. To ensure multi-functionality, sustainability and competitiveness of EU agriculture Objectives of the pillar two: Rural development policy 1. To create a stronger agriculture and forestry sector 2. To improve the competitiveness of rural areas 3. To maintain the environment and preserve Europe's rural heritage	1. Decoupled payments 2. Single farm payment (SFP) based on historical claims for direct payments in the base period 3. Cross-compliance to meet for direct payment Pillar one focuses on the economic aspects of agriculture Pillar two focuses on the rural development measure such as providing support for LFAs, with the forestry, early retirement and agri-environment measures. The 'Second Pillar' aiming to address the economic, social and environmental aspects of rural development Modulation: Budgetary transfer from pillar one to pillar two
2003 Midterm	1. To improve the market orientation and environmental sustainability of EU	1. Decoupling measure provided through a Single Farm Payment

Review	agriculture. 2. To have a more market-orientated agriculture The reform was to respond to the budget pressure of the EU East enlargement in 2004 and Franco-German agreement in October 2002 on the CAP. Financial discipline: The farm budget was fixed until 2013	2. Cross-compliance requirements such as respect of environmental, food safety, animal and plant health and animal welfare standards 3. Mediterranean products (cotton, tobacco, hops, olive oil and table olives) and sugar
Rural Development	1. To improve the competitiveness of agriculture and forestry (Axis 1). 2. To improve the environment and countryside by supporting land management (Natura 2000) (Axis 2). 3. To improve the quality of life in rural areas and encourage diversification (Axis 3).	1. "Transfer of knowledge and information measures (training, information campaigns, etc.); 2. Advisory services, farm management and farm relief services; 3. Quality systems applicable to farm produce and foodstuffs (new ways for farmers to participate in quality systems); 4. Physical investment (processing of farm products, infrastructure, improving the performance and sustainability of farms, etc.); 5. Restoring agricultural production potential damaged by natural disasters and catastrophic events and introducing appropriate prevention actions; 6. Development of farms and businesses (business start-up aid for young farmers, non-farm business operations in rural areas, etc.); 7. Basic services and revitalization of villages in rural areas (broadband, cultural activities, tourist facilities, etc.); 8. Investment in the development of forests and improving their viability (afforestation and creation of woodland); 9. Setting-up of producer groups and organizations; 10. Preservation of farming practices which have a beneficial effect on the environment and climate and foster the necessary changes (agri-environment-climate measures). These measures have to be included in rural development programs. 11. Subsidies for organic farming (conversion or support payments); 12. Payments linked to Natura 2000 and the Water Framework Directive; 13. Payments for areas facing natural or other specific constraints; 14. Animal welfare payments;

		15. Payments for forest, environmental and climate services and forest conservation; 16. Encouragement of cooperation between farmers and forestry operators and those involved in the food production chain (establishment of centres and networks, operational groups of the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP)); and 17. 'Risk management toolkit': crop, livestock, and plant insurance; mutual funds for adverse climate events, animal and plant diseases, pest infestations and environmental incidents; income stabilization tool, in the form of financial contributions to mutual funds, providing compensation to farmers for a severe drop in their income" (https://www.europarl.europa.eu/factsheets/en/sheet/110/second-pillar-of-the-cap-rural-development-policy).
2008 Health Check	To improve the sustainability of agricultural land use	1. Further decoupling of direct payments 2. Transferring budget between Pillar One and Pillar Two through compulsory modulation 3. Reinforcing the priorities and focus of the EAFRD Extending the provisions of 'national envelopes' 4. New cross-compliance standards The arable set-aside was abolished. Milk quotas were increased gradually. Market intervention was converted into a genuine safety net.
2010 Sustainable Development Strategy (SDS)	CAP and its future development should encourage healthy, high-quality products, environmentally sustainable production methods, including organic production, renewable raw materials and the protection of biodiversity to contribute to achieving sustainable development	
2013 Reform	1. To ensure food security 2. To protect farmers from price volatility due to climate change 3. To reduced levels of market intervention 4. To focus on the delivery of public goods 5. To manage the natural resources and climate action sustainably 6. To balance territorial development 7. To foster knowledge transfer and innovation 8. To enhance competitiveness 9. To manage the food chain organization and risk 10. To restore, preserve and enhance ecosystems 11. To promote resource efficiency and transition to a low carbon economy 12. To promote social inclusion, poverty reduction and economic development of rural areas"	1. Direct payments will be distributed in a fairer way between Member States, regions and farmers, 'historical references will be ended'. Member States will continue the aid to less-favoured areas. 2. Young farmers will be encouraged. 3. Sugar quotas will be abolished by 2017. 4. Professional and inter-professional organizations will be promoted, and there will be specific regulations on competition law for milk, beef, olive oil, cereals. 5. A crisis reserve will be established. 6. Member States encourage farmers to take part in risk prevention mechanisms under rural development programs (income support schemes or mutual funds 7. Environmentally friendly farming practices and rural development programs will gain more importance to meet the challenges of soil and water quality, biodiversity and climate change.
2021-27	To aim at a simpler and more efficient policy to incorporate the sustainable ambitions of the European Green Deal Objectives 2021-2027 1. Support viable farm income and resilience across the EU territory to enhance food security; 2. Enhance market orientation and increase competitiveness including greater	Most of the CAP rules applied during 2014-20 period will be extended for the period of 2021-22

	focus on research, technology and digitalization; 3. Improve farmers' position in the value chain; 4. Contribute to climate change mitigation and adaptation, as well as sustainable energy; 5. Foster sustainable development and efficient management of natural resources such as water, soil and air; 6. Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes; 7. Attract young farmers and facilitate business development in rural areas; 8. Promote employment, growth, social inclusion and local development in rural areas, including bio-economy and sustainable forestry; 9. Improve the response of EU agriculture to societal demands on food and health, including safe, nutritious and sustainable food, as well as animal welfare.	
2023 onward	CAP strategic plans are due to be implemented in all EU countries from 1 January 2023 once the new legal framework has been agreed	

Source: Compiled by the authors, 2023.