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BAE 10th Anniversary paper

The Bioeconomy in economic literature: looking back, looking ahead

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Abstract. The objective of this paper is to provide a review of recent economic literature related to the Bioeconomy, in particular aimed at identifying relevant pathways for future research in this field. The paper is organised in four main parts. First, we illustrate the economic role of the Bioeconomy and its key statistics in the EU. Second we review economic topics related to the Bioeconomy production in a mainly private (company, consumer, market) perspective. Then we extend our attention to the review of wider social and environmental aspects with a focus on ecosystem services. Finally, we discuss the interplay of the above topics and cross cutting issues in the attempt to identify the most promising pathways for further research. While the economic literature is growing fast in all the fields of the Bioeconomy, we highlight in particular the need of more economic research focusing on transitions and innovation. However, we also highlight the need to take a system perspective and accounting explicitly for the trade-offs among the many objectives that the Bioeconomy is expected to target and to better account of the costs and benefits affecting different stakeholder groups.

Keywords: bioeconomy, sustainable development, bio-based economy, circular economy, ecosystem services.
JEL codes: Q57.

1. INTRODUCTION AND OBJECTIVES

The editorial of the first issue of the journal Bio-based and applied economics in spring 2012 was entitled "From Agricultural to Bio-based economics? Context, state-of-the-art and challenges". The paper reviewed the trends in agricultural economic literature and asked whether there was a shift from traditional sectoral economics, such as agricultural economics, towards a more general discipline that could have been called "bio-based economics" (Viaggi et al., 2012). That title, in itself, provided somehow an agenda for the journal, and envisaged a potential evolution of the discipline in the next decade, though, at that time, the Bioeconomy was largely unknown by academic research in economics.

Since that article appeared, a lot of events and changes occurred: the Bioeconomy has become mainstream, while more and more countries have

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their Bioeconomy strategy. The EU published an update of its Bioeconomy strategy in 2018, while Italy went under two versions of its country strategy.

The recent strategies in Europe, in particular the one from the EU, re-define the Bioeconomy as an aggregate of sectors using biological resources, emphasising the interconnection with ecosystems and the general contribution to economic development, while technologies, in particular biotechnologies, are much less prominent (European Commission, 2018). The Green Deal strategy has renewed the importance of the Bioeconomy and the circular economy, as the main means to achieve the transformative changes required to addresses global challenges, as the Bioeconomy can potentially create synergies among the various dimensions of sustainability (Giampietro, 2019; Peters, Jandrić and Hayes, 2020) secondary and tertiary resource flows and helps to identify what can and cannot be re-circulated within the metabolic pattern of social-ecological systems. Adopting the biophysical view, it becomes clear that the industrial revolution represented a linearization of material and energy flows with the goal to overcome the low pace and density of biological transformations. The required level of productivity of production factors in contemporary developed economies (flows per hour of labor and per hectare of land use).

The economic literature on the Bioeconomy has been growing steadily. At the end of April 2021, Scopus reports 849 papers in the fields of Social sciences, Economics and econometrics, and Business management and accounting, with title, keywords or abstracts mentioning the Bioeconomy. Papers published in 2020 were 187 in comparison to 21 published in 2012, while papers published in 2021 were already 97 at the time of writing this paper.

The literature on the Bioeconomy is taking shape, but did not substitute the literature in agricultural economics or food economics, both sectors being, on the contrary, flourishing. The Bioeconomy literature is rather focusing on new value chains and on topics that are more relevant for the Bioeconomy as a whole than for individual sectors.

The objective of this paper is to provide a review of recent economic literature related to the Bioeconomy, in particular aimed at identifying relevant pathways for future research in the field.

The approach is based on a literature review, but is far from being systematic. The papers used derive mainly from a screening of the Scopus database after searching for the keyword "Bioeconomy" and selecting papers in Economics, Business & management and Social sciences, or Bioeconomy and Ecosystem services. Then papers were selected based on a subjective evaluation of their ability to provide insights about recent trends, focusing mostly on the more recent papers. The outcome is discussed following an organisation of topics derived from an update of the structure proposed by Viaggi (2018). Though potentially relevant, for reasons of space we on purpose exclude studies focusing on descriptive developments on one single product and environmental assessment studies such as LCA, as well as studies describing the Bioeconomy in individual countries.

The remainder of the paper is organised as follows. In section 2 we illustrate key statistics and trends of Bioeconomy in the EU. In section 3 we review economic topics related to the Bioeconomy production in a mainly private (company, consumer, market) perspective. In section 4 we extend the topic to the review of wider social and environmental aspects with a focus on ecosystem services. In section 5, we discuss the interplay of the above and selected cross-cutting issues, in the attempt to identify the most promising pathways for further research. Section 6 concludes.

2. STATISTICS AND TRENDS OF THE BIOECONOMY IN THE EU

In spite of the relevance of the Bioeconomy, statistics related to the sector are still at a development stage. The main problem to obtain clear figures is the lack of a consolidated and harmonised methodology, which makes also difficult the comparison of results across countries. Also for sectors with well-established statistics (e.g. energy) disaggregating the Bioeconomy component may be a challenge.

The two main approaches for quantifying the Bioeconomy are the input-based and the output-based approach. The former attempts to measure the proportion of biomass in inputs used for the production of bio-based products (see for example Efken et al., 2016; Luke, 2019), while the latter tries to measure the biomass content of bio-based products (see for example Capasso and Klitkou, 2020; Vandermeulen et al., 2011).

In 2018 the International Sustainable Bioeconomy Working Group (ISBWG) published a review of approaches, applications and indicators to measure economic, social and natural resources aspects of Bioeconomy in different EU countries (Bracco et al., 2018). From 2017, the European Commission and the Nova-Institute have presented a common output approach for a cross-country comparison in some publications where a quantification of performance indicators relying on sectors and sub-sectors of the Bioeconomy for all EU member States are illustrated (Ronzon and M'Barek, 2017; Ronzon et al., 2017; Ronzon and M'Barek, 2018; Piotrowski et al., 2019).

Ronzon et al. (2020) updates the methodology and data presented previously in 2018 and proposes a methodology based on the following approaches: a) for the sectors that fully belong to the Bioeconomy, existing statistics are harmonized and used; b) for those sectors which only partially belong to the Bioeconomy, estimation of a "bio-based share" is derived from experts' consultations. In particular, agriculture, forestry, fishing, the manufacturing of food, beverages, tobacco, and paper are considered as sectors fully belonging to the Bioeconomy. Other sectors, like the manufacture of textiles, wearing apparel, leather, wood products, furniture, chemicals, pharmaceuticals, plastics and rubber and the production of electricity are included only partially in the Bioeconomy. Eurostat is the main data source for a quantification of socio-economic relevance in all sectors of the Bioeconomy in EU. In particular, PRODCOM (Eurostat, 2020) and the Structural Business Statistics (SBS, Eurostat, 2020a) database are the two main data sources. The principal indicators presented in the reports are the turnover, the employment and the value added.

From Porc et al. (2020) Figure 1 reports the percentage share of turnover in the Bioeconomy in EU-28 in 2017 and the trends between sectors over the 2008–2017 period. The Bioeconomy as a whole shows a continuous increase from 2008 (turnover less than 2 trillion) to 2017 (turnover over 2,4 trillion Euro). Almost half of the Bioeconomy turnover comes from the food and beverages sectors, that also account for the majority of the increase over the period, while about a quarter is produced by agriculture and forestry. The last quarter is obtained by bio-based industries.

Ronzon et al. (2020) provide the EU Bioeconomy data in the post Brexit situation (Table 1). They estimated that Bioeconomy employed around 17.5 million people, and created €614 billion of value added in 2017. It is relevant to note that this data represents about 8.9% of the EU-27 labour force and 4.7% of the EU-27 GDP.

The updated analysis of Ronzon et al. (2020) also elaborates on the different trends and country developments of the Bioeconomy. In particular, they identify four groups of EU countries based on their performances on two dimensions: a) apparent labour productivity, and b) location quotient of the Bioeconomy (i.e. the specialisation rate of labour market in the Bioeconomy). The groups showing structural differences between national Bioeconomies, are:

- High specialisation (location quotient≥ 1.5) and below average apparent labour productivity (≤ half the EU-27 level): Eastern Member States (Romania, Bulgaria, Poland, Latvia, Croatia, Lithuania), Portugal, and Greece; this group is characterized by manufacturing of textiles and/or wood products with labour-intensive production and an high rate of Bioeconomy jobs located in agriculture, forestry, and fishing and aquaculture (biomass production sectors).
- Low specialistation (location quotient ≤ 1.3) and medium-high apparent labour productivity (between half the EU-27 level and the EU-27 level): Estonia and Central Member States (Slovenia, Hungary, Cyprus, Czech Republic, Slovakia) and Malta; in this group, apparent labour productivity is higher than the previous group, mainly in agriculture, forestry, and bio-plastics manufacturing.
- Low specialisation (location quotient ≤ 0.9) and an apparent labour productivity above the EU-27 level (but less than double the EU-27 level): Western

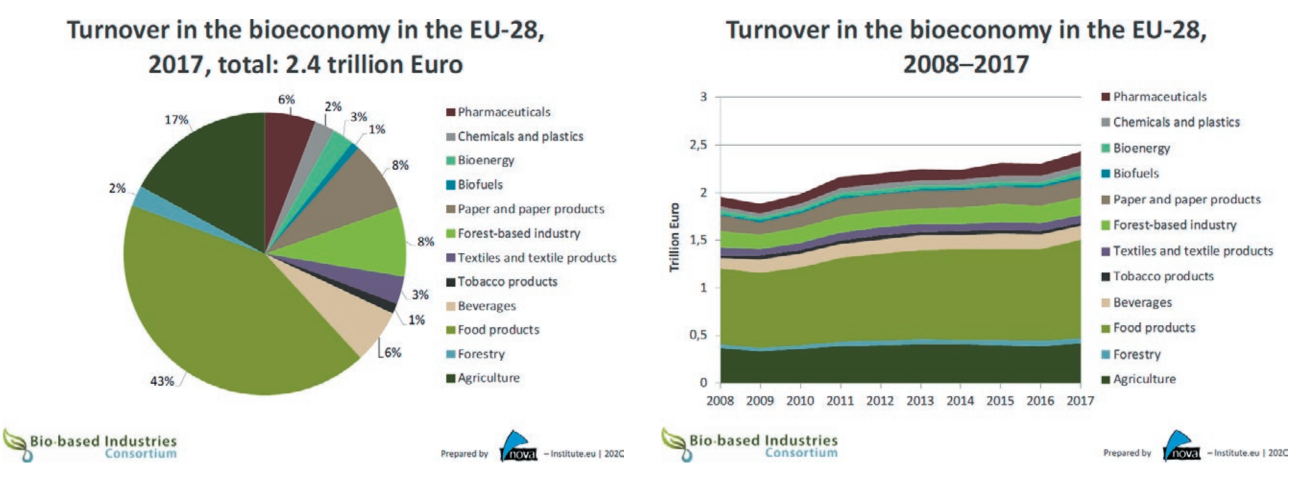

Figure 1. Turnover in the Bioeconomy in EU 28: percentage between sectors and trends over 2008-2017 (Porc et al., 2020).

Table 1. Number of persons employed, value added, and apparent labour productivity by sector of the Bioeconomy (EU-27, 2017). (Ronzon et al., 2020).

Sector	Workers	Value Added	**Apparent Labour Productivity**
	(Number of Persons Employed)	(€ million)	(€000 per Person Employed)
Agriculture	9,273,470	188,519	20
Forestry	517,480	25,301	49
Fishing	166,610	6698	40
Manufacture of food, beverages, and tobacco	4,398,761	215,311	49
Manufacture of bio-based textiles	692,906	21,103	30
Manufacture of wood products and furniture	1,424,540	47,268	33
Manufacture of paper	590,456	41,702	71
Manufacture of bio-based chemicals, pharmaceuticals, plastics, and rubber (excluding biofuels)	396,712	60,312	152
Manufacture of liquid biofuels	20,506	3216	157
Production of bioelectricity	22,550	4208	187
Bioeconomy	**17,503,992**	**613,637**	**35**

Member States (Austria, Italy, Spain, France Germany, Luxembourg), characterised by more diversified in high productive biomass manufacturing sectors.

- Low specialisation (location quotient ≤ 0.9) and an apparent labour productivity more than double the EU-27 level: Northern Member States (Belgium, Denmark, Finland, Ireland, Netherlands, Sweden).

The study by Ronzon et al. (2020) also highlights trends over the 2008-2017 period for the apparent labour productivity and location quotient of the Bioeconomy in the EU27 member states, showing that different speed of increase are in place. Consequently, while the composition of the four groups did not change, the heterogeneity of the EU's Bioeconomy remains and get stronger.

The quantifications presented in this section refer mainly to a set of studies that apply the same analytical methods refining and updating over time. Nevertheless, the discussion on alternative methods, different rate in sectors or choice in including/excluding sub-sectors still evolves and needs to be further developed in order to ensure advances in the Bioeconomy definition for practical purposes (see for example Vivien et al., 2019).

3. DEMAND, SUPPLY, MARKETS AND CHAIN ORGANISATION IN THE BIOECONOMY

3.1 Demand

Demand for Bioeconomy products come from the combination of two main forces, consumers and policy, that need to be understood in the light of major scenarios and driving forces providing incentives for societal change.

Part of the literature focuses on classical analyses of demand elasticity of Bioeconomy products (Schier et al., 2021; traditional forest products markets change and diversify. Fossil-based inputs in the chemical, textile, apparel and downstream industries can be replaced by lignocellulose-based products such as dissolving pulp, cellulose-based chemical derivatives and textile fibres. When looking ahead, these previous niche products are likely to gain in economic importance. So far, little attention has been paid to the characteristics of macroeconomic relations of emerging lignocellulose-based materials on macroeconomic level. Key economic parameters for such materials are not available neither at regional nor at global level. Schier et al. (2021) to contribute to a better understanding of the market behavior of emerging forest products that are not yet covered by forest products market analysis. Therefore, they investigate how lignocellulose-based products respond to changes of main economic drivers and compute global market elasticities for dissolving pulp, cellulose-based chemical derivatives and textile fibres. To conduct the evaluation, they first test historical input data for non-constancy in time series due to structural changes using change-point estimator (MOSUM test in Skjerstad et al., 2021). However, a large part of the literature rather points attention to consumers behaviour in the Bioeconomy as linked to the issue of acceptance of new product and differential willingness to pay.

Early literature was largely driven by attention to potential negative impacts of biotechnologies and willingness to pay (WTP) to avoid products implying the use of e.g. GMO crops. The most recent literature is more related to WTP for positive Bioeconomy-related attributes (such as bio-based nature of feedstock in comparison to fossil materials) or for new products. For example in Petruch and Walcher (2021) the the public perception of wood as a sustainable building material that can facilitate the shift towards a bio-based economy is crucial. This study aimed to explore the attitudes towards timber construction among young millennials in Austria, a cohort that in the coming years will increasingly occupy decision-making positions and gain purchasing power.

Most recent studies tend to integrate concepts from psychology and behavioural economics into consumer studies, revealing the complexity of choices on Bioeconomy products. An example is provided by Wensing et al. (2020) explaining why the food industry is increasingly interested in pro-environmental packaging alternatives-such as bio-based plastic. As the market share for bio-based plastic packaging is still small, strategies to raise consumer awareness and willingness to pay are increasingly investigated.

Another relevant area of recent research concerns the fact that consumers are not deciding in isolation and, on the contrary, are more and more networked. In this context, how the digitalisation and the role of online intellectual capital impact on consumers behaviour related to the Bioeconomy is a key issue. Vătămănescu et al. (2018) address a demand-side perspective of bioeconomy by laying emphasis on the digitalization of markets and, subsequently, on the consumption patterns at the macroeconomic scale. They investigates the influences of online intellectual capital on bio products consumption in two European countries (Romania and Italy). The imperative for a sustainable economic model corroborated with the advances in digital technologies usage have reconfigured consumers' approaches and expectations and availed new forms of consumer behaviour. Among these, the development of consumer-based online communities and of the online intellectual capital have often come forth as an undertaking of empowered consumers pursuing knowledge-based consumption patterns. The quest for sustainable, bio-labeled products on the digital markets has cemented the formation of new social aggregations built on the similarity of interests, goals, values, expectations, preferences, etc., giving way to consistent communication and interaction flows among their members and engendering profound transformations in today's society.

The behavioural aspects highlighted above can be detected through consumer studies but also by addressing stakeholder views (Kakadellis, Woods and Harris, 2021), which may help in gaining a more aggregated view of different positions and understanding interactions among groups.

Being a new concept, in addition attached to a number of socially relevant attributes (such as climate change, sustainability, biological resources), the development of the Bioeconomy is connected to visions, imagery and perceptions by the different stakeholders involved. Several papers address this issue. Some of them emphasise the general positive perception of renewable vs. non renewable products, in particular at consumer level (Navrátilová et al., 2020), while others emphasise the contrasting views and the different potential positions by different stakeholders. However, the review by Holmgren, D'Amato and Giurca (2020) concludes that most of the scientific literature tends to reproduce policy concepts linked to weak sustainability rather than introducing original ideas into the process of Bioeconomy development.

Media and communication are also important in shaping these aspects. Early work on genetic modifications has shown the potential role of media in changing public opinion. More recent research on this topic thought reveals relatively little attention on elaborating novel ideas and rather a discourse mostly driven by government positions (Sanz-Hernández et al., 2020).

An important part of demand is driven by public policies. This has been relevant up to now in particular in the bioenergy sector, with studies largely focusing on biofuel mandates or biogas production depending on aspect most relevant in each country.

3.2 Supply

The primary production of biomass needed for the Bioeconomy is the first issue in supply analysis. This is addressed in different ways through technical economic studies investigating, for example, the land footprint, land bio-capacity, degree of (de)coupling and self-sufficiency (Naah, 2020).

From an economic point of view, supply elasticity of specific products is also an issue for analysis (Schier et al., 2021). Also concepts such as the need to exploit economies of scale and reduce transaction costs are addressed with respect to biomass production (Wen and Chatalova, 2021).

Farm level incentives and trade-offs among different product streams are a key to supply analysis (Jansen et al., 2021), in particular in the context of the competition for land use by most Bioeconomy supply chains.

Not surprisingly, in a growing and innovative sector, many supply-side papers focus on specific new products either at the level of biomass production or processing, such as microalgae (Orejuela-Escobar et al., 2021), new sources of protein including insects and seaweeds (van der Heide et al., 2021), forest Bioeconomy and new forest-based products (Kallio, 2021; Jonsson et al., 2021).

Biorefinery are a key approach to biomass processing, aimed at the valorisation of different sources (including waste) into a range of valuable products and are becoming the object of a dedicated stream of economic research (Clauser et al., 2021).

Another interesting area of research is that concerning emerging links among different value chains. These are rather countless and are part of the main nature of the Bioeconomy. Some of them are even surprising from the point of view of old technologies, for example the connection between the wood production and aquaculture (Solberg et al., 2021).

3.3 Markets

The study of markets for Bioeconomy products largely relates to two issues: development of new markets and relationships among markets of Bioeconomy products and other products, in particular competing products based on fossil resources.

The first point entails in particular the issues of launching new products on the market, even when they are already at a stage advanced enough for marketing and even more when they are in the process of moving from research to market through innovation processes. The difficulties and the actions needed to activate new products is visible in the example on market implementation of active and intelligent packaging (AIP) technologies specifically for fiber-based food packaging provided by (Tiekstra et al., 2021). They identify the following areas of concern: a) market drivers that affect development; b) the gap between science and industry, c) the gap between legislation and practice; d) cooperation between the producing stakeholders within the value chain, and e) the gap between the industry and consumers.

The second point (relationship with non-Bioeconomy markets) concerns directly the perceived specificity of Bioeconomy products. Assuming Bioeconomy products are perfect substitutes of fossil-based products, the early models mostly focused on interaction between bio-based and non-bio-based products, and related market shares, due to different marginal costs. In addition, in the most recent literature this has expanded to considering the issue for recycled vs. non recycled. The interaction among the three (four) types can be addressed as well.

When the product is different in terms of attributes, instead, the issue is more market differentiation than costs-competition, also in relation to consumer segmentation.

Finally, the problem of externalities and public goods needs to be taken into account. Many positive attributes of Bioeconomy products take the nature of public goods or externalities, which implies that market itself cannot take them fully into account and will tend to produce the Bioeconomy goods in a sub-optimal amount. This issue is better discussed in the next section.

To address some of the topics above, the role of policies is key. Besides direct incentives, mentioned in demand and supply, certification, often related to sustainability, can be a strategic tool to connect demand and supply (Vogelpohl, 2021).

3.4 Organisation and business models

Organisation aspects of the Bioeconomy derives from two main issues. The first is the growing degree of separability among different stages in Bioeconomy processes. The second is the emergence of specific technologies in the treatment of biomass around the concept of biorefinery. An intermediate and connected issue is that of flexibility both in feedstock and processing, that allows plants to switch from one feedstock to the other and from one product to the other.

As an answer to these trends, new concepts are increasingly being used to represent complex systems. One is that of value web approaches. Biomass value webs can be defined as “complex systems of interlinked value chains in which biomass products and by-products are produced, processed, traded, and consumed” (Callo-Concha et al., 2020). Examples of use of value webs concern the representation of different Bioeconomy systems in the context of developing countries (Callo-Concha et al., 2020; Naah, 2020; Virchow et al., 2016). Some of these approaches are supported and build on analyses of biomass flows (Gonçalves, Freire and Garcia, 2021).

Networking and collaboration are an important part of the new organisation landscape emerging for the Bioeconomy and several papers address this issue, in particular looking at collaboration among companies (Guerrero and Hansen, 2021), but also among different actors. In most cases, the key topic for collaboration is that of innovation.

Also part of the literature focuses on innovative business models related to the Bioeconomy. They rather often address the specific topic of circular Bioeconomy (Donner and Radić, 2021; Donner et al., 2021). Business models are a particularly relevant concept in relation to the innovation process and to the interpretation of the ability of the innovation systems to speed up innovation development and uptake, also in relation to appropriate policy instruments (Gatto and Re, 2021). Salvador et al. (2021) review the literature on business models and Bioeconomy and identify key aspects for implementing and managing business models, namely; "the role of innovation and new markets, taking the customer perspective into account in the value creation process and being close to customers, adequate management of logistics and feedstock collection systems, being aware of different routes for valuing biomass, seeking technological development, building resilient value chains, and focusing on value creation to cover costs. Issues that need addressing in the existing literature include product-service-systems, take back-systems, seasonal availability of resources, social impacts, rebound effects, and aquatic activities."

The topic of circular Bioeconomy has taken an increasing relevance over time, due to its potential to reduce environmental impact and better exploit the economic value of biological resources. Large part of it is related to food waste (Ferreira, Pié and Terceño, 2021; Santagata et al., 2021). The current state of the art in patents shows that this field is still far from expressing its full potential. Ferreira, Pié and Terceño (2021) conclude their review by highlighting that for further progressing towards an impactful circular Bioeconomy, further evidence is needed that circular Bioeconomy products "are indeed preferable to their fossil-based counterparts, from both the economic and societal points of view, including environmental sustainability, and to communicate extensively the findings to the society at large."

3.5 Innovation mechanisms and entrepreneurship

Innovation is at the core of the Bioeconomy and was actually the main field of research at the early stages of the development of the sector. Two main areas of concern appear from the literature. The first regards the shape taken by innovation systems. This partly connect to wider approaches to innovation, for example the triplequadruple or quintuple helix approach (Grundel and Dahlström, 2016). The second concerns the impact of regulation and its effects in shaping innovation pathways.

With growing investment in demonstration plants, for example in the field of biorefineries, attention is also moving to managerial difficulties. For example, using a survey concerning pilot and demonstration plants in Sweden, Mossberg et al. (2020) provide a description of various challenges, such as the division of responsibility for the operation and ownership, unclear roles and objectives, and the lack of specific competences and resources in the actor networks.

Research also concerns new areas of innovation and technology as they emerge. Large part of economic research related to Bioeconomy is in the field of biotech innovations. Recently, an emerging field of research is that of digitalisation also in view of its potential support to collaboration in management and innovation processes (Ryymin, Lamberg and Pakarinen, 2021). The application of digital innovation hub concept to the Bioeconomy is a promising pathway to boost networking and innovation (Aragonés et al., 2020).

Governance of innovation systems is also a widely addressed issue (Toivonen, Vihemäki and Toppinen, 2021), with implication in shaping the form of supply chain network and its impact on the sustainability (see section 4).

Innovation and research are connected to economic development also through education and intellectual capital. Though little explored by the literature, Cristea et al. (2020) highlight that education, innovation and research, along with main Bioeconomy features, are at the core of economic development in the EU.

New business models and innovation are strictly linked to the issue of entrepreneurship. Kuckertz, Berger and Brändle (2020) provide a holistic framework on the role of entrepreneurships in the Bioeconomy identifying three main aspects: entrepreneurial activity on the micro level, entrepreneurial ecosystems (or clusters and innovation systems) on the meso level, and governmental vision and support on the macro level. While entrepreneurship is identified as important in most of the Bioeconomy strategies worldwide, actions to strengthen its role are often lacking or too weak (Kuckertz, 2020).

The connection between entrepreneurship and academic activities is also a relevant area of debate, in particular in relationship to emerging new processes (Rosenlund and Legrand, 2021).

3.6 Governance and political economy

Governance and policies are cross-cutting areas of concern in all the previous points and specific policies are mentioned above in relation to issues they intend to address. Some cross cutting issues are however worth to be mentioned here. While there are now many Bioeconomy strategies worldwide, Bioeconomy policies as such are almost absent. On the contrary, there are important policy interventions in specific sectors of the Bioeconomy (e.g. energy, agriculture). As a result, the literature on policies related to the Bioeconomy is rather fragmented and largely incorporated in sectorial policies, such as agriculture and forestry. This is a more or less important topic depending on the sector. For example the topic of Bioeconomy has a much higher degree of attention in connection to forestry (Elomina and Pülzl, 2021) than in connection to agriculture. Governance landscape for forest Bioeconomy and ecosystem services in Europe is mapped by Primmer et al. (2021).

Besides a lot of work on national or local policies and governance approaches, the international dimension of the Bioeconomy is now emerging, together with a growing attention at the role of international institutions (Bößner, Johnson and Shawoo, 2021).

Political economy analyses of regulation have accompanied the development of the Bioeconomy, with a stronger focus on new technologies and, in particular, biotechnologies (Smith, Wesseler and Zilberman, 2021).

Recent political economy contributions also touch the more theoretical and global vision of the Bioeconomy. For example, Vertommen, Pavone and Nahman (2021) propose the concept of "global fertility chains", which "articulates the reproductive Bioeconomy as a nexus of intraconnected practices, operations, and transactions between enterprises, states, and households across the globe, through which reproductive services and commodities are produced, distributed, and consumed".

Potential for sharing good practices and replication in policy and governance solutions is also an issue in a period when the sector is expanding (Andersson and Grundel, 2021).

A notable area of research is that concerning the potential of the Bioeconomy for development. At local level, this discussion is partially related to the valorisation of marginal areas. The recent literature advocated that this opportunity is not straightforward in the current settings and it would require the designing of a new "'resilience governance' based on integration, innovation and future orientation to rural transformation" (Sanz-Hernández, 2021)

4. BIOECONOMY, SDG AND ECOSYSTEM SERVICES

The literature shows conflicting views on the potential contribution of the Bioeconomy to sustainability, with the academic debate on its benefits and risks driven by strong polarised opnions (Kirkels, 2012). Pfau et al., (2014) identify different visions on the impact of the Bioeconomy on society that span from unconditional sustainability as an inherent characteristic (i.e. using biomass to replace fossil resources, see for example Székács, 2017) to potential harm due to increasing competition with the food sector, changes in the demand for productive factors or unknown environmental and social consequences (see for example DeBoer et al., 2020). These multiple visions of the Bioeconomy can be a consequence of the evolution of the Bioeconomy concept itself (Vivien et al., 2019), or of the nature of the socio-technological transition of the Bioeconomy that requires deep knowledge and technology as drivers of its development (Vainio, Ovaska and Varho, 2019). Therefore, reconciling environmental and social goals with economic development requires a deep understanding of the human-biosphere-technosphere nexus (Giampietro, 2019). This complexity has the practical consequences that the economic literature on Bioeconomy fails to provide a comprehensive assessment of their positive or negative impact on sustainability and ecosystem service (Heimann, 2019) and properly addressing these issues requires strong multidisciplinary and interdisciplinary research. The sustainable management of biological resource and their circular transformation in food, feed, energy, and biomaterials relies on improving social wellbeing through ecosystem services (Figure 2).

Although El-Chichakli et al., (2016) consider the Bioeconomy as directly or indirectly involved in reaching several millennium development goals, (i.e. food security (SDG 2), prosperity and economic growth (SDG

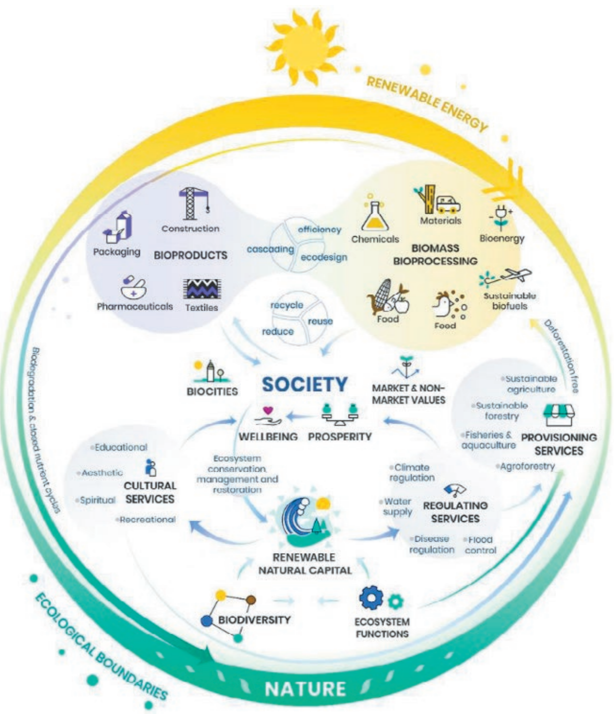

Figure 2 Circular Bioeconomy and wellbeing. Source: European Forest Institute.

2; 8, 9, 11, and 12), protection of natural capital (SDG 6; 7; 14 and 15) and the mitigation of climate change (SDG 13), its linkages to the provision of ecosystem services are not yet established (D'Amato, Bartkowski and Droste, 2020). The prerogative of the ecosystem services concept is to help understanding the synergies and trade-offs between various societal objectives highlighting the natural capital contribution to human wellbeing (Fisher, Turner and Morling, 2009). However, the provision of services depends on the socio-technological context of individuals or groups of beneficiaries (Oteros-Rozas et al., 2014).

While the contribution of the Bioeconomy on provisioning services is quite evident, other ecosystem services (i.e. regulating, cultural and supporting) are less investigated (D'Amato, Bartkowski and Droste, 2020). Lower attention is often given to the indirect effects on ecosystem services through a different land and resource management. Table 2 provides an overview of the possible Bioeconomy contribution on the ecosystem service.

The bulk of studies that link the Bioeconomy with ecosystem services concerns the provisioning service by forest and agricultural systems. They are perceived as a primary source of biomass from the Bioeconomy (Bugge, Hansen and Klitkou, 2016; D'Amato, Bartkowski and Droste, 2020). Differently, the literature studying circular-economy in the Bioeconomy sector remains anchored to the provisioning sector but with the use of municipality or industrial waste or co-products as a primary source of biomass (DeBoer et al., 2020). Except for biomass from algae for animal feed or energy provision, the contribution of marine ecosystems to the Bioeconomy is less investigated. Van Schoubroeck et al. (2018), in a recent review, compare the sustainability of different types of bioeconomic products. The authors observe that bio-based chemical production has been investigated less than bioenergy and biofuels. Hamelin et al. (2019) argue that the source of biomass is the main factor leading to sustainability. While the urban greenery management (i.e. residue from managing public green spaces or roadside vegetation) and, agricultural, industrial, and municipal waste are considered sustainable as implicit in the circular economy[1], the sustainability of biomass from dedicated crops or by-products (i.e. straw, manure, residues, co-product from food (wheat, maize), and non-food crops (i.e. hemp) or by forestry and forestry residues is largely debated. Many studies have described a potentially harmful impact of Bioeconomy on ecosystem services due to shirking the global food security or reducing the adaptive capacities of local food system due to simplification of cultivated crops (Marsden and Farioli, 2015). As for a local or regional biorefinery, cultivation of first- or second-generation biomass affects ecosystem services. The development of biomass crops instead of traditional crops can impact the landscape quality (Cattaneo, Marull and Tello, 2018) and reduce the crop diversity (Bartolini, Gava and Brunori, 2017) with a further increase in exposure to climatic or market risks (Bartolini et al., 2015). Some authors, comparing the dedicated crops to invasive species, consider the food systems more likely to be food-insecure (see, for example, Ferdinands et al., 2011). In contrast, other authors have highlighted the positive impact on soil quality (Schrama et al., 2018) and on reducing water demand (Bartolini, Gava and Brunori, 2017) and the synergies in providing a feedstock supply while enhancing ecosystem services for perennial crops (Mitchell et al., 2016). The other ecosystem services are less investigated by the literature due to the complexity of socio-technical transformation of the ecological system (Giampietro, 2019), to the difficulties in define and assess the counterfactual carbon-based production and technology (Spierling et al., 2018) or to the lack of understanding of the nexus between direct and indirect changes in land use with multifunctional ecosystem (Egenolf and Bringezu, 2019).

The contribution of the Bioeconomy to climate change is a debated topic. On the one hand, the literature has shown that the Bioeconomy can sequester carbon from the atmosphere into biomass or store carbon in bioproducts, consistently with its main objective to replace fossil-based feedstocks with renewable sources (European Economic and Social Committee, 2018). On the other hand, several studies provide shreds of evidence supporting incremental effects of CO2 emissions due to mainly indirect land-use changes or deforestation (Weiss et al., 2012; Marchetti et al., 2014; Haddad, Britz and Börner, 2019). Bais-Moleman et al. (2018) pinpoint that the cascade approach could shrink the climate change mitigation potential of biomass used by altering the efficiency of solutions among alternative uses.

Egenolf and Bringezu (2019) show that a very complex multilevel interaction exists, highlighting possible trade-offs and synergies across scale and space. Such complexity can be a consequence of the different governance structures of the Bioeconomy (Dietz et al., 2018), as governance can affect either the typology of the supply chain itself and the value exchanges

[1] Although the debate about circular economy assumes implicitly and simultaneously economic growth, protection of natural environment and social equity, its real contribution on ecosystem services remains quite vague. Millar, McLaughlin and Börger, (2019) note a minor effect of circular economy with respect the linear model due to the existence of a) absence of an agreed definition of circular economy; b) the persistence of trade-off among sustainability dimensions and c) lack of knowledge about long term and rebound effects.

Table 2. summarises the linkages between ecosystem services, SDGs and Bioeconomy.

Ecosystem service	SDGs[1]	Examples of Bioeconomy contribution
Provisioning	SDG 2 End huger	More efficient animal production and cultivation (i.e. new vaccines and molecular diagnostics to reduce antibiotic use or use of a bio-based product as feed for animal)
	SDG 3 Good Health and well being	Sustainable medicines: biopharmaceuticals and microbiome-based approaches; improving knowledge on genetic resources
	SDG 7 Affordable and Clean Energy	Use of biomass instead of carbon-based products (Biofuel, biogas, wood from forestry systems)
	SDG 8 Economic Growth (Economy)	Re-connect local and actors in new supply chain networks based on form better material/ energy flow. New green and innovative business model, income and job opportunities
	SDG 9 Industry, Innovation & Infrastructure	Substitution of non-renewable with bio-based and renewable products could link a rural regeneration or re-industrialisation process; investment in R&D in marginal areas. Development of green infrastructure of new green section (i.e. bio-construction, pharmaceutical and medical technology)
Regulating	SDG 6 Clean Water (Water)	Biological wastewater treatment (in developing countries), with the inclusion of water nutrients removal
	14 Life Below Water	Increasing aquatic biodiversity by reducing pressure on marine ecosystems making more efficient aquaculture productions and bio-products products (i.e. genetically modified tilapia in developed countries)
	15 Life on Land	Increase terrestrial biodiversity through decoupling farm and industry from the fossil-fuel industry Soil regeneration through co-products or by-products (i.e. digestate used as fertiliser) Mediation of wastes or toxic substances
Cultural	Aesthetics 17 Partnerships (Partnerships) Build partnerships	Develop new business opportunities from the extensive farming system and agro-forestry Re-balance the material and energy flows between rural and urban systems
Supporting	SDG 11 Sustainable Cities	Reduction of emission and waste by using biomass form local production, recycling systems or from urban waste
	SDG 12 responsible production and consumption	Integration and use of renewable resources, or the diffusion of innovative and sustainable production and biotechnology can improve the efficiency of material and energy cycles as well as create new and multiple material and energies loop. Diffusion of bio-based products and material would alter reduce the plastic waste or improve the efficiency of waste disposal and/or material recycle
	13 Climate Action (Climate)	Bioeconomy is contribute strongly in carbon storage and in reducing emission by making C02 into the bio-based chemicals and biofuels

Source Own elaboration.
[1] Yang et al. (2020) provide an explanation of the linkages between Ecosystem services and SDGs.

among the constellation of actors involved in the supply chain. Growing concerns arose about bioprocessing due to access to technology and knowledge, with the possibility of further creating disparities among countries between those with high capacities to create and internalise added value from industrial biotechnology and those that remain biomass growers. Moreover, the environmental upgrading of some Bioeconomy value chain may cause outsourcing of environmental damages in these countries with high export but low environmental and social standers (Fuchs, Brown and Rounsevell, 2020). The inclusion of a specific concept on the governance of Bioeconomy (i.e. cascade and circularity) can move toward sustainability by prioritising high-value biomass uses (health, pharmaceuticals, chemistry, construction), instead of, for example, bioenergy (El-Chichakli et al., 2016).

5. DISCUSSION

The concept of Bioconomy is in the process of becoming mainstream. Over time it has moved from a focus on innovation in some specific sectors (biotech, bio-based materials, bioenergy), to the broader identification with all sectors using biological resources. In addition, the connections with sustainability, ecosystem services, circular economy and climate change have become more prominent and taking shape in more concrete policy and business actions.

In this section, we discuss the most promising pathway for research after considering two horizontal issues: the topic of conflicting objectives on the Bioeconomy and the issue of methods.

The transition to the Bioeconomy is subject to trade-offs among different sustainability dimensions, including the possibility to alter ecosystem services functioning. While strategies promoting the Bioeconomy typically put emphasis on the expected beneficial effects it can bring, the consideration of SDGs clearly highlights a number of potential conflicts among different objectives related to the Bioeconomy.

The different views on Bioeconomy can generate tension among stakeholders and shrink the Bioeconomy impact on sustainability or make its transition more difficult or risky. Some authors have argued that difficulties in social acceptance of the Bioeconomy arise from the typology of innovation itself, which implies a large amount of asymmetric information among actors along the supply chain. Other authors argue that the development of technology often has not paid attention to stakeholders' needs and to its acceptability, but merely to achieving a large adoption, making very complex the communication about the practical benefits of the Bioeconomy (Mukhtarov et al., 2017). This was particularly evident in the early stages of Bioeconomy development, in which the advanced biotechnological innovation has shaped the debate on the transition towards a Bioeconomy purely on the acceptability of GMOs, which is partially a misleading debate without fully understanding the potential of many other existing technologies (Chapotin and Wolt, 2007). In addition, Gava et al. (2017) show that the actors involved in Bioeconomy value chains are strongly different from the traditional agricultural networks, making dialogues among these stakeholders difficult.

Partly for this reason, perception and vision studies are key to the understanding of the Bioeconomy. Vision analysis of the transition process start to emerge also for the agricultural sector, moving attention beyond sustainable intensification and rather highlighting the topic of landscape and country level diversification (Bayne and Renwick, 2021).

Some of the trends above have been dramatically touched by the COVID pandemic. Some literature is emerging about the Bioeconomy in the post-covid era, in particular in relation to food security (Farcas et al., 2021).

Different branches of Bioeconomy research have been using different methods and concepts, with a large use of qualitative methods.

To fully understand the possible trade-off implied by the Bioeconomy, there is a strong requirement for scientific advances to understand different opportunity costs and environmental benefits and costs among alternatives pathways in each specific ecosystem. Although the LCA is the most used method in the literature, it is still far from measuring the proper impact of the Bioeconomy on the ecosystems and the complexity of nexus between biomass sources, bioproducts, supply chain governance and ecosystem services provided (D'Amato, Bartkowski and Droste, 2020)

The changing landscape and the increase in data is also bringing changes in methods. Among others, modelling intended for simulation and forecasting is a growing field of activity for the Bioeconomy. Cingiz et al. (2021) use an input-output model of the EU Bioeconomy. Ferreira, Pié and Terceño (2021) use a bio-socio accounting matrix approach to assess the impact of Bioeconomy in Spain. Gatune, Ozor and Oriama (2021) model Bioeconomy futures in eastern Africa using the International Futures (IFs) modelling platform, based on the dynamic interaction of demographic, social, economic and environmental factors.

Farm level models including Bioeconomy-specific concerns are also emerging. For example, Jansen et al. (2021) develop a farm level decision making model including the choice of quality, losses and bio-based alternatives.

Given the number of variables affecting the development of the Bioeconomy, it is not surprise that several studies further cast the problems in the framework of scenario analysis (Rojas Arboleda et al., 2021) and/or transition theory (Wydra et al., 2021). An example of modelling scenarios related to forestry is provided by Morland and Schier (2020).

Based on the above, the most interesting trends of the recent Bioeconomy literature rest probably in the search for a more systemic view of the sector, or, at least, in the attempt to account for cross-sector interrelationships and for the consequent market and organisational changes. The areas of innovation and organisation are probably two of the most relevant for understanding the Bioeconomy, with a growing role of the latter. The combination of qualitative and quantitative methods can allow to provide evidence-based support to policy while at the same time offering the possibility to account for views from different stakeholder groups.

6. CONCLUSIONS

Looking back and looking forward, the economic literature on the Bioeconomy appears to be still at this inception while the sector of the Bioeconomy is taking shape and tends to become mainstream. The period from the 2010 to 2020 has been to some extent exploratory in keeping pace with strategy and policy documents providing a vision of the Bioeconomy, as well as in exploring new sectors developing within the Bioeconomy. A variety of different economic aspects of the Bioeconomy have been addressed, from consumer behaviour to governance issues.

The drivers that have pushed for the development of the Bioeconomy remain very prominent and attention can be expected to grow in the next future. This will also depend on the ability of policy to bring together in a consistent way the many areas of intervention presently affecting the Bioeconomy. Although many countries have developed specific policies or even programs on the Bioeconomy, the literature shed light on the lack of a clear policy landscape to support a sustainable transition of the Bioeconomy. Reaching the challenge set out by UN 2030 agenda also requires a multilevel policy framework with the design of a mix of policy instruments addressing the negative impacts (short term objectives), together with policies promoting ecosystem services provision and supporting the scaling up of a sustainable Bioeconomy (long term objectives).

Altogether, this promises to become an even more interesting field for economic research in the next future. In this context, it may be expected that the next decade will be key to see to what extent the literature on the Bioeconomy will consolidate into a well-defined field of economic research. In turn, economic literature can likely help the further development of the sector.

Two key challenges can be envisaged in this direction. First, economics will need to take up the need for more holistic and systemic views required by the sector. Secondly, research will need to better account for the role of citizens and institution, with a stronger consideration of equity in the distribution of private and public costs and benefits. Summing together these issues, economics may contribute to the engagement of different views and in facilitating reflexive spaces to co-create shared transition pathways toward a sustainable Bioeconomy.

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BAE 10th Anniversary paper

The contribution of research to agricultural policy in Europe

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Abstract. This paper surveys some of the key themes in European agricultural policy research in recent decades. It identifies three main drivers of this research: a gradual broadening of the scope of the discipline in response to changing political priorities and values; an enlarged toolbox of policy instruments that has raised new questions and required the development of new modes of analysis; and the availability of new data sources, increased computing power, as well as the introduction of new methodological advances from economics, statistics and psychology that have opened the way to new and more powerful analytical tools. Particular attention is paid to direct payments and agri-environment-climate measures as examples of new policy instruments that have driven the research agenda. The paper concludes by identifying requirements to ensure that agricultural policy research remains vibrant and relevant in the future.

Keywords: agricultural policy, Common Agricultural Policy, direct payments, agri-environment-climate measures, policy research.
JEL Codes: Q18, Q58.

INTRODUCTION

This paper discusses some significant trends in European agricultural policy research in recent decades as a contribution to the celebration of the 10th anniversary of the *Bio-based and Applied Economics* journal published by the Italian Association of Agricultural and Applied Economics (Santeramo and Raggi 2021). This field of enquiry relates to the implementation of practical agricultural policy. In Koester's words, 'Agricultural policy is the entirety of all efforts, actions and measures aimed at regulating, influencing or directly determining the course of economic activity in the agricultural sector' (Koester 2020, 2). Agricultural policy research includes analysis of the objectives of agricultural policy; diagnosis of actual outcomes compared to policymakers' objectives or overall social welfare; the evaluation of interventions and instruments that might bring the actual situation closer to the desired policy outcome; and the reasons for policy change. While political economists and political scientists have been concerned with the *why* of government intervention in agricultural markets, agricultural economists have been more concerned with the *how* and *how well* – how food and agricultural policies should be designed to achieve specific objectives and how well

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policies have succeeded in their aims. This review is confined to the contribution of agricultural economists. The frame of the discussion in this paper is further narrowed by only tangentially considering issues to do with the food industry and agricultural trade, both of which are inextricably bound up with agricultural policy, but which are discussed in separate review articles in this celebratory series (Mazzocchi, 2021; Olper and Raimondi, 2021).

Reviews of agricultural policy research in Europe tend to take the Common Agricultural Policy (CAP) as the starting point and examine the CAP's impact on various policy dimensions, for example, agricultural income (Szerletics and Jámbor 2020), environment (Alliance Environnment 2017), jobs (Schuh et al. 2016), developing countries (Blanco 2018), nutrition and health (Recanati et al. 2019), or several dimensions at once (Pe'er et al. 2017). One of the few attempts to systematise the evolution of agricultural policy research, albeit still rooted in the dynamics of CAP reform, is Erjavec and Lovec (2017). This paper notes the shifting focus of the CAP over time and proposes that this requires greater cooperation between disciplines in order to broaden the theoretical underpinnings of explanations for this shift. Their paper builds on the idea that successive CAP reforms represent a paradigm shift (meaning changes not only in mechanisms but also in principles and objectives (see also Skogstad 1998; Daugbjerg and Swinbank 2011 for elaboration of the role of paradigm shifts).

This paper has a more modest objective. It is neither intended as a systematic review of recent European agricultural policy research nor does it enter the debate whether recent reforms of the CAP can be attributed to paradigmatic changes or not (Rac, Erjavec, and Erjavec 2020). It presents a narrative describing recent trends in agricultural policy research and the factors that have driven these changes. Three factors are highlighted in subsequent sections: a gradual broadening of the scope of the discipline in response to changing political priorities and values; an enlarged toolbox of policy instruments that has raised new questions and required the development of new modes of analysis; and the availability of new data sources, increased computing power, as well as the introduction of new methodological advances from economics, statistics and psychology that have opened the way to new and more powerful analytical tools (Figure 1).

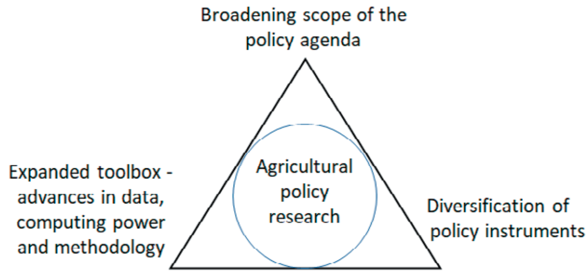

Figure 1. Major influences on European agricultural policy research. Source: Own elaboration.

BROADENING SCOPE OF THE POLICY AGENDA

Agricultural policy analysis has always been an applied discipline that has responded to the changing priorities and objectives of practical agricultural policy. The competence for agricultural policy in the EU is formally shared between the Union and the member states, although the Treaties require that the Union shall define and implement a common agricultural policy with common objectives and a common implementation. Thus, one driver of the changing agricultural policy research agenda has been changing priorities and objectives of the CAP. Another driver has been the growing awareness of the market failures around agricultural production, both in terms of the under-provision of public goods but even more sharply the external costs imposed on society in terms of both health and the depletion of natural capital. Yet another driver has been shifts in social values and expectations around the way food is produced, notably with respect to animal welfare, quality attributes, short supply chains and farm structures.

It should be stressed that new objectives have been layered on top of existing ones rather than substituting for them. Further, the emergence of new objectives has been a gradual and evolving process rather than marked by sharp discontinuities. Daugbjerg and Swinbank (2016) introduced the idea of policy layering into agricultural policy analysis. They characterise the path of CAP reform, with its redesign of EU farm price support into WTO-compatible decoupled payments, together with the greening of the CAP, as a stepwise process of dual policy layering aimed at addressing new policy concerns while retaining the core objective of farm income support. Their objective was to suggest a causal relation between policy layering and the sustainability of the reform path. Here, I use the concept of policy layers simply to highlight that new policy objectives have emerged in addition to earlier concerns rather than replacing them. An illustration of the evolution in agricultural policy priorities is shown in Figure 2. I now show how agricultural policy research has reflected this growing multi-dimensionality.

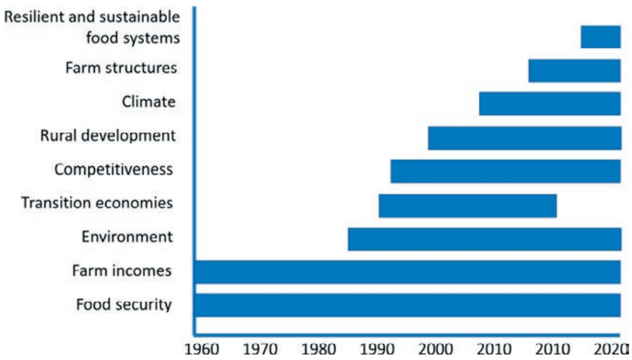

Figure 2. Overview of changes in CAP priorities over time. Source: Own elaboration.

Ensuring food security

Assuring the availability of food supplies and at reasonable prices are among the five objectives specified for the CAP in the original Treaty of Rome and which have remained unchanged to this day. The tagline on the European Commission's webpage explaining the CAP continues to affirm that 'The common agricultural policy supports farmers and ensures Europe's food security'.[1] Despite the harrowing experiences of food shortages in the immediate aftermath of the second World War, national-level food security has not been an issue in the EU since before the CAP came into force, though individual households can suffer food insecurity due to lack of means to purchase sufficient nutritious food rather than due to any problems of availability (Borch and Kjærnes 2016). Nonetheless, food security continues to be prominent in agricultural policy debates, although with very different framings of how the objective is interpreted (Candel et al. 2014), including the appropriate role for European agriculture in contributing to global food security. The COVID-19 pandemic and the associated lockdowns underlined the potential vulnerabilities in food supply and the issue has once again become live, even though it is generally recognised that EU food supply chains proved remarkably resilient to date during the pandemic (Montanari et al. 2021; Meuwissen et al. 2021). The Commission has since announced a contingency plan for ensuring food supply and food security in times of crisis which includes a food crisis response mechanism (European Commission 2021b). The pandemic also triggered a literature reflecting more widely on the conditions for resilient food systems and the measures needed to realise them, which we consider further below.

Support for farm incomes

Income issues in agriculture refer to the level, stability, and distribution of income (Finger and El Benni 2021). The objective of 'ensuring a fair standard of living for the farming community' is also a Treaty objective, although there has been much debate over whether the Treaty wording sees this as a stand-alone objective or as the consequence of increased productivity and structural change. There is no doubt that for policymakers and farm organisations support for farm incomes is a major justification for the CAP. The Commission regularly produces a comparison of average farmer income (measured per work unit of family labour) with average gross wages and salaries in the total economy to show that farmers' income are 'still lagging behind', while emphasising that direct income support payments 'partially fill the gap between agricultural income and income in other sectors' and 'remain an essential part of the CAP' (European Commission 2017; 2018a).

Whether there is indeed an income gap between farm and non-farm incomes and the extent to which this reflects agriculture-specific characteristics is a matter of definition and measurement (Hill 2019). Taking its cue from the Treaty reference to 'standard of living for the farming community', the European Court of Auditors has argued that the disposable income of the farm household is the relevant indicator for family farms but that relevant data to make comparisons on this basis are not available (ECA 2016). Such data are collected in the EU Survey on Income and Living Conditions (EU-SILC) but the small number of farm households in this survey makes it difficult to draw valid conclusions. By pooling these data across EU countries, Rocchi, Marino, and Severini (2020) find evidence that, on average, farm household incomes are lower than in non-farm households and even more so if the comparison is made with self-employed households in the non-farm sector. Controlling for observable differences such as age, education, marital status and health status markedly reduces the size of the disparity, as does accounting for a wider definition of income to include nonmonetary factors, but it does not completely eliminate it.

In addition to these observable characteristics that can account for differences in income, non-observable characteristics might also differ systematically between the two population groups. For example, unobservable preferences might determine the sorting of households into the farm sector while unobserved characteristics, such as skills, might affect incomes. Marino, Rocchi, and Severini (2021) revisit the EU-SILC dataset using a fixed effects regression methodology to control for these

[1] European Commission, 'The common agricultural policy at a glance', https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en, accessed 2 September 2021.

individual unobservable characteristics. Again, the raw data show that farm household incomes are much lower than for nonfarm households, particularly in the newer member states, but there are also significant differences in observable characteristics. By further controlling for unobservable characteristics, their conclusions are revised. Broadly-defined farm households still generally have a lower household income than comparable non-farm households but except in the newer member states the differences are not significant. However, narrowly-defined farm households (those mainly dependent on their farm income) are better off than comparable non-farm households in nearly all comparisons. They further find that being self-employed in agriculture instead of in other industries no longer represents a relative disadvantage across the EU countries.

To summarise, this research confirms that farm household incomes are on average lower than non-farm household incomes across the EU, though with important differences in the size of the disparity across countries. The conditional income comparisons identify the factors that account for this and it appears sector-specific issues related to working in agriculture are not an important explanatory factor. It can be noted that the income of farm households in the dataset includes support payments under the CAP as well as remuneration from the ownership of substantial farm assets including land. Furthermore, the European Commission data, even if not helpful in throwing light on relative standards of living, are still important in highlighting the relative difference in labour productivity between the two sectors which will have implications for future structural change.

Promoting rural development and employment

The Treaties note that, in working out the common agricultural policy, 'account shall be taken of the particular nature of agricultural activity, which results from the social structure of agriculture and from structural and natural disparities between the various agricultural regions'. The Treaties also specify territorial cohesion as an EU objective, with the aim of reducing disparities between the levels of development of the different regions paying particular attention, *inter alia*, to rural regions. The socio-economic disparities between rural and other regions are well documented. This led in 1999 to the introduction of a common rural development policy as the second Pillar of the CAP, building on precedents emerging in the previous decade (the Commission's Communication on *The future of rural society* COM (88) 501 in 1988 marks the beginning of a territorial rural policy). Rural development policy has a complex series of objectives, including modernisation of the agricultural sector, integrating environmental concerns, generational renewal, and broader socio-economic development particularly emphasising community-led local development and job creation. However, overall expenditure on territorial measures within the CAP has always been low. Recurring themes include the desirability of moving towards a more integrated concept of rural development built around a 'place-based' approach, developing more explicit synergies with EU cohesion policy, and focusing on the endogenous development of territorial capital and particularly the role of LEADER groups (Dax and Copus 2016). Most recently, the Commission's proposed long-term vision for rural areas, accompanied by proposals for a Rural Pact and a Rural Action Plan (European Commission 2021a), will no doubt stimulate a further wave of rural research.

Integrating environmental concerns

The integration of environmental goals into the CAP began in the 1980s with the growing awareness of the adverse environmental consequences of more intensive agricultural practices but also of the role that farmers can play in terms of management of natural resources and landscape conservation. Attention shifted to the interactions between agricultural production and water, air, soil, landscape and biodiversity. Agricultural pollution issues were addressed mainly by regulation, while the model of paying farmers to provide desired environmental outcomes was made mandatory for member states in the agri-environment regulation that accompanied the MacSharry CAP reform in 1992 (Latacz-Lohmann and Hodge 2003). Environmental cross-compliance for those in receipt of CAP payments was introduced in the Fischler 2003 CAP reform, while the 2014-2020 CAP saw the introduction of a greening payment in Pillar 1 requiring farmers to follow three specific practices seen as beneficial for climate and the environment (Matthews 2013). The huge literature stimulated by these developments is discussed later in the paper.

The political agreement on the CAP post 2020 includes a revised green architecture where the greening payment conditions have become part of a revised cross-compliance (now referred to as enhanced conditionality), while at least 25% of a member state's direct payments envelope must be allocated to eco-schemes to fund measures beneficial to the climate and environment as well as animal welfare. The urgency to strengthen interventions to improve environmental outcomes on agricultural land has been underlined by the specific targets set out in the Commission's Farm to Fork and Biodiversity Strategies to reduce the use of pesticides, mineral fertilisers and antimicrobials, to increase the area under organic farming, and to reserve more space for nature on farmland (European Commission 2020a; 2020b). Whether the implementation of the new green architecture in member state CAP Strategic Plans will be up to the challenge of achieving these targets will likely become a major focus of agricultural policy research in the coming period (Baldock 2020).

The economics of transition

A specific issue that attracted the attention of agricultural policy researchers in Europe after 1989 and the fall of the Berlin Wall was the economics of transition in agriculture from central planning to a market economy (the countries affected included not only those that later become EU members, but also the Balkans, Russia, Belarus, Ukraine and Moldova, Transcaucasia and Central Asia). The socialist system left a legacy of a badly distorted economic system and prices. The institutional and relative price changes associated with the reorganisation of this system resulted in major disruptions and immediate declines in investment and output. State-owned assets such as input supply, credit and food processing and distribution companies were privatised as were state-owned farms using different privatisation models (e.g. direct sale, vouchers). In those countries where land had been collectivised, land was either restituted to former owners, physically distributed to farm workers, or ownership was transferred to workers through certificates. Nonetheless, the share of land now farmed by large corporate farms in many of these countries remains very high, though often co-existing with many very small-scale individual farms that produce only for their own consumption (semi-subsistence farms). These institutional changes gave rise to a significant research effort addressing issues such as trade competitiveness (Bojnec and Fertő 2008; 2015), price reforms (Bojnec and Swinnen 1997; Anderson and Swinnen 2008), farm restructuring, privatisation and land reform (Koester 2005; Swinnen 2009), and productivity growth (Gorton and Davidova 2004).

This research effort was extended after 2000 to the implications for the CAP of the accession to the EU of the former Soviet-bloc economies in central and eastern Europe. Both the importance of agriculture in these economies, particularly in employment terms, as well as the low productivity and consequential low incomes of those working in agriculture, were seen as posing a financial threat to EU agricultural policy which was still largely conceived as an income support policy for farmers (Bojnec 1996; Gaisford, Kerr, and Perdikis 2003; Hartell and Swinnen 2017). Many papers have also focused on the performance of the agri-food sector in these economies after accession (Csáki and Jámbor 2013). As institutional structures have stabilised the topic of transition economics is one of the few layers that has now largely disappeared, although comparisons of the performance of older and newer member states within the EU continue to attract the interest of researchers (Csáki and Jámbor 2019).

Pursuing competitiveness

Increased productivity is also one of the Treaty objectives for the CAP. Post-war agricultural production in Europe increased dramatically with the adoption of mechanisation, chemicals, intensive livestock breeding, new seed varieties and the extension of irrigation (Martín-Retortillo and Pinilla 2015). Increased production was supported with high tariffs against imports and the use of export subsidies to dispose of surpluses. During this period of "Fortress Europe" (cost) competitiveness was given little explicit attention. This began to change with the 1992 CAP reform that began the process of switching CAP support from the product to the producer. A decade later, the Commission reflected on the success of this move in promoting greater market orientation and competitiveness when introducing the Mid-Term Review (European Commission 2002). This focus on market orientation has been maintained through successive reforms. One of the nine specific objectives for the CAP post 2020 is 'to enhance market orientation and increase competitiveness, including greater focus on research, technology and digitalisation'.

Productivity is an important determinant of competitiveness in the longer term and can be measured using either parametric, non-parametric or index number approaches (Latruffe 2010).

Policy researchers have been interested in measuring the rate of growth in total factor productivity; in differences in relative productivity across member states; and in whether productivity levels are converging over time (Baráth and Fertő 2017). Developments have taken place in measuring farm level productivity using new estimation techniques to address classical problems of endogeneity and identification when trying to estimate production functions using farm level data (Sauer et al. 2021). Contributions have sought to identify the factors responsible for productivity trends, building on the decomposition of productivity growth into technical change (shifts in the technical frontier), technical efficiency change (catching up with a shifting technical frontier), scale efficiency change, and efficiency change due to changes in the mix of inputs and outputs. There have also been attempts to integrate the use of environmental resources into productivity measures led by the OECD Network on Agricultural Productivity and the Environment. Finally, researchers have examined the effectiveness of policies to stimulate productivity growth (Viaggi 2015; Zezza et al. 2017; Détang-Dessendre et al. 2019). Relevant work has been done by the Standing Committee on Agricultural Research (SCAR) in developing the concept of Agricultural Knowledge and Innovation Systems (AKIS) as an interactive innovation system involving farmers, education, extension and research (SCAR 2019).

Addressing climate policy

Successive reports by the International Panel of Climate Change have warned about the dangers of anthropogenic climate change. The Paris Agreement which has the objective to limit global warming to well below 2˚C and preferably below 1.5˚C compared to pre-industrial levels entered into force in 2015. To achieve this temperature goal, the parties including the EU have committed to achieve a balance between emissions by sources and removals by sinks in the second half of the twentieth century, on the basis of equity. The European Climate Law adopted in 2021 commits the EU to reach climate neutrality by 2050.

Agriculture is both affected by climate change and a contributor to it. Agricultural emissions contribute around 11% of total EU emissions while the land use, land use change and forestry (LULUCF) sector is a net sink. Policy research has investigated the impacts of climate change (Bozzola et al. 2018; Van Passel, Massetti, and Mendelsohn 2017), the ability of farmers to adapt to climate change (Moore and Lobell 2014), and the mitigation potential of agriculture, using marginal abatement cost curves to shed light on the cost-effectiveness of different interventions (De Cara and Jayet 2011; Eory et al. 2018; Pérez Domínguez et al. 2020). The literature on policy design to bring about emissions reduction in agriculture in an efficient way remains surprisingly underdeveloped (Ancev 2011; De Cara and Vermont 2011; Grosjean et al. 2018) but the Commission proposal in the Farm to Fork Strategy to introduce a carbon farming initiative to reward farmers for carbon sequestration may spark greater interest in market-based approaches. Climate action has been an explicit objective of the CAP since the 2007-2013 programming period. Evaluations suggest that the measures taken to date have had a very limited impact on reducing agricultural emissions, although some measures may have helped to reduce emissions in the LULUCF sector (Alliance Environnment 2019; ECA 2021). The Commission's recent Fit for 55 package of legislative initiatives designed to achieve the more ambitious greenhouse gas emissions reduction target included in the Climate Law for 2030 will increase the need to reduce agricultural emissions in the coming CAP programming period (Matthews 2021).

Farm structure concerns

Interest in farm structures arguably goes back to the early years of the CAP when the then Agriculture Commissioner Sicco Mansholt proposed to offer financial incentives to drastically reduce the farm population to release land to enable remaining farms to grow to a viable size. However, the regulations that followed were only a pale shadow of the original proposal (Stead 2007). The central role of the family farm in the European model of agriculture is taken as a given, although nowhere explicitly stated as an agricultural policy objective. The eastern enlargements of the EU in 2004, 2007 and 2013 radically altered the farm structure distribution by introducing a significant duality. On the one hand, a large number of farm holdings were now subsistence or semi-subsistence farmers (Davidova 2011). On the other hand, the conversion of former collective or state farms into joint stock companies in some new member states created a new type of farm holding that was virtually unknown in the older member states (Maurel 2012).

By the middle of the following decade political concern was growing over trends in farm consolidation and farmland concentration. For some, the focus has been on land grabbing and the rise of large-scale land deals (van der Ploeg, Franco, and Borras 2015; Kay, Peuch, and Franco 2015); for others, it is safeguarding the position of the family farm (Davidova and Thomson 2014; Hennessy 2014); for some, it is opposition to industrial farming and the growth of 'mega' farms (Greenpeace 2019); for others, the issue is generational renewal (European Commission 2018d; Zagata et al. 2017); while yet others focus on the decline in the overall number of farms and its impact on rural vitality. Common to all is the view that current patterns of farm structural change should be halted or even reversed (Falkenberg 2016). This concern over the pace of structural change has been forcefully articulated by the current Commissioner for Agriculture and Rural Development Janusz Wojciechowski on many occasions since he took up office. However, the Commission's own figures showing the disparity in the returns per work unit in agriculture relative to the rest of the economy suggests that the outflow of labour and thus farm consolidation will continue for some time to come.

Resilient and sustainable food systems

In recent years, the issue of resilient and sustainable food systems has moved centre stage in recognition of the multiple and interrelated challenges they face including poor diets, poor health outcomes, food waste, biodiversity loss, environmental degradation, resource scarcity, inequality and climate change at both the global and EU levels (European Commission 2020a; SAPEA 2020; SCAR 2020; Webb and Sonnino 2021). The food systems approach links these issues together, in contrast to sectoral analyses that look at the individual issues separately. The adoption of the UN Agenda for Sustainable Development in 2015 with its 17 Sustainable Development Goals has given further impetus to this research direction (Scown and Nicholas 2020), as has the apparent vulnerabilities in food supply chains revealed by the COVID-19 pandemic (Bisoffi et al. 2021).

Food systems encompass the entire value chain from ecosystem services to primary production, processing, packaging, distribution, retailing, food service, waste stream management, safety assurance, to consumers, their nutrition, the food environment and diet-related diseases. Sustainable food and nutrition security has been defined as the capacity of a food system to deliver food and nutrition security in an environmentally, economically and socially sustainable manner, thus combining nutrition and health with a social-ecological systems perspective (Zurek et al. 2018). The food systems perspective draws attention to the interactions, including synergies and trade-offs, between different policy domains and levels of government. There is a strong normative element in this literature. Many studies conclude that 'business as usual' is no longer a viable option and that radical system-wide change is required. Their aim is to identify workable paths towards a healthier, more socially just and environmentally sustainable food system (SAPEA 2020).

Achterbosch et al. (2019) review the way in which food systems thinking has been reflected in EU research grouped around themes such as food system governance; sustainable diets; food, nutrition and health; agroecology; agricultural innovation; alternative methods of food distribution; food waste and the circular bioeconomy; and development. The food systems literature draws attention to new research questions such as the future role of animal agriculture in Europe; the most effective ways to reduce food waste and to build a circular bioeconomy; how to redesign food environments to encourage more healthy eating habits; the balance between extensification and intensification in contributing to more sustainable food production; how to implement true cost accounting to reflect fully the role of externalities and environmental impacts; and improving resilience.

DIVERSIFICATION OF POLICY INSTRUMENTS

Agricultural policy research has been influenced not only by the expanding scope of topics to be addressed but also by the introduction of new policy instruments that have raised new issues in terms of assessing their effectiveness as well as their interactions with other policy goals. For reasons of space we choose to highlight two examples here: direct payments and agri-environment-climate measures.

Direct payments

Direct payments were introduced into the CAP from 1994 onwards, first as coupled payments and then, after 2005, as decoupled payments. Given the important contribution they make to farm income, they have attracted much research: how equally are they distributed; do they have production effects; are they capitalised into land values; do they impact on productivity growth; how do they influence the process of farm structural change?

The concern with how direct payments are distributed arises from the well-known statistic that 80% of payments accrue to the largest 20% of farms, which in turn is driven by the allocation mechanism of direct payments which is related to land. Distributional analyses have used either the annual Commission data on payments by size of payment or micro-level farm data from the Farm Accountancy Data Network (FADN). The most recent analysis using Commission data shows a trend towards a more equitable distribution of aid in the older member states, but the opposite trend for the newer member states (Alfaro-Navarro et al. 2021). Farm-level analysis has been used to investigate the dependence of farm incomes on direct payments by investigating scenarios that assume the complete abolition of the CAP (Ciaian et al. 2020). By linking a farm-level model with the CAPRI partial equilibrium model they overcome the limitations of a purely static analysis. They conclude that a small sub-set of farms (pigs, poultry, dairy and horticulture) could experience an increase in income due to improvements in both prices and yields but those farms that are currently most dependent on CAP subsidies (arable and cattle farms) would experience significant income losses. Another farm-level analysis concluded that the 2013 CAP reform only partially succeeded in its objective to equalise payments across farms, but also showed that CAP subsidies (and direct payments in particular) contribute to a reduction in the inequality of total farm income (Espinosa et al. 2020). Severini and Tantari (2015) reached the same conclusion using Italian farm level data.

It is no surprise that coupled direct payments stimulate production (Smit et al. 2017; Jansson et al. 2020), but views have differed on the importance of the production effects of decoupled payments (Moro and Sckokai 2013). This is a vital parameter when modelling the impact of changes to CAP instruments (Balkhausen, Banse, and Grethe 2008; Boulanger, Boysen-Urban, and Philippidis 2021). Truly decoupled payments do not affect the marginal incentive to produce but economists have pointed to various mechanisms whereby such payments might affect production compared to the absence of such payments. Payments that are decoupled in a static and riskless world may not be production neutral in a dynamic and risky world. Studies have therefore tried to assess directly whether direct payments have kept land and labour in production that might otherwise have exited the sector, or influenced investment through wealth effects or by increasing access to credit where imperfect credit markets exist. A drawback of this literature is that empirical work has often been constrained to comparing decoupled payments with the previous system of partially-coupled payments rather than being able to undertake a test of the impact of these payments compared to the absence of these payments.

For payments to be fully decoupled they must be fully capitalised into land values. Another way to estimate the 'degree of decoupling' is therefore to examine the extent to which these payments are capitalised into land values and land rents. A high rate of capitalisation into land values implies a low transfer efficiency of support to farmers (if we exclude the benefits they receive as owners of land), and thus a lower likelihood that the payments will distort production. Economic theory can describe the degree to which support is capitalised into land rents as a function of three parameters: i) how the policy is implemented, specifically its initial incidence (targeted to land, inputs or labour); ii) the ease which land can be shifted to alternative uses (its elasticity of supply); and iii) the ease with which land can be substituted with other factors of production (its elasticity of substitution) (Floyd 1965). However, specific features of the CAP payments implementation mechanism seem to play a dominant role.

Varacca et al. (2021) undertake a meta-analysis of the capitalisation of CAP payments into land prices. In line with expectations, they find that the introduction of decoupled payments increased the capitalisation rate, although the extent of this effect hinges on the implementation scheme adopted by a member state. In particular, the rate of capitalisation is influenced by the relationship between the number of eligible hectares and the number of payment entitlements in those member states that adopted the Single Farm Payment. Other factors can also reduce the rate of capitalisation, including the time-limited commitment to payments, the costliness of cross-compliance conditions, rural land market imperfections, and differences in the value of entitlements (Ciaian, Kancs, and Swinnen 2008). Allowing for multiple estimates from individual papers, the range of estimates for the capitalisation rate is strikingly large. The Varacca et al. (2021) study concludes that the capitalisation rate for coupled payments is around 11 cents per euro of payment. Decoupled payments have a higher capitalisation rate, depending on the implementation model, while capitalisation in rental transactions is higher still, varying between 15 and 49 cents per euro. Guastella et al. (2021) find that between 28 and 52 cents per euro of additional subsidy capitalise into land prices in member states that adopted the hybrid and the regional model, respectively, but find no evidence of capitalisation in farmland prices in member states that adopted the historical model.

The corollary of these findings is that the residual payment increases the returns to the remaining production inputs, including intermediate inputs, capital and labour, and will likely influence production through these routes. Biagini, Antonioli, and Severini (2020) throw further light on this issue by directly estimating the income transfer efficiency of CAP payments in Italy. Italy made all land uses (except forests) eligible for entitlements, generating an abundance of eligible hectares compared to entitlements. Studies show that as a result the capitalisation of direct payments into land values was negligible. An income transfer efficiency of unity would indicate the payments do not affect production decisions. They find that the income transfer efficiency of most CAP measures is less than unity, pointing to the existence of leakages. Their paper highlights that policy participation costs differ across farms and across instruments and also play a role in determining transfer efficiency.

A recurring theme has been the investigation of the impact of CAP subsidies on productivity growth (Minviel and Latruffe 2017; Garrone et al. 2019). In theory, the direction of this effect could go either way. Positive effects might arise if direct payments provide farmers with the necessary financial means to keep technologies up to date or to invest in efficiency-improving on-farm organisation. Negative effects might arise if farmers are less motivated to perform well with more income due to subsidies or where a soft budget constraint means that farmers over-invest leading to inefficient use of resources. Early literature that focused on the impact of coupled payments found a predominantly negative relationship. More recent studies suggest that decoupled payments may have a positive effect on technical efficiency, although this may vary across different farming systems (Bonfiglio et al. 2020).

Another issue that agricultural policy research has investigated has been the impact of direct payments on the pace of structural change in agriculture. Direct payments can, in principle, influence the entry, growth and exit of farms. If direct payments are capitalised into land values and land rents, increased land rents and prices may represent significant barriers to entry into the agricultural sector and may also impede restructuring within the sector. Direct payments may also influence a producer's decision to exit the industry, particularly for low-profit farmers, given that receipt of the payment is contingent on having access to land. There is evidence at least for the EU-15 member states that the change to a decoupled payments regime after 2005 may have slowed the rate of farm consolidation in the EU (Brady et al. 2009; Kazukauskas et al. 2013). There is also evidence from survey intentions and simulation modelling (Bartolini and Viaggi 2013; Brady et al. 2009) that decoupled payments slow down the rate of structural change relative to a situation of no agricultural policy support. The CAP's income support payments have created incentives for some farmers not to exit agriculture, reduced land reallocation towards more efficient farms, and helped to keep less efficient farms active. If new entrants or enlarging farms are seen as more productive, this mechanism may mitigate any production-stimulating effect of these payments through other channels.

Environmental interventions

The second policy instrument that has generated a significant volume of research is the voluntary agri-environment-climate measure (AECM) in the CAP. It is distinguished from the income support instruments by its focus on environmental outcomes, its voluntarism, its contractual nature, and its reliance on an objective mechanism to establish payment levels. This has given rise to a vast literature focusing on the ecological effectiveness of these measures, the factors that influence farmer participation, the most efficient ways of designing contracts, their impact on other CAP objectives such as farm income and employment, and their cost effectiveness (Uthes and Matzdorf 2013).

An obvious question is whether the agricultural practices supported by AECM payments have delivered the desired environmental effects (ecological efficiency). Such studies are usually undertaken by ecologists rather than economists. Although AECMs are often seen as the poster boy of the CAP and the type of payment for public goods to which the CAP as a whole should aspire, the literature on ecological effectiveness is surprisingly critical (ECA 2011). This may partly reflect the findings of the highly influential seminal review of AECM effectiveness by Kleijn and Sutherland (2003) which is still frequently cited despite the experiences with AECMs since then. However, a more recent meta-analysis concluded that the expectation that results of previous evaluations would be used to improve future policy was not borne out in practice (Batáry et al. 2015). These authors found that schemes implemented after revision of the EU's agri-environmental programs in 2007 were not more effective than schemes implemented before revision. For the 2014-2020 period, it seems many managing authorities continued with the interventions used in the previous programming period even where the Rural Development Programmes state that the AECM measures have been improved (ENRD 2016). Still, evaluation studies suffer from methodological weaknesses that make it difficult to draw strong conclusions (Josefsson et al. 2020). AECMs often have multiple goals such as the protection of environmentally valuable landscapes, reduction of pollution, enhancement of biodiversity, and climate mitigation that makes outcomes difficult to quantify. Furthermore, few studies examine whether farmers maintain their conservation practices over time, or the extent of rigour of these practices.

A large literature has explored the factors affecting adoption of AECMs by farmers. Farmers receive financial support to participate but uptake is patchy and there is evidence of systematic non-participation in schemes. Understanding the factors that influence farmer participation in AECMs can help to design schemes that better incentivise farmers to participate. There is a widespread view that, at least in some countries, it can be difficult to attract farmer participation and thus there is a low uptake of AECMs but firm evidence on this is hard to obtain. Numerous analyses indicate that the main factor encouraging farmers to participate in AECMs is financial incentives rather than environmental concerns (Pavlis et al. 2016; Wąs et al. 2021), although Dessart, Barreiro-Hurlé, and van Bavel (2019) highlight the importance of behavioural factors. Brown et al. (2021) argue that over-emphasising economic considerations may hamper the effectiveness of environmental payments, potentially corroding farmer attitudes to policy and environmental objectives.

Adoption studies initially focused on factors such as farm structure (intensive vs extensive) or farmers' socio-demographic characteristics (education, age). More recent work has investigated the influence of behavioural factors such as farmers' motivations and attitudes, the role of social capital and farmer's networks, as well as the role played in diffusion by whether one's neighbours have adopted the practices. Most papers focus on individual schemes and specific countries. A review paper by Lastra-Bravo et al. (2015) surveyed ten papers that used a probit/logit model to examine the determinants of adoption. Over 160 variables affecting uptake were identified, and grouped into five major categories: economic factors, farm structure, farmer characteristics, farmers' attitudes towards AECMs, and social capital (i.e. the connections, shared values and understandings between individuals and groups). Results indicate that farms less likely to join an AECM are those where there is a high dependence on agricultural activities for farm income, those where there is the presence of a successor on a farm, and farms with a high proportion of family labour. In one of the few studies that take an EU-wide perspective based on FADN data, Zimmermann and Britz (2016) show that participation in AECMs is more likely in less intensive production systems where, however, per committed hectare premiums tend to be lower.

Another line of research addresses the contractual design of AECMs, starting from the dominant action-based approach that requires participants to demonstrate compliance with specific management actions (prescriptions) to potentially more cost-effective contract designs, such as payments by results, auctions, spatial targeting, and collective implementation (Berkhout, van Doorn, and Schrijver 2018). The popularity of action-based approaches can be explained by lower transactions and monitoring costs as well as less risk for farmers. However, these approaches may have contributed to the disappointing results of AECMs to date given that they often encourage enrolment of less intensively farmed areas at lower risk of environmental losses, encourage farmers to choose those actions that require the least change to their management practices, and do little to promote long-term attitudinal change or commitment to improving environmental outcomes. As one paper noted: 'Thus far, no consensus exists whether [AECMs] incentivize adoption of pro-environmental production or simply offer windfall profits for those already operating at lower intensities' (Uehleke, Petrick, and Hüttel 2019).

Results-based schemes (RBS) in which farmers are paid for achieving agreed environmental outcomes rather than performing specific management actions are advocated on the grounds that they give farmers greater flexibility in the way they achieve environmental outcomes which may be more in line with their own farm characteristics, can encourage innovation in successful practices, and by giving farmers a greater sense of ownership of the outcomes they may be more successful in promoting behavioural change (Burton and Schwarz 2013; Chaplin, Mills, and Chiswell 2021). Despite these apparent advantages, RBS have largely remained as pilot and small-scale initiatives. Partly it can be difficult to define indicators for the desired ecological outcomes, partly RBS imply greater risk for farmers, while administrations worry about higher transactions costs (Šumrada et al. 2021). Research is seeking to address these issues, for example, by looking at the potential for hybrid schemes using a mixture of action- and results-based approaches, and by exploring the use of self-assessment by farmers to reduce monitoring costs (Herzon et al. 2018).

Many policy problems in the design of AECMs can be understood within the framework of principal-agent theory. The issue is to design a policy that results in agents (farmers) doing what is in their best interests while also achieving the objectives of the principal (the state). Designing such a policy faces problems of asymmetric information resulting in adverse selection (arising from the availability of information known to the agent but not to the principal, such as the opportunity costs of farmers in providing the environmental outcome) and moral hazard (because it is difficult for the principal to monitor compliance, the agent has an incentive to cheat). Adverse selection means that farmers with the lowest compliance costs (perhaps because they are already managing their land in an environmentally-friendly way) have the greatest incentive to join a scheme, resulting in comparatively limited environmental gains and overcompensation of compliance costs (Latacz-Lohmann and Schilizzi 2005). Different contract designs have been proposed to overcome these problems, including the use of targeting mechanisms, incentive-compatible screening mechanisms, and auctions (Vergamini, White, and Viaggi 2015). Collective implementation can also be important to widen the adoption of AECMs and to lower transactions costs. Olivieri et al. (2021) provide a systematic review of relevant papers to understand better how these innovative contract solutions can improve the effectiveness of AECMs under asymmetric information and help to avoid policy failures relative to action-based approaches.

AN EXPANDED TOOLBOX

Agricultural policy research relies on a large and sophisticated toolbox of methods and databases comprising statistical and experimental approaches, various farm-level, agent-based as well as sector models, and a dedicated collection of microeconomic data in the form of the farm accountancy data network (FADN) as well as census, survey, and administrative data (Finger and El Benni 2021). Developments in data collection and access, models and new methodologies have been an important driver of the policy research agenda.

Availability of data

Agricultural policy research has a strong empirical focus and relies heavily on the availability of accurate and reliable data. Agricultural and other statistics collected by national statistical agencies and coordinated by Eurostat have been and remain a primary source of data, supplemented by administrative data, and survey data collected by researchers themselves. Recent developments in data availability, accessibility and diffusion have helped to drive the expanding agenda of agricultural policy research by opening new areas of enquiry and permitting the use of new methodologies. Nonetheless, both Eurostat and the Commission recognise that the absence of data in many new policy areas is likely to be a constraint for future policy analysis.

The European agricultural statistics system (EASS) maintained by Eurostat consists of 10 legal acts and their implementing measures, as well as of a number of gentlemen's agreements. Eurostat embarked in 2016 on a strategy for agricultural statistics for 2020 and beyond with multiple objectives to clarify and streamline definitions, diversify data sources and improve the speed, flexibility and effectiveness of the EASS while preserving high quality data and long time series. It recognised new data needs linked to the greening of the CAP, climate change challenges, production structures, food supply chains, price volatility, yields and geo-referenced information (Eurostat 2016).

Agricultural policy research has greatly benefited from the farm-level micro data collected through the Commission's Farm Accountancy Data Network (FADN) intended to provide reliable information on farm incomes in the EU (Vrolijk et al. 2004). Many of the papers cited in this review made use of FADN data for income comparisons and distribution analysis, efficiency studies, environmental assessments, microsimulation modelling, and policy impact analysis. The Farm to Fork Strategy proposes to extend the current FADN to a Farm Sustainability Data Network (FSDN) to include a broader set of indicators on the sustainability performance of farms. Given resource constraints, this may require a trade-off between the size of the representative sample and the breath of coverage of data collected (Vrolijk and Poppe 2021).

The administration of the CAP requires the collection of a huge amount of data through the Integrated Administration and Control System (IACS) that centralises data on agricultural subsidies paid by the EU in each member state. Data collected under the CAP's Common Monitoring and Evaluation Framework (soon to become the Performance Monitoring and Evaluation Framework) also includes administrative data supplied by member states as well as Eurostat data (European Commission 2018c). Researchers' access to these data seems to vary across member states although the Commission has invested heavily in developing data platforms such as the Agri-Food Data Portal.[2] The attempt by the Commission to increase transparency around the distribution of CAP payments by requiring member states to publish information on the names of beneficiaries, the municipality and the postal code where available on nationally-managed websites with a search tool, first introduced in 2009, has generated very limited research (one exception is Scown, Brady, and Nicholas 2020). This may be because member states have not made much effort to make these sites user-friendly and considerable effort is required to turn these data into usable information. The European Data Strategy proposed by the Commission includes rules on open data and the reuse of public sector information that will hopefully improve researchers' future access to administrative datasets.

The ongoing digital revolution is greatly increasing the amount of data collected regarding both farms and consumer behaviour. In addition to the traditional public sector actors involved in collecting and aggregating agricultural data, the digital revolution engages additional actors such as agricultural equipment manufacturers, software developers and other private actors. Managing rights to agricultural data and privacy concerns relating to the use of both personal and non-personal data is emerging as a key regulatory challenge (Kosier 2019). The voluntary Code of Conduct for agricultural data sharing launched by a coalition of associations from the EU agri-food chain in 2018 represents an important first step in building the necessary trust and transparency (van der Burg, Wiseman, and Krkeljas 2020). The development of a common agriculture data

[2] The portal can be accessed at https://agridata.ec.europa.eu/extensions/DataPortal/home.html.

space will be facilitated by Commission initiatives as part of its European Data Strategy.

The role of modelling

Agricultural economists have put significant effort into the development of policy models which are increasingly used in impact assessment and to support policymaking. Policy models come in many forms – programming models, agent-based models, microsimulation models, partial equilibrium models and computable general equilibrium models – and increasingly include links to biophysical, land use and other models in order to evaluate impacts on a wider range of indicators than the narrowly economic ones of production, prices, income, trade and economic welfare. As the focus of policy has shifted from markets to farms, models have evolved to capture the heterogeneity of farm responses, for example, to changes in direct payments (Espinosa et al. 2020; Gocht et al. 2013). In the past, models were often developed for specific purposes and rarely re-used, encouraged by a pattern of research funding that prioritised novelty rather than the maintenance and development of existing models. Two developments at European level have improved this situation.

One is that the EU research programme has begun to fund a cluster of research projects that aim to improve modelling capabilities while also interacting with each other.[3] The other is the creation of a modelling platform (the integrated Modelling Platform for Agro-economic Commodity and Policy Analysis, iMAP) at the Commission's Joint Research Centre since 2005 that includes selected partial and general equilibrium models (M'barek and Delincé 2015). iMAP facilitates the analysis of a given policy question with different tools, allowing comparison of results to substantiate the findings as well as extending the range of outputs given that the different models complement each other. The impact assessment undertaken for the Commission's legislative proposal for the CAP post 2020 illustrates the contribution of the iMAP models (European Commission 2018b). iMAP also contributes to making model results and harmonised data sources publicly available, thus increasing transparency and facilitating their scientific review.

Future directions for agricultural policy modelling were identified as part of the SUPREMA project (Gonzalez-Martinez, Jongeneel, and Salamon 2021). In line with the narrative in the earlier part of this paper, the conclusions noted the increasingly wide range of issues and outcomes that policies sought to address. In particular, more effort is needed to integrate environmental and social aspects as well as economic outcomes. As no model can attempt to provide all the answers, the project emphasised the need to ensure that models can be coupled and work together which adds another layer of complexity to their design. Models will increasingly be designed in a modular fashion so that depending on the question being asked discrete components can be included or not as needed. Resources also need to be found to support the ongoing work of model maintenance and development as well as to undertake model comparisons.

Experimental methods and behavioural insights

Experimental approaches are a relatively recent but rapidly-growing addition to the methodological toolbox both for agricultural policy design and impact evaluation. Insights from behavioural economics are also increasingly applied to understanding how farmers respond both to stronger regulations and to the broader range of voluntary measures now offered as part of agricultural policy. Although they are quite distinct (experimental economics is a methodological approach while behavioural economics is a research programme informed by a richer set of assumptions about human behaviour than mainstream economics) they are often seen as complementary as experiments can be used to test predictions of human behaviour drawn from behavioural economics (Thoyer and Préget 2019).

Experiments are particularly useful in trying to establish cause-effect relationships because they seek to control all extraneous factors in order to isolate the impact of the 'treatment' (the policy intervention or different designs of the intervention). Colen et al. (2016) survey the contributions of experimental approaches to agricultural policy, relatively limited at that time, and discuss the main challenges of integrating these approaches into the toolbox for agricultural policy impact assessment and evaluation. Lefebvre et al. (2021) give examples of policy insights from experiments and also review the challenges in making better use of experimental approaches. A network of experimentalists, the Research network on Economic Experiments for the CAP (REECAP) has been established with the aim of promoting the increased recourse to economic experiments for CAP evaluation.

Behavioural economics explores the implications of observing how farmers and consumers actually make decisions rather than assuming that they are rational,

[3] These include SUPREMA: https://cordis.europa.eu/project/id/773499; AGRICORE: https://cordis.europa.eu/project/id/816078); BESTMAP: https://cordis.europa.eu/project/id/817501; MIND STEP: https://cordis.europa.eu/project/id/817566.

self-interested, utility-maximising individuals. Psychology and other social sciences help to rationalise deviations in behaviour from the standard model and underpin the notion that there are systematic biases that if accounted for in designing policies can help to improve policy outcomes. Much of this literature has focused on ways to improve participation in agri-environment schemes due to their voluntary nature (Dessart, Barreiro-Hurlé, and van Bavel 2019). The EU created in 2019 the Competence Centre on Behavioural Insights within the Commission's Joint Research Centre to promote the use of behavioural insights in policymaking and the use of behavioural research is foreseen in the Better Regulation guidelines for evidence-based policymaking (Baggio et al. 2021). As behavioural change among both consumers and farmers is central to achieving the objectives of the European Green Deal when it comes to food systems, the extent and relevance of this research is only going to increase in future.

CONCLUSIONS

This review of recent agricultural policy research has highlighted its expanding breadth and the growing use of innovative datasets and methodologies. Yet it is far from comprehensive, and some readers will regret the omission of specific mention of topics such as the bioeconomy, risk management, or political economy. We have highlighted the close relationship between research efforts and topics with the changing needs and priorities of practical agricultural policy. We have used the concept of layering to suggest that new policy needs and priorities have been added cumulatively to the agricultural policy research programme rather than deleting or substituting for previous themes. It is impressive to observe how responsive the discipline has been to the changing needs and demands of policymakers and stakeholders.

In looking to the future, it seems appropriate to highlight two themes. The growing breadth of policy research brings with it a growing need for interdisciplinary collaboration. Erjavec and Lovec (2017) have already observed that the shift in focus of CAP research from market distortions to broader societal issues such as food, environment and development requires greater collaboration with political and other social sciences to avoid policy failures. I would argue that the expanded research programme described in this paper points to the need for an even greater range of disciplinary collaborators including ecologists, climate scientists, nutritionists, food technologists, and other natural scientists. My impression, which requires further empirical testing, is that many of the most cited papers that are driving the broader food systems and food policy agenda are not published in the traditional agricultural economics journals and often do not include economists among their authors (Fresco et al. 2021). In the past, agricultural economists often had a training in basic agricultural science which facilitated their contribution to, for example, farm management research. Being able to communicate across disciplinary boundaries will become an increasingly important skill. The downside, of course, is that investment in developing such skills takes time and resources that could otherwise be used to build research competences and output within one's own discipline. The ready access to information and the accompanying problem of information overload may, paradoxically, have the effect of encouraging greater specialisation where researchers can feel confident that, at least in their own specific areas, they have a full and complete understanding of the state of play.

A second question that comes naturally to an agricultural policy researcher is whether their research has any actual impact on practical agricultural policy. Researchers will be aware that research funding applications increasingly require evidence of impact or policy relevance. The commitment to the Better Regulation agenda within the EU and many national administrations includes a requirement for impact assessments (IAs) to gather and evaluate evidence to support policymaking. Reidsma et al. (2018) examine the use of scientific evidence in IAs in the area 'Agriculture and rural development' undertaken by the Commission between 2003 and 2014. Examining the total of 24 IAs conducted during this period, they concluded that this policy area 'provided relatively much scientific background compared to other policy areas' based on the inclusion of references to scientific studies. Both the European Parliament and the European Court of Auditors regularly publish studies which draw on research outputs in support of their policy recommendations.

However, actual impact is difficult to evaluate. While the above evidence suggests that policy research is referenced when taking decisions, it is often far from determining policy outcomes. The simple linear model whereby knowledge drives policy and that policymaking is driven by 'evidence' produced by science has been heavily criticised by the literature in political science, policy studies, and public administration (Boswell and Smith 2017). Most studies show that the use of evidence is highly selective. Some commentators attribute this to weaknesses in research communication and call for improved methods of knowledge exchange (e.g., policy briefs) as well as greater interaction (e.g. through stakeholder workshops) with policymakers to build trust. Increasingly, we see such initiatives as part of H2020 projects while the European Association of Agricultural Economics and the UK Agricultural Economics Society have jointly published *Eurochoices* with the specific aim of better communicating research results to policymakers. One might also make the case that agricultural policy research, even if not immediately visible in changes to CAP policy instruments, for example, has nonetheless had an influence over a longer timespan in shifting the range of what are deemed to be relevant responses to specific policy problems.

This instrumentalist view of the role of research in policymaking is challenged by other conceptual framings, most strongly the notion that it is politics that determines the research that is undertaken, or at least determines the research that is considered relevant, rather than the other way round. The way in which research funded by commercial interests often results in research findings that are of direct use to those interests is well documented. Similar mechanisms can be at play in policy research if research funders signal what is likely to be funded (or not) and what the expected outcomes are likely to be. In other cases, the research process itself is not informed by politics but the use made of research findings (or not) may ultimately be decided through a political process. Researchers need to be careful in criticising this outcome as research findings are not value-neutral. Implementing new policies or policy reforms will likely have distributional impacts by affecting various interests differently and may also challenge underlying values. While researchers can play an important role in highlighting the way power relations can affect the outcomes of political decision-making, it is ultimately the role of policymakers to weigh up and evaluate the trade-offs and make the final decision.

In conclusion, it is interesting to compare the narrative in this paper with one I wrote 25 years previously assessing the policy interests of agricultural economists at that time based on contributions to the 1996 Congress of the European Association of Agricultural Economists (Matthews 1997). It is striking how many of the themes mentioned in that paper are also highlighted here. The concluding paper to that Congress by Claus-Hennig Hanf was entitled "Agricultural economics in Europe: a thriving science for a shrinking sector?" (Hanf 1997). Hanf poses the question how agricultural economics can maintain its relevance as a discipline (or quasi-discipline, to use the term suggested by Fresco et al. (2021) when they pose a similar question) when the economic size of its focus of enquiry diminishes in importance.

Hanf was writing at a time when in his own country and elsewhere there was great pressure to close and amalgamate university departments of agricultural economics. He noted that the profession had maintained its numerical strength partly because the CAP gave rise to an almost inexhaustible supply of research projects, but also because agricultural economists enlarged their research domain to tackle new research problems. That these continue to be successful survival strategies is supported by the narrative in this paper. However, he also identified several pitfalls, including a potential loss of identity, a tendency to apply a narrow toolbox of theories and methods based on a strict neoclassical paradigm, and the dangers of losing the familiarity with the natural and technical environment in these newer research fields that has been the hallmark of agricultural economists in the past.

With these strictures in mind, it seems reasonable to suggest that agricultural policy research can maintain its relevance to practical agricultural policy if it continues to take up issues of societal concern, maintains its independence, encourages methodological innovation and supports a variety of methodological approaches, collaborates closely with other disciplines, while building on its long tradition of empirical analysis and working with data.

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Drinking Covid-19 away: wine consumption during the first lockdown in Italy

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Abstract. In Italy, wine is an integral part of most people's habits and lifestyles. The advent of a traumatic event like the Covid pandemic brought profound changes to people's lives: economic instability and normality disruption led consumers to revise their priorities and modify their consumption and purchase behavior. This study analyses the impact of socio-demographic, psychological, and context-related modifications induced by the pandemic on wine consumption and purchase patterns. Participants completed an online, structured survey, and the sample is constituted by Italian wine consumers. Logistic regression and descriptive techniques are applied to analyze data. Results highlight that wine consumption is a deeply rooted habit among Italian consumers, which resisted the great context modifications that occurred with the pandemic. Moreover, changes in wine consumption are connected to that of other alcoholic beverages. Significant short-term and potential long-term effects are discussed. Information collected is paramount to understanding wine consumers' reactions and behavioral changes induced by the pandemic and effectively plan marketing strategies during new infection peaks.

Keywords: Covid-19, wine consumption, Italy, consumer behavior, logistic regression.
JEL codes: D12, L66.

1. INTRODUCTION

The Covid pandemic is a traumatic event that led to significant changes in people's lives and Italy is among the hardest-hit European countries (Ministero Della Salute, 2021). The rapid and insidious spread of the virus, causing a severe and potentially life-threatening respiratory disease, forced the national Government to take a drastic step by forcing the country into a first, extended lockdown that lasted from March 10th to May 4th, 2020. This period had a profound impact on two significant aspects of the national community: on economy and productivity due to the forced shutdown of most activities, and on mobility and social occasions through the prohibition of physical gatherings and trips both outside and within the region. The disruption of people's habits and lifestyles generated severe psychological discomforts (Colbert, Wilkinson, Thornton, and Richmond, 2020, Arpaci, Karataş and Baloğlu, 2020).

The food-and-beverage industry and retail trade were among the few activities allowed to operate by the national law, so access to wine and other alcoholic beverages was still available. Although wine is an essential component of Italian culture and lifestyle (Seghieri, Torrisi, and Casini, 2007), the lockdown profoundly transformed wine consumers' routines, leading to potential modifications in wine consumption patterns. Such changes can potentially affect future wine demand, thus the role of wine in Italian culture and lifestyle. Considering the unprecedented circumstances of uncertainty the wine industry is facing, there is a need for reliable information on the impact of the lockdown on wine consumption.

This study aims at responding to this need, identifying factors that triggered modifications of wine consumers' behavior during the first national lockdown. The effect of new consumption habits such as online purchasing is also explored to provide insights into whether such factors can affect demand in the long term. An online survey was conducted on a large sample of Italian consumers of wine and alcoholic beverages (beer and spirits) to achieve these goals. A descriptive analysis is undertaken to highlight significant changes in alcoholic beverage consumption during the lockdown, focusing on both wine and substitution effects among wine, beer and spirits. Finally, factors inducing positive and negative modifications of wine consumption frequency are identified.

2. THEORETICAL BACKGROUND

The Covid pandemic is a one-of-a-kind, extraordinary event. Although world economies have already experienced health emergencies due to virus outbreaks such as SARS, the Covid pandemic crisis is unprecedented due to the multi-level and interdependent changes it has induced on a global scale. Consequently, to the best of the authors' knowledge, no similar phenomena in nature and magnitude have been analysed in the existing literature on consumer behavior. Nevertheless, researchers extensively explored the effect of habit disruption and stress on the consumption of both wine and alcoholic beverages. The following sections present the state of the art on these two key aspects, which are identifiable as significant consequences of the pandemic on consumers' lifestyles. Additionally, the role of wine and wine consumption in Italy is discussed.

2.1 Wine and alcohol consumption in Italy

Italy is among the major players in the wine market, with a production exceeding 50 million hl/year (OIV, 2020), and being the third world wine consumer after the USA and France. The Italian population consumes over 20 million hectoliters a year (22.4 in 2018), corresponding to 35 liters per capita (OIV, 2020). The latter has considerably shrunk in the last decades (Sellers and Alampi-Sottini, 2016). Still, its decrease is primarily due to changes in the way of consuming wine rather than to a switch of consumer preferences towards other alcoholic beverages. The function of wine has indeed gradually switched from nutrition to pleasure (Hertzberg and Malorgio, 2008), leading the share of daily wine consumers to decrease (17.6% of the population) in favor of non-daily ones, which are growing (36.6% of the population) (ISTAT, 2020). Generally, older generations tend to drink more wine and more often than younger ones (ISTAT, 2020), and contemporary daily wine consumers are likely to be males rather than females (25.9%; ISTAT, 2020). Females, indeed, are generally less prone to alcohol drinking. Compared to other alcoholic beverages such as beer and spirits, wine consumption is to a greater extent rooted in the Italian population's habits: indeed, only 5.3% and 0.6% of consumers, respectively, are daily beer and spirits drinkers (ISTAT, 2020). The widely diffused habit of having wine during meals could be an explanation, and makes food and gatherings with family members important consumption motivations in the Italian scenario. Social relations also represent a relevant consumption motivation, mainly due to the habit of the pre-meal *aperitivo,* when wine is consumed either by the glass or mixed in cocktails. Almost 40% of the Italian population usually drink alcoholic *aperitivo* (ISTAT, 2020).

Finally, health has been thoroughly explored as a factor influencing alcohol drinking behavior. Generally, alcohol consumption can be either considered a potential threat because of the poisonous effect of alcohol overconsumption and the related health risks, or an unhealthy dietary choice, increasing the caloric intake while providing low nutritional value (Bazzani et al., 2020). In this respect, the new post-pandemic lifestyle could prompt a recalibration of priorities (Sigala, 2020), leading people to re-evaluate the outcomes of their behaviors (Wood, Tam, and Witt, 2005). Therefore, the pandemic may constitute a deterrent to alcohol consumption, as human health and survival are at stake.

As regards to wine past research highlights the potential beneficial effects of moderate wine consumption on human health, mostly related to antioxidants in red-colored berries (e.g., Nijveldt et al., 2001; De Lorimier, 2000). The Mediterranean diet can potentially improve such effects. In this sense, wine can be seen as a healthy dietary choice (Fiore, Alaimo, and Chkhartishvil, 2019).

On a broader scale, a moderate wine intake can also contribute to hedonistic health and well-being (Fiore, M., Alaimo, L. S., & Chkhartishvil, N., 2019), which is associated with focusing on the self and the present moment (Huta, 2015), favoring sociability and inducing a stress-free mood (Cooper, 1994). The unprecedent circumstances of the lockdown and the uncertainty generated by the pandemic may have emphasized the role of wine drinking in emotional and mental well-being, positively impacting on its consumption frequency.

2.2 Psychological difficulties and alcohol consumption behavior

As mentioned above, the Covid-19 pandemic constituted a source of stress and anxiety that have long been associated with increased alcohol consumption. Among the first theories, there is Horton's Tension-reduction hypothesis (1943), identifying alcohol consumption as a way to diminish the feeling of anxiety prompted by stress, which arises either from traumatic events or from environmental stressors. Later studies further explored this connection, specifying that alcoholic beverages consumption can be a way to mitigate negative feelings (Powers and Kutash, 1985). Stress, moreover, may increase alcohol intake when the intention to drink is already present (Dawson, Grant, Stinson, and Zhou, 2005). In this respect, a stronger association exists with being male (Dawson et al., 2005), which can be explained by gender-related stress resistance. Indeed, men and women tend to react differently both to stress and to single stressors, intended as factors inducing stress (APA, 2012). As regards age, older people tend to deal better with negative emotions when subject to stressors, which is believed to be an indicator of stress resilience (Ong et al., 2006), while mainly endorsing positive feelings (Scott et al., 2014). Nevertheless, it should be considered that aging is associated with increased emotional complexity connected to the awareness of "running of time" (Carstensen et al., 2000). Such complexity peaks at middle age (Labouvie-Vief et al., 2007).

In the context of this research, we expect the fear of the SARS-CoV-2 illness, jointly with economic uncertainty and isolation, to trigger an increase in wine and, more generally, in alcohol consumption frequency, especially in males and middle-aged people. Indeed, other researchers have already outlined the high risk of potential alcohol overconsumption prompted by the pandemic's emergence (e.g., Clay and Parker, 2020).

2.3 Disrupting (wine) habits

Habits are defined as behavioral dispositions to repeat a set of everyday activities when specific circumstances occur (Wood et al., 2005). As an individual repeats the behavior, triggering factors – e.g., performance time, location, or people the activity is usually shared with – are associated in the memory with specific activities, leading to a set of cognitive, neurological, and motivational changes. Habits, indeed, tend to be context-dependent (Wood et al., 2005). Consequently, habitual actions lose their explicit instrumental nature, separating them from intentions (Neal, Wood, and Quinn, 2006; Wood et al., 2005) and being performed almost unconsciously. As regards wine, its recurrent consumption in Italy is strongly connected with a multitude of attitudes, behaviors, and consumption situations (Presenza, Minguzzi, and Petrillo, 2010), mainly conviviality, e.g., the *aperitivo* or gatherings with friends, colleagues, family and dining out. In this sense, wine drinking can be considered a habit for a large slice of the population. With the closure of restaurants, cafes and the ban of social gatherings during the lockdown, most factors driving wine consumption habits disappeared inducing changes in most wine consumers' drinking habits. Mainly, people usually drinking wine on social occasions may reduce their consumption frequency. At the same time, consumers who were used to consume wine alone are expected either to keep their consumption frequency stable or to increase it. The direction of this change may differ based on the strength of the role of wine in one's habits. The literature highlights that stronger habits survive context changes as intentions may come into play, creating the conditions to preserve them (Wood et al., 2005). Given the strength of the habit of *aperitivo* in Italy, people may look for alternative ways to pursue this activity during the lockdown: the virtual *aperitivo*.

To sum up, the strength of wine consumption as a habit among the Italian population before the pandemic leads to assuming that intentions arose to preserve this, despite the drastic context changes. In this respect, physical barriers imposed with the national lockdown may prompt the emergence of new ways to maintain usual wine consumption habits.

Conversely, the lockdown may show disrupting effects on wine drinking, resulting either in a reduced consumption or in substitution effects.

3. MATERIALS AND METHODS

A structured questionnaire was developed focusing primarily on wine while incorporating information on the consumption of other alcoholic beverages. The survey includes seven sections: consumption and purchase patterns before and after the pandemic (for wine, beer, and spirits), wine consumption context pre- and post-Covid, online wine-related interactions, psychological difficulties (i.e., feeling of isolation, fear of the virus and the economic crisis), positive feelings (i.e., willingness to support local wine producers, possibility to refocus on the self while in lockdown) and socio-demographics. Specifically, isolation is expressed as a latent construct focusing on relational connectedness. Indeed, relational connectedness represents social loneliness, one of the most significant consequences of the lockdown. For this purpose, a 3-items scale based on Hawkley et al.'s (2005) loneliness scale (UCLA scale) was adopted. The 3 items were reduced to a single factor (α=.87; KMO=.72) and the resulting Isolation scale is inverted (1=strong isolation; 5= weak isolation). The three items used are "since the beginning of the lockdown, there are people I feel close to", "since the beginning of the lockdown, there are people I can talk to", and "since the beginning of the lockdown, there are people I can turn to". Fear of Covid-19 was captured by the statement "I feel vulnerable to Covid-19 outbreak", while fear of the economic crisis is captured by the statement "I am concerned about the economic impacts of the crisis on myself and my family". Two statements represented positive feelings: "quarantine has allowed me to focus on the essentials", and "since the quarantine has begun, I feel like I should buy more local wine to support my country's economy". All items were measured by 7-points likert scales (1= strongly disagree; 7=strongly agree).

Online data collection was carried out between April 16th and April 29th, 2020 – i.e., during the first lockdown in Italy. As previously mentioned, given the impossibility of reaching the population of interest – consumers of alcoholic beverages – due to the ongoing pandemic and the short time window available, snowball sampling was adopted. This technique represents an efficient and cost-effective data collection method in contexts where subjects of interest are challenging to reach (Ghaljaie, Naderifar and Goli, 2017). Data were collected according to the guidelines provided by the Declaration of Helsinki (WMA General Assembly, 2013).

Drawbacks reported in the literature connected to this sampling technique, primarily due to its convenience nature, can be compensated by the large sample size. The survey was diffused through social networks and via direct contacts. The original study, designed in collaboration with the EuAWE (European Associations of Wine Economists) research group, involved several big players in the wine sector – i.e., Spain, Italy, Portugal and France. The current analysis refers exclusively to the Italian sample, with a total of 1076 valid questionnaires collected. Table 1 summarizes the descriptive statistics of the sample. The majority of interviewees (57.8%) are males employed in the service sector (57.4%) and with either good (50.1%) or sufficient (36.2%) economic situation. Almost half of the sample live in an urban context, while 30% come from suburban residential areas. A minor share of respondents live alone, with an average household size of three adults (45.7%) and no children (68.4%). Almost all age groups are homogeneously represented, with a slight predominance of 41-50 year old subjects. The age class of over 70s was poorly represented and was aggregated into the 60-70 age group. Similarly, for wine consumption frequency before the lockdown (WCONS_B), respondents drinking wine once a month or less were aggregated into one category of occasional consumers.

Data analysis relies on descriptive techniques and binary logistic regression (LR), given the categorical nature of the dependent variables (DV) and the use of human-sourced data. This statistical approach was chosen due to its capacity to provide higher robustness when multivariate normality assumptions and equal variance-covariance matrices across groups are not met, as commonly happens in social science research (Hair et al., 2019). Specifically, two LR models were developed to identify factors triggering positive (model B), and negative (model A) changes in wine consumption frequency during the first lockdown. For the sake of the analysis, consumers of alcoholic beverages who do not drink wine and missing income values were excluded through listwise deletion, thus reducing the sample to 1018 respondents. The enter method was preferred to the stepwise procedure, as the latter tends to produce sample-specific results (Hair et al., 2019). Regressors were selected based on the literature. Variance Inflation Factor (VIF) and Tolerance were used to check for multicollinearity, and all values were within the recommended thresholds (VIF<5; Tolerance>0.2; Hair et al., 2019). Although the primary aim of the analysis is explanatory, additional fitting diagnostics were performed. Overall predictive accuracy of the models was assessed through Receiver Operating Curves (ROC) and Area Under Curve (AUC). According to Hosmer et al. (2013) thresholds, both models show excellent discrimination power (AUC model A = .82; AUC model B = .87).

4. RESULTS

4.1 Wine consumption: the pre-lockdown scenario

Before the beginning of the pandemic, most respondents were regular wine consumers drink-

Table 1. Descriptive statistics of the sample.

	Frequency	%
Gender		
Male	622	57.8
Female	454	42.2
Age		
18-29	223	20.7
30-40	176	16.4
41-50	269	25.0
51-60	244	22.7
>60	164	15.2
Employment (n=1075)		
Agriculture	146	13.6
Industry	104	9.7
Service	618	57.4
Student	125	11.6
Retired	58	5.4
Unemployed	24	2.2
Has children		
No	736	68.4
Yes	340	14.6
Res. Area		
Rural	240	22.3
Residential	331	30.8
Urban	505	46.9
Freq. digital gatherings during the lockdown		
Did not do it	161	15.0
Rarely	517	48.0
At least once a week	181	16.8
Every day	217	20.2
Wine consumption frequency before the lockdown		
Never (0)	19	1.8
<1 a month (1)	50	4.6
At least 1 a month (2)	134	12.5
At least 1 a week (3)	568	52.8
Daily (4)	305	28.3
Beer consumption frequency before the lockdown		
Never (0)	127	11.8
<1 a month (1)	158	14.7
At least 1 a month (2)	265	24.6
At least 1 a week (3)	486	45.2
Daily (4)	40	3.7
Spirits consumption frequency before the lockdown		
Never (0)	279	25.9
<1 a month (1)	309	28.7
At least 1 a month (2)	260	24.2
At least 1 a week (3)	214	19.9
Daily (4)	14	1.3

	Frequency	%
n° adults (respondent included)		
1	22	2.0
2	145	13.5
3	492	45.7
4	199	18.5
5	161	15.0
≥6	57	5.3
Income		
Very problematic	13	1.2
Problematic	76	7.1
Sufficient	390	36.2
Good	539	50.1
No answer	58	5.4
Motivations for wine consumption		
Socialization (yes)	372	34.6
Relax (yes)	290	27.0
Health (yes)	118	11.0
Food (yes)	738	68.6
Taste (Yes)	788	73.2
Average bottle price wine before the lockdown (n=1052)		
<5€	148	13.8
5-10€	439	40.8
11-20€	359	33.4
21-30€	75	7.0
>30€	31	2.9
Has a wine app		
No	750	69.7
Yes	326	30.3
Wine consumption frequency in lockdown		
Less frequent	478	44.4
Unchanged	251	23.3
More frequent	347	32.2
Beer consumption frequency in lockdown		
Less freq.	563	52.3
Unchanged	333	30.9
More freq.	180	16.7
Spirits consumption frequency in lockdown		
Less freq.	565	52.5
Unchanged	414	38.5
More freq.	97	9.0

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Willingness to support Italian wine producers buying national wine	2.6	2.6	24.6	37.7	32.4
Feeling of isolation (inverted)	0.9	3.6	26.4	47.8	21.3
Fear of the economic crisis	0.8	5.8	14.2	46.0	33.2
Fear of the virus	3.8	15.0	33.0	40.1	8.1
Refocus on me during the lockdown	2.4	8.7	30.9	44.3	13.7

Notes: where not specified, n=1076. The % column reports the valid percentage.

ing wine at least once a week (52.8%) or daily (28.3%) (Table 1). Concerning other alcoholic beverages, the majority used to consume beer weekly (48.9%) and spirits sporadically (54.6% less than once a month). Based on ISTAT data, the share of daily wine consumers in the sample is higher than the Italian national average (17.6%). Wine was mostly consumed for its taste, paired with food during meals, and to socialize (Table 1). Coherently, it was prevalently drunk with friends and relatives. Adapting the Rabobank wine classification (Heijbroek, 2003), two main segments of wine consumers can be identified based on the average price per bottle: premium wine consumers, purchasing wine ranging between 5 and 10 Euros per bottle (40.8%) and super-premium ones, who usually buy wines priced between 11 and 20 Euros (33.4%). Accordingly, half of the respondents declared a good economic situation (50.1%). Results suggest that the sample comprises wealthier, higher-end consumers compared to the average Italian population, since market data on domestic wine sales report an average price-per-liter of 3.27 € (IRI, 2009). However, such average price is likely underestimated being referred to off-trade sales in supermarkets and discounts. Such sales channels are usually offering wines at a lower average price point compared to restaurants and *enoteche*, i.e., Italian specialized wine shops, which are excluded. Accordingly, *Enoteche* are the third most important shales channel for wine in the sample (45.5%) after cellar door sales (direct sales, 48.0%) and supermarkets (51.2%). Other channels such as e-commerce (12.8%) play a minor role, despite the digitalization level of respondents: indeed, 40% declared that they have a wine app on their smartphone. Anyhow, the share of online buyers in the sample more than doubles the average data reported in the sector literature for online wine sales in developed countries, which is approximately 5% (Higgins et al., 2015). Additionally, 70% of respondents declared a great willingness to support local wine producers in response to the Covid-crisis by preferring domestic wines.

4.2 Psychological difficulties during the lockdown

As expected, psychological difficulties are strongly felt by all respondents. In particular, the greatest worry concerns the negative economic impact of the pandemic (79.2%; Table 1). Economic concerns are strong enough to overcome fear of the virus, which, notwithstanding its life-threatening nature, is suffered by less than a half of the sample. A feeling of isolation, intended as the impossibility to relate with, talk with, and rely on others, also emerges as a dominant feeling for most respondents (69.1%; Table 1), despite most of them not living alone. Positive feelings also emerged, as a large share of interviewees see the lockdown as a chance to refocus on themselves (58.0%). Therefore, among the multitude of negative feelings, respondents could see the bright side of the situation.

4.3 Changes in wine consumption during the lockdown

Most of the wine consumers interviewed kept purchasing wine during the lockdown (75.7%) without changing the average bottle price (Table 2). However, part of the sample either reduced the average bottle expenditure (34.1%) or completely stopped purchasing the product (22.5%).

Table 2. Changes in wine purchase pattern following the lockdown.

	Frequency	%
Wine purchase behavior in lockdown		
Does not buy wine	19	1.8
Stopped buying wine	242	22.5
Kept buying wine	815	75.7
Average bottle price variation in lockdown		
Reduced	367	34.1
Unchanged	647	60.1
Increased	62	5.8

Notes: n=1076.

Table 3. Evolution of consumption contex and sale channel before and during the lockdown.

	BEFORE the LOCKDOWN		DURING the LOCKDOWN		Δ
	n.	%	n.	%	
Wine consumption context					
Friends	857	79.6	83	7.7	-90%
Family	754	70.1	840	78.1	11%
Colleagues	215	20.0	31	2.9	-86%
Alone	193	17.9	284	26.4	47%
Digital gatherings	11	1.0	145	13.5	1218%
Source of the wine consumed					
Supermarket	551	51.2	510	47.4	-7%
Direct sales	517	48.0	154	14.3	-70%
Specialized Wine shop	489	45.4	112	10.4	-77%
Online	138	12.8	198	15.8	43%
Personal wine stock	103	9.6	241	22.4	134%
Food shop	66	6.1	66	6.1	0%
Take away shopping	6	0.6	10	0.9	67%

Note: n=1076

Table 4. Online wine shopping during the lockdown.

Online wine shopping in lockdown	n.	%
Purchased wine online in lockdown	*198*	*15.8*
for the first time	86	43.4
as usual	66	33.3
more frequently	46	23.2

Notes: n=1076.

In this regard, the presence of over 22% of respondents drinking wine from their personal stock while in lockdown (a 134% increase compared to the pre-pandemic scenario) suggests that a stop in wine purchases does not necessarily correspond to a reduction in its consumption. Crosstabulations support this hypothesis, as the stop in wine purchase is not significantly related to reducing wine drinking frequency during the lockdown (chi-square: .67, $p = .418$). Among respondents who kept purchasing wine, results highlight several changes in their wine consumption habits during the lockdown. First, mobility restrictions and confinement impacted both consumption occasions and buying channels. As can be observed in Table 3, during the lockdown respondents consumed wine mostly with their relatives (78.1%) or alone (26.4%). Virtual meetings became an alternative social drinking occasion for 13.5% of the sample. Although the share of respondents is limited, this finding suggests virtual gatherings constituted a tool to keep the social dimension of wine alive since the majority of respondents who drunk wine on such occasions also reported socializing as a motivation for drinking it (57.2%; chi-square: 38.07, $p<0.001$).

As regards sales channels, the mandatory closure of several business activities inevitably impacted on wine purchase patterns, especially for the large share of consumers who used to purchase wine directly from the producer (48.0%) or specialized wine shops (45.4%) (Table 3). Online wine shoppers increased by 43% (Table 3), 43.4% of whom were first-timers (Table 4). This picture leads us to assume that online wine sales partially counterbalanced the inaccessibility of most sales channels.

The lockdown imposed by the Covid-19 pandemic significantly affected wine consumption frequency as well: 23% of the sample kept drinking wine as often as before the pandemic, while the great majority either increased (32.2%) or decreased it (44.4%). Model A and model B investigate factors impacting the decrease (DV1) and increase (DV2) in wine consumption frequency among wine consumers during the first lockdown (Table 5). First, results reveal that none of the psychological difficulties directly affects neither DV1 nor DV2. Both decrease and increase in wine consumption frequency are connected to a parallel modification of beer (VARBC) and spirits (VARSC), suggesting variations in wine consumption are attributable to a change in the overall alcoholic beverages' consumption pattern. Nevertheless, the effect of beer consumption frequency is considerably greater than that of spirits. Accordingly, when considering the total expenditure for all alcoholic beverages in the lockdown, only that of wine (for model A and B) and beer (for model B) significantly affect the DV.

Focusing on model A (DV1), a reduced wine consumption frequency is related to a decreased beer consumption (VARBC_RED). Accordingly, these respondents did not increase total expenditure on wine (INCREXP_W) and no significant effects emerge for variations in the total expenditure on beer (INCREXP_B). None of the sales channels show significant impact on the DV1. Families with children (CHILDY) are less likely to have reduced wine consumption in lockdown. On the contrary, a significant positive effect emerge with age, suggesting that older subjects have greater odds of shrinking their wine consumption frequency in lockdown. Among the reasons for drinking wine, health and relaxation emerge as significant factors impacting DV1: while drinking to relax (R_RELAX) decreases the odds of reducing wine consumption frequency in lockdown, consuming wine for its health properties (R_HEALTH) seems to promote this behavioral modification. Despite

Table 5. LR on the decrease (DV1; Model A) and increase (DV2; Model B) of wine consumption frequency in lockdown.

	A - Reduced wine consumption frequency in lockdown (DV1)								B - Increased wine consumption frequency in lockdown (DV2)							
	B	S.E.	Wald	Exp(B)	95% C.I.for EXP(B)		Sig.		B	S.E.	Wald	Exp(B)	95% C.I.for EXP(B)		Sig.	
					Lower	Upper							Lower	Upper		
AGE	0.12	0.06	3.67	1.13	1.00	1.28	0.06	*	-0.08	0.07	1.28	0.92	0.80	1.06	0.26	
GENDER	-0.13	0.17	0.57	0.88	0.63	1.23	0.45		-0.68	0.20	11.32	0.51	0.34	0.75	0.00	***
INCOME (good)			0.10				0.95				0.31				0.86	
INCOME 1 (sufficient)	0.05	0.16	0.08	1.05	0.76	1.45	0.78		-0.01	0.19	0.00	0.99	0.68	1.44	0.96	
INCOME (bad)	0.06	0.29	0.04	1.06	0.60	1.89	0.84		-0.19	0.34	0.31	0.83	0.43	1.61	0.58	
CHILDY	-0.44	0.17	6.71	0.65	0.46	0.90	0.01	**	0.46	0.19	5.67	1.58	1.08	2.30	0.02	***
CRISFEAR	-0.10	0.09	1.28	0.90	0.76	1.08	0.26		0.04	0.10	0.13	1.04	0.85	1.27	0.72	
ISOFEEL	0.16	0.10	2.45	1.17	0.96	1.42	0.12		-0.14	0.12	1.52	0.87	0.69	1.09	0.22	
VIRUSFEAR	0.08	0.09	0.92	1.08	0.92	1.28	0.34		-0.08	0.10	0.67	0.92	0.76	1.12	0.41	
REFOFEEL	-0.11	0.09	1.42	0.90	0.76	1.07	0.23		0.18	0.10	3.02	1.20	0.98	1.46	0.08	*
VARBC_NO			61.74				0.00				46.82				0.00	
VARBC_RED	1.28	0.19	44.28	3.59	2.47	5.24	0.00	***	0.45	0.23	3.68	1.56	0.99	2.47	0.06	*
VARBC_INCR	-0.18	0.31	0.33	0.84	0.46	1.53	0.57		2.24	0.34	44.17	9.40	4.86	18.20	0.00	***
VARSP_NO			11.44				0.00				12.95				0.00	
VARSPC_RED	0.52	0.19	7.91	1.68	1.17	2.41	0.01	***	0.28	0.22	1.57	1.32	0.86	2.03	0.21	
VARSPC_INCR	-0.29	0.35	0.66	0.75	0.38	1.50	0.42		1.37	0.38	12.94	3.94	1.87	8.30	0.00	***
INCREXP_W	-1.80	0.21	77.15	0.17	0.11	0.25	0.00	***	2.77	0.21	169.74	15.92	10.50	24.13	0.00	***
INCREXP_B	0.36	0.27	1.72	1.43	0.84	2.44	0.19		-0.96	0.32	9.14	0.39	0.21	0.71	0.00	***
INCREXP_SP	0.33	0.38	0.76	1.40	0.66	2.96	0.39		-0.36	0.41	0.78	0.70	0.31	1.56	0.38	
BL_ALONE	0.34	0.21	2.57	1.41	0.93	2.14	0.11		-0.19	0.25	0.62	0.83	0.51	1.33	0.43	
BL_FAM	0.36	0.19	3.76	1.44	1.00	2.07	0.05	**	0.13	0.21	0.38	1.14	0.75	1.72	0.54	
BL_FRICOL	-0.15	0.22	0.46	0.86	0.56	1.32	0.50		0.32	0.26	1.49	1.38	0.82	2.31	0.22	
LC_ONLINE	0.39	0.24	2.59	1.47	0.92	2.36	0.11		-0.31	0.28	1.25	0.73	0.43	1.26	0.26	
FREQ_DIGIMEET	0.02	0.08	0.04	1.02	0.86	1.20	0.84		-0.10	0.10	0.96	0.91	0.75	1.10	0.33	
R_SOC	-0.22	0.17	1.66	0.80	0.57	1.12	0.20		-0.09	0.20	0.20	0.92	0.62	1.36	0.66	
R_TASTE	-0.11	0.19	0.35	0.89	0.62	1.30	0.56		0.50	0.23	4.59	1.65	1.04	2.61	0.03	**
R_FOOD	-0.11	0.18	0.41	0.89	0.64	1.26	0.52		0.18	0.21	0.73	1.19	0.80	1.79	0.39	
R_HEALTH	0.81	0.26	10.22	2.26	1.37	3.72	0.00	***	-0.18	0.28	0.41	0.84	0.48	1.45	0.52	
R_RELAX	-0.43	0.19	4.84	0.65	0.45	0.96	0.03	**	0.74	0.22	11.86	2.10	1.38	3.20	0.00	***
SCBL_SUPER	0.06	0.17	0.11	1.06	0.76	1.46	0.74		-0.13	0.20	0.44	0.88	0.60	1.29	0.51	
SCBL_ONLINE	0.39	0.23	2.70	1.47	0.93	2.32	0.10		-0.11	0.27	0.17	0.90	0.53	1.51	0.68	
SCBL_DSALE	0.15	0.17	0.79	1.16	0.84	1.61	0.37		0.01	0.20	0.00	1.01	0.69	1.48	0.98	
SCBL_WSHOP	-0.07	0.16	0.16	0.94	0.68	1.28	0.69		-0.18	0.19	0.93	0.84	0.58	1.21	0.34	
WCONS_B (occasional)			30.26				0.00				24.37				0.00	
WCONS_B (regular)	-0.57	0.26	4.77	0.57	0.34	0.94	0.03	**	0.85	0.32	7.20	2.33	1.26	4.34	0.01	**
WCONS_B (daily)	-1.04	0.19	28.84	0.35	0.24	0.52	0.00	**	1.15	0.23	24.21	3.16	2.00	5.01	0.00	***
LOC_SUPP	-0.21	0.09	6.18	0.81	0.68	0.96	0.01	**	0.22	0.10	4.65	1.24	1.02	1.51	0.03	**
Constant	0.30	0.75	0.15	1.34			0.69		-4.26	0.90	22.43	0.01			0.00	

Notes: n=1018. * $p < .09$; ** $p < .05$; *** $p < .001$.
A: Hosmer and Lemeshow Test: chi-square 10.24, sig. 0.249. Pseudo R-square: Cox & Snell=0.28, Nagelkerke=0.38. Accurancy= 75.6%.
B: Hosmer and Lemeshow Test: chi-square 11.93, sig. 0.154. Pseudo R-square: Cox & Snell=0.36, Nagelkerke=0.50. Accurancy= 82.3%.

the closure of bars and ban on social gatherings, no significant effects emerge from drinking wine to socialize (R_SOC) as well as from drinking with friends and colleagues before Covid (BC_FRICOL). Wine consumption frequency before the pandemic (WCONS_B) negatively impacts DV1 for regular consumers (i.e., drinking wine

Table 6. Substitution effect in favor of wine and beer during the lockdown.

	Increased wine consumption frequency in lockdown			
	No		Yes	
	Count	%	Count	%
Other	287	40.8%	175	53.2%
<sp, beer unchanged	54	7.8%	16	4.9%
<beer, spirits unchanged	81	11.6%	37	11.2%
<beer&sp	273	39.6%	106	30.7%

Notes: n = 1018. Pearson's Chi-square test: 15.39; p = .002.

at least once a week, and daily wine drinkers). Moreover, people who used to drink wine with family members before Covid (BC_FAM) show higher odds for a decreased consumption frequency. Finally, consumers willing to support Italian wine producers (LOC_SUPP) show significantly lower odds of drinking less frequently in lockdown.

Factors driving an increased consumption frequency in lockdown (model B; DV2) are having children (CHILDY), willingness to refocus on oneself (REFOFEEL), drinking wine for relaxation (R_RELAX) and for its palatability (R_TASTE), and the willingness to support domestic wine producers. Indeed, all these predictors are connected to greater odds of drinking wine more often in lockdown. Conversely, being female and spending more on beer decrease the odds of having consumed wine more often during the lockdown.

Model B highlights a potential substitution effect in favor of wine. DV2 is significantly affected by increasing (VARBC_INCR) and decreasing (VARBC_RED) beer consumption frequency, although the former's effect shows a greater magnitude. Crosstabulations (Table 6) reveal that 30.7% of interviewees who drink wine more often in lockdown have simultaneously reduced both beer and spirits consumption frequency, and the 11.2% has reduced beer drinking only. This substitution effect involves less than half of the sample, since 53.2% respondents have increased wine and at least one other alcoholic beverage.

5. DISCUSSION AND CONCLUSIONS

Covid-19 has profoundly changed people's lifestyle, disrupting everyday habits and exposing them to considerable psychological pressure. Our results highlight that such pressure arises primarily from concerns for the economic and financial uncertainty caused by the pandemic, followed by the fear of the virus.

Wine consumption is confirmed to be deeply rooted in the Italian population's habits. Descriptive analysis reveals a major pre-existing preference for wine, which was the most assiduously consumed alcoholic beverage before the lockdown. Despite the disruptive effect of the pandemic, our results highlight that the vast majority of the sample kept purchasing wine (75.7%) without lowering the average price per bottle (60.1%). Market data on agri-food products and supply during the pandemic confirm a moderate but positive trend for wine sales during the lockdown (+9%), performing better than other beverages (+6%) (ISMEA, 2020a, 2020b, 2020c). Accordingly, most respondents kept consuming wine notwithstanding the substantial context changes. In this respect, both regular and daily wine drinkers, who are the most common consumers within the Italian population (ISTAT, 2020), are likely to have drunk wine more frequently during the lockdown rather than the reverse. Consistent with Wood et al. (2005), these findings represent an indicator of strength of the wine consumption habit. Results also show that 22.5% of the sample stopped purchasing wine in lockdown, with a similar number of respondents (22.4%) who consumed wine from their wine stock. Although the current study did not investigate the size of this stock, this finding partially explains the non-significant association between a stop of wine shopping and reducing wine consumption in lockdown. It also reveals the presence of a wine stock in an interesting slice of Italian wine consumers, which calls for further investigations.

Nevertheless, the impact of shock and habits disruption emerges on sales channels, consumption occasions, and wine consumption frequency. Following the pandemic, most consumers kept buying wine in supermarkets, while mobility restrictions significantly penalized other important sales channels such as wine shops and direct sales. The online channel partly benefited from the lockdown, recording a 43% increase and managing to attract new buyers. Although the relevance of online wine sales is limited, these extraordinary circumstances may lead to long-run effects on this sale channel, accelerating its growth in two ways: by pushing consumers to try online wine shopping, and by encouraging wine retailers to improve/create their online offer. This positive trend is in line with market data, with the online demand for agri-food products recording a 141% growth during the two months of lockdown (IRI, 2020). Consumption occasions also suffered from the stringent limitations imposed, as the only options during a lockdown is consuming wine alone or with household members.

It is reasonable to believe that such effects are temporary, as the reduction of wine consumption frequency in lockdown by people who used to drink wine at family gatherings is likely a consequence of a forced separation from other family members.

Virtual gatherings emerge as a new drinking occasion, although for a limited share of consumers. In this study, the new trend of the virtual *aperitivo* is intended solely as virtual gatherings organized independently by consumers. Given the prolonged duration of the pandemic and the importance of social occasions as a wine consumption motivation, the diffusion of virtual drinking activities may have increased. Moreover, wineries and wine shops started offering online tasting experiences as both a marketing tool to keep existing loyal consumers and to attract new ones. Therefore, further investigations are needed to deeply explore the future potential of virtual wine experiences and their role in wine marketing, providing suggestions on how to effectively design them.

Regarding wine consumption frequency, most respondents modified it either positively (32.2%) or negatively (44.4%). Being a woman reduces the odds of having increased wine consumption frequency. Since the whole population was subjected to the same considerable pressure originating from the pandemic, it seems that drinking wine did not represent a relief for women in lockdown as it potentially did for men. This result is in line with past findings from, e.g., Dawson et al. (2005) and APA (2012).

Variations in wine consumption frequency appear to go hand-in-hand with other alcoholic beverages, moving in the same direction. Notably, the increase in wine consumption frequency in lockdown is associated with a simultaneous change in spirits and especially beer. In this respect, we can assume that the lockdown may constitute a burden encouraging alcohol consumption. This finding is in line with the existing literature identifying traumatic situations as a promoter of alcoholic beverages consumption (e.g., Bartone and Homish, 2020; Bartone et al., 2017; Clay and Parker, 2020; Horton, 1943; Powers and Kutash, 1985). In this regard, it should be noted that this study focuses on consumption frequency, while no information is collected on volumes consumed.

Substitution effects are qualitatively evaluated based on changes in consumption frequency. A minor substitution effect in favor of wine is detected. Still, its limited extent suggests that the lockdown pushes consumers to drink more often the alcoholic beverages they are used to consume rather than switching from one to another.

Regarding families, the model shows that having children increases the odds of a higher consumption frequency in lockdown. This finding suggests that forced 24-hour cohabitation and the prolonged home-confinement may turn parenthood into a reason for drinking more frequently. Further analyses should be conducted to explore this relationship and the behavioural role of parenting as a stressor in the context of the pandemic.

Accordingly, relaxation and hedonistic health and well-being – i.e., focusing on the self (Huta, 2015) – trigger an increase in wine consumption frequency, highlighting wine may have played a role in mitigating the psychological pressure caused by the lockdown in a context where other alternatives to relax where not available.

Besides, the fact that drinking wine for its health benefits is linked to a reduced wine consumption frequency in lockdown, jointly with the connection between a reduced wine and beer drinking frequency, suggest the context of the pandemic brought a share of respondents to re-evaluate their personal priorities (Sigala, 2020; Wood et al., 2005), while discouraging alcoholic beverages consumption. Indeed, drinking alcohol in a context where people's survival is at stake may assume a negative connotation (Bazzani et al., 2020).

To conclude, many factors impacting wine consumption seem to be context-related and therefore are expected to have short-term effects. Nevertheless, some of them may affect wine demand in the long term: mainly, the emergence of virtual wine experiences and the growth in online wine shopping. Still, wine consumption appears to be a strong habit among Italian consumers, which managed to survive the profound context changes induced by the pandemic. These are encouraging signals for Italian wine producers, especially considering the strong willingness to support domestic wineries that emerged among respondents. Indeed, willingness to support domestic wine producers by purchasing their wines shows positive effects on wine consumption frequency in lockdown, promoting its increase. Future studies should validate the results of this survey and highlight potential changes occurred with the evolution of the pandemic in light of the uncertainty around its future evolution, which creates a metamorphic context that makes it particularly difficult to forecast how consumers will react. Indeed, on the short-run, similar phenomena are capable of jeopardizing sectors dynamics (Vergamini et al., 2021) with relevant financial consequences for the involved stakeholders. Within the perspective of a prolonged health emergency, information on the development of wine consumers' behavior in the current, unprecedented circumstances such as that provided by this study, is strategic to help actors of the wine sector in planning future market strategies. Indeed, the continued circulation of the virus requires wine producers and stakeholders to adapt to Covid-induced changes in consumer behavior that can no longer be looked at exclusively as transitory.

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Estimating a global MAIDADS demand system considering demography, climate and norms

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Abstract. Based on data mainly from the International Comparison Program for 156 countries, we conduct a global cross-sectional estimation of an extended rank-3 MAIDADS demand system for nineteen commodity groups including agri-food detail for integration in a Computable General Equilibrium model. We render both marginal budget shares and commitment terms depending on the implicit utility level and consider age shares on the population, the Gini-Coefficient, the share of Islamic population, a sea access indicator and mean temperatures as further explanatory variables. We find that especially demographic factors, the share of Islamic population and mean temperature considerably improve model selection statistics and the fit of commodity groups with a low fit in a variant where prices and income only are used. Graphics of the estimated Engel curves, with details for agro-food commodity groups, highlight income dynamics of budget shares.

Keywords: demand system estimation, AIDADS, General Equilibrium Modelling.
JEL codes: D12, C33, C68.

1. INTRODUCTION

Partial and Computable General Equilibrium Models (CGE) are widely used tools for policy impact assessments, but simulated outcomes depend on model structure and parameterization. In their review of how final demand is modelled in long-term analysis, Ho et al. 2020 underline the importance of the choice of functional form for final demand. They find differences in baseline results for 2050 for an otherwise identical CGE model of up to factor two between a Linear Expenditure System (LES), a Constant-Difference-in-Elasticity (CDE) demand system[1] and an AIDADS specification for single sectors, and still for up to 11% in total global aggregated output, all calibrated against the same data and own and income elasticities. Similarly, Britz and Van der Mensbrugghe 2018 compare outcomes of different model configurations and find sizeable differences in comparative-static analysis under a trade liberalisation shock between variants using different functional forms, calibrated against the same data and elasticities. But besides moving to more flexible functional forms, especially with regard to Engel curves, also

[1] The CDE demand system underlies the widely used GTAP Standard model.

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the parameterization of the demand systems in equilibrium model can certainly be improved. The widely used GTAP model, for instance, depicts up to 65 sectors, but its demand system is parameterized drawing on an estimation with ten aggregated sectors, only (Hertel and Van der Mensbrugghe 2019), such that elasticities for many sectors are identical.

This paper focuses on improved representation of final demand in equilibrium models for long-run analysis, specifically on the GTAP model and its variants, as the most widely used CGE models globally. The GTAP Data Base covers in its latest version 10 141 single countries or group of countries for which consistent long-term time series on final demand, related price and income are not available. A country specific estimation of parameters is therefore not feasible, such that the established practise estimates generic demand systems at global level, based on cross-sectional analysis, such as in Seale et al. 2006, Reimer and Hertel 2004, Preckel et al. 2010, Roson and Van der Mensbrugghe 2018, Britz and Roson 2019.

Given the large differences in per capita income across countries at global level and high projected income dynamics for current low and middle income countries, flexibility in Engel curves is deemed important during estimation and simulation. Here, an AIDADS system with its exponential Engel curves is often found as a sensible choice (cf. Rimmer and Powell 1996) and also used to estimate the current GTAP parameter (Hertel and Van der Mensbrugghe 2019). Ho et al. 2020 stress additionally in their review that demography, income distribution and other factors such as religious norms are found as important drivers of consumption choices in many micro-level studies, but are basically not considered as consumption drivers in any of the global CGE models.

Against this background, we aim at an improved final demand representation in CGE models in several directions, by (1) extending the sectoral detail in the global cross-sectional estimation of the AIDADS system, by (2) moving to a more flexible MAIDADS specification where also the commitment terms change with income, and by (3) controlling for additional factors which are likely to shape preferences such as religious norms. The resulting demand system is then integrated in the G-RDEM model (Roson and Britz 2019) for construction of long-run baseline, as a module of the flexible platform for CGE modelling CGEBox (Britz and Van der Mensbrugghe 2018). But the findings in here are also of relevance of partial equilibrium models focusing on specific sectors, or more generally of interest to economists interested in income dynamics of demand.

The paper is organized as follows. We first motivate the use and detail the extended MAIDADS demand system and the estimation approach before we present key results. Next, we discuss key findings with a focus on differences across variants which consider additional drivers such as demography or income distribution. Finally, we summarize and conclude.

2. METHODOLOGY

2.1 Extended MAIDADS demand system

We empirically estimate an extended AIDADS (An Implicit Additive Demand System, Rimmer and Powell 1996) demand system for nineteen product groups: ten broader non-food groups and nine food categories, where the extension refers to utility depending commitment terms. Detail for food is introduced as income effects are here especially relevant such as expressed, for instance, by Bennet's law (Bennet 1941). The AIDADS system can be understood as a generalization of a LES demand system where marginal budget shares are not fixed, a property also described as a rank three demand system with regard to income effects. Other rank three candidates are, for instance, the Quadratic Expenditure System (QES, Pollak and Wales 1978) and the quadratic AIDS (QUAIDS, Banks et al. 1997). Cranfield et al. 2003 estimated all three demand systems based of an older version of the data set employed in here with less demand categories, and compared them against the rank-two systems LES and AIDS from which they are derived. In their comparison, AIDADS and QUAIDS performed best and they recommend AIDADS if the income differences in the estimation or later simulations are high. One reason for this recommendation is the global regularity of AIDADS. Specifically, compared to QUAIDS, it ensures that marginal budget shares stay between zero and unity. Moreover, compared to the quadratic marginal budget shares of for instance a QUAIDS or QES specification, the exponential marginal budget shares of an AIDADS system might be considered more appropriate when covering a data set with extreme per-capita differences (Rimmer and Powell 1996).

In the AIDADS demand system, the marginal budget shares are a linear combination of two vectors, depicting the marginal budget structure at very low and very high utility (income) levels. A logistic function depending on the implicit utility level determines the linear combination. Given that the marginal budget shares in each of the two vectors fulfil the adding up condition to unity, any linear combination of the two also leads to regular budget shares. We follow Preckel et al. 2010 who extend the original Cranfield approach by rendering also the commitment terms depending on income, to what they call the MAIDADS for modified AIDADS demand system. With regard to the estimation strategy we follow Cranfield et al., 2000 who improve on the original Rimmer and Powell 1996 approach by developing an estimation method that does not rely on an approximation of utility. As usual, the independent data in estimations are the per capita incomes Y and consumer prices p for countries c and commodity groups i,j, and the dependents the budget shares w. Equation (1) determines the estimated budget shares $w^*_{c,i}$. It is identical to a LES specification with the exception that the marginal budget shares δ and commitment terms γ are not fixed, but depend on the endogenously determined utility level.

The marginal budget shares δ_i are expressed in (2) as a linear combination of two vectors δ^{lo} and δ^{hi} driven by a logistic function depending on the utility level u, implicitly defined by (5):

$$w^*_{c,i} = \frac{x^*_{c,i} p_{c,i}}{Y_c} = \frac{\gamma_{c,i} p_{c,i}}{Y_c} + \delta_{c,i}\left[1 - \sum_j \frac{\gamma_{c,j} p_{c,j}}{Y_c}\right] = w_{c,i} - e_{c,i} \quad (1)$$

$$\delta_{c,i} = \frac{\delta_i^{lo} + \delta_i^{hi} \exp(\omega_\delta u_c - \kappa_\partial)}{1 + \exp(\omega_\delta u_c - \kappa_\partial)} \quad (2)$$

δ_i^{lo} can be interpreted as the marginal budget share at minimum utility level, i.e. very low per capita income, while δ_i^{hi} is the share at very high incomes. The utility level u_c is calculated at the given $\delta_{c,i}$ and $\gamma_{c,i}$ in (5). It drives in (2) a logistic function with the parameters $\omega_\delta > 0$ and κ_∂ which in turn determines the marginal budget share; this shows the implicit utility definition. At the point where the expression $\omega_\delta u_c - \kappa_\partial$ is zero, the average between the two marginal budget share vectors is chosen, based on (5), that point is defined by κ_∂. For larger negative $\omega_\delta u_c - \kappa_\partial$, the exponent term approaches zero and the lower $\delta_{c,i}$ share is chosen; for larger positive ones, the exponent term approaches infinity such that δ_i^{hi} is selected. In opposite to the original Rimmer and Powell 1996 proposal and subsequent work, we also consider a multiplicative factor ω_δ.

Different from previous work with AIDADS or MAIDADS specifications we are aware off, the two vectors δ^{lo} and δ^{hi} are country specific in here as they depend on a set f of further country specific attributes a as detailed below, see equation (3).

$$\alpha_{c,i} = \alpha_{i,0} + \sum_f \alpha_{i,f} \bar{a}_f$$
$$\beta_{c,i} = \beta_{i,0} + \sum_f \beta_{i,f} \bar{a}_f \quad (3)$$

γ are the constant terms, typically termed commitments. As suggested by Preckel et al. 2010, we render also the commitment terms an exponential function of utility, see equation (4). This allows especially better differentiating price sensitivity across income differences.

$$\gamma_{c,i} = \frac{\gamma_i^{lo} + \gamma_i^{hi} \exp(\omega_\gamma u_c - \kappa_\gamma)}{1 + \exp(\omega_\gamma u_c - \kappa_\gamma)} \quad (4)$$

Equation (5) defines the additive utility from the consumption bundle and is identical to the LES definition[2]:

$$u_c = \sum_i \delta_{c,i} \ln\left(x_{c,i} - \gamma_{c,i}\right) \quad (5)$$

Besides considering additional factors in the determination of the marginal budget shares, our approach is therefore slightly more general compared to Preckel et al. 2010 who, first, have κ identical in determining δ and γ, and, second, introduce ω into (4), only.

2.2 Estimation approach

We follow closely Cranfield et al. (2000) and Preckel et al (2010) in our estimation by performing a log-likelihood estimation on cross-sectional data from the International Comparison Program (ICP) referring to the year 2011[3] which provides a harmonized data set on expenditures (2), consumer prices and purchasing power parities. However, we don't use the publicly available data, only, but based on an agreement with the ICP, add more detail for food.

[2] The usual definition of the implicit utility definition in the (M)AIADS is $\sum_i \delta_{c,i} \ln(x_{c,i} - \gamma_{c,i}) - \ln(A) - u_c = 1$ with δ and γ expressed by (2) and (4). Our formulation is equivalent as the term (-ln(A)-1) could be recalculated from the expressions $\omega_\gamma u_c - \kappa_\gamma$ and $\omega_\delta u_c - \kappa_\delta$.

[3] The current GTAP Data Base versions in use are Version 9 for 2011 and Version 10 for 2014, which fits to the year of the ICP data. Long-run baseline construction with recursive-dynamic CGE models projects decades into the future. With regard to consumption behaviour, this is only defendable if one assumes that observed differences in consumption patterns across countries with different per capita income level provide guidance of how pattern might change in future under stronger income dynamics. If using data from 2014 instead of 2011 would lead to distinct differences in the estimated parameters, the assumption would be challenged. But as we don't have access to newer data, we leave such evaluations to other scholars.

As Preckel et al. (2010) we define a quadratic covariance matrix E of dimension $(n\text{-}1)\times(n\text{-}1)$ comprising the error terms $e_{c,i}$ from (1). Dropping the last column and row reflects that budgets shares and their error terms are linear dependent due to adding up. Assuming normally distributed error terms e, their concentrated log-likelihood function becomes $-½\ln|E^*|$ which elements defined as

$$E_{ij}^{*} = \frac{1}{C}\sum_{c} e_{i,c}e_{jc} \wedge i \neq n, j \neq n \quad (6)$$

Where C is the number of countries observed. In order to improve estimation speed, we follow Preckel et al. 2010 and apply a Cholesky decomposition $E^*=R'R$ which eases defining the log of the determinant of E due to $\ln|E|=2\ln|R|$. The decomposition does not itself constrain the estimation outcome as the (reduced) covariance matrix E^* is by definition positive definite. The decomposition is defined as:

$$E_{i,j}^{*} = \sum_{k}^{n-1} r_{ki}r_{kj} \ \forall i \neq n, j \neq n \quad (7)$$

The Cholesky matrix R as an upper triangular matrix comprises with $(n\text{-}1)$ $(n\text{-}1\text{+}1)/2$ elements far less elements than E^*. The lower triangular part of the matrix R with elements $r_{kl}=0\forall k>l$ must be set to zero while for the diagonal elements non-negativity is required to guarantee finiteness. This requires small positive bounds, here chosen as 1.E-8 which turned out to not become binding (this would imply perfect fit). The overall concentrated log-likelihood to maximize is derived from the diagonal elements of R:

$$-C\,½\ln\prod_{i=1}^{n-1} r_{ii}^{2} = -C\,\mathrm{n}\prod_{i=1}^{n-1} r_{ii} \quad (8)$$

Exhaustion of income requires adding up of the marginal budgets to unity. This leads to the following adding up restrictions during estimation:

$$\begin{aligned} \sum_{i}\alpha_{c,i} \equiv 1 \Leftrightarrow \sum_{i}\alpha_{i,0} \equiv 1, \sum_{i}\alpha_{i,f} \equiv 0 \\ \sum_{i}\beta_{c,i} \equiv 1 \Leftrightarrow \sum_{i}\beta_{i,0} \equiv 1, \sum_{i}\beta_{i,f} \equiv 0 \end{aligned} \quad (9)$$

As seen from equation (9), the regression coefficients $\alpha_{i,f}$ and $\beta_{i,f}$, must add up to zero to maintain the adding up condition as they update marginal budget shares at low and high utility depending on country specific additional factors in equation (3). As some of these regressions coefficients are therefore necessarily negative, we restrict all estimated marginal budget shares to be non-zero. In order to prevent negative estimates in later simulations with the CGE model, we introduce two artificial observations at 75% of the lowest income and 125% of the highest one. These two observations do not impact the estimated log-likelihood directly as there are no error terms attached to them, but the estimator needs to ensure that the estimated budget shares for these two observations are between zero and unity. Moreover, we ensure that the estimated commitment terms don't exceed 95% of the estimated demand at the minimum and maximum observations additionally introduced, beside an observation at the mean income of the sample. This provides additional safeguards against implausible outcomes when simulating with the system in later applications. These details clearly reflect the specific aims of the exercise[4].

The use of the *exp* function can provoke mathematical overflows during estimation and simulation. We therefore replace is with the following smooth quadratic exponential function:

$$\mathrm{sqexp}(x,S) = \begin{cases} e^{x} & x < S \\ e^{x}\left(1+[x-S]+½[x-S]^{2}\right) & x \geq S \end{cases} \quad (10)$$

Where S is a smoothing factor chosen here as S=10. The usefulness of this smoothing approach becomes obvious if we consider the point x = 100. The exponential function will yield ~2.7E+43 while the smoothed one results in ~1.E+8. For the resulting linear combination of the estimated parameters in (2) and (4), differences in values of this dimension are irrelevant for any reasonable estimate. This becomes visible if we consider their bounds. The marginal budget shares δ are bounded by [0,1] and the $\gamma_{lo,i}$ by $[0,Y_{min}]$ where the minimum yearly per capita income Y_{min} is around 250 USD. This acts as a maximal bound for commitment terms as utility in (5) is only defined if $x_{c,i} > \gamma_{c,i}$ such that even with a budget share of 100%, $\gamma_{lo,i}$ can never exceed the minimum income level observed. Setting $\gamma_{up,i}$ to its lowest possible value of zero and $\gamma_{lo,i}$ at its possible maximum yields an commitment parameter of $\gamma_{c,i}=\gamma_i^{lo}[1+\mathrm{sqexp}(x)]$ driven by utility based on $x = \omega_\gamma u_c\text{-}\kappa_\partial$. That means that if $1+\mathrm{sqexp}(x) >> \gamma_i^{lo}$ for larger values of u, the resulting marginal budget share will be, as desired, almost zero. As $\exp(10) \sim 5.5E4$, that is already given at the point where the smoothing starts to make a difference with the $\gamma_{lo,i}$ and $\gamma_{up,i}$ at their most critical values for the approxi-

[4] For the selected model, none of these additional safeguards became active during estimation and impacted the estimates.

mation. More generally, one could define demand systems similar to the (M)AIDADS based on any function returning values on the domain [0,1] for any value of utility *u*.

We estimate different variants of the model by considering besides price levels and income further country specific attributes relating to income distribution, religious norms, climate, access to sea and demography, separately or jointly. Such additional controls are often found in demand system estimations drawing on household samples, where such attributes refer to individual households and not, as in here, to a country.

Adding these controls aims at insights if and to what extent these drivers systematically improve the fit, both with respect to the overall model and to individual categories, and reflects that these attributes have been found in micro studies as relevant to explain differences in demand behaviour (Ho et al. 2020). The usefulness of integrating further explanatory factors might deserve some discussion. In our and similar exercises, the utility structure of the representative household of any country is assumed to be identical. This implies, for instance, that consumers in a country with a mainly Islamic population would spend as much on beverages and tobacco as the ones in a country dominated by Christians when facing the same prices and enjoying the same income level. This is not very likely as consuming alcohol is often forbidden in countries where the Islamic belief dominates. Such impacts might be only partially captured by price differences in goods. Similarly, a larger share of older people might imply different expenditures on health at the same prices and identical average per capita income, motivating the use of demographic factors.

Demand system estimations based on a cross-section of country data set might face collinearity issues. First, price levels for some of the aggregated commodities are likely related in a systematic way to income levels, while we miss variability over time as found in a panel data set to dampen this effect. For instance, the so-called "Beaumol"-disease stipulates that labour-capital substitution is harder in certain service sectors, such that in countries with higher wages (and income levels), some services are systematically more expensive, the costs of a hair-cut serve often as an archetypical example. Indeed, we find R^2 values for a simple regression of prices on the logarithm of per capita income (see Table 3) for non-food groups in the range of 50-60% with the exemption of communication (~30%). For agri-food groups, the correlation between income and prices is still high (>40% R^2) for meats, fish and other food, and otherwise quite small. Any estimation using cross-country data with larger income differences will likely face these issues. In our estimation, some additional factors are also correlated to income, especially demographic factors with R^2 values of 60% and 70%, using again logarithms of income levels as explanatory factors. The problem is hence of a similar magnitude as for prices and will hinder a clear separation of demographic factors from income level effects. The R^2 for other factors are below 25% and give little reason for concern. Still, if additional factors systematically improve model selection criteria despite collinearity issues, they contribute to a better explanation, but collinearity will make it harder to tell income and price effects apart from the influence of these additional factors. We will come back to that point when discussing which of the different model variants to use for actual simulation purposes with the CGE model.

Technically, we implement the estimator in GAMS, updating and improving the codes by Britz and Roson 2019 which draws on the ones originally used by Reimer and Hertel 2004. The use of GAMS is motivated by an estimation which comprises highly-nonlinear equations and constraints, such as the endogenous Cholesky-Decomposition in (7). This asks for robust non-linear programming solvers such as CONOPT4 employed here which are not available in statistical packages.

GAMS is not a specialized statistical package which implies that any statistics and tests need to be programmed manually. Beside these technical issues, we see several reasons why we don't develop code to estimate p-values for the individual parameters. First, in our demand system estimation, dropping prices or income as independents is impossible, due to constraints, the same holds for dropping additional factors in individual equations. Even for additional factors, single p-values can therefore not guide the selection of these controls. Second, even in the models with many additional factors, we still have thousands of degrees of freedoms. This renders it likely that p-values always suggest most parameters significantly different from zero, even if their relevance might be low. Moreover, the interpretation of p-values is challenging in the context of parameter restrictions. We instead carefully discuss the trade-off between considering more additional factors and model selection statistics such as the Akaike's Information Criterion when deciding which of the model variants to choose for simulation.

2.3 Data

As other global exercises, we draw on data by the ICP as it provides standardized and consistent observations on many countries with different per capita income levels.

This should help to find a robust representation of global, country-wide Engel curves. As our ultimate aim is to integrate the estimates into the GTAP derived G-RDEM model, we aggregate detailed ICP data on food expenditures covering 34 items to (aggregates of) GTAP sectors and keeping otherwise the ICP classification for non-food as shown in Table 1. Per capita demands are real expenditures in U.S. dollars, the prices are derived from these and nominal expenditure per capita in U.S. dollars.

The GTAP data base differentiates between wheat, paddy rice and other coarse grains which are potential substitutes in consumption. Keeping here more detail likely violates the assumption of additive utility such that we rather aggregate here to a category "cereals". The same holds for the two GTAP sectors ruminant meat and other animal products, the latter comprising pig and poultry meat and eggs. Moreover, the "Other meats and meat preparations" reported by the ICP might comprise both ruminant and non-ruminant meat and can therefore not clearly be linked to individual GTAP sectors. The reader might wonder why we don't consider bread and pasta under the cereals product aggregate. The reason is that in the GTAP SAM, cereals refer to primary production and thus the farm scale, while bread or pasta as processed product are reported under the other food industry sector which comprises many more products such as ready-to-eat menus etc.. Britz and Roson 2019 therefor argue that the input coefficients of this food processing industry aggregate are likely depending on per capita income, as empirical analysis consistently shows that bulk calorie products such as cereals, bread or potatoes are inferior goods while convenience food is a rather a luxury good. We aim with the aggregation shown in Table 1 above to get a good match between the definitions in the ICP data set and the GTAP data base which motivates this specific aggregation scheme.

Table 1. Commodity groups in estimation and ICP detail.

Commodity group	ICP
Identical	Clothing and footwear
	Housing, water, electricity, gas and other fuels
	Furnishings, household equipment and maintenance
	Health
	Communication
	Recreation and culture
	Education
	Restaurants and hotels
	Miscellaneous goods and services
Cereals	Rice; Other cereals; Flour and other products
Meats and eggs	Beef and veal; Lamb, mutton and goat; Pork; Poultry; Other meats and meat preparations; Eggs and egg-based products
Fish	Fresh, chilled or frozen fish and seafood
Dairy	Fresh milk; Preserved milk and other milk products; Cheese; Butter and margarine
Vegetable oil and cakes	Other edible oils and fats
Fruits and vegetables	Fresh or chilled fruit; Fresh or chilled vegetables other than potatoes; Fresh or chilled potatoes
Sugar	Sugar
Beverages and tobacco	Spirits; Wine; Beer; Mineral waters, soft drinks, fruit and vegetable juices; Coffee, tea and cocoa; Tobacco
Other food processing	Food products nec; Narcotics; Preserved or processed fish and seafood; Frozen, preserved or processed vegetables and vegetable-based products; Frozen, preserved or processed fruit and fruit-based products; bread; Other bakery products; Pasta products; Jams, marmalades and honey; Confectionery, chocolate and ice cream

An overview on key metrics of the budget shares as the dependent variables provides Table 2 below. We observe that for the non-food items shown in the upper part, with the exemption of costs related to housing, the minimum shares are all below 1.5%. The maxima reveal that the categorisation of non-food items is rather balanced, with the exemption of housing, they are all in the 10-20% range. The same holds, with the exemption of vegetables oils and sugar for the food categories, also. Here, all minima are, with the exemption of the other food category, all close to zero. The R^2 of a simple regression on log of income reaches up to 33% of cereals, but is in most case in the 10-20% range which leaves ample room for improvement by a demand system estimation.

Table 3 reports key metrics for the prices and income levels as key independents. The spread of prices is astonishingly high which can also seen from their standard deviation. There is also a stronger impact of the income level on the prices, a point touched upon before. When moving from the lowest income of around 250 USD to the maxima of around 55.000 USD, the regressions suggest that prices of non-food items would increase by 0.36 to 0.45 (note that the US price is set to unity and serves for normalization).

Data on demography are taken from the IASSA data repository[5] for the Socio-Economic Pathways which ensures that the same data can be used in model appli-

[5] https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about

Table 2. Statistics on budget shares derived from ICP data.

	Mean	Min	Max	Std.Dev	R^2 on log(Y)[1]
Clothing and footwear	0,047	0,010	0,145	0,023	0,11
Housing, water, electricity, gas and other fuels	0,153	0,049	0,389	0,057	0,11
Furnishings, household equipment and maintenance	0,049	0,009	0,132	0,020	0,00
Health	0,076	0,009	0,197	0,035	0,22
Transport	0,092	0,014	0,183	0,034	0,02
Communication	0,028	0,001	0,098	0,015	0,16
Recreation and culture	0,045	0,004	0,112	0,028	0,29
Education	0,072	0,013	0,178	0,028	0,05
Restaurants and hotels	0,045	0,000	0,141	0,032	0,18
Rest	0,077	0,015	0,194	0,044	0,08
Cereals	0,049	0,001	0,311	0,063	0,33
Meats, eggs	0,053	0,006	0,239	0,035	0,03
Fish	0,013	0,000	0,103	0,016	0,14
Dairy	0,026	0,001	0,108	0,019	0,14
Vegetable oils	0,011	0,000	0,047	0,010	0,20
Fruit & veg	0,049	0,006	0,210	0,037	0,28
Sugar	0,008	0,000	0,038	0,008	0,20
Other food	0,060	0,020	0,159	0,031	0,10
Beverages and tobacco	0,048	0,009	0,149	0,023	0,00

Source: ICP 2011, aggregated according to Table 1.
Notes: [1] Linear regression with log of income per capita as independent.

Table 3. Statistics on income and prices.

	Mean	Min	Max	Std.Dev	R^2 on log(Y)[1]
Income	9.030	220	55.835	12.196	
Clothing and footwear	0,771	0,229	2,053	0,368	0,61
Housing, water, electricity, gas and other fuels	0,540	0,074	2,400	0,413	0,55
Furnishings, household equipment and maintenance	0,853	0,422	1,778	0,288	0,63
Health	0,439	0,098	1,678	0,328	0,65
Transport	0,943	0,385	2,349	0,380	0,54
Communication	0,678	0,101	1,742	0,288	0,31
Recreation and culture	0,768	0,330	1,948	0,323	0,59
Education	0,313	0,037	1,905	0,320	0,55
Restaurants and hotels	0,799	0,265	2,240	0,341	0,55
Rest	0,640	0,233	1,993	0,333	0,69
Cereals	0,916	0,258	3,588	0,395	0,15
Meats, eggs	0,994	0,277	3,313	0,467	0,51
Fish	0,593	0,155	1,723	0,289	0,53
Dairy	1,080	0,412	2,159	0,293	0,02
Vegetable oils	1,386	0,719	2,331	0,325	0,04
Fruit & veg	0,732	0,234	2,614	0,356	0,39
Sugar	0,915	0,239	2,329	0,304	0,06
Other food	0,844	0,268	1,902	0,297	0,33
Beverages and tobacco	0,716	0,128	2,289	0,329	0,33

Source: ICP 2011, aggregated according to Table 1.
Notes: Price of United States = 1, [1] Linear regression with log of income per capita as independent.

Table 4. Additional factors considered.

Factor	Variable(s)
Income distribution	Gini Coefficient
Religious norms	Share of islamic population
Climate	Mean temperature
Sea access	Coast line relative to country size [m/skm], in log
Demography	Share of persons < 15 year Share of persons > 65 years

cations for long-run analysis. We use the shares of two age groups as additional factors which can be expected to be not part of the working population (<15 and > 65 years). Not only are these age groups likely to show consumption patterns different from other age groups, they also might (indirectly) control for differences in household sizes, especially the share of <15 years old. As some household expenditures comprise a fix-cost share, household size at the same average per capita income of the household members is likely to change budget shares (Deaton and Paxson 1998). We took access to sea into account especially in the hope to better control for spending on hotels and restaurants, and to explain fish consumption. Mean temperature as the climatic variable chosen not only could impact the food consumption bundle, for instance with regard to dairy, but also impact housing and clothing expenditures (Sheth 2017). To check for the influence of different income distributions, we use Gini coefficients taken mostly from the CIA factbooks, a few missing observations were filled by data from Liberati 2009. Data on the share of Islamic population were taken from a study by the Pew center, 2011 (Pew center 2011).

In total, we observed for C=156 countries budget shares, prices and additional factors. The 19 commodity groups lead to 2,964 observations. The extended AIDADS model where also the commitment terms depend on the utility level has four vectors of parameters (α, β, γ^{lo}, γ^{hi}), two utility multiplier κ and two exponents ω, considering the adding up conditions, this implies m = (2*n + 2*(n-1) + 4) = 78 parameters for the MAIDADS variant without additional factors. Each additional explanatory variable adds two additional vectors of marginal budget shares at low and high income, again considering adding up, that means for each factor 2*(n-1) = 36 additional parameters to estimate. For the model considering all six additional independents, we hence estimate 294 parameters. This reduces the degrees of freedom more than a QUAIDS system which would estimate m = (3 * (n-1) + (n-1)*(n-1)/2 = 192 parameters. But the full model is not used for simulation in here, but rather serves as a benchmark to select a suitable set of additional factors beyond per capita income and price levels.

2.4 Integration in the CGE

Using the estimation results for benchmarking of a CGE model is far from straightforward as observed budget shares for a country or country aggregate might deviate considerably from what the econometric model suggests. Additionally, with the exemption of the agri-food sector, the commodity groups are still rather aggregated compared to, for instance, the 57 sector resolution of the GTAP 9 data base or the 65 sectors of GTAP 10.

During estimation and later simulation, the utility is implicitly driven by the demands which depend on the marginal budget shares and commitment levels which are functions of utility. In order to ease benchmarking, we follow therefore the approach of Britz and Roson 2019 which perform a regression of the estimated utility levels from (5) on per capita income and add here as further independents the additional factors. The estimate of the utility level allows deriving an estimate of the country and sector specific $\delta_{c,i}$ and $\gamma_{c,i}$ for benchmarking. We cannot introduce the error term in the simulation model directly. Instead, we have, as usual for benchmarking with CGE models, to correct some of the parameters in order to line up the observed data with the estimated ones. The errors cannot be simply added to the commitment terms $\gamma_{c,i}$ as this changes non-committed income as well. Doing so also runs the risk to introduce rather curious elasticities in the model. This becomes visible from the Marshallian demands in equation (11).

$$x_{c,i} = \gamma_{c,i} + \frac{\delta_{c,i}}{p_{c,i}}\left[Y_c - \sum_j \gamma_{c,j} p_{c,j}\right] \tag{11}$$

If, for instance, the observed x is large compared to what the estimations suggests as x^*, simply increasing the related commitment term will mean that income and price effects are considerably dampened compared to the estimation. Increasing the marginal budget shares at unchanged commitment terms will instead increase price and income responsiveness.

We therefore suggest first scaling both vectors of estimated parameters by the relation between the observed and the estimates, next scale the commitment terms such that they add up to unity and finally penalize squared deviations from the original estimates and under adding up conditions.

3. RESULTS

3.1 Fit of different model variants

In order to assess the different model variants, we compare the value of the likelihood function, the Akaike's Information Criterion, the information inaccuracy, the Schwartz's Criterion and the system wide Root Mean Squared Error. The calculation of the statistics follows Cranfield et al. 2003, i.e. the Root Mean Squared Error for the estimation of the budget shares w for the products i is calculated as $RMSE_i$=[1/C$\sum_c \omega_{ic}$-ω^*_{ic} with C being the number of countries and the system wide RMSE by using the mean budget share as weights, i.e. $SMRSE=\sum_i \overline{w_i}$ $RMSE_i$. The value of the likelihood function is defined as LLF=-1/2Cln|E^*|, the information inaccuracy as $IIA=1/C \sum_{c,i} \omega_{c,i}(\omega_{c,i}/\omega^*_{c,i})$, Akaike's Information Criterion as $AIC=2/Cm$+ln|E^*| and the Schwartz's Criterion as SC=1/Cln(T) m+ln|E^*|. We calculate a system wide R^2 by weighting the individual R^2 with the budget shares.

The full model which uses all additional explicatory factors clearly has the best fit with a likelihood function value of 11.472 and a system R wide ^{2} of 54,2%, see Table 5. It shows also the best IIA value, but the AIC and SC statistics suggests that it might be over specified when compared to other variants. Specifically, it adds 6 times 2 parameter vectors to the base model, such that we estimate (around) ten parameters for each commodity from 156 observations. Both in the groups of model variants using one factor or two factors, the religious norm and the demographic variables tend show the best values for the model selection statistics.

Overall, the three factor model using the religious norm, the climate factor and demographic attributes gives the best AIC criterion. Its LLF and the system wide R^2 are close to the full model, but its AIC and SC selection criteria are considerably better. We therefore consider it the most suitable candidate based on the model selection statistics. The SC criterion would favour the model without any additional factors. But, as expected, the System wide R^2 and the value of the likelihood function put it on the last position.

Table 5. Model selection statistics.

	LLF	System R^2	SRMSE	AIC	IIA	SC
Base	11.219	45,3	2,86	-142,9	9,47	-141,4
Norms	11.295	48,6	**2,75**	**-143,4**	9,01	**-141,3**
Demography	**11.326**	**49,5**	**2,75**	-143,3	**8,83**	**-140,5**
Sea access	11.252	46,5	2,82	-142,8	9,22	-140,7
Climate	11.275	47,7	2,80	-143,1	9,07	-141,0
Gini	11.260	47,1	2,82	-143,0	9,26	-140,8
Norms + Demography	**11.379**	**51,3**	**2,68**	**-143,6**	**8,53**	-140,0
Norms + Sea acess	11.328	49,7	2,72	-143,4	8,74	-140,5
Norms + Climate	11.345	50,5	2,71	**-143,6**	8,68	**-140,7**
Norms + Gini	11.328	50,0	2,73	-143,4	8,82	-140,5
Demography + Sea acess	11.360	50,5	2,72	-143,3	8,60	-139,7
Demography + Climate	11.367	50,8	2,72	-143,4	8,54	-139,8
Demography + Gini	11.359	50,6	2,72	-143,3	8,62	-139,7
Sea acess + Climate	11.302	48,7	2,77	-143,0	8,86	-140,2
Sea acess + Gini	11.290	48,2	2,79	-142,9	9,04	-140,0
Climate + Gini	11.300	48,6	2,78	-143,0	9,12	-140,1
Norms + Demography + Sea acess	11.413	52,4	2,66	-143,5	8,28	-139,3
Norms + Demography + Climate	**11.425**	**52,6**	**2,65**	-143,7	**8,25**	**-139,4**
Norms + Demography + Gini	11.405	52,2	2,66	-143,4	8,34	-139,2
Demography + Sea acess + Climate	11.395	51,6	2,70	-143,3	8,39	-139,0
Demography + Sea acess + Gini	11.390	51,5	2,70	-143,2	8,40	-139,0
Sea acess + Climate + Gini	11.327	49,6	2,75	-142,9	8,78	-139,3
Full	11.472	54,2	2,62	-143,4	7,99	-137,7

Source: Own estimation.
Notes: Numbers in bold indicate the best statistic in the group of models and red ones the overall best model.

While the overall model statistics are reported in Table 5, the tables shown in the following report the R^2 for the individual equations as a widely used and easy to interpret statistics to compare the fit, here both across estimated equations in the systems and across competing model variants. For comparison, we add always the system wide R^2.

Table 6 reports in the column "Base" a model using prices and income levels only as independent variables, i.e. the slightly extended MAIDADS model as proposed by Preckel et al. 2010. The best fit is found for "Recreation and culture" with 81% as a clear luxury good, followed by "Fruits and vegetables" by 76%. As seen from Table 6, these product groups also include staple food such as potatoes or root and tubers as classical examples of Barnett's law. This might explain the relatively high fit for that category. Disappointing is the fact that "Furnishings, household equipment and maintenance" even has a negative R^2 while for "Beverages and Tobacco", 8% only of the variance are explained. Similar low fits are also reported in Britz and Roson 2019.

The low explanatory power of the base model for some of the categories motivates considering additional factors which might drive consumption patterns. In order to assess how the additional factors impact results, we estimate versions where each factor is considered without the others, any combination of two or three factors and a full model comprising all of them. Note here that we always consider the two demographic variables jointly.

We first find that adding any additional factor to the base model improves the fit as seen from Table 5. Demography gives the best results of the models with single factors, but is actually introducing two additional dependents variables in the model. While it improves the fit for each single product group compared to the base model, it is not always better than model variants using another additional factor. The best results for any model variant considering one additional factor only are shown in bold in Table 6. This highlights that for eleven out of the nineteen product groups, the two demographic factors give jointly the highest R^2. The share of Islamic population follows with seven groups. Sea, access, climate and the Gini coefficients trail both with regard of the overall fit and with regard to categories where they provide the best fit. However, one needs to consider that demography is based on two additional dependents.

The bad performance of the Gini coefficient - we also tested a variant using logs instead of the linear model for which results are reported – might come as a surprise. One might have assumed that, for instance, higher

Table 6. Fit of different model variants by commodity group, single factors.

	Base	Norms	Demography	Sea access	Climate	Gini
System wide R^2	45,3	48,6	**49,5**	46,5	47,7	47,1
Clothing and footwear	13,4	18,2	**18,4**	13,7	14,8	17,3
Housing, water, electricity, gas and other fuels	45,4	**51,3**	48,7	46,7	46,8	45,7
Furnishings, household equipment and maintenance	-0,5	1,5	**9,9**	0,3	4,8	3,1
Health	65,7	71,5	**71,6**	66,1	70,2	66,5
Transport	32,5	33,7	**38,2**	33,4	36,0	36,5
Communication	26,4	**30,6**	30,2	27,4	30,4	30,3
Recreation and culture	80,9	**85,3**	84,1	81,2	81,5	81,3
Education	29,9	33,6	**35,8**	30,0	31,6	31,7
Restaurants and hotels	34,4	**38,3**	35,5	37,2	37,9	35,7
Rest	74,4	76,0	**76,4**	74,5	75,1	74,5
Cereals	73,1	74,4	**74,6**	**73,4**	73,5	73,2
Meats, eggs	49,4	**49,6**	**49,5**	52,6	49,5	**49,6**
Fish	33,2	34,0	34,4	**38,7**	**37,6**	35,0
Dairy	34,7	38,9	36,0	36,7	39,9	**40,6**
Vegetable oils	63,0	**63,7**	**63,1**	63,2	63,3	63,2
Fruit & veg	63,7	**65,2**	64,8	63,9	65,1	64,2
Sugar	60,9	61,2	**65,2**	62,3	61,3	60,9
Other food	61,6	61,8	64,1	63,6	62,5	**65,6**
Beverages and tobacco	8,5	16,5	**23,5**	14,2	16,5	14,1

Source: Own estimation.
Notes: Numbers in bold indicate the best fit in the group of models.

income inequality at low income levels might increase the observed budget share of luxury goods. A potential explanation why the Gini coefficient does not improve the fit strongly might be that the impact of, for instance a small group of rich households, on average spending shares of the aggregate might still be rather limited.[6]

Results for individual commodity groups of the models which consider two factors jointly are shown in Table 7. Here, combining the two demographic variables with the share of Islamic population gives the best fit based on the system wide R^2, closely followed by adding the mean temperature to them. Equally, the best fit found for any of the different product groups is more equally distributed over the different model variants. While the best model considering one of the factors adds around 4% to the overall R2 of the base model (see Table 6), considering two jointly improves at best by around 6%.

Results for the models which consider three factors jointly are shown in Table 8. Perhaps as expected from the results found for single additional factors, combining the share of the Islamic population with the two demographic variables and the mean temperature to control for climate effects gives the best fit. It misses the fit of the model will all factors (i.e. adding the Gini coefficient and the sea access indicator as well) by less than just 2%. This full model performs considerably better for "Clothing and footware" (+5%), "beverages and tobacco" (+4%) and "Meat and eggs" (+4%) compared to this best candidate model with three additional factors. It is interesting to see that simpler models give a better fit in two cases compared to the full specification, for which the fit is shown in bold if it is better than any other specification.

Besides considering the model selection statistics from Table 5 and considerations of the fit for individual model groups, the choice of a suitable model variant depends also on how its estimates can be integrated into long-run simulations with a CGE. Suitable variants comprise factors which are likely rather stable over time or are explicitly controlled by dynamic updates. As the IASSA data base reports projections of the demographic composition of the population for all countries and the different SSPs, the two demographic factors are obvious candidates. They also have shown to improve con-

[6] We also tested with gini coefficient provided by UN with quite similar results.

Table 7. Fit of different model variants by commodity group, two factors.

	Norms Demog	Norms Sea acc	Norms Climate	Norms Gini	Demog Sea acc	Demog Climate	Demog Gini	Sea acc Climate	Sea acc Gini	Climate Gini
System wide R^2	**51,3**	49,7	50,5	50,0	50,5	50,8	50,6	48,7	48,2	48,6
Clothing and footwear	18,7	18,4	18,7	19,9	19,3	**20,6**	19,9	15,3	18,0	17,7
Housing, water, electricity, gas and other fuels	**51,9**	51,7	51,5	50,9	49,0	49,0	48,9	47,4	46,9	46,9
Furnishings, household equipment and maintenance	10,4	2,0	6,7	4,2	10,4	**12,0**	11,4	5,9	3,6	6,0
Health	**73,1**	71,4	72,9	71,1	71,8	72,5	71,9	70,4	66,6	70,1
Transport	**40,3**	34,5	37,6	37,3	38,8	38,9	39,0	38,3	37,5	37,7
Communication	31,4	32,1	**33,4**	32,8	30,9	33,2	32,0	30,3	30,9	32,0
Recreation and culture	**86,4**	85,6	85,4	85,3	84,3	84,2	84,2	81,8	81,6	81,6
Education	**37,2**	34,1	34,9	35,4	35,9	36,7	36,8	32,4	31,8	32,4
Restaurants and hotels	38,6	42,0	**44,6**	39,8	39,5	43,9	39,0	39,3	37,8	38,1
Rest	**76,9**	76,0	76,2	75,8	76,3	76,3	76,5	75,3	74,7	75,0
Cereals	**76,6**	75,0	74,8	74,7	75,5	75,5	75,4	74,1	73,5	73,9
Meats, eggs	50,2	**52,7**	49,9	49,8	52,5	50,2	50,7	52,1	52,6	49,7
Fish	35,2	**40,1**	38,5	35,5	39,4	39,5	37,0	**40,1**	39,7	38,3
Dairy	**42,9**	41,0	45,1	42,2	37,6	39,5	41,9	40,2	41,5	42,8
Vegetable oils	64,2	63,7	64,1	**64,3**	63,1	63,4	63,2	63,8	63,3	63,8
Fruit & veg	**67,6**	65,6	66,3	66,3	65,3	66,0	65,9	64,8	64,6	65,8
Sugar	66,0	62,6	61,5	61,4	66,3	**66,6**	65,5	62,2	62,4	61,5
Other food	64,4	64,1	62,6	66,0	67,1	64,7	67,2	64,2	67,0	65,8
Beverages and tobacco	25,2	20,6	21,5	21,4	**26,9**	24,7	24,3	19,6	18,4	17,9

Source: Own estimation.
Notes: Numbers in bold indicate the best fit in the group of models.

siderably the fit either alone or combined with others. The share of the Islamic population in a country could clearly change when simulating over multiple decades into future, but cultural habits related to current or former shares of Islamic population are properly more stable. It seems therefore defendable to use the share of Islamic population as well as an additional control. Finally, mean temperatures can be either considered stable or updated according to climate change projections. Considering both factors besides the demographic ones clearly could improve the model selection satistis and the fit of most commodity groups. While in some cases, considering the Gini coefficients gave best results for certain categories, the Gini coefficient is likely to change if average per capita income increase considerably over the projection period and is therefore here excluded. Sea access seems mostly to impact fish consumption and it is likely that the benchmarking process will address outliers here anyhow.

Based on these arguments and the model statistics, we opt for the model specification with uses the two demographic factors, the share of Islamic population and the climate variable as additional explanatory variables.

Table 9 reports the estimated parameters. Quantities during the estimation are expressed in USD dollars per capita and corrected for differences in prices, setting the US price to unity. The commitment terms are all modest to low, when considering that income reaches up to around 55,000 USD in the sample. Generally, the reader should keep in mind the difference between expenditure levels and budget shares. Let us take education as an example: the expenditure at low income levels (250 USD) is based on budget share of around 7%, plus forty dollars committed, i.e. around sixty dollars. At 50,000 USD, the about 5% marginal budget share implies an expenditure of 2,500 USD plus 2,000 USD of committed income, i.e. 4,500 USD. But, production costs and thus prices for educational services are also generally higher in high income countries.

Scatter plots are shown in Figure 1 for non-food and in Figure 2 for food-items jointly with logarithmic regression lines dependent on income. Note that the income axis is logarithmic. The plots highlight two observations. First, the variation in the observed budget shares in countries of the same income range can be rather large, as seen for instance from the panel for the housing costs. There

Table 8. Fit of different model variants by commodity group, three and all factors.

	Norms Demog Sea acc	Norms Demog Climate	Norms Demog Gini	Demog Sea acc Climate	Demog Sea acc Gini	Sea acc Climate Gini	Full
System wide R^2	52,4	52,6	52,2	51,6	51,5	49,6	**54,2**
Clothing and footwear	20,4	20,6	20,4	22,9	21,5	18,3	**25,2**
Housing, water, electricity, gas and other fuels	52,0	**52,5**	52,3	48,9	49,2	47,4	52,5
Furnishings, household equipment and maintenance	10,9	12,8	12,6	12,4	12,0	7,3	**15,8**
Health	73,1	74,1	73,2	72,8	72,2	70,4	**74,5**
Transport	40,8	41,6	40,5	40,7	39,7	40,1	**43,2**
Communication	32,3	34,2	32,5	33,4	32,4	31,9	**35,1**
Recreation and culture	86,4	**86,5**	86,3	84,4	84,4	81,8	86,4
Education	37,7	37,9	38,5	36,6	36,8	33,1	**39,4**
Restaurants and hotels	43,0	46,5	40,4	45,0	41,8	39,5	**47,9**
Rest	76,9	76,7	**77,0**	76,1	76,4	75,2	76,6
Cereals	77,0	77,3	76,8	76,2	75,9	74,5	**78,0**
Meats, eggs	53,7	50,6	51,1	52,9	53,3	52,2	**54,6**
Fish	40,6	40,4	37,3	41,0	41,4	41,0	**42,9**
Dairy	45,5	47,0	46,0	39,4	42,8	43,1	**49,2**
Vegetable oils	64,3	64,7	64,9	64,1	63,3	64,4	**66,1**
Fruit & veg	67,8	68,3	67,9	66,0	66,4	65,7	**68,4**
Sugar	67,0	67,5	66,3	67,4	66,5	62,4	**68,4**
Other food	67,4	65,1	68,1	67,4	69,4	67,6	**70,3**
Beverages and tobacco	28,3	26,8	26,5	28,4	28,0	20,8	**30,7**

Source: Own estimation.
Notes: Numbers in red indicate the best fit in the group of models. Results in bold indicate best value including the full model.

Table 9. Estimated base coefficients for selected model.

	Alpha	Beta	Gamma, lo	Gamma, high
Clothing and footwear	4%	5%	6	136
Housing, water, electricity, gas and other fuels	1,00E-07	20%	121	1.354
Furnishings, household equipment and maintenance	5%	6%	1	158
Health	4%	9%		781
Transport	2%	13%	3	423
Communication	2%	3%		290
Recreation and culture	1,00E-07	6%		133
Education	7%	5%	39	2.037
Restaurants and hotels	0%	6%	5	181
Miscellaneous goods and services	1,00E-07	12%		252
Cereals	10%	1,00E-07	19	
Meats, eggs	12%	3%		203
Fish	3%	1%	1	
Dairy	8%	2%		84
Vegetable oils	4%	0%		
Fruit & veg	15%	1%		131
Sugar	2%	1%		
Other food	13%	3%	7	209
Beverages and tobacco	9%	3%	10	301
Food (sum of the categories above)	76%	15%	37	928

Source: Own estimation.
Note: Model considers two demographic factors and temperature as additional explanatory variables. The gamma parameters are expressed on a per capita basis.

are some observations in the 500 USD range where just 5% are spent on housing, whereas the average household in others countries spends 30%. At the same time, estimates also scatter around the simple logarithmic regression line which reflects the impact of price differences across countries, but also of the other explanatory factors. The diagrams also highlight the usefulness of the using the exponential marginal budget lines of the AIDADS system to capture, for instance, the clear saturation effect seen for cereals in Figure 2. For meats and eggs as well as dairy, the plots suggest that budget shares first increase up to around 2000 USD to drop afterwards.

Figure 3 shows the expenditure shares resulting from the AIDADS estimation, for income levels between 250 and 50,000 USD evaluated at mean prices and mean explanatory factors. At very low income levels, more than a third of the income is dedicated to food (37%), around 13% is spent on housing and 8% on transport, 5% on furnishing, household equipment and maintenance and 2% on health. At very high expenditure levels, the share for food drops to about 17%, while shares for housing increase moderately to around 16%. Shares for health care are more than tripling, reaching 11%, whereas for restaurants and hotels they increase by a factor five, from 1.7% up to 7%. A similar large increment is observed for "Recreation and culture" growing from less than 1.6% to over 7%.

An interesting observation is the rather drastic change in budget shares for some product groups when moving from 250 USD to 1000 USD per capita and year. Housing cost half from 37% to 18%, while expenditures for food change only slightly. Instead, budget shares for health (1.7% versus 5.6%), communication (0.08% to 2.3%), Furnishings (2.2% to 4.3%), Transport (2.8% to 6.7%), Recreation and culture (0.5% to 2.3%) and other items (0.9% to 4.6%) increase substantially. That underlines that at very low incomes, expenditures are concentrated on food, shelter and utilities, where the later might serve also as input into, for instance, food preparation in the household, which is outsourced at higher income levels.

Figure 4 below provides more detail for food categories in the AIDADS system by reporting shares on total food expenditure. At very low income levels, cereals have the highest shares with around 28%, followed by the other food category (19%) which comprises, for instance, bread, and 12 % are spent on fruits and vegetables. Expenditures on meat in total food consump-

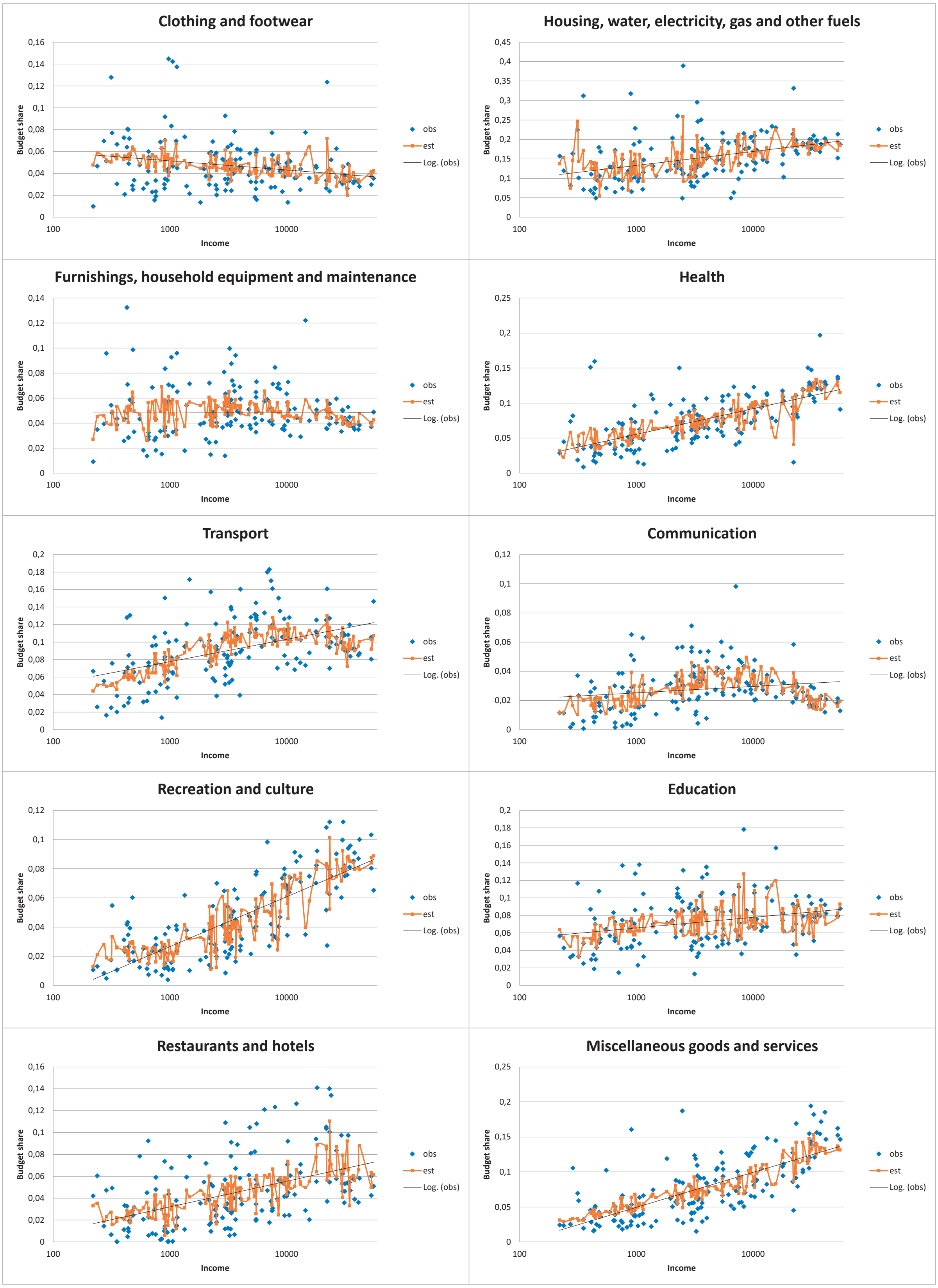

Figure 1. Scatter plots, Non-Food items.

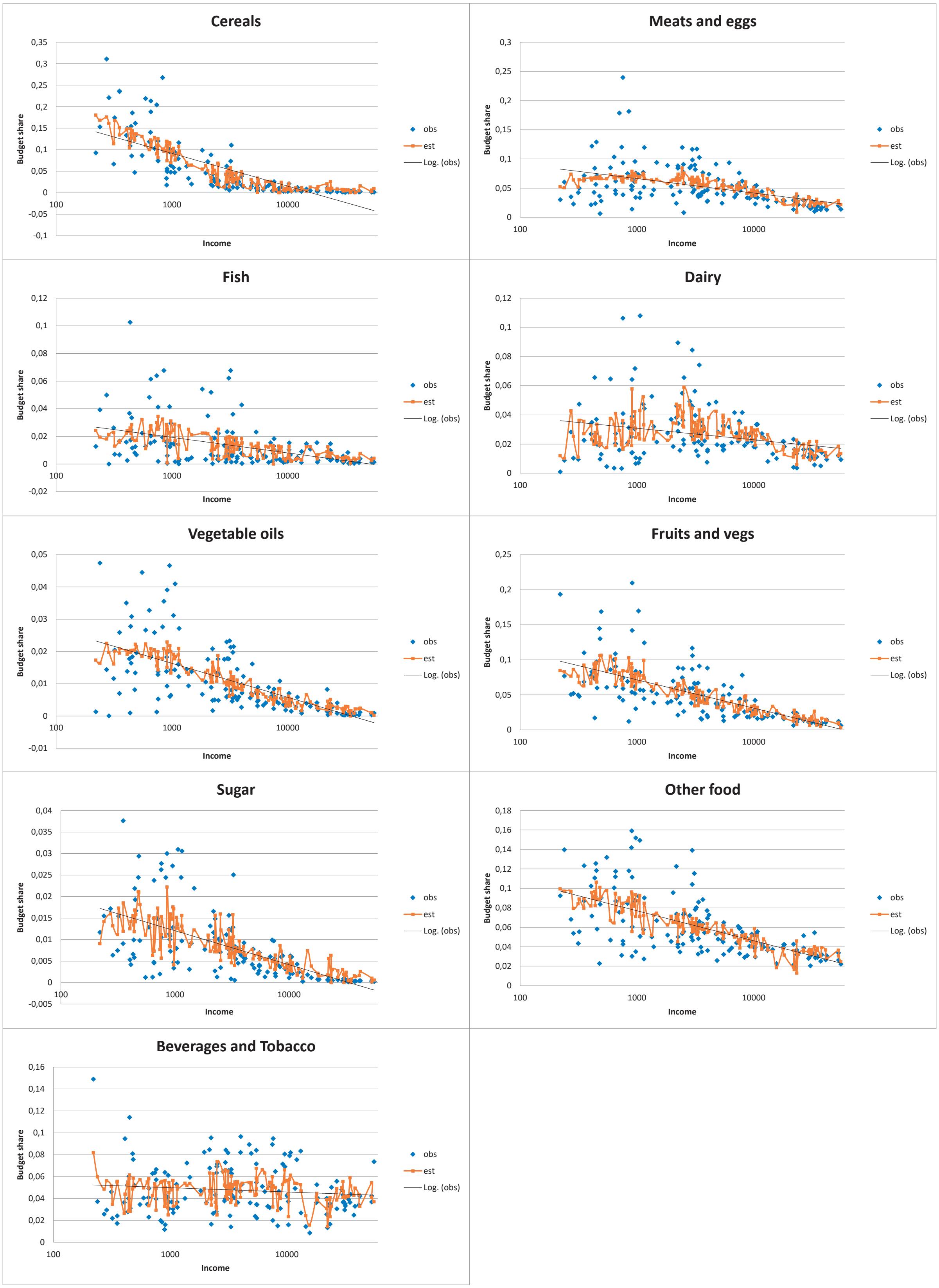

Figure 2. Scatter plots, Food items.

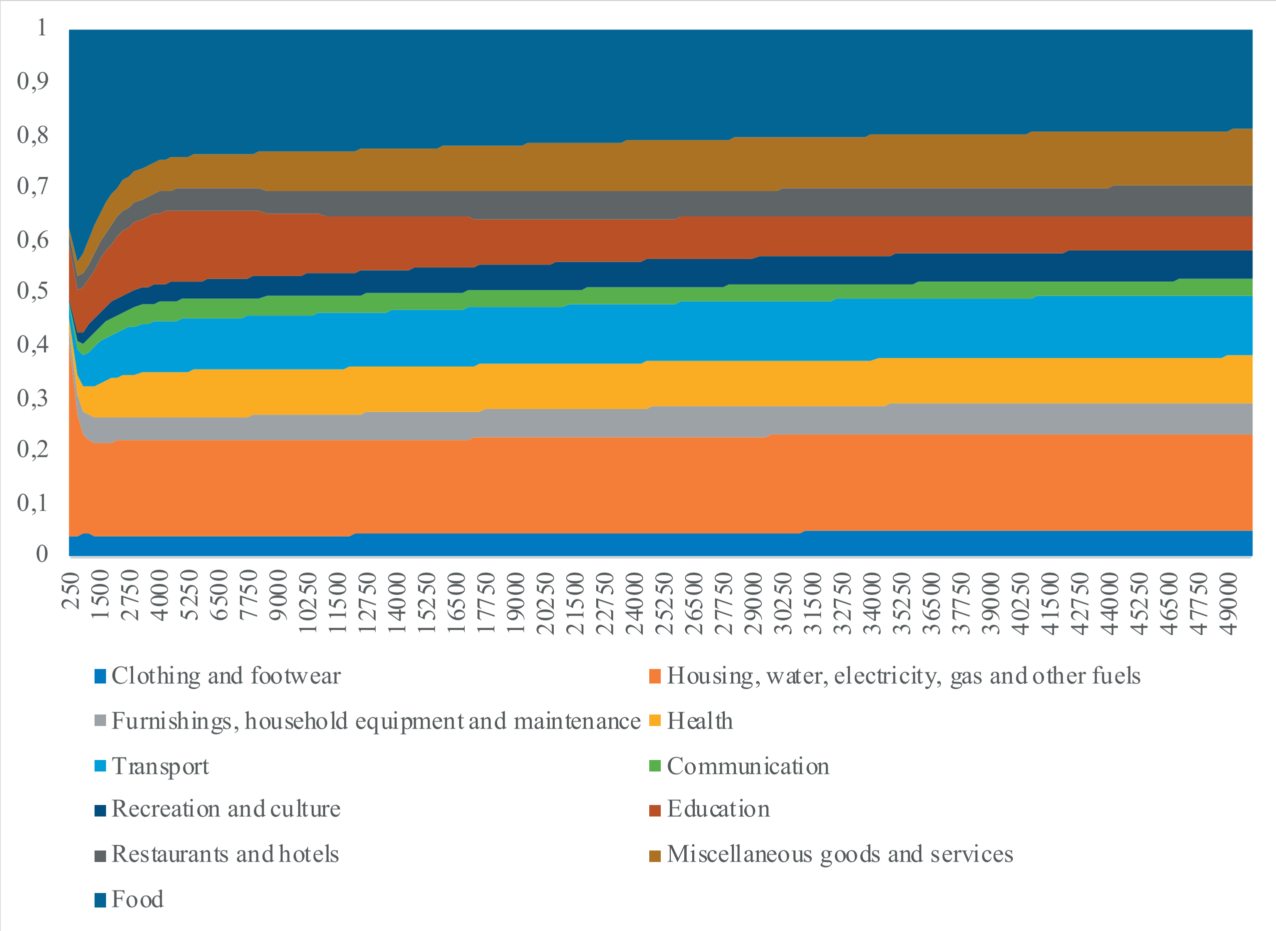

Figure 3. Simulated expenditure shares, non-food items and total for food. Note: Calculated at mean sample prices and mean sample values of the additional factors.

tion are estimated at 10%, while dairy accounts for 7% at such low income levels. There is again a distinct difference between the 250 USD to the 1000 USD consumption pattern, as the cereals share is halved to 14%, while the share of meat (+6% to 16%) and dairy (+3% to 10%) increase considerably. At very high incomes, other food (22%) followed by meat (18%) and beverages and tobacco (18%) are the largest expenditure groups inside the food bundle. The cereal shares on total food expenditure is still 3%, but the overall drop of the budget share of food implies that a very high income levels, less than 1% of the income is spent on cereals.

The income dynamics become also visible from the Engel curves shown in Figure 5. Recreation and culture as well as the other service category show very high Engel elasticities at low income in the range of five. Interestingly, at high income levels, education and communication have elasticities below unity, different from all other non-food items.

For the food items, cereals show negative Engel elasticities over a wider ranger of the income variation. Below 100 USD, basically all food items besides cereals are luxury goods, as indicated above, this becomes possible by a quite low income elasticity for housing expenditure, also visible from the upper panel. But food item elasticities drop rapidly below 0.5 around 1000 USD, with the exemption of beverages and tobacco as well as meat and eggs, and increase slightly again up to income levels around 5.000 USD. A potential reason is the falling elasticity for housing costs suggested by the upper panel. Above 1000 USD yearly per capita income, none of the food items is a luxury good any longer and the crop based food items with the exemption of sugar have elasticities below 0.5. The reader should keep in mind that these estimates also capture the effect of compositional changes, for instance, the average household in a rich country spent income on imported fresh fruits and vegetables, while in poor countries, this product

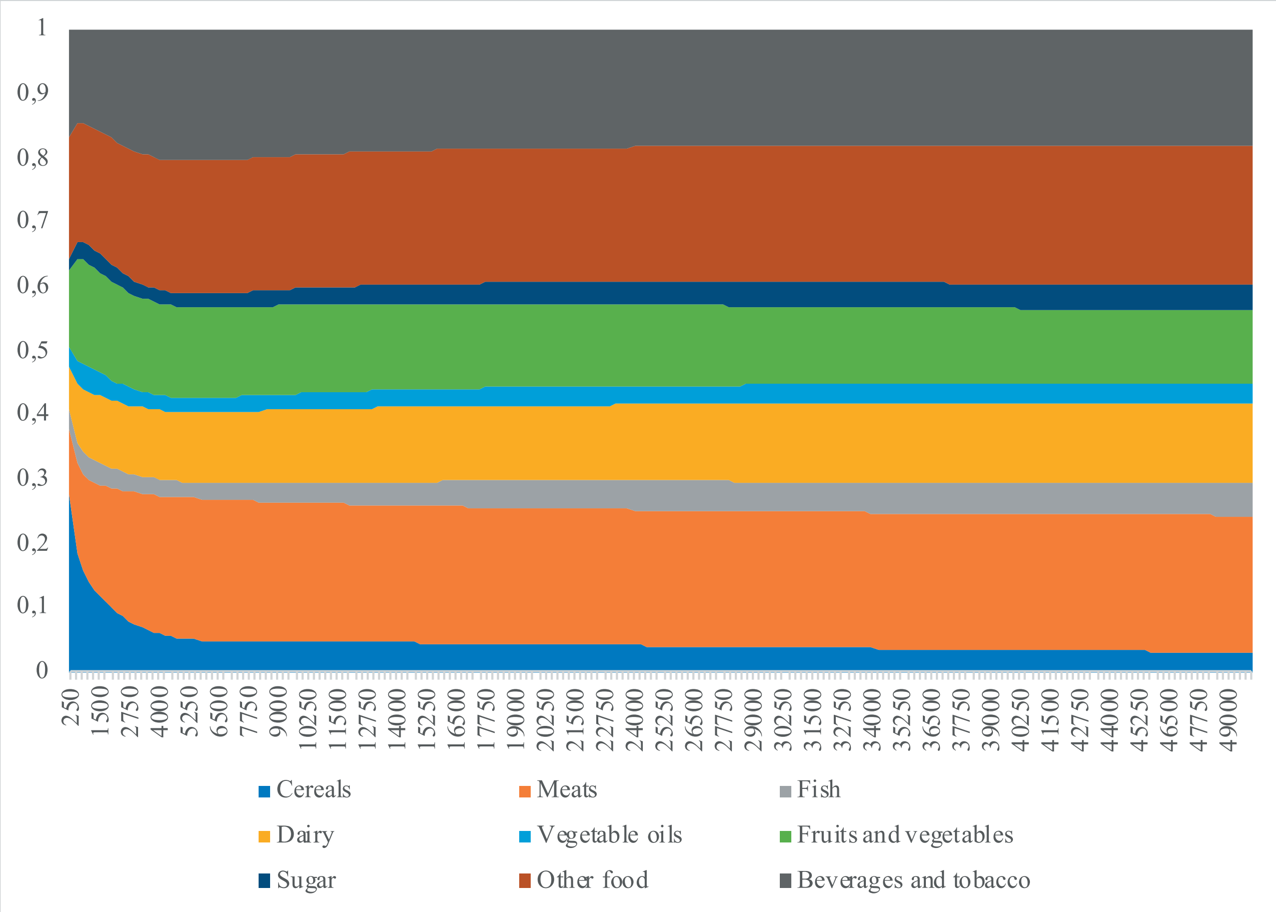

Figure 4. Expenditure shares for food categories. Note: Calculated at mean sample prices and mean sample values of the additional factors.

group might mainly comprise locally available roots and tubers.

6. DISCUSSION

A suitable specification for aggregate household demand in a CGE model needs to reflect the targeted applications. For detailed policy analysis such as changing subsidies and/or taxes differentiated across energy carriers, income changes are mostly limited and the focus is rather on own and cross price effects. This motivates the use of nested demand systems e.g. in the GTAP-E (McDougal and Golub 2007) model to capture in detail substitution effects between different energy carries. We focus instead on long-run analysis with large income dynamics which motivates the use of the MAIDADS functional form.

Stronger Hicksian substitution effects between the commodity groups considered in here are not very likely such that second-order flexibility with regard to prices is probably not needed to identify the Engel curves. This motivates also the use of a simpler additive utility function. In this respect, we don't follow the argumentation line of Reimer and Hertel 2004 who consider the AIADS as not appropriate for more than ten product categories in estimation, an argument which would also apply to an LES or CD specification. As the G-RDEM model as our main application target also uses CES nests to substitute between different cereals and between different meats, we deliberately aggregate here beyond the individual GTAP sectors in the estimation as discussed above. Differentiating to individual cereals or meats would indeed render the use of an additive demand system dubious. An estimation exercise of an MAIDADS system for food only by Gouel and Guimbard 2019 estimates calorie demands for seven food categories, introducing hence similar detail for food as in our exercise, however estimating demands based on producer prices.

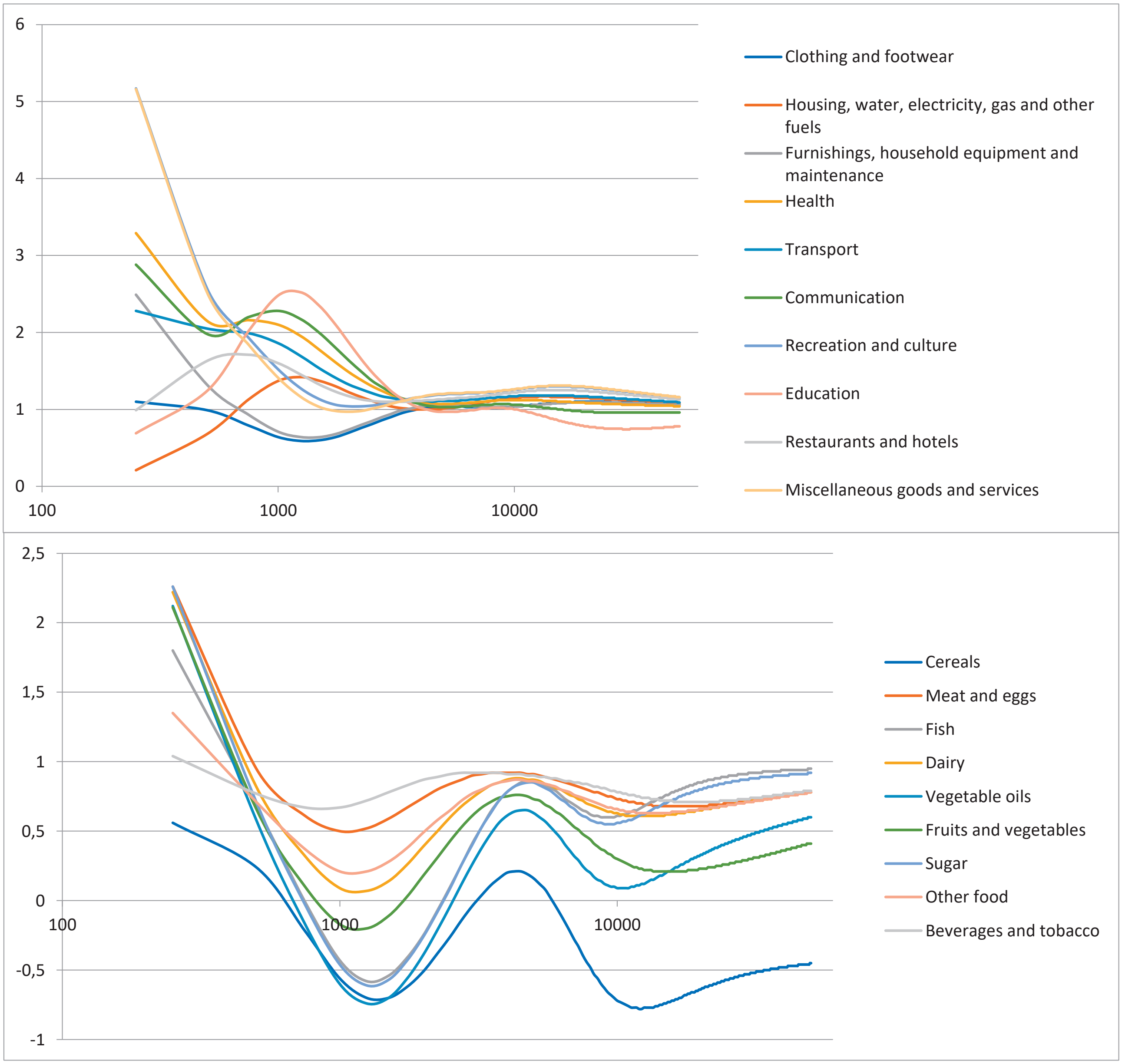

Figure 5. Estimated Engel elasticities at mean prices. Note: Calculated at mean sample prices and mean sample values of the additional factors. Formula based on Preckel et al. 2010.

We opted in here to render marginal budget shares depending on additional factors besides prices and income. Alternatively, the commitment terms could be updated. Using the marginal budget shares has the advantage that additivity can be imposed on the impact of these additional factors. This at least prevents that more unusual observations for the additional factors can provoke e.g. negative consumption quantity estimates, or that the non-committed income overshoots the observed one when commitment terms are increased. The estimates for the commitment terms (see Table 9) suggest that they are all mostly small compared to income levels. At least for the vector at low utility, that is not an astonishing outcome as estimation of negative budget shares is not allowed even at the quite low minimal per capita income levels in the estimation. Here, neither larger increases of the commitment terms nor larger decreases are able without violating the non-negativity condition, while updates to the marginal budget share cannot provoke problems in that respect.

Switching to, for instance, a QUAIDS to better capture cross-price effects while also considering some additional factors would introduce many new parameters in the estimator. The review of Ho et. al. 2020 of demand systems in CGEs mentions only one example (Jorgenson et al. 2013, a dynamic single country CGE for the US) where a rank 3 Translog demand system is used which gives also flexibility for coss-price effects, however for four aggregate expenditure groups, only, which are further dis-aggregated to more detail based on homothetic functions. Given the non-homothetic character of e.g. food expenditure groups above, a nested approach where the lower nests assume homotheticy is probably less appropriate for our exercise. Vigani et al. 2019 estimate a QUAIDS for Kenya with detail for food, but only mention that this can improve economic models without discussing how. It is also interesting to see that in their estimation, the QUAIDS gives for most product and product groups income elasticities quite close to unity. Their hierarchical demand system layout might render it hard to link their results into CGE models, especially if flexible aggregation with regard to commodity is maintained, as in case of the GTAP family of CGE models. Furthermore, given the often high correlation between prices and income levels in our cross-sectional data where time variability of prices is missing, it could be challenging to introduce a non-additive demand system with full flexibility for price effects

Several statistic packages allow estimation of a (non-linear) system with parameter restrictions. For highly non-linear specifications such as in here, convergence and feasibility issues with the solvers inbuilt in these packages are not uncommon. It is therefore not astonishing that all authors estimating (M)AIDADS systems (Reimer and Hertel 2004, Preckel et al. 2010, Roson and Van der Mensbrugghe 2018, Britz and Roson 2019) rather use GAMS to access robust NLP solvers such as CONOPT. Estimating one of the more detailed systems in here requires up to 10 minutes of computing time using the parallelism of CONOPT4 on a fast four core machine. We consider a larger-scale bootstrapping exercise to determine the distribution of the parameters and p-values as not feasible. Arata and Britz 2019 propose instead to construct a Fisher information matrix by simulating the error terms at changed parameters. While this would be computationally feasible, we don't consider that the additional coding efforts would help us in better assessing the choice of models.

SUMMARY AND CONCLUSION

We present an estimation of an extended MAIDADS demand system from global cross-sectional data. Existing literature in this field is extended in multiple dimensions. Compared to Britz and Roson 2019 who use the same data set, we integrate the extension proposed by Preckel et al. 2010 to render the commitment terms depending on utility. In both Britz and Roson 2019 and Preckel et al. 2010, only prices and income are used as independents while we now also consider demographic factors, the share of Islamic population to control for religious norms and cultural habits, mean temperature to check for climatic influences and test if access to sea and the Gini coefficients have a systematic impact on consumption shares. According to our knowledge, this is the first time that the (M)AIDADS specification is extended in these respects. Compared to Reimer and Hertel 2003 or Preckel et al 2010, we also introduce more detail for food expenditure and render the functional form somewhat more flexible. We find that especially demography, religious norms and temperature considerably improve the fit in our global cross-sectional analysis. We compare different model variants, considering only one, two or three factors in combination compared to the base model and a variant with all factors. Considering model selection statistics and the need to integrate estimates into long-run dynamic long run analysis with a CGE model, we opt for a version where demography, religious norms and mean temperatures are maintained as additional factors. Data selection and definition of food categories in here reflects our aim to integrate the estimates in a global dynamic CGE model. We deliberately removed some detail for food available from the underlying data set to render Hicksian substitution effects between groups less likely, to better motivate the use of an additive demand system. Substitution effects are instead considered by CES nests in our simulation model. Our estimation has the potential to improve the representation of demand dynamics in global long-run analysis. Further work could introduce more detail in so far more aggregated consumption categories such as the costs of housing.

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The evolution of organic market between third-party certification and participatory guarantee systems

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Abstract. Quality assurance is a dominant feature of organic production and, currently, third-party certification is recognized as the official authenticity assurance strategy by the majority of worldwide organic regulations. This model, however, is less accessible to smallholders because it is costly and its application time-consuming. Furthermore, this certification system has been accused on several fronts to be responsible for the standardization of the organic production process leading to a "conventionalization" of organic productions. Contextually, in several countries, groups of small producers have started to implement alternative quality assurance systems for their organic products, better known as Participatory Guarantee Systems. Research to date has not yet determined how these models can survive within a highly competitive market such as that of certification. In this framework, the paper aims to theoretically unveil and explain the alternative certification phenomenon and its coexistence with third-party certification by applying an evolutionary game (rationally bounded agents that adopt the more rewarding strategy). The results of simulations suggest that symbolic attributes such as localness, healthiness, quality, producers and consumers embeddedness can differentiate products guaranteed by alternative schemes, meeting consumers' preference. The discussion of findings provides an assessment of the performance of both quality assurance systems, explain their coexistence within the organic market, identify critical aspects, and suggest some policy implications.

Keywords: organic market, certification system, Participatory Guarantee Systems, Evolutionary Game.
JEL codes: C73, O13, Q01, Q12, Q13.

1. INTRODUCTION

Recent trends in the analysis of organic food led to a proliferation of studies closely related to the process adopted for ensuring the integrity and authenticity of organic products (Hatanaka et al., 2005; Vogl et al., 2005; Zorn et al., 2012; Bauer et al. 2013; Janssen and Hamm, 2014; Veldstra et al., 2014). The mainstream approach is the so-called Third-Party Certification

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(TPC) which plays, among others, an important role for consumers in proving organic food authenticity. In general terms, in TPC an independent private body verifies the production process of a good and independently determines if the final product complies with organic standards. The verification typically includes comprehensive formulation/material reviews, testing as well as facility inspections. If the verification obtains a positive assessment, products bear the right of the organic logo usage on their packaging that can help consumers and other stakeholders to make oriented purchasing decisions. Currently, many organic regulations worldwide adopt TPC as their official authenticity assurance strategy (National Organic Program of USDA, European Union Council Regulation (EC) No. 834/2007, Japanese Agricultural Standards, Australian National Standard for Organic and Biodynamic Produce, etc.). In several developing countries organic-certified products have been growing in recent decades with the purpose of being exported to European and North America markets (Ayuya et al., 2015) gaining a price premium. Furthermore, TPC is beyond question less accessible to worldwide smallholders, both in terms of the big amount of time required to the accomplishment of the paperwork, and in economic terms because of its costs (Harris et al., 2001; Milestad and Darnhofer, 2003; Vogl et al., 2005; Courville, 2006; Eernstman and Wals, 2009). Finally, it has emerged a debate on the evidence that certification and standardization of organic production have led to unintended consequences towards a new form of governance (Guthman, 2004; Vogl et al., 2005; Courville, 2006), from the movement-oriented to the market-oriented organic production practices. In the same vein, other authors argue that the standards set by the organic regulations brought to a "corporatization" of organic agriculture (de Lima et al., 2021) which threaten the original principles of the organic movement of health, ecology, fairness, and care towards a more process-based production system. In other words, and according to Courville (2006), "Paradoxically, the regulatory systems that were developed to protect the integrity of organic agriculture including standards-setting and conformity assessment systems are now reshaping the organic landscape in ways that threaten many of the values held by the movement that created it." (p. 201).

In the attempt to cope with these problematic issues, in several countries, groups of small producers have started to implement "alternative" quality assurance systems for their organic productions. There are two main alternative certification and guarantee systems to TPC, better known as Internal Control Systems (ICS) and Participatory Guarantee Systems (PGS). ICS, or Group Certification, "was originally created to increase equity and access of smallholder to certification schemes" (Pinto et al., 2014, p. 60). It consists in the development of cooperatives, associations, or networks of farmers that voluntarily adhere to common organic production standards (usually based on national regulations). Afterward, an independent certification body verifies the process functioning as well as a limited number of randomly selected companies/farmers. The results of the inspection, in both positive and negative cases, affect the whole group. Adopting such a quality assurance scheme simplifies certification procedures for smallholders, who are often unfamiliar with all the paperwork required for third-party certification requests. In addition, it is more affordable compared to the mainstream certification model. ICS is used primarily by smallholders of developing countries willing to access the markets of developed countries for the price premium advantage linked to organic production (Latynskiy and Berger, 2017).

On the other hand, according to the official IFOAM definition, PGS are "locally focused quality assurance systems. They certify producers based on the active participation of stakeholders and are built on a foundation of trust, social networks, and knowledge exchange" (IFOAM Official definition, 2008). IFOAM Organics International provides further details by describing such initiatives as "a verification system to ensure that a produce is organic. It is an alternative to third party certification for organic products, especially adapted to local markets, small farmers and short supply chains. They allow certified organic produce to be available to a wider consumer group, at a lower cost". Also, "PGS initiatives involve groups of farmers and groups of consumers; they are normally supported by an NGO or local association that provides the participants with administrative and technical help" (IFOAM Organics International).

To the best of our knowledge, the PGS approach has been widely observed empirically, nevertheless, a theoretical framework or a modelling effort suitable for the interpretation of these phenomena is still missing in the academic international literature.

In this perspective, the present paper aims to propose a mathematical modelling framework by using the Game Theory approach to assess and explain PGS model, in the attempt to shed light on its coexistence within a highly competitive market such that of certification. Examples of evolutionary games application do exist in academic literature. Indeed, thanks to its adaptability, the evolutionary context has been applied to several topics as well as to environmental economics and agricultural markets (Antoci and Bartolini, 2004; Antoci et al., 2013; Blanco and Lozano, 2015; Antoci et al., 2019).

On the contrary, its application to organic market and organic certification represents a novelty which allow us to a) analyse the evolution of the share of PGS firms within the organic market; b) study the bounded rationality of small firms which usually characterize organic market (Bonfiglio and Arzeni, 2020); c) present some implications on the market composition due to the comparative dynamics performed by changing parameter values of the model.

The reminder of the paper is organized as follows: Section 2 provides an overview of worldwide PGS development, the main features and functioning mechanisms as well as an outline on academic literature focused on these initiatives. It then will go into presenting the model in Section 3, its dynamic regimes in Section 4, while Section 5 provides a discussion of the main economic results together with some policy implications. Finally, in Section 6 conclusions are drawn.

2. PARTICIPATORY GUARANTEE SYSTEMS FOR ORGANIC PRODUCTS

The pioneering experiments that led to PGS development date back to the 1970s and were linked to a growing interest towards agroecological principles in general (Altieri, 1987; 1995) and organic agriculture in particular.

The first communities of organic producers consisted of family farmers and small companies interested in methods of production aimed at the promotion of social and environmental sustainability. The achievement of their objectives implied the development of a strategy to make their products recognizable to consumers.

These communities have been growing over the decades, stimulating a great debate around the need to formalize their work and their alternative actions in both developing and developed countries. In 2004, the first International Conference on Alternative Certification was organised by the International Federation of Organic Agricultural Movement (IFOAM) and the Latin American and Caribbean Agro-Ecological Movement (Movimento Agroecologico de America Latina y el Caribe, or MAELA) in Brazil.

Although different methodology could be applied and norms and processes might vary, the key features of PGS remain consistent worldwide. In general terms, PGS are usually based on the IFOAM International Organic Standards, and they require the involvement of *all* actors within the production process and along the supply chain (from producers to consumers) by taking place at the community level. A PGS model aims at minimizing bureaucratic procedures and costs (in economic terms) by employing simple verification methods. It also incorporates elements of environmental and social education towards quality improvement for both producers and consumers. The basic common elements of several PGS initiatives are the following: i) a participatory approach; ii) social control; iii) a shared vision and shared responsibility among stakeholders regarding quality, transparency, trust building, and reinforcing mechanisms; and iv) a non-hierarchical relationship between stakeholders (Fonseca, 2008; IFOAM, 2008). Furthermore, a key feature of PGS models relates to the close relationship between producers and consumers, or co-producers. The process, in fact, involves direct selling allowing the reduction of transaction costs. In this way, as also experienced by Fair Trade practices, producers obtain a higher price by decreasing the numbers of middlemen, and this effect decreases contextually the price of organic products, with a positive impact for the final consumers. In a sense, in absence of an alternative procedure for quality assurance, in most cases, the possibility of access the (local) market is excluded to disadvantaged and/or small producers (Nelson et al., 2010; IFAD, 2004) and it also threatens the possibility of purchasing organic products by potential local consumers. In other words, the mission, and at the same time the challenge of PGS, is favouring and facilitating smallholders' production towards the promotion of local food systems that meet agroecological principles, biodiversity protection, workers' rights, and an easier access to organic food.

These schemes are quite popular in less developed countries such as Brazil, India, and Costa Rica, but there are also several cases of PGS adoption in Western countries like the United States, France, New Zealand, and Italy. The most famous networks adopting PGS are the Brazilian Rede Ecovida de Agroecologia, Certified Naturally Grown (USA), Nature et Progrès (France), Keystone Foundation (India), Organic Farm NZ (New Zealand).

Recently, the IFOAM has developed a navigable map sponsored by the Food and Agriculture Organization of the United Nation (FAO) which records worldwide PGS initiatives. Figure 1 reproduces a static image of it.

Through this map, it is possible to find PGS projects at a global level, as well as the number of producers certified by PGS schemes by different countries. The yellow pointers define self-declared PGS initiatives (operational or under development), the green ones PGS projects officially recognized by local authorities, while the blue pointers define PGS models recognized by IFOAM. According to the data collected in 2019 by IFOAM (IFOAM Global PGS Survey, 2019), at least 223 PGS initiatives have been recorded at a global level. These projects involve about 567.142 farmers and spread over 76

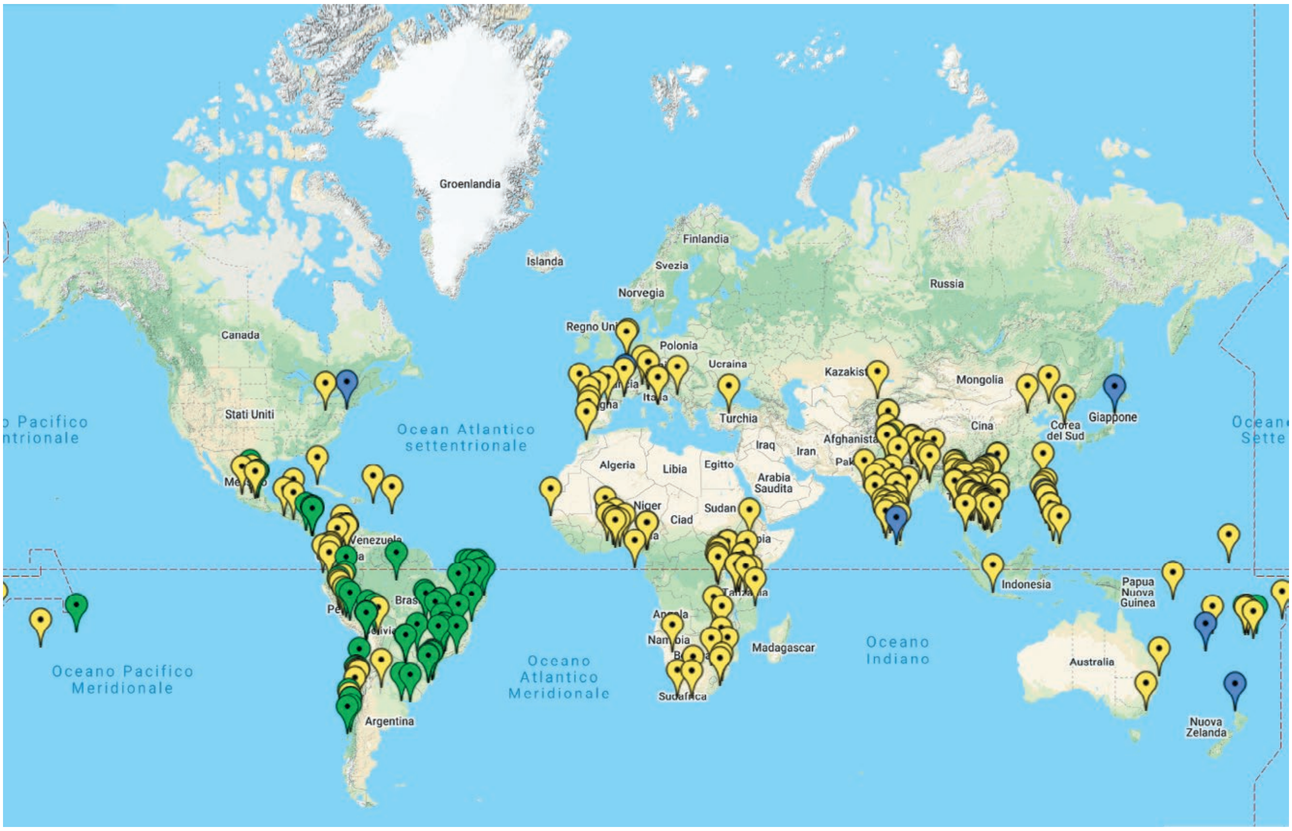


Figure 1. Worldwide PGS distribution. Source: IFOAM website (https://pgs.ifoam.bio/).

countries. Since the submission to the IFOAM Global survey (and the consequent registration within the IFOAM database) is on a voluntary basis, it is reasonable to assume that the numbers reported are underestimated (Sacchi, 2015; 2019). In some cases, PGS initiatives (such as the Brazilian and French ones) are older than national organic regulations, establishing third-party certifications as the official guarantee system, and in some countries (especially in Latin America) PGS are officially recognized in national organic regulations and, in these cases, PGS are also defined as Participatory certification.

But how do PGS function in practical terms?

Usually, farmers are organized into local groups that have the responsibility to ensure that all participants adhere to the PGS principles and processes. Each farmer receives an annual visit at least by one peer, namely another farmer/breeder/bees keeper of the group pertaining to the same product category. Other stakeholders, such as consumers, technicians, support staff of NGO, can join, and they are encouraged to do so, the peer during the visit. Results of these visits are documented and serve as the basis for the group of farmers to take decisions on the certification status of each network member. A summary of the documentation and the outcome is communicated to a higher level, for example, to a National or Regional Council. The Council approves/denies the certification decision taken by the groups or, more generally, allow/reject the use of the PGS logo, if any, to each local group.

As far as academic literature is concerned with PGS phenomenon, it mainly focuses on producers' motivation in PGS adoption (Zanasi et al., 2009; Binder and Vogl, 2018; López Cifuentes et al., 2018; Kaufmann and Vogl, 2018; Fonacier Montefrio and Johnson, 2019), on social innovation, empowerment and spill-overs effects deriving from PGS adoption (Home et al., 2017; Rover et al., 2017; Sacchi, 2019; Lameilleur and Sermage , 2020), on issues linked to consumers attitude and behaviour towards organic products guaranteed by PGS (Sacchi et al., 2015; Kaufmann and Vogl, 2018; Sacchi, 2018; Carzedda et al., 2018) to institutional matters (Fonseca et al., 2008; Nelson et al., 2010; Loconto et al., 2016; Cavallet et al., 2018).

As mentioned above, what is currently missing is a mathematical theoretical model able to capture PGS worldwide initiatives to understand how such systems can survive within the organic market competing with third-party certification.

3. THE MODEL

The model considers the existence of a food organic market composed by a n-size population of firms that assure the authenticity of their organic productions following two possible modes. The first one consists in delegating the certification to a third-party body and paying a certification cost (TPC firms); while the second mode implies the adoption of participatory guarantee strategies (PGS firms).

We assume perfect competition; therefore, farms compete choosing the level of output. Furthermore, we assume that the market is horizontally differentiated. Consumer has a unique reservation price but there is a certain degree of substitution between the goods that determines different output prices (when it is lower than 1). Finally, the third assumption of the model regards the slope of the marginal cost of PGS farms that is greater than the slope of the marginal costs of the TPC farms, therefore produce using PGS mode is more expensive. These assumptions have been introduced for the following reasons:

1) perfect competition is a standard way to model food market,
2) horizontally differentiation can capture a price differentiation between goods (without assuming higher quality from one good, as in vertically differentiation), and
3) the PGS standards can be more stringent than TPC.

Finally, we endogenize the choice to adhere to PGS or to TPC introducing a dynamic selection process, the replicator equation, given by the evolutionary game theory. At each instant of time, farms can revise the mode or adopt a new one, following the differential profits that allow to compare the two strategies[1].

Denoting PGS and TPC firms with subscripts $i = g$, c respectively, and assuming their profit functions as follows:

$$\pi_g = p_g q_g - \frac{e_g}{2} q_g^2$$
$$\pi_c = p_c q_c - \frac{e_c}{2} q_c^2 - \phi q_c \tag{1}$$

where p_g and p_c are the unit prices of the good produced by PGS and TPC firms respectively, e_i>0 is the slope of the marginal cost, q_i represents the quantities produced, and ϕ>0 is the certification cost (ϕq_c is the total certification cots). To consider the higher effort of PGS firms in favour to the environment and workers' rights, as well as to non-financial costs linked to participation, engagement to association, time and efforts to manage visits to peers, it is assumed that $e_g > e_c$.

The market is horizontally differentiated[2], and therefore, it has a unique reservation price and consumers substitute the goods at a certain degree (see, for further details, the seminal work by Spence, 1976)[3]. Denoting with $x \in [0,1]$ and 1-x the shares of PGS and TPC firms respectively, the inverse demand of the goods produced by the firms is given by the following linear functions:

$$p_g = \bar{p} - xnq_g - \alpha(1-x)nq_c$$
$$p_c = \bar{p} - (1-x)nq_c - \alpha xnq_g \tag{2}$$

where $\bar{p}$>0 represents the organic market reservation price and $\alpha \in [0,1]$ is the substitution degree between goods. It is important to underline that if the goods are independent (no substitution), while if α=1, the goods are homogeneous (perfect substitution). The following proposition and corollary hold.

Proposition 1 Let

$$\tilde{x} = \frac{(\bar{p} - \phi)e_g}{[\phi - (1-\alpha)\bar{p}]n} \tag{3}$$

with $\tilde{x}$>0. If x<$\tilde{x}$ then the optimal quantity chosen by PGS firms is:

$$q_g^\star = \frac{\phi + (e_c + (1-\alpha)(1-x)n)q_c^\star}{e_g + (1-\alpha)xn} \tag{4}$$

while the optimal quantity chosen by TPC firms is

$$q_c^\star = \frac{\bar{p} - \phi - \frac{\alpha xn\phi}{e_g + (1-\alpha)xn}}{e_c + (1-x)n + \frac{(e_c + (1-\alpha)(1-x)n)\alpha xn}{e_g + (1-\alpha)xn}} \tag{5}$$

Otherwise, if x≥$\tilde{x}$, then the optimal quantity chosen by PGS firms is:

[1] To learn more on replicator dynamics as well as other selection mechanisms, see, among others, Hofbauer and Sigmund (2003).

[2] Differently, a vertical differentiated market supposes that one good is perceived with higher quality by consumers (see, for further details, the seminal work by Jaskold Gabszewicz and Thisse, 1979).

[3] It is not assumed a different reservation price between goods.

$$\hat{q}_g = \frac{\overline{p}}{e_g + xn} \tag{6}$$

while the optimal quantity chosen by TPC firms is:

$$\hat{q}_c = 0 \tag{7}$$

Proof. Given the value of variable x, the quantities q_g and q_c are chosen according the first order conditions:

$$\frac{\partial \pi_g}{\partial q_g} = p_g - e_g q_g = 0 \tag{8}$$

$$\frac{\partial \pi_c}{\partial q_c} = p_c - e_c q_c - \phi = 0 \tag{9}$$

From (8) and (9) it derives:

$$p_g - e_g q_g = p_c - e_c q_c - \phi$$

and therefore

$$q_g = \frac{\phi + (e_c + (1-\alpha)(1-x)n)q_c}{e_g + (1-\alpha)xn}$$

that is always positive. Substituting (2) and q_g in (9), we obtain:

$$\overline{p} - \phi - \frac{\alpha x n \phi}{e_g + (1-\alpha)xn} =$$

$$= \left(e_c + (1-x)n + \frac{(e_c + (1-\alpha)(1-x)n)\alpha x n}{e_g + (1-\alpha)xn}\right) q_c$$

Solving with respect to q_c, we get:

$$q_c = \frac{\overline{p} - \phi - \frac{\alpha x n \phi}{e_g + (1-\alpha)xn}}{e_c + (1-x)n + \frac{(e_c + (1-\alpha)(1-x)n)\alpha x n}{e_g + (1-\alpha)xn}}$$

which is positive if:

$$x < \tilde{x} := \frac{(\overline{p} - \phi)e_g}{[\phi - (1-\alpha)\overline{p}]n} \tag{10}$$

Conversely, if $x \geq \tilde{x}$, then

$$\hat{q}_c = 0$$

and, consequently

$$\hat{q}_g = \frac{\overline{p}}{e_g + xn}$$

Corollary 2. Assuming $\phi > (1-\alpha)\overline{p}$, then $\tilde{x} > 0$ always. However, $\tilde{x} < 1$ if and only if:

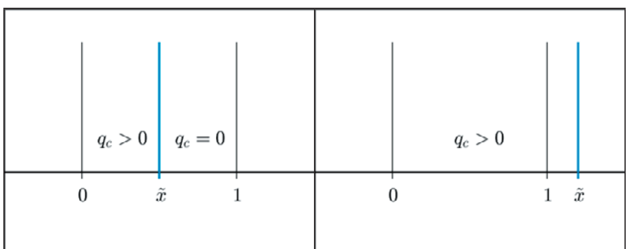
$$\phi > \frac{[e_g + (1-\alpha)n]\overline{p}}{n + e_g}$$

From Proposition 1 it emerges that $q_g > 0$ always, while $q_c > 0$ only if $x < \tilde{x}$. Therefore, if $\tilde{x} \in [0,1]$, then $q_c > 0$ $\forall x \in [0, \tilde{x})$, and $q_c > 0$ $\forall x \in [\tilde{x}, 1]$. Otherwise, if $\tilde{x} \geq 1$, then $q_c > 0$ $\forall x \in [0,1]$. To clarify this point, see Figure 2a-b.

Moreover, from Corollary 2 it is possible to notice that $\tilde{x} \leq 1$ if the certification cost is sufficiently high. This means that ϕ if is relatively low, then $\tilde{x} > 1$ and so $q_c > 0$ in the interval [0,1]. Conversely, if ϕ is relatively high, then $\tilde{x} \leq 1$ and so $q_c > 0$ only in the interval $[0, \tilde{x})$. Therefore, it is possible that in the transitional dynamics TPC firms produce zero output. However, at increasing time their number converges to zero, and the market will be composed by only firms that produce a positive amount (namely, PGS type).

4. DYNAMICS

Suppose now that a firm can choose to be PGS or TPC. Therefore, we can consider the two different modes as two different strategies. This means that, from now, the share x of PGS firms is not fixed but it can change. To do so, we introduce a differential equation that represents the law of motion of x. At each instant of time, firms can revise their strategy and choose to change or to continue with that strategy. This selection process is given by the following replicator dynamics (see, among others, Friedman, 1998; Nowak and Sigmund, 2004; Antoci et al., 2019):



(**a**) When $\tilde{x} \in [0,1]$ (**b**) When $\tilde{x} \geq 1$

Figure 2. TPC firms' quantities intervals.

$$\dot{x} = x \cdot (1 - x) \cdot \left[\pi_g(x) - \pi_c(x)\right] \tag{11}$$

where $\dot{x}$ is the time derivative (dx/dt) of the share of PGS firms. The mechanism of the replicator dynamics (11) is the following. If $\pi_g(x)<\pi_c(x)$, then the strategy PGS is dominated by the strategy TPC and so the share of PGS firms decreases, namely $\dot{x}<0$. If $\pi_g(x)>\pi_c(x)$, then the strategy PGS dominates the strategy TPC and so the share of PGS firms increases, namely $\dot{x}>0$. Finally, if $\pi_g(x)=\pi_c(x)$, then there is no dominance of strategies and the share x does not change over time, namely $\dot{x}=0$. Moreover, the dynamics (11) admits three types of stationary states: $x=0$ (all firms adopt strategy TPC, namely only TPC firms exist at the equilibrium, in mathematical terms $\pi_g(x)<\pi_c(x)\forall x\in[0,1]$),$x=1$ (all firms adopt strategy PGS, namely only PGS firms exist at the equilibrium, in mathematical terms $\pi_g(x)>\pi_c(x)\forall x\in[0,1]$),$x=x^*$ (some firms adopt TPC strategy, others PGS one, namely both types of firms coexist at the equilibrium, in mathematical terms $\exists x:\pi_g(x)>\pi_c(x)$).

Considering that $p_g=e_g q_g$ (from condition (8)) and that $p_c=e_c q_c+\phi$ (from condition (9)), in the interval $[0,\dot{x})$ where $q_g>0$ and $q_c>0$, the replicator equation becomes:

$$\dot{x} = x(1 - x)\left[\frac{e_g}{2}\left(q_g^\star\right)^2 - \frac{e_c}{2}\left(q_c^\star\right)^2\right] \tag{12}$$

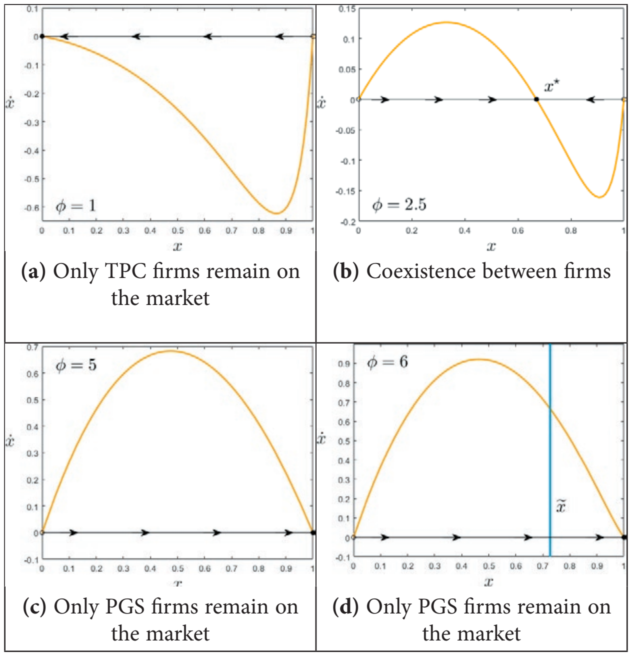
while, in the interval $[\tilde{x},1]$, where $q_g>0$ and $q_c=0$, the replicator equation becomes:

$$\dot{x} = x(1 - x)\left[\frac{e_g}{2}\left(\hat{q}_g\right)^2\right] \tag{13}$$

Numerical simulations show that under dynamics (11) three regimes may be observed:

i. the case in which the market is eventually composed of only TPC firms, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, x will always converge to the stationary state $x=0$ (see Fig. 3a);
ii. the case in which both types of firms coexist at the equilibrium, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, x will always converge to the inner stationary state $x=x^*$ (see Fig. 3b);
iii. the case in which the market is eventually composed of only PGS firms, namely, whatever the initial distribution of modes $x(0)\in(0,1)$, x will always converge to the stationary state $x=1$ (see Fig. 3(c) in case of dynamics with $q_c>0$.

In Fig. 3a, Fig. 3b, and Fig. 3c, condition (10) is not satisfied ($\tilde{x}\geq1$), and consequently $q_c>0\forall x\in[0,1]$. A situation in which condition (10) is satisfied ($\tilde{x}<1$) is represented by Fig. 3d, where $q_c>0$ in the interval $[0,\tilde{x})$ and $q_c=0$ in the interval $[\tilde{x},1]$.



(a) Only TPC firms remain on the market; **(b)** Coexistence between firms; **(c)** Only PGS firms remain on the market; **(d)** Only PGS firms remain on the market

Figure 3. Dynamic regimes. Parameter values: α=0.95, $\bar{p}$=10, e_g=5, e_c=5, n=5. Legend: • sinks, ∘ sources.

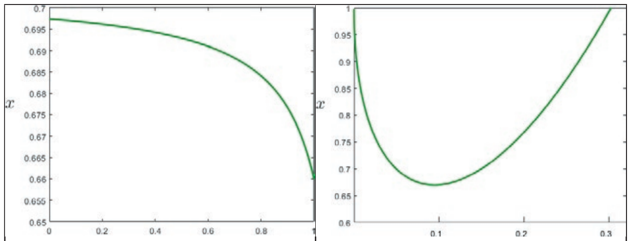
Numerical simulations shown that at most one inner stationary state $x=x^*$ may exist and it is always attractive. The parameters used to perform Fig. 3 have been chosen to illustrate clearly the three regimes that may be observed under dynamics (11). In more detail, the parameters α, $\bar{p}$, e_g, e_c and n are the same in all diagrams of Fig. 3. The parameter chosen to show the different dynamic regimes is the certification cost. Indeed, if ϕ is relatively low, as in Fig. 3a, then the strategy PGS is dominated by the strategy TPC, and, at the end, the market will be composed of only TPC firms. If the certification cost ϕ assumes an intermediate value, as in Fig. 3b, then no strategies dominate, and, since x^* is attractive, at the end, the market will be composed of both types of firms. Finally, if ϕ is relatively high, as in Fig. 3c and Fig. 3d, then the strategy PGS dominates the strategy TPC, and, at the end, the market will be composed of only PGS firms.

5. SIMULATIONS AND DISCUSSION

In the present section, it has been performed a numerical simulation to analyse the evolution of the share x of PGS firms that occurs when varying some key parameter values, namely, the substitution degree between PGS and TPC goods α, the certification cost ϕ, and the production costs ratio e_c/e_g. The parameters underlying the simulations are the same as in Fig. 3b, namely, the case in which both types of firms coexist. The simulations results have to be evaluated in qualitative terms. Indeed, the focus of the present research is on the relations between parameters and market composition. For a quantitative interpretation of the results, the parameter values should have been estimated, nevertheless, this is out of the scope of the paper.

Fig. 4a shows how the share of PGS firms monotonically decreases at increasing values of the substitution degree between goods α. The share x reaches its maximum value when α=0, namely when there is no substitution between goods (and the output prices, p_g and p_c, are independent). Conversely, the share x reaches its minimum value when α=0, in case of full substitution (and the output prices, p_g and p_c, are the same). Therefore, as $\alpha \to 1$, PGS firms change their strategy adopting the TPC one. This means that the more the PGS product is differentiated, the more it will survive within the organic market. Besides, a rise in α initially causes a slow decrease of x, while at higher values of α produces a rapid decrease of x. This means that initially (when the goods are enough differentiated) only few firms change their mode to become TPC, while for higher values of α (when the goods tend to be homogeneous) many firms change their mode and become TPC. The model suggests therefore that PGS firms have to differentiate their good to compete with TPC firms. As seen, PGS firms do differentiate their products and they also operate according to a different strategy and philosophy of production by incorporating strong peculiarities of environmental and workers' rights protection as well as elements of social education in relation to quality-of-life improvement. In other words, symbolic attributes such as localness, healthiness, quality, embeddedness among producers and consumers, seem to be able to differentiate PGS products to TPC ones. PGS, indeed, adheres to a model that mirrors the recent critical consumption trends advantaging PGS productions compared to those certified by TPC, accused of being one of the main causes of the conventionalization of the organic model (Raynolds, 2004; Courville, 2006; Hatanaka, 2014).

Finally, Fig. 4b shows the behaviour of x at increasing values of the ratio of the slope of the marginal costs functions e_c/e_g. The ratio is always lower than 1 if we assume $e_g \geq e_c$. This ratio can be considered as an increase in the relative marginal costs of the TPC mode compared to the PGS one, or, alternatively, as a decrease in the relative marginal costs of the PGS mode compared to the TPC one. The graph of x in Fig. 4c shows a U-shaped trend. This suggests that a costs saving of the PGS mode compared to the TPC one may initially have adverse effects on the dynamics of the PGS firms. An increase of the production costs ratio has a negative effect on the quantities produced by TPC firms (see (5)) and an ambiguous effect on the quantities produced by PGS firms (see (4)). Clearly, in the early stages, the raise of e_c/e_g has a negative effect on q_g more than on q_c and consequently the PGS mode is less rewarding than the TPC one. However, if then production costs ratio continues to increase, then the positive effect on q_g prevails and so the PGS mode will be more rewarding than the TPC one.



(**a**) Substitution degree. (**b**) Slope of the marginal costs ratio

Figure 4. Evolution of the share of PGS firms at increasing values of α, e_c/e_g.

According to these results, if the goal of policy-makers is to gradually change unsustainable consumption and production patterns and move towards a better integrated approach of sustainable food systems, they should consider ensuring to PGS firms the access to payments and subsidies supporting and compensating additional costs and income foregone due to the application of environmentally friendly farming practices. Indeed, access to subsides is able to explain Fig 4(b) in the sense that financial support to PGS firms compensate non-financial additional costs linked to their production by lowering and consequently improving the raise of . By financially supporting those farmers, environmentally sound farming techniques could be adapted to region-specific needs meeting the preservation of sustainable production potential according to sustainability criteria. As far as Western countries are concerned, they could also consider the possibility to officially include PGS schemes within organic regulation as to recognize the crucial role played by those operators in the agricultural sector who address a sustainable use of public goods (Schmidt et al., 2012) by adopting environmentally friendly farming techniques that go beyond legal obligations.

6. FINAL REMARKS

Worldwide organic standards, certification schemes and regulations ensure organic integrity, but they should do so in a way that does not create unnecessary technical barriers to organic trade, and that respects geographical as well as regional differences. Currently, organic food market has shifted away from its original niche consisting of outlets such as specialized stores, organic farmers markets, direct selling, etc., towards more conventional grocery stores, supermarkets, as well as hypermarkets and even discount stores that have their organic brands. According to previous research, "the globalization of the organic food market could also be associated with the role played by the third-party assurance system" (Sacchi et al., 2015). If on the one hand TPC has produced an increase in trust and reliability in organic goods and their commercialization worldwide, on the other it has meant the occurrence of several problems linked to certification costs as well as difficulties to accomplish all technical and bureaucratic paperwork needed for its request.

In this framework, alternative assurance schemes, known as Participatory Guarantee Systems, have been developed worldwide since the 1980s, originally to assess and guarantee the organic quality of products to consumers, and currently to overcome the barriers posed by TPC. Furthermore, often farmers refer to PGS to differentiate their organic production from those more industrialized traded on mainstream channels. Alternative initiatives suggest that PGS are a valuable tool in differentiating organic productions embracing a philosophy of production that goes beyond the organic production standards and process.

The present research applied the Game Theory approach to develop a mathematical modelling framework able to explain the coexistence of PGS phenomenon within the certification market for organics. From the analysis of the model, it emerges that three dynamic regimes may be observed: (1) an organic market composed of only TPC firms, (2) an organic market composed of only PGS firms, (3) coexistence between firms. Numerical simulations performed in the third scenario, show that by increasing the substitution degree between goods, the share of PGS firms progressively decreases until it reaches 0. This result means that the main way for PGS firms to compete against TPC ones is to differentiate their goods. Numerical simulations also show the possible existence of non-linear effects in response to the change in production costs, so that the share of PGS firms sees an initial (and surprising) decrease before seeing an increase as the TPC mode gets relatively less remunerative.

The present study explicates in mathematical terms the diffusion of PGS behaviour in a population of agricultural firms. On the one hand, the strength of the approach developed is represented by the possibility of presenting in a simple and organized context complex relationship such as those typical of the organic market. On the other hand, one could argue that the present model simplifies the reality by its assumptions. To this purpose, future research could amplify the model by including aspects not considered for analytical simplicity or by modifying some assumptions. For instance, a future line of research could be focused on a model that allows to the same firm to be contextually in a PGS group and certified by TPC, or rather considering a non-competitive but oligopolistic market that could emphasize even more the strategic component of the model. To this respect, our hope is that the present findings will pave the way for more research on PGS certification programs, their strengths and pitfalls, to stimulate a greater debate on both organic producers' and consumers' actual needs. The insights gained from this study, indeed, represent an attempt of indications to policymakers, producers' associations, professionals involved in the sustainability standards discourse, in the improvement of the livelihoods, working conditions, and income of rural populations. From another perspective, the importance of PGS model is also represented by its potential in promoting sustainable consumption by directly involving the participation of consumers. In academic literature there are many examples of consumers concerns about the production, distribution as well as the guarantee processes of agricultural products (Murdoch and Miele, 1999; Murdoch et al., 2000; Caputo et al., 2013; Schnell, 2013; Sacchi, 2018; Kurtsal et al., 2020). Several scholars claim that localness is an attribute often associate to consumer preference and willingness to pay more for local products compared to non-local counterparts (Willis et al., 2013; Carroll et al., 2013; Sanjuán-López and Resano-Ezcaray, 2020). In the same vein, it has also been broadly demonstrated that consumers have a positive WTP for the organic attribute (Loureiro and Hine, 2002; Costanigro et al., 2011; Hu et al., 2011; Zanoli et al., 2013; Gracia et al., 2014; Meas et al., 2014). In this sense, it should be interpreted the advantages of PGS: these systems, in fact, allow for quality assurance for products that conjugate values and attributes of localness and organic production and that can be purchased at a reasonable price. In this sense, policymakers and local authorities should pay attention to these systems that can positively impact both local economies and small farmers' welfare. From a Western perspective, European Union opened a discussion on the possibility of recognizing alternative certification systems to TPC for small farmers. This discussion will lead to the official inclusion within EU countries of the Group Certification as a possible certification strategy within the last Regulation on organic production issued by the Parliament and the Council of the European Union (Reg (EU) 2018/848), that will enter into force on 1st January 2022. At the point (85) the Regulation states that "A system of group certification should be allowed in order to reduce the inspection and certification costs and the associated administrative burdens, strengthen local networks, contribute to better market outlets and ensure a level playing field with operators in third countries". Establishing rules and procedure for implementing group certification could represent a step forward to the recognition of Participatory Guarantee Systems and, eventually, to the access of support payments to small farmers adopting these alternative guarantee strategies.

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