Adapting to climate change: what really drives the choices of the 1 producers of Geographical Indications? 2 Francesco Pagliacci^a, Dana Salpina^{ab} 3 ^a Department of Land, Environment, Agriculture and Forestry, University of Padua, Via 4 dell'Università 16, 35020 Legnaro (PD) Italy 5 ^b Current affiliation: Euro-Mediterranean Center on Climate Change and Ca' Foscari University of 6 Venice, Porta dell'Innovazione Building - 2nd Floor Via della Libertà, 12 - 30175 Venice (VE), 7 8 Italv 9 This article has been accepted for publication and undergone full r view but has 10 not been through the copyediting, typesetting, pagination and proofreading process, which may lead 11 Version version differences between this and the of Record. 12 to 13 Please cite this article as: Pagliacci F., Salpina D. (2024). Adapting to climate change: what really 14 drives the choices of the producers of Geographical Indications? . Bio-based and Applied Economics, 15 Just Accepted. DOI: 10.36253/bae-15221 16

17 ABSTRACT

In an era of rapid climate change, there is an increasing call for the efforts directed at detecting best practices 18 of climate change adaptation in agriculture and understanding the factors behind producers' willingness to 19 implement adaptation strategies. Many studies consider solely traditional agriculture and specific sectors (e.g., 20 wine), while little attention has been paid to certified and high-quality products, as a whole. To fill this 21 knowledge gap, in 2022 a questionnaire-based online survey was administered to 137 producers of agri-food 22 Geographical Indications in the Veneto Region (north-eastern Italy). Using a multinomial logit model, this 23 24 study highlights the factors explaining adaptation strategies distinguishing three cases: (i) farmers who have 25 implemented adaptation strategies; (ii) farmers intending to implement them in the future; (iii) farmers neither 26 having implemented nor willing to do so. Results suggest that socio-demographic characteristics, particularly 27 education, matter, with producers holding a high school degree in agriculture showing a greater willingness to adapt. Also, being full-time farmer couples with higher probability of having already implemented adaptation 28 29 strategies. Lastly, also a direct observation of climate change in the production area affects farmers' adaptation decisions. 30

- 31
- 32 Keywords: climate change, adaptation, PDOs, PGIs, producers' survey
- **33 JEL Classification codes**: Q1, Q15, Q54

34 1. INTRODUCTION

One of the major recommendations of the United Nations Climate Change Conference COP27 (in 2022) is the recognition of the importance of sharing best adaptation practices among public and private key stakeholders, while adjusting them to country-specific context (UNFCCC, 2022). In such a setting, national governments have the direct responsibility of detecting best practices, highlighting the main factors behind climate change adaptation.

For the agri-food sector, both incremental and transformational climate change adaptation strategies have a paramount importance (Howden et al., 2010; Ingram, 2012; Fedele et al., 2019). Although incremental adaptation strategies alone are commonly considered insufficient to achieve the zero-hunger target of Sustainable Development Goal 2 (SDG2) and address the impacts of climate change (FAO, 2018), they can indeed contribute to national and regional transformative adaptation processes, especially in the case of local level strategies (Rahman et al., 2021).

46 However, adaptation to climate change for agri-food geographical indication (GI) systems is even more complex process, due to the legislative and institutional framework characterising them. Indeed, for each GI, 47 a Product Specification (hereinafter, PS) defines the delimited area of production as well as production rules 48 (e.g., plant varieties, harvest dates, size and colour). According to the World Trade Organisation (WTO, 1994), 49 GIs are indications aimed at identifying goods as produced in a given geographical area, whose quality and 50 reputation are attributable to the geographical origin itself. In practice, GIs are considered as a sort of social 51 constructions (Belletti et al., 2017), which play a crucial role in fostering endogenous rural development, hence 52 contributing to the preservation of the traditional agri-food systems and related social networks 53 (Vandecandelaere et al., 2010), and thus, to socio-economic and environmental sustainability of the concerned 54 rural areas (Owen et al., 2020). However, to contribute to this goal, GI management must be implemented 55 56 effectively (Giacomini and Mancini, 2015) and GI regulations put producers under obligation to comply with 57 the respective PS. The complex policy and socio-economic processes on which GIs rely on (Thompson and 58 Scoones, 2009) often makes the modification of their PS complex, even if for the urgent purpose of climate 59 change adaptation. In particular, the introduction of such changes requires an agreement among the involved producers, which can be concerned with long and costly authorization processes (Belletti et al., 2015; 60 Quiñones-Ruiz et al., 2018) on the one hand, and with the product's quality and reputation at stake, on the 61 other hand. All these reasons explain why agri-food GIs are quite vulnerable to climate change. 62

In this setting, GIs adaptation to climate change depends on the capacity of agents and institutions to innovate, hence finding new solutions. Information on already-existing adaptation practices and a better understanding of the drivers behind the willingness of GI agents to adapt is crucial in informing public policies. Indeed, policies can foster anticipatory adaptation strategies within the agri-food sector. This is particularly important when self-investment for adaptation is insufficient, also due to the existence of major financial constraints, both in high-income and low-income countries (Ignaciuk, 2015; Deressa et al., 2009).

For the last decade, the studies addressing climate change adaptation of farmers have increased, 69 70 especially in low-income countries. They have focused either on specific territories, e.g., the "char" islands in 71 Bangladesh (Ahmed et al., 2021), the Amazon basin (Bauer et al., 2022), Laikipia District in Kenya (Ogalleh 72 et al., 2012); or on specific productions, such as tea (Muench et al., 2021), coffee (Bro, 2020), honey (Vercelli, 73 et al. 2021). In fact, only a few studies focused on the nexus of climate change adaptation and GIs in high-74 income countries. According to Marescotti et al. (2020), safeguarding Protected Designations of Origins 75 (PDOs) and Protected Geographical Indications (PGIs) from the effects of climate change is a rather new topic mostly disregarded by international literature. Some studies addressed climate change perception of wine 76 77 producers (e.g., Lereboullet, 2013; Lamonaca et al., 2021), while there is paucity of studies focusing on agrifood GIs, specifically. To this regard, a recent study by Henry (2023) suggested the chance for agricultural 78 supply relocation as an option to adapt to climate change, even in the case of GI labels. Although this chance 79 is currently excluded outside of the boundaries of the designed geographical area of production, it is still true 80 that - at least in principle - changes in the geographical area of production are admitted as non-minor 81 amendments by Regulation (EU) No 1151/2012 (Article 53). However, according to an analysis of the 82 amendments in the fruit and vegetable sector in the EU by Marescotti et al. (2020), only one out of 81 non-83 minor amendments until 2018 affected the area of production, justifying the need to enlarge the production 84 area with climate change. Actually, Henry (2023) also stressed the existence of expected negative impact on 85 quality of products, limiting similar relocations. 86

This research aims to shed new light on local adaptation strategies in the case of agri-food GIs in the Veneto Region (north-eastern Italy), i.e., one of the regions with the highest climate change risk in Italy (ARPAV, 2017). In particular, its objective is to highlight the main factors influencing the decision of producers to counter climate change impact. The main research questions of this study are: What are the main adaptation practices used by producers of agri-food GIs? And what are the main factors influencing the willingness of agri-food GI producers to adapt?

In order to answer these questions, the study is based on a structured online survey, targeted to agri-food 93 GI producers in the case-study area. With the help of primary data, it highlights the main adaptation practices 94 in place as well as the factors influencing the willingness of farmers to implement them (either currently or in 95 the future). Adaptation revolves around the complex interplay of socio-demographic characteristics (e.g., age, 96 97 education), management characteristics and networking activity, production type, altitude as well as climate change perception itself. To estimate these factors, a multinomial logit model is used. Findings suggest that 98 99 despite a generalised awareness of climate change, this has not yet turned into widespread decision to implement adaptation measures. Rather, developing peer-to-peer learning practices among farmers and 100 fostering collaborations among those GI systems that face similar risks is of utmost importance. 101

102 The paper is structured as follows. Section 2 provides the theoretical background on adaptation to 103 climate change and on the factors affecting adaptation. Section 3 discusses the materials and methods used, by 104 briefly describing the case study area, the sample, data collection and analysis. Section 4 presents the results of the study, while Section 5 discusses them. Section 6 explores the main policy implications of this study andSection 7 concludes.

107 2. THEORETICAL BACKGROUND: FACTORS OF CLIMATE CHANGE ADAPTATION

Within climate change literature, adaptation is defined as a process of adjustment to current or future 108 109 climate and its effects, so as to reduce harm or take advantage of some positive opportunities (IPCC, 2014). In 110 agriculture, there are many climate change adaptation measures (e.g., technological and behavioural, reactive and anticipatory; tactical and strategical) (Ingram, 2012). Adaptation options can be grouped into the following 111 categories: cultivars and breed improvements; changing management practices; switching crops, breeds and 112 farming systems; managing water; diversifying agricultural systems; managing fisheries and supply chain 113 options (FAO, 2018). However, in the case of GIs, adaptation is somehow hindered by the PSs, given that they 114 define bounded production areas and well-codified production rules (Thompson and Scoones, 2009). For 115 example, many GIs include the specifications on crop varieties and breeds (Salpina and Pagliacci, 2022a), 116 hence adaptation requires a modification of the code of practices, turning into long and costly authorization 117 processes (Belletti et al., 2015; Quiñones-Ruiz et al., 2018). However, despite the extensive literature on GI 118 products, just a few studies provide insights into PSs amendments justified by climate change (e.g., Marescotti 119 et al., 2020; Belletti et al., 2015). Thus, according to Marescotti et al. (2020), compliance with the PSs might 120 121 be more difficult to attain due to climate change, which would limit adaptation options.

Overall, scholars distinguish between two types of adaptation processes (i.e., incremental and 122 transformational), based on the expected complexity of their implementation, their costs, expected risks, and 123 the number and heterogeneity of the different stakeholders who are engaged (Howden et al., 2010). Incremental 124 adaptation refers to short-term measures implemented at local level based on farmers' knowledge and 125 experience (e.g., introduction of rain covers). Transformational adaptation refers to long-term measures 126 implemented at a larger spatial scale (region, state), suitable when impact intensity is high (e.g., changes in the 127 boundaries of the production area). FAO (2007) also distinguishes between 1) autonomous or on-farm 128 adaptation, i.e., the reaction of a single farmer to climate change; and 2) planned adaptation, as policy options 129 or response strategies, which modify adaptive capacity or ease the introduction of given adaptation strategies. 130 Being GIs "social constructions" (Belletti et al., 2017), both types of adaptation matters, involving both single 131 producers and broader managing authorities. In particular, the understanding of both incremental (autonomous) 132 133 and transformational (planned) methods of adaptation is crucial for the agri-food sector (Ingram, 2012; Fedele 134 et al., 2019). The transformational or planned adaptation are usually influenced by the socio-economic and 135 political structure of a given country or region. However, at farm level, the factors behind climate change 136 adaptation can vary considerably.

In the case of GIs, these factors can be grouped into four areas: socio-demographic characteristics of
 producers, farm management and networks; product characteristics; climate change magnitude and its
 perception.

Socio-demographic characteristics. Studies on climate change adaptation usually claim that a number of socio-demographic variables influence the development and the transmission of innovations at the farm level, including age (Morel and Cartau, 2023), sex (Zamasiya et al., 2017) and education level (Guo et al. 2021). These factors affect the absorptive capacity of farmers towards innovations and the introduction of new agricultural practices, including adaptation to climate change, making easier the acquisition, assimilation, use, and transformation of external knowledge in the decision making process (Asrat and Simane, 2018; Abdala et al., 2022).

147 Farm management and networks. Besides socio-demographic characteristics of producers, other 148 characteristics of the farm management matter, as well as the networks in which a farm is involved (Below et al. 2012; Khan et al., 2020; Gao et al., 2022). With regard to management practices, the difference between 149 part-time and full-time farmers is important. Although declining in Europe (Shahzad and Fischer, 2022), part-150 time farming is still present, hence affecting the decisions about climate change adaptation. Full-time farmers 151 are more likely to have more information and knowledge on changes in climatic conditions than part-time 152 farmers, hence the former being more prone to adaptation (Maponya and Mpandeli, 2012). This can also be 153 associated with less time dedicated to farm-related activities by a part-time farmer. Also, the presence of formal 154 and informal networks as a part of social capital (Akahoshi & Binotto, 2016), within and outside each single 155 GI system, can explain diffusion of innovation, hence encouraging agri-food GI producers to innovate (Wang 156 157 et al., 2021). According to Ingram & Kirwan (2011), informal relationships can facilitate the formation of joint ventures for information exchange and business partnerships, and thus accelerate the adaptation in agriculture. 158 Product characteristics. Adaptation to climate change can be also affected by some characteristics 159

related to the type of production as well as regulatory issues. Firstly, the effects of climate change – hence, the adaptation practices – differ considerably among, e.g., crop-based or animal-based productions (FAO, 2018). Secondly, and in the case of GIs, type of the certification (i.e., either a PDO or a PGI) may influence adaptation to climate change. Actually, the restrictions imposed by each denomination, particularly in terms of size of production area, provenance of raw materials and production processes, are different, with the former being tighter than the latter.

Magnitude and perception of climate change. When addressing climate change-related risks, several 166 studies have claimed that adaptation decisions can depend both on the (measurable) magnitude of climate 167 change and on individual perceptions. Therefore, in the context of adapting to climate change at the farm level, 168 the effectiveness of adaptation measures can depend both on the overall increase of temperature and on 169 170 farmers' ability to perceive climate-related hazards, evaluating their impact on production. According to many 171 theories aimed at explaining the risk-reducing behaviour of economic agents against natural hazards, different 172 perception of climate change can emphasise subjective aspect in assessing the risks associated with it. For 173 instance, according to the Protection Motivation Theory (PMT), rooted in the theory of planned behaviour 174 (Fishbein and Ajzen, 1975; Grothmann and Reusswig, 2006), individuals' decisions to engage in a protective response against natural hazards are driven, among others, by threat appraisal (also known as 'risk perception'), 175 176 which encompasses perceived probability and perceived consequences that an individual associates with a

certain hazard (Fishbein and Ajzen, 2010; Fahad et al., 2020; Ahmed et al. 2021; Talanow et al., 2021).
Similarly, in the case of climate change adaptation strategies, Guo et al. (2021) claimed that perceived
temperature change can have a significant impact on farmer's adaptive behaviour. However, it should also be
noticed that farmers' perception of climate change is usually aligned with observed real climatic trends in
specific regions (Ogalleh et al. 2012; Alam et al., 2017; Bauer et al., 2022).

182 3. METHODS AND DATA

183 3.1. *Study area*

The Veneto Region is located in the North-East of Italy. It is characterised both by several PDOs and PGIs produced in the area, and by large climate change hazard, making this area perfectly suitable for studying adaptation to climate change and for obtaining insights which might be expanded to agricultural areas in other temperate regions of the EU.

Veneto is among the first Italian regions in terms of the economic impact of food GI, which amounted 188 to € 433m in 2021, including about 800 economic agents. In the region, GIs represent 48% of the total agri-189 food sector (well above the national average, which is equal to 21%) (ISMEA-Qualivita, 2022). Moreover, in 190 the Veneto Region, 36 different agri-food GIs (18 PDOs and 18 PGIs, respectively) can be produced, according 191 to the PSs that set the boundaries for the production of each GI. Among them, there are some of the GIs with 192 the highest production value in Italy, e.g., Grana Padano cheese, Asiago DOP cheese. Moreover, both crop-193 194 based GIs and animal-based GIs are produced. Among crop GIs, there are fruits and berries (e.g., cherries, 195 chestnuts), vegetables (e.g. radicchio chicory, asparagus), and olive oil. Animal-based GIs include processed 196 meats (e.g., ham), cheeses, and honey.

- At sub-regional level, the production areas mainly concentrate in the NUTS3 regions (*province*, in Italian) of Treviso, Verona, and Vicenza, where some municipalities are eligible for the production of more than 9 different GIs each (Fig. 1).
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- 205 206

Figure 1. Distribution of the GI production areas across the region. 211



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In addition to the widespread diffusion of GIs, the Veneto Region is also highly prone to climate change 214 (Pagliacci and Salpina, 2022), having experienced a rapid increase in average temperatures (Regione Veneto, 215 2021), since the 1990s. In particular, when comparing the decades 1961–1970 and 2009–2018, temperature 216 increase has been large across the entire Veneto region, ranging from a minimum increase of less than +1°C 217 218 in the plains near the Adriatic Sea to an increase of more than +3°C in some areas of the Alpine region 219 (Pagliacci and Salpina, 2022). In terms of rainfall, there has been a significant change in precipitation patterns. 220 Although the region's annual total precipitation has not changed widely, there has been an increase in both the maximum annual values of short-term rainfall, on the one hand (Sofia et al., 2017), and in the frequency, 221 length, and severity of droughts and related heat spells, on the other (Bonzanigo et al., 2016). In general terms, 222 it can be observed that climate variability has increased, with a large number of extreme events (e.g., heavy 223 rainfall, strong winds, hailstorms...) observed in almost every municipality of the region, in the decade 2010-224 225 2020. Given these characteristics, climate change hazard can be considered high across the whole region, with 226 almost all agri-food sectors being largely affected (Pagliacci and Salpina, 2022).

227

Data collection

3.2.

228

To answer the research questions, primary data was collected using a questionnaire-based online survey 229 administered to agri-food GI producers in the study area.

230 Consortia or Producer Organizations (POs) helped in identifying respondents. As not all of them agreed 231 upon providing a full list of producers, due to privacy reasons, they were asked to send the questionnaire directly to their members/producers, or alternatively information available online were considered. After a 232 pilot phase (December 2021), the entire survey was administered between January and August 2022. 233 234 Comprehensively, 183 responses were collected, with 46 of them being discarded after the first data cleaning. Thus, the final database includes data from 137 producers that answered all the questions necessary for theanalysis.

Among the respondents, 29 producers of animal-based GIs¹ and 108 producers of crop-based GIs participated in the survey. It is approximately 18% of the overall population of GI producers located in the region², excluding the producers of the raw materials. The sample size – ranging from 5 to 15% – can be considered as adequate for a household survey (Bartlett et al., 2001; Alam et al., 2017).

241 All agri-food GIs factually produced in the region were considered in this study. To further classify them, the current analysis refers to the clusters of agri-food GIs of the Veneto Region identified by Salpina 242 and Pagliacci (2022a) on a broad set of variables (i.e., type of GI, category, total revenue, decade of 243 registration, share of production occurring in the region). Their classification returned six clusters of GIs. Three 244 of them include PDOs only, distinguished according to revenue, territorial concentration at the local level and 245 decade of registration ("Little revenue PDOs"; "Large-scale PDO cheeses"; "Second-generation PDOs"). The 246 remaining clusters include PGIs (the "Unexploited opportunities", namely GIs for which the production in 247 Veneto is actually nil; "First-generation crop PGIs", i.e., early PGIs, with higher revenue; "Second-generation 248 crop PGIs with little revenue", i.e., PGIs with little turnover, more territorially concentrated, and registered 249 more recently) (Salpina and Pagliacci, 2022a). In the current analysis, all the clusters were considered, with 250 the only exception of the 'unexploited opportunities', given that the four meat-based PGIs included are not 251 produced in Veneto. Actually, the focus on clusters, rather than on single products, enables us to provide 252 information that can be useful for GI products with similar characteristics (e.g., size of production area, total 253 254 turnover).

With regard to the contents of the survey, the questionnaire addressed a broad series of topics: farm 255 management and networks, GI production, perception about climate change, implementation of adaptation 256 measures, barriers to adaptation, additional socio-demographic information of the respondents. Some of those 257 258 questions were used to retrieve some core variables for the econometric model (see the following section 3.3). 259 This includes the questions on socio-demographic characteristics, farm management and network, product 260 characteristics, and climate change perception and adaptation decisions (i.e., those mentioned in the theoretical background section). Additional questions included in the survey were instead used as ancillary variables to 261 enhance the primary findings of the study, through some additional descriptive statistics. Among others, they 262 263 include the questions on the impact of extreme weather events on agri-food GIs, on adaptation measures implemented or planned to be implemented by producers and on cost-effectiveness evaluation of these 264 measures, as well as on barriers to adaptation. 265

¹ In the case of animal-based GIs, producers of the final products (e.g., cheesemakers) were surveyed, asking them to report also details about their suppliers. Except for a few large dairy companies, often cheesemakers were also milk-producers, hence able to provide first-hand information. Moreover, t he answers of a few cheesemakers producing 2 GIs were duplicated.

 $^{^2}$ The total number of producers for all GIs is not available. According to the authors' estimations based on data of Qualivita and numbers provided by Consortia, there are approximately 800 producers of agri-food GIs in the region (around 700 in the case of crop-based, and around 100 for animal-based GIs), excluding the producers of raw materials, i.e., only milk or meat producers.

In particular, the adaptation practices proposed in the questionnaire are based on the results of Salpina and Pagliacci (2022b), who had used semi-structured interviews and focus-group discussions involving managers of Consortia and POs in the same study area to understand how agents involved in agri-food GIs production are adapting to climate change.

270 3.3. *The econometric model*

Firstly, preliminary descriptive statistics are analysed, considering: observations on climate change,
extreme events and adaptation practices, distinguishing between crop and animal-based GIs.

Secondly, the main drivers of adaptation of GIs producers to climate change are analysed through econometric models. As a dependent variable, the analysis considers the implementation of adaptation strategies by GI producers. In particular, three alternative situations are distinguished: (i) the one in which producers have already implemented adaptation strategies at the farm level; (ii) the one in which producers are willing to implement them in the next future; (iii) the one in which producers neither have implemented them in the past nor are willing to do so in the future.

A set of covariates are considered to analyse the occurrence of the different situations (Table 1). The table bases on the theoretical background presented in Section 2, thus distinguishing the core variables in terms of socio-demographic characteristics of the producers, farm management and networks, production characteristics, magnitude and perception of climate change, Lastly, a control variable (altitude) is considered as well, by distinguishing farms in the lowlands, hills, and mountains.

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285	Table 1. Classification	of the core variable	s considered for the	e analysis of th	e factors of adap	tation
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Factor	Label	Levels (when categorical)			
Factor Lab Age Socio- demographic characteristics Edu Farm management and networks Product characteristics Clux Product Clux Product Clux Typ		0 = Less than 35			
		1 = 35-44			
	Age	2 = 45-54			
		3 = 55-64			
Sacia		4 = more than 64			
domographic	Sex ^a	1 = Male			
characteristics		0 = Elementary school			
Characteristics		1 = Middle school			
	Education loval	2 = High school (agrarian)			
	Education level	3 = High school (non-agrarian)			
		4 = University degree (agrarian)			
		5 = University degree (non-agrarian)			
Farm	Farm management	1 = Part-time			
management and networks	Nr. of adhesions (memberships to different networks)	Continuous			
		0 = Custer "Little revenue PDOs"			
		1 = Custer "Large-scale PDO cheeses"			
	Cluster, according to Salpina and	2 = Custer "Second-generation PDOs"			
Product	Pagliacci (2022a)	3 = Custer "First-generation crop PGIs"			
characteristics		4 = Custer "Second-generation crop PGIs			
		with little revenue"			
	Certification type (PDO vs. PGI)	1 = PGI			
	Type of the product	1= Crop-based			

		Climate change observation in the production area	1 = Yes
		Observation of extreme events in the production area	1 = Yes
	Climate change	Long-term temperature change (Difference in °C of the mean temperature of the period 2009-2018 and the mean temperature of the period 1961-1970) ^b	Continuous
			0 = Mountains
	Control factor	Altitude	1 = Hills 2 = Lowlands
286	^a The research uses a	a binary sex categorisation (male/female), as a	a set of biological attributes associated with physical
287	and physiological feat	ures.	is located Data subjected and depted by
288 289	bttps://climatechange	the municipality where the producer europeandataiournalism eu/en/about (see Fe	is located. Data retrieved and adapted by grari and Giergii. 2020, for further methodological
290 291	details).		
292	All these fact	tors affect farmers' decision to implement	adaptation strategies. To test this hypothesis, a
293	comprehensive mul	tinomial model is used. In particular, we e	stimate five different models:
294	$Y = \beta_p P + \mu$	$B_a A + \varepsilon$	(1)
295	$Y = \beta_f F + \beta_f F$	$\beta_a A + \varepsilon$	(2)
296	$Y = \beta_d D + \mu$	$\beta_a A + \varepsilon$	(3)
297	$Y = \beta_c C + \beta_c$	$\beta_a A + \varepsilon$	(4)
298	$Y = \beta_p P + \mu$	$\beta_f F + \beta_d D_e + \beta_c C + \beta_a A + \varepsilon$	(5)
299			
300	Where:	XV	
301	• Y is the $(n \times 3)$	B) matrix, where $n = 137$ respondents, indic	ating the alternatives decisions about adaptation
302	(No, Yes, Ye	es in the future), and assuming the unwill	ingness to implement any adaptation strategies
303	(both in the p	ast and in the future) as the reference base	line.
304	• P is the $(n x)$	3) matrix of the proxies of the socio-demo	ographic characteristics of producers (including
305	age range, set	x and education level) and β_p is the (3 x 1)) vector of respective unknown parameters.
306	• F is the $(n x $	2) matrix of the proxies for farm manage	ement (i.e., full-time/part-time activity) and the
307	number of fai	rm adhesions, or networks the farm is invo	lved in, such as POs and associations (e.g., CIA
308	– Confagri) a	nd β_f is the (2 x l) vector of respective un	known parameters.
309	• D is the $(n x \cdot $	3) matrix of the proxies for the product cha	aracteristics (type of certifications, clusters, and
310	type of produ	(act) and β_d is the (3 x 1) vector of respective	ve unknown parameters.
311	• C is the $(n x 3)$?) matrix of the proxies for climate change	variables, encompassing both variations in mean
312	temperature b	between 2009-2018 and 1961-1970,and pro	oducer perception of climate change and extreme
313	events in the	production area. Additionally, β_c is the (3	x I) vector of respective unknown parameters.
314	• A is the $(n x \cdot x)$	l) vector of control variables about altitude	e and β_a is the (1 x 1) unknown parameter.

- 315 ε is the (n x 1) vector of error terms.
- The implementation of the models was performed by using the software R (R Core Team, 2021).

317 4. RESULTS

318 4.1. Characteristics of respondents

All the statistics about the socio-demographic characteristics of the producers, farm management, and product type characteristics under consideration in this study are shown in Table 2 and commented in this subsection. The following subsection 4.2 will focus on magnitude and perception of elimate change.

With regard to the geographical distribution of the respondents, most of them are from the NUTS-3 regions of Treviso (30%), Verona (23%), and Vicenza (19%) which also host the largest number of agri-food GIs in the region (Fig.2).

In terms of socio-demographic characteristics of the producers, most of the respondents are young producers. The rate of female respondents (23%) is low, but somehow similar to the share of women who are agricultural holders in the Veneto Region (26% of the total, according to 1stat, 2022). The largest share of respondents has a diploma of non-agrarian high school, followed by those with a university degree in nonagricultural field.

With regard to farm management and networks, respondents are mostly full-time farmers, with only 38 out of 137 being part-time farmers. They are small-size farms, 50% of the total cases being family-run. Moreover, they are also members of only 1.66 networks on average.

When considering the characteristics of the produced GIs, most respondents are crop-based GI producers (108 out of 137), and PGI producers (63 out of 137). With regard to the 6 GI cluster classification by Salpina and Pagliacci (2022a), most of the respondents belong to the cluster of "Second-generation crop PGIs", "Little revenue PDOs", and "Second-generation PDOs", which include the largest number of agri-food GIs.

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Figure 2. Geographical distribution of the sample.



Table 2. Producer, farm, and production characteristics of the respondents (137 total respondents).

Factor	Label	Levels (when categorical)	Valu e	Missin g values
		0 = Less than 35	17	
		1 = 35-44	25	
	Age	2 = 45-54	30	24
	0	3 = 55-64	19	
		4 = more than 64	22	
Socio-	Sex	1 = Male	81	25
demographic		0 = Elementary school	1	
characteristics		1 = Middle school	20	
		2 = High school (agrarian)	11	
	Education level	3 = High school (non-agrarian)	43	24
		4 = University degree (agrarian)	10	
		5 = University degree (non- agrarian)	29	
	Farm management	1 = Part-time	38	38
Farm	Nr. of adhesions (memberships		1.66	
management	te different networke)	Average number (std. Dev.)	(1.1	0
and networks	to different fietworks)		5)	
		0 = Custer "Little revenue PDOs"	29	
		1 = Custer "Large-scale PDO cheeses"	18	
Desiduat	Cluster, according to Salpina	2 = Custer "Second-generation PDOs"	27	0
characteristics1 = Middle schoolEducation level2 = High school (agraria 3 = High school (non-ar 4 = University degree (r agrarian)Farm management and networksFarm management to different networks)1 = Part-timeNr. of adhesions (memberships to different networks)Average number (std. I 0 = Custer "Little reven 1 = Custer "Large-scale cheeses"Product characteristicsCluster, according to Salpina and Pagliacci (2022a)0 = Custer "Second-ge PDOs" 3 = Custer "First-gener PGIs" 4 = Custer "Second-ge crop PGIs with little rev	3 = Custer "First-generation crop PGIs"	16		
		4 = Custer "Second-generation crop PGIs with little revenue"	48	
	Certification type (PDO vs. PGI)	1 = PGI	63	0
	Type of the product	1= Crop-based	108	0

343 4.2. *Climate change magnitude and perception and adaptation practices*

With regard to climate change, data on long-term temperature change provided by Ferrari and Gjergji 344 (2020) and some of the ancillary variables collected in the survey help to better characterise the sample. On 345 average, the set of the municipality in which the respondents are located have experienced an increase of +2.7 346 °C, when comparing the period 1961-1970 and the period 2009-2018. Thus, 95% of the respondents producing 347 crop-based GIs and 86% of the respondents producing animal-based GIs had direct experience of climate 348 349 change in the production area. The main concern for both groups is an increased irregularity of precipitation (80%, on average), followed by temperature increase (72%, on average) (Fig 3). In terms of extreme weather 350 events, 73% of the respondents have directly observed them in their production areas, over the last decade. On 351 average, the impact of the extreme events under consideration in this research is evaluated as medium, except 352 353 for frost, which seem to have the lowest effect among the respondents. Producers of animal-based GIs reported 354 also a high impact of drought (Table 3).

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Figure 3. Observations on climate change.



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358

- 359 Table 3. Average impact of extreme weather events on agri-food GIs (as evaluated by producers, scale from
- **360** 1 to 5)

	Impact (Yes)	Drought	Frost	Hailstorm	Heavy rainfall/ Flood	Insects/ diseases outbreaks
Crop-based GIs	84/108	3.1	2.6	3.3	3.0	3.4
Animal-based GIs	16/29	3.7	2.3	3.5	3.1	3.3
Average	100/137	3.2	2.5	3.3	3.0	3.4

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More specifically, among the effects of climate change on crop-based GIs, respondents pointed out the effect on the volume of production and water availability. Conversely, the perceived effect on soil quality is relatively lower. Among animal-based GI producers, the major concern is heat stress, affecting cattle and milk production during summer, with negative consequences in terms of both product quality and quantitiesproduced.

367

368 Despite the large and direct experience of climate change, only 24% of the respondents have already 369 adopted some types of adaptation measures to cope with climate change. Moreover, 33% of them are planning 370 to adopt them in the next future.

Among the managerial measures, which are implemented by both crop-based GI producers and animal-371 based GI producers, insurances (45%) are the most popular anticipatory measures of adaptation, followed by 372 373 the use of advisory services and training. Among more technical measures (namely, those specific to either crop-based GIs or animal-based GIs), introduction of new crop varieties (49%), followed by increased 374 efficiency of pests (46%), irrigation (45%) and crop rotation (45%) are the ones most mentioned by crop-based 375 GI respondents. As for the producers of animal-based GIs, they mostly opt for barn cooling systems to deal 376 with heat stress of animals (34%), followed by importing forage from outside the production area (21%) (Fig. 377 4). 378

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In terms of costs and effectiveness of adaptation measures, the ranking for managerial and technical adaptation measures of crop-based GIs is quite heterogeneous. For crop-based GIs, introduction of new irrigation systems and increased efficiency of pesticides were attributed the highest scores in terms of cost/effectiveness ratio (3.6/5.0), whereas pest increase received the lowest score (2.1/5.0). For animal-based GIs, the lowest score is for pasture management plans (1.0/5.0), while the highest one is for barn cooling systems (3.8/5.0) (Table 4).

Managerial methods of adaptation (average)		Adaptation measures for crop-based GIs		Adaptation measures for animal-based GIs	
Short-term forecast	3.0	New crop varieties	2.8	Imported forage	2.3
Seasonal forecast	2.7	Changed dates of planting	2.6	Storage capacity (forage)	2.2
Warning systems	2.9	Diversified crop varieties	3.5	Pasture management plans	1.0
Insurance	3.2	Crop rotation	3.5	Cooling systems for barns	3.8
Cooperation	2.7	Soil conservation	2.8	New animal breeds	2.8
Trainings	3.4	Shading	2.5	Less animals	2.0
Advisory services	3.0	Supplementary irrigation	3.6		
Involvement of external actors	2.7	New irrigation system Increased efficiency of pests Pests increase	3.6 3.6 2.1		

Table 4. Average score of adaptation measures (as evaluated by producers, scale from 1 to 5).

389

4.3. Drivers affecting climate change adaptation

The factors influencing farmer willingness to implement adaptation measures are analysed under models
(1)-(5) admitted in this study. Table 5 returns the results of these models.

392 In (1), which includes sociodemographic variables, education plays an important role. As expected, the respondents with a high school degree in agriculture show a greater willingness to adapt (either in terms of 393 already-implemented adaptation strategies or in terms of future adaptation). Conversely, age is never 394 significant. In (2), part-time management negatively affects adaptation decisions, while larger number of 395 adhesions to associations and other sectoral networks couples with a higher probability of having already 396 397 introduced some forms of adaptation practices. When considering production features, in (3), no covariates are significant. In (4), direct perception of the effects of climate change plays a major role in driving adaptation 398 399 decisions, while, as an unexpected result, an increase in average temperature in the production areas shows a 400 negative coefficient. Lastly, when considering all covariates jointly, in (5), education level remains the main 401 factor influencing on-farm adaptation to climate change. In particular, education in agrarian field is positively 402 associated with adaptation strategies. It is also confirmed that part-time farmers are less willing to undertake 403 adaptation measures. As for GI products, "large-scale PDO cheeses" (Cluster 2) show negative coefficients, 404 in terms of both current and future adaptation to climate change. Similarly, when considering the type of GIs, 405 producers of crop-based GIs are less willing to adapt than those of animal-based GIs, both when considering already existing adaptation strategies and future ones. Nevertheless, adaptation to climate change remains 406 407 significant among producers that do observe climate change in their production areas. In addition, altitude of the production areas only shows a small effect, suggesting a negative relation between flatland locations andadaptation strategies.

Table 5 also shows the results of the McFadden test (Hausman and McFadden, 1984), the Akaike Information Criterion (Sakamoto et al., 1986), and the Bayesian information criterion (Schwarz, 1978), computed for each model. Although the computed tests do not point to the full model (5), however it is the one with the largest accuracy ratio.

Table 5. Results of the models.

	(*	1)	(2	2)	((3)		(4)	(5)
	Yes	Future	Yes	Future	Yes	Future	Yes	Future	Yes	Future
Sex (Male)	0.890	0.246							1.731	0.649
	(0.633)	(0.575)							(1.097)	(0.861)
Age (35-44)	-0.155	0.872							1.468	1.491
	(0.938)	(0.969)							(1.375)	(1.230)
Age (45-54)	0.245	1.592							0.803	1.900
	(0.956)	(0.983)							(1.393)	(1.262)
Age (55-64)	-0.118	0.768							1.302	0.782
	(0.983)	(1.023)							(1.608)	(1.443)
Age (over64)	-0.493	-0.156							0.034	0.055
	(0.893)	(1.023)							(1.494)	(1.232)
Education (Middle)	15.073***	12.502***							-	-
	(0.678)	(0.653)								
Education (High non-										
agrarian)	16.046***	13.403***							2.403*	1.792
	(0.456)	(0.458)							(1.417)	(1.172)
Education (High										
agrarian)	50.949***	49.297***							41.679***	42.209***
	(0.361)	(0.361)							(0.652)	(0.652)
Education (University										
non-agrarian)	14.830***	12.654***							1.021	2.380*
	(0.543)	(0.503)							(1.601)	(1.328)
Education6 (University										
agrarian)	17.094***	14.883***							1.840	2.804
	(0.976)	(0.966)							(1.841)	(1.726)
Farm management (Part-										
time)			-2.598***	-1.677***					-3.724***	-2.400**
			(0.755)	(0.643)					(1.173)	(1.033)
Nr. of adhesions			0.564*	0.244					0.514	-0.030
			(0.301)	(0.283)					(0.384)	(0.375)
Clusters CL2					0.994	1.316			-13.671***	-12.405***
					(1.164)	(1.230)			(1.588)	(1.543)
Clusters CL3					0.220	0.191			-0.611	1.232
					(0.750)	(0.748)			(1.580)	(1.491)
Clusters CL5					0.190	0.362			-1.094	-0.452
					(0.609)	(0.561)			(0.870)	(0.855)
Clusters CL6					-0.597	-0.444			0.211	0.419
					(0.458)	(0.412)			(0.739)	(0.673)
Certification type (PGI)					-0.408	-0.082			-0.883	-0.033
					(0.468)	(0.437)			(0.760)	(0.660)
Type (crop)					0.950	1.431			-10.467***	-10.939***
					(0.868)	(0.950)			(1.419)	(1.416)

414

Climate change observation (Yes)							1.889*	0.731	7.088***	4.506***
							(1.047)	(1.002)	(1.675)	(1.519)
Observation of extreme							()	, , , , , , , , , , , , , , , , , , ,	· · · ·	,
events (Yes)							-0.007	0.767	-0.062	1.334
							(0.709)	-0.783	(1.355)	(1.326)
Long-term temperature										
change							-1.471**	-0.624	-1.494	0.146
							(0.735)	(0.695)	(1.238)	(1.106)
Altitude (hills)	-0.312	-0.121	-1.136	-1.006	-0.463	-0.399	0.278	-0.266	-1.277	-1.545
	(0.856)	(0.801)	(0.937)	(0.820)	(0.860)	(0.820)	(0.870)	(0.771)	(1.462)	(1.342)
Altitude (lowlands)	-0.094	-0.093	-1.746*	-1.445	0.276	0.015	0.061	-0.351	-2.572*	-1.920
	(0.880)	(0.829)	(1.020)	(0.917)	(0.840)	(0.804)	(0.840)	(0.758)	(1.388)	(1.280)
Constant	-16.063***	-13.910***	1.382	1.814*	-0.606	-0.872	1.889*	0.731	7.088***	4.506***
	(1.033)	(1.012)	(1.109)	(1.021)	(1.085)	(1.137)	(1.047)	(1.002)	(1.675)	(1.519)
Obs.	1(06	ç	3	1 <i>*</i>	15	9	9	8	36
AIC	253	3.56	196	6.86	273	3.61	229	9.16	218	8.17
BIC	322	2.81	222	2.18	317	7.53	255	5.11	32	1.25
McFadden	0.	13	0.	13	0.04		0.04		0.29	
Accuracy	53	.77	49	.46	49	.57	42	.42	63	.95

415 Notes: statistically significant *p<0.1; **p<0.05; ***p<0.01

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416 5. **Discussion**

This study offered important insights into the extent of adaptation to climate change in the case of the 417 high quality agri-food GIs of the Veneto Region (Italy). The results show that agri-food GI producers are 418 highly aware of climate change, having experienced both its direct and indirect impacts. In the case of animal-419 420 based GI productions, mainly indirect impacts of climate change are observed (e.g., alteration in fodder quality 421 and quantity). In the case of crop-based products, the spectrum of direct impacts seems to be larger. However, 422 although producers are perfectly aware of climate change and of its effects on GI production, adaptation has not reached its full potential among them. Only 50% of the respondents have already adapted to climate change 423 or are expressing their willingness to do so in the next future. In particular, their decisions seem to be driven 424 425 by a large number of factors.

426 All the different types of admitted drivers (i.e., socio-demographic characteristics of producers, farm 427 management, type of product, climate change observation) matter in predicting adaptation measures at the 428 farm level. Producers with an educational degree related to agriculture, who adhere to sectoral networks, and who perceive more directly climate change in their production area tend to be more willing to adapt to climate 429 change. These findings are consistent with previous studies that claim the critical role played by risk 430 perceptions (Fishbein and Ajzen, 2010; Grothmann and Reusswig, 2006; Menapace et al., 2015; Hasan and 431 Kumar, 2019; Zagaria et al., 2021), involvement in social networks (Bairagi et al., 2021; Bazzana et al., 2022) 432 and education (Muench et al., 2021; Guo et al. 2021), when explaining adaptation attitudes. The 433 counterintuitive negative relationship between magnitude of climate change and willingness to implement 434 adaptation strategies (as observed in just one of the selected models) might be explained with the intuition that 435 further decreases in economic profitability, due to global warming, could make any adaptation investments too 436 costly compared to any potential future benefits. 437

However, among the most interesting findings, rigidity of the PS deserves specific attention. Indeed, it 438 439 can be observed that some of the adaptation practices implemented by conventional farmers, either in Italy 440 (Bonzanigo et al., 2015) or elsewhere (Song et al., 2019; Antwi-Agyei et al., 2021; Nor Diana et al., 2022), 441 are also adopted by some of the producers of agri-food GIs in the Veneto Region. This is the case, for example, 442 of some varietal improvements as well as by the introduction of barn cooling systems. The main difference in adaptation strategies between agri-food GI producers and conventional ones is the existence of regulative 443 barriers imposed by PSs. However, the fact that the certification type (i.e., producing either a PDO or a PGI) 444 445 is never significant might suggest that rigidity of code of practices (i.e., more stringent PS in the case of PDOs than in the case of PGIs) is not a big issue in climate change adaptation for GI producers. This finding seems 446 447 to be supported also by the analysis of the main barriers, according to the respondents' perspectives (Table 6). 448 Indeed, the restriction imposed by PSs is one of the least perceived concerns by producers, who are worried much more by the lack of financial resources or by difficulties in having access to public funds (e.g., those of 449 450 the Rural Development Policy). Moreover, information issues seem to play a key role in the adaptation process.

Similarly, to what is observed across Europe (Simonet and Leseur, 2019) or elsewhere (Alam et al., 2017; Belay et al., 2022), the economic aspect of adaptation is proved to matter, as on-farm adaptation mostly relies on producers' own resources. On top of that, there is an issue of uncertainty, associated with the high cost of investments, and with the uncertain long-term benefits. In other words, uncertain future costs of climate risks compared to the certain and immediate costs of adaptation measures together with uncertain expected returns on investment represent one of the major barriers to climate change adaptation (Lefebvre et al., 2014), also in the case of agri-food GI producers.

The barriers discussed above couple with external factors, mainly involving policy and governance issues: observed complexity in having access to public funds, a lack of technical assistance in obtaining such help, market dynamics and the current geo-political conditions. In this context, climate change adaptation, which is of utmost importance given the impacts already affecting GI farmers and producers, seems to require specific policy interventions.

463

464 Table 6. Barriers to climate change adaptation, as perceived by producers of agri-food GIs (as evaluated by

Barriers	Adaptation					
(Number of respondents)	No (40)	Yes (33)	Yes_future (45)	Total (118)		
Lack of financial resources	3.6	3.1	3.9	3.6		
High cost of investments and long-term benefits	3.9	3.2	3.5	3.5		
Accession to RDP funds	3.6	3.9	3.8	3.7		
Long waiting time for the accession RDP funds	3.8	3.5	3.9	3.7		
Lack of technical assistance	3.4	3.0	3.4	3.3		
Lack of information on effectiveness of certain adaptation measures	3.8	3.5	3.8	3.7		
Restriction imposed by PSs	3.5	3.1	3.2	3.3		
Land property	2.8	2.4	2.8	2.6		
Lack of local and production networks	2.1	2.8	2.5	2.5		
Lack of producers' representation in the decision-	3.3	3.3	3.3	3.3		

465 producers, scale from 1 to 5.

466

467 6. POLICY IMPLICATIONS

The results of this study represent an important contribution, not only to inform policymakers at regional level (i.e., in the Veneto Region), but also for national and EU policymakers and stakeholders. Indeed, the results of this study are highly generalizable in terms of suggested approach and adopted empirical strategy. In particular, the suggested strategy, distinguishing three alternative situations (farmers who have implemented adaptation strategies; farmers intending to implement them in the future; and farmers neither having implemented nor willing to do so in the future) holds promise for delivering a relatively elevated degree of accuracy and interpretability, also when implemented in other case studies.

Moreover, the results suggest that the main policy instruments for high-quality agri-food products might
be largely improved across the EU. Firstly, a more targeted support within the new Common Agricultural
Policy (2023–2027) will largely help. This is true also in a region such as Veneto, where in the 2014-2020

programming period just 1.5% of the total funds of the Rural Development Programme was earmarked to themeasure aimed at supporting quality schemes (i.e., measure 03).

Besides a larger public fund allocation, in this context, reliability of new technologies and clear 480 481 information regarding their effectiveness might help. This will provide new incentives to the producers of agri-482 food GI, when considering their options of investing in new adaptation measures to climate change. Moreover, 483 it could also be helpful developing peer-to-peer learning practices among producers together with fostering 484 further collaborations among GI systems that face similar risks. Indeed, the role of public policies is not limited 485 to allocation of financial resources to prevent the financial barriers of adaptation, but it can also ease knowledge 486 transfer (Ignaciuk, 2015), fosteringcollaborations between farms and Consortia, and across sectors (e.g., public and private). To this regard, the framework of Agricultural Knowledge and Innovation Systems (AKIS) could 487 be strengthened, in terms of a multi-stakeholder process (Cruz Maceín et al., 2023). Analogously, also the 488 functions of Consortia and POs could be strengthened to better facilitate the coordination among the 489 490 stakeholders for the implementation of adaptation strategies at GI level. These entities, which frequently offer advisory support, can serve as innovation intermediaries, cooperating with research organisations (Salpina and 491 Pagliacci, 2022b) and facilitating horizontal and vertical diffusion of information. Thus, Consortia and PO's 492 can play a pivotal role in sustaining adaptation efforts, and guide farmers in investing in new adaptation 493 measures. Lastly, the findings of this empirical study hold the potential to contribute significantly to 494 international discourse surrounding food policy, by providing an in-depth examination of climate change 495 adaptation practices within the GI agri-food sector, the policy area that has thus far received limited attention 496 within academic circles. 497

498 7. CONCLUSION

This study aimed at analysing climate change adaptation strategies in the case of high-quality agri-food 499 sector, shedding light on the main factors influencing the decision of producers to adapt. In the past, this topic 500 was largely neglected in the literature. Actually, to the authors' best knowledge, only a few other studies have 501 already focused on the topic of climate change adaptation, taking agri-food GIs into consideration. The key 502 findings of the research suggest that despite a generalised (and high) awareness of climate change among GI 503 farmers and producers, this has not yet turned into widespread adoption of adaptation measures. The main 504 505 factors influencing the willingness of producers are confirmed to revolve around the complex interplay of socio-demographic characteristics (e.g., age, education), farm management and networks, and production 506 507 characteristics, in addition to the perception of climate change.

Despite the potential limitations of any online surveys (e.g., some bias in respondents' characteristics, in favour of younger and more educated ones), further studies could eventually replicate the questionnairebased survey in other countries and regions, making use of the same methods proposed here. Moreover, it should be noticed that this study encompassed the certified agri-food sector in general. Thus, future works, focusing on a specific sector (e.g., only cheese products), would allow for a more targeted examination of key variables affecting climate change adaptation. One additional limitation of this study is the absence of a 514 comparison between farmers operating within GI schemes and the ones operating outside such schemes. 515 However, such a limitation was due to the complexity of such a comparison and mostly to the data collection 516 process, which was primarily done through Consortia and POs. Future research will eventually address this 517 gap, providing valuable insights into this phenomenon. Moreover, future lines of research will also involve the 518 analysis of the drivers contributing to the adoption of specific adaptation measures and will consider additional

- and more sophisticated proxies for climate change perception.
- 520

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