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# Healthy food traditions? Nutritional quality and food composition of EU geographical indications

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# Healthy Food Traditions?
# Nutritional Quality and Food Composition of EU Geographical Indications

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# Healthy Food Traditions? Nutritional Quality and Food Composition of EU Geographical Indications

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**Abstract**

The EU Green Deal aims to promote healthier diets that include more nutritious and natural foods instead of ultra-processed products. EU geographical indications (GIs) protecting traditional foods such as Roquefort cheese or Parma ham will be reinforced under the corresponding 'Farm to Fork Strategy'. Although several GI producers advertise their products as artisanal and healthy, little is known yet about whether GI foods can actually contribute to these EU policy ambitions. Therefore, we examine the nutritional quality and food composition of GIs compared to non-GIs. We base our analysis on extensive open-access data of more than 6,000 cheeses and prepared meats marketed in France including about 1,200 products regulated under 79 different GIs. We find that GIs are associated with lower overall nutritional quality based on the Nutri-Score metric, which has become one of the major candidates for harmonised nutritional labelling in the EU. Thus, future GI specifications may allow for innovative reformulations towards healthier alternatives of local food traditions. Second, our probit regressions indicate that GIs tend to be less likely to be ultra-processed and to contain food additives. However, this seems to be truer for protected designations of origin (PDOs) with typically stricter provisions than protected geographical indications (PGIs). Hence, more harmonised rules on additives could be considered to foster the natural character of GIs and consistency across PDOs and PGIs. Finally, a revised Nutri-Score may also account for the use of additives.

**Keywords:** Geographical indications, front-of-pack labelling, processed foods, Nutri-Score, NOVA, food additives

**JEL classifications:** O34; Q18

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## 1. Introduction

Can century-old food traditions help to ensure a sustainable future? The European Union's (EU) Green Deal highlights geographical indications (GIs)[1] such as Italian Parma ham or Greek Feta cheese as contributors. In line with the EAT-Lancet report (Willett et al., 2019), the EU's corresponding flagship 'Farm to Fork' (F2F) strategy emphasises the need for healthier diets as part of the transition to sustainable food systems (European Commission, 2020). Under the F2F strategy, GIs are planned to be reinforced and the prospects of some GIs to represent a healthier food choice sound promising (FAO, 2021; Vandecandelaere et al., 2021). However, little is known yet about the extent to which the GI sector may contribute as a whole.

The EU highlights GIs as one of the most important quality labels. Yet high quality food need not be healthy. First and foremost, GIs certify origin and allegedly related quality (Deconinck & Swinnen, 2021; Menapace & Moschini, 2014; Zago & Pick, 2004). The contribution of GIs is especially debatable regarding the EU's sustainability goal of promoting healthier diets because almost 40% of all agri-food GIs are of animal origin such as cheeses and meats that should be consumed more moderately (European Commission, 2020). While certain content-related aspects of some GIs such as amino acids levels in Parmesan cheese may have potentially positive health effects (FAO, 2021), extant research has not examined nutritional quality and food composition of GIs on a broader basis.

The overall nutritional quality of GIs represents a highly contentious topic in recent front-of-pack nutritional labelling debates. The Nutri-Score, which translates the nutrition facts table into a single score using traffic-light coding from high to low nutritional quality, represents one of the European Commission's options regarding more informative and harmonised nutritional labelling (WHO, 2021). Nutri-Score opponents point out that their traditional foods, i.e. GIs in particular, are penalised by the Nutri-Score categories and score unjustifiably low (Borrillo, 2021). Thus, our first objective is to analyse whether GIs indeed tend to have worse Nutri-Scores values compared to non-GIs.

Apart from their overall nutritional quality, case studies on GIs suggest that their traditional production methods make them less processed and thus allegedly healthier (FAO, 2021; Glogoveţan et al., 2022). Therefore, our second objective is to contribute to existing

[1] The EU GI regulation 1151/2012 protects traditional foods with two major origin labels: protected designations of origin (PDOs) and protected geographical indications (PGIs). For PDOs like Roquefort cheese all production processes must take place in a denominated region. For PGIs like Ardennes sausage only the most defining production steps must take place in the denominated region. According to the EU, the local "terroir", a combination of natural and human factors, ensures unique quality attributes.

exploratory studies by analysing the degree of processing and the presence of food additives in numerous GIs and their generic counterparts.

Our contribution to previous literature is based on a two-fold approach. We go beyond the scope of previous work that focused on specific products. Such limited scope inhibits more generalizable conclusions regarding the overall potential of GIs to contribute to healthier diets. Thus, we base our quantitative analyses on the extensive French open-access database of Open Food Facts (https://world.openfoodfacts.org/), which grants access to thousands of observations including more than 1,200 products representing 79 GIs from 10 countries.

We find that GIs are associated with worse Nutri-Scores. In contrast, our probit regressions confirm the potential of GIs to represent the less processed and more natural alternative containing fewer food additives. However, this finding is only true for PDOs, which are typically more strictly regulated than PGIs. All in all, while GIs may tend to have worse Nutri-Scores, they do seem to be less processed.

## 2. GIs and healthy diets

Obesity represents a major health concern in developing as well as developed countries (Ameye & Swinnen, 2019). Thus, it is evident that policy-makers must tackle forcefully the issue of unhealthy diets that burdens health care systems (Tremmel et al., 2017). In general, the health-related aspects of GIs have not been examined on a broader basis. In what follows, we map out our paper's contribution to the two strands of related literature on nutritional quality and (ultra-)processing of GIs.

### 2.1 GIs and nutritional quality

Grunert and Aachmann (2016) highlight that consumers tend to associate GI labels with authenticity and high quality. Some consumers apparently regard GIs not only as traditional but also healthy food products (Glogoveţan et al., 2022). A consumer survey conducted by AND-International (2020) even revealed that more consumers perceive GIs to be healthy rather than tasty products. Hence, it comes as no surprise that many GIs such as Comté, Parmesan and Roquefort cheese or San Daniele and Parma ham actively advertise health benefits of their products, e.g. the avoidance of food additives and richness in vitamins (see e.g. San Daniele, 2022). Nonetheless, the aforementioned GI products score low on overall nutritional quality based on the new Nutri-Score (see e.g. Roquefort, 2022), which has become a candidate for a harmonised nutrition label at EU level.

Breda et al. (2020) call for more informative nutrition labels to enable consumers to choose healthier products. In the EU, food producers are required to report on the package the energy value and amounts of sugars, proteins, salts, carbohydrates, fats and saturates. However, these so-called nutrition facts panels, which are often on the back of packages, do not seem to be as appealing to consumers as more intuitively designed front-of-pack labels (Becker et al., 2015; Jones & Richardson, 2007).

According to the International Agency for Research in Cancer (IARC) the Nutri-Score represents such a more appealing alternative (WHO, 2021). It has been developed by a French team of scientists and summarizes the nutrition facts panel into a single score that categorizes products with traffic-light coding (Julia & Hercberg, 2017): from A (dark green, high nutritional quality) to E (red, low nutritional quality). Extant research confirms that the Nutri-Score is well-understandable, intuitive, informative and recognizable to consumers (Egnell et al., 2020; Hagmann & Siegrist, 2020; Sarda et al., 2020). A recent consumer experiment in Belgium provides evidence that consumers actually chose foods of better nutritional quality when Eco- and Nutri-Scores are displayed (De Bauw et al., 2021).

The Nutri-Score was first introduced in France (Julia & Hercberg, 2017), but has been endorsed by several other EU countries such as Belgium, Germany, the Netherlands and Spain (WHO, 2021). Also, major retailers such as e.g. Delhaize and Carrefour in Belgium or REWE and EDEKA in Germany started labelling their products with the Nutri-Score (see e.g. REWE, 2022). Due to its successful implementation in several Member States it has become the preferred option for harmonised labelling outlined in the F2F initiative. The European Commission is expected to make a corresponding proposal by the end of 2022 (WHO, 2021).

However, especially GI producers and Southern Member States like Italy and Greece with a high number of GIs (Huysmans & Swinnen, 2019) are fiercely trying to prevent the implementation of the Nutri-Score system across the EU (Fortuna et al., 2022). In Italy, some retailers were even forced by Italian authorities to abandon the Nutri-Score score label (EFA, 2022). The opponents criticise that the Nutri-Score assigns categories of lower nutritional quality to e.g. prepared meats by summarizing the nutrients of the nutrition facts table into a single score without accounting for favourable ingredients such as vitamins and proteins. Also, that it does not consider unhealthy ways of preparation, e.g. frying. Finally, as the Nutri-Score is calculated per 100 grams it may be more comparable, but does not account for portion size.

Nonetheless, although a single score may sound overly simplified, Hagmann and Siegrist (2020) highlight that the Nutri-Score still achieves its goal to transfer an informative message to consumers about nutritional quality. It is important to note that the Nutri-Score

should be used to meaningfully compare products of certain categories (e.g. oils) and not across categories. Hence, one should not compare Nutri-Scores of olive oils and soft drinks, but within oils, e.g. olive oils compared to palm oils (BEUC, 2019). This intended use of the Nutri-Score has often been misunderstood and criticised. For example, the Nutri-Score has been dubbed as an "attack on Italy" as potatoes designated to become fries had a better score than precious Italian olive oil (Borrillo, 2021).

In terms of health, not much speaks against consuming cheese and meat GIs with bad Nutri-Scores moderately as part of a balanced diet. However, dark orange or red Nutri-Score categories could lead consumers to avoid these products. According to GI producers, this avoidance could undermine food heritage -which GIs are meant to protect- as consumers may consume less traditional foods.

In addition, the Nutri-Score should not only incentivise consumers, but also producers to make healthier choices, i.e. to reformulate their products and offer healthier alternatives with e.g. lower fat contents. The reformulation aspect represents a major goal of the F2F strategy (European Commission, 2020). Already now, major supermarkets like Delhaize and Carrefour in Belgium dedicate own websites to "products with an improved Nutri-Score" (see e.g. Delhaize, 2022). The Nutri-Score may actually become an even more severe issue for GIs if also products of the same category (e.g. hams) offer products with better Nutri-Scores than GIs. For example, in France, many non-GI hams are sold as "less fat" or "less salt" alternatives that target health conscious consumers. Such flexible reformulations may be straightforward to implement for non-GI producers, but not necessarily for GIs that are bound to strict production rules.

Opponents of the EU's GI system such as the US criticise that EU GIs hamper innovation (Osgood & Feng, 2018) by "mummifying" certain product specifications and hence, impeding reformulations. Gocci and Luetge (2020) point out that by stiffly holding on to traditions GIs may struggle to meet new market conditions and consumer expectations. This aspect may also be true regarding the increasing demand for healthier and nutritious foods.

All in all, despite stiff opposition and backlash from southern Member States such as Greece and Italy as well as GI producers, the bottom line is that the Nutri-Score remains on the Commission's table of options. This fact is mainly driven by its easily understandable design as well as an approximate, but overall helpful assessment of nutritional quality based on crucial nutrients. For the above reasons, we examine how GIs compare in their nutritional quality based on the Nutri-Score metric to generic alternatives.

### 2.2 GIs and ultra-processed foods

Ultra-processed foods are characterized by numerous ingredients that are often exclusively used in industrial production. As a result, ultra-processed foods are often very durable and hyper-tasty (Adams et al., 2020; Monteiro et al., 2019, 2017). These advantages come at a cost because ultra-processed foods have health costs (Adams et al., 2020; FAO, 2021). Hence, a shift to less processed, more natural products is advocated and traditional foods such as GIs may represent a healthier alternative (FAO, 2021).

One of the main characteristics of ultra-processed foods is the use of food additives (Monteiro et al., 2019; Sanchez-siles et al., 2019). The European Food Safety Authority (EFSA) authorises the use of additives (also known as "E-numbers") below given thresholds. In general, the use of food additives, harmless or potentially harmful, is widespread (Chazelas et al., 2020). The EU recently banned the use of titanium dioxide (E 171) due to accumulating scientific evidence concerning potential health risks (EFSA, 2022). Other potentially adverse additives include nitrites, nitrates, phosphates and monosodium glutamate (Chazelas et al., 2020, 2021).

A recent re-evaluation of nitrites and nitrates sparked a spirited debate because threshold levels were not changed. Especially for ham the use of nitrites or nitrates is widespread but concerns about cancer risk and other health hazards remain (ANSES, 2022). Hams are a major and economically relevant GI category (Török & Jambor, 2016) and prominent GIs such as PDO Parma ham actually ban the use of preservatives like nitrites. However, other GI hams such as Belgian PGI Ardennes ham do not restrict their use at all.[2] While GIs might have the general reputation to be more artisanal and natural products, the use of food additives is not generally forbidden (Galli et al., 2020) and extant research has not yet systematically classified the presence of food additives in GIs. This gap in the literature is surprising as some GIs such as aforementioned Parma ham as well as Parmesan and Comté cheese explicitly ban the use of food additives.

## 3. Method

### 3.1 Hypotheses

Based on the literature we formulate our main hypotheses to test.

[2] All basic information about certain GI product specifications in this article is derived from the EU's eAmbrosia database: https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/ .

Higher contents of unfavourable ingredients such as salt and fat lead to higher Nutri-Scores, i.e. lower nutritional quality. Many GI product specifications mandate certain salt and fat contents to preserve an authentic and pleasant taste. Thus, our first hypothesis to test reads:
*H1: GIs are associated with lower nutritional quality compared to non-GI products*

By definition GIs stipulate the use of traditional production practices to ensure certain quality standards and organoleptic characteristics. These GI specifications may let GIs preserve a more artisanal character and thus, let GIs usually not fall within the category of ultra-processed foods (FAO, 2021). Therefore, our corresponding second hypothesis is:
*H2: GIs have a lower likelihood to be ultra-processed compared to non-GI products*

Moreover, ultra-processed foods typically contain food additives. Some commonly used additives are indeed related to adverse health effects (Chazelas et al., 2020, 2021). Several GIs explicitly ban the use of food additives and emphasise accordingly a healthier and more natural character of their products in their advertisements. Consequently, our corresponding third hypothesis is:
*H3: GIs are less likely to contain additives compared to non-GI products*

### 3.2 Data and variables

Following Chazelas et al. (2020) we opted for the open-access and crowdsourced Open Food Facts (OFF) database that provides data on millions of food and drink products, mainly sold in France. However, given the EU Single Market we expect these products to be representative for the EU as a whole – especially for GIs, which are subject to the same rules throughout the EU.

We downloaded OFF data in November 2021. As about 30% of GIs represent cheeses and processed meats, we focused on the following food categories: cured sausages, cured hams, white hams, cow cheeses, goat cheeses and sheep cheeses. Also, these categories represent processed products prone to the use of food additives (Chazelas et al., 2020) and tend to fall in bad Nutri-Score categories. OFF provides extensive data on the degree of processing, the presence of food additives and nutritional quality per product. Our systematic data cleaning process resulted in 6,088 final observations. Please consult appendix 1 for further information on this process and our final data.

OFF reports the Nutri-Score for all our observations as a continuous value. Nutri-Scores follow a standard calculation (Julia & Hercberg, 2017) that summarizes the reported amounts in the nutrition facts panel into a single score per 100 grams of product that falls into a range between -15 i.e. best nutritional quality to 40 i.e. worst nutritional quality (FOD, 2022). We use

the continuous variable *Nutri-Score* to test *H1*. This continuous variable is preferred compared to the corresponding Nutri-Score categories (A to E) because it allows for a more precise assessment of nutritional quality.[3]

Moreover, OFF reports the degree of processing of products with the help of the NOVA classification system for most products in our sample (N=5,680). The NOVA system became the most commonly used and established concept in health and research policy to assess the overall degree of processing of food products (Adams et al., 2020; Monteiro et al., 2017). The score classifies products in 4 different groups from unprocessed (group 1) to ultra-processed (group 4). As we focus on processed foods, all our observations except one fall either in group 3 (processed food) or group 4 (ultra-processed foods). Thus, we create the binary dependent variable of *ultra-processed* that takes the value of 1 if the product is in NOVA-group 4 and is 0 if it is in NOVA-group 3 to test *H2*.

All our observations are either coded as "with" or "without" additives by OFF. We define our second binary dependent variable *contains additives* to test *H3* as follows. *Contains additives* is 1 if additives are present and 0 if additives are absent.

Our main explanatory variable regarding all our hypotheses is the dummy variable *GI dummy*. OFF mentions so-called "label tags" for each product. These tags report labels that the product possesses, e.g. the EU organic label or GI labels. Thus, we checked all products in our sample for GI label tags (i.e. PDO/PGI and AOP/IGP in French) and corresponding protected names of GI products. In total, we have 79 different GIs in our sample accounting for more than 1,200 product observations (see appendix 8 for a list). If the product is a GI, the variable *GI dummy* takes the value of 1. In addition, we define a categorical variable *GI label* that distinguishes between *PDOs* and *PGIs* to the reference group of *non-GIs*. PDOs typically have stricter product specifications than PGIs and the variable *GI label* accounts for these differences.

We use the OFF food categories to introduce *food category* controls to our models. While 82% of processed meats include additives, this was only the case for 30% of cheeses in the study of Chazelas et al. (2020). Also, certain food types naturally tend to fall in certain NOVA-groups (FAO, 2021) and Nutri-Score categories. As our approach spans several food categories we control for unobserved heterogeneity among these types of foods with controls for each *food category*, namely *cow cheese*, *sheep cheese* and *goat cheese* as well as *cured* (raw) *ham*, *white* (cooked) *ham* and *cured sausages* (meats are made from pork).

[3] Nutri-Score values for solid foods from -15 to -1 fall into category A, 0 to 2 into category B, 3 to 10 into category C, 11 to 18 into category D and 19 to 40 in category E.

Moreover, the EU has a harmonised regulation on organic production that qualifies products to bear an organic label (Seufert et al., 2017). Today, organic producers must follow EU regulation 2018/848, which also restricts the use of food additives. Thus, we create the dummy *organic* that takes the value of 1 if the product is organic to control for organic production.

Finally, there exists another national quality certification on the French market, which is not restricted to French products. The so-called "label rouge" (red label) is granted to products that provide allegedly superior quality. Compliance is monitored by INAO, which is the French National Institute of Origin and Quality (INAO, 2022). Again, we control for corresponding stricter production rules with the dummy *label rouge* that is 1 if the product bears a label rouge.

### 3.3 Descriptive statistics

Table 1 states the descriptive statistics of our sample and summarizes our defined variables.[4] Our sample provides some interesting insights from a descriptive point of view. In the food categories considered for our study, about 50% of products are ultra-processed and contain additives. This finding already underscores previous studies that highlight the prevalence of ultra-processed products and the widespread use and consumption of food additives (Adams et al., 2020; Chazelas et al., 2021, 2020; Monteiro et al., 2017).

The average Nutri-Score of all these processed products is around 15, which corresponds to the category D and indicates an overbalance of unfavourable nutrients in processed meat and cheese categories.

Finally, while the share of GI products is considerable with 20%, only 11% of products are organic. This number is far off from the EU's ambitious goal under the F2F strategy to achieve a share of 25% (European Commission, 2020).

While there are GIs in all categories, they are not equally distributed (see Table A2 in appendix 3). While only four white hams include a GI, the majority of sheep cheeses have a GI. Moreover, PDOs and PGIs are not equally represented in each category. While there are almost only PGIs in the category of cured sausages, there are no PGI goat and sheep cheeses in our sample.

The importance of controlling for food categories also becomes clear when looking at descriptive statistics of our dependent variables in Table A3 (appendix 3). For example, while the average Nutri-Score of cow and goat cheeses is about 14 and 13 (D) respectively, the average of sheep cheeses and cured hams is about 17 (D). White hams have the best Nutri-

[4] The correlation matrix of all our independent variables can be consulted in appendix 2.

Score on average with a value of around 6 (C) and cured sausages have the worst average Nutri-Score with approximately 23 (E). Also, while less than one fourth of cow and sheep cheeses are ultra-processed and contain additives, the same is true for more than 90% of white hams and cured sausages in our sample.

**Table 1** Descriptive statistics of variables

| **Variable** | N | Min. | Max. | Mean | Description |
|---|---|---|---|---|---|
| *Nutri-Score* | 6,088 | 0 | 30 | 15 | Nutri-Score of product |
| *NOVA-group* | 5,680 | 0 | 1 | 0.50 | 1 if NOVA-group 4 (ultra-processed) |
| *Contains additives* | 6,088 | 0 | 1 | 0.51 | 1 if product contains additives |
| *GI dummy* | 6,088 | 0 | 1 | 0.20 | 1 if GI |
| *GI label* | | | | | |
| *PDO* | 6,088 | 0 | 1 | 0.16 | 1 if PDO rather than PGI or non-GI |
| *PGI* | 6,088 | 0 | 1 | 0.04 | 1 if PGI rather than PDO or non-GI |
| *non-GI* | 6,088 | 0 | 1 | 0.80 | 1 if non-GI rather than PDO or PGI |
| *Organic* | 6,088 | 0 | 1 | 0.11 | 1 if organic product |
| *Label rouge* | 6,088 | 0 | 1 | 0.02 | 1 if label rouge product |
| *Food category* | | | | | |
| *White ham* | 6,088 | 0 | 1 | 0.16 | 1 if white (cooked) ham |
| *Cured sausage* | 6,088 | 0 | 1 | 0.19 | 1 if cured sausage |
| *Cured ham* | 6,088 | 0 | 1 | 0.09 | 1 if cured (raw) ham |
| *Cow cheese* | 6,088 | 0 | 1 | 0.42 | 1 if cow cheese |
| *Goat cheese* | 6,088 | 0 | 1 | 0.09 | 1 if goat cheese |
| *Sheep cheese* | 6,088 | 0 | 1 | 0.05 | 1 if sheep cheese |

## 4. Statistical models

We go beyond simple descriptives in our analysis to examine whether the expected tendencies of GIs formulated in our hypotheses are significant across all products in our sample. However, note that despite a possible overall tendency of GIs, there may be differences within specific categories as shown in Table A3 (appendix 3). In a robustness check, we also run category-specific regressions to check whether our main results also hold within certain categories.

First, we estimate the continuous expected *Nutri-Score* based on an OLS fixed effects regression:

$$NutriScore_i = \alpha + \beta_1 GI_i + \beta_2 organic_i + \beta_3 labelrouge_i + \delta_c + \varepsilon_i \quad (1)$$

With $\beta_1$ measuring the expected difference in *Nutri-Score* of a *GI* relative to a non-GI product.[5] $\beta_2$ concerns the effect of *organic* products and $\beta_3$ concerning the effect of a *label rouge* product. $\delta_c$ represents the controls corresponding to the respective *food category*.

Finally, we estimate the probability of product *i* to be *ultra-processed* and to *contain additives* with the following probit models:

$$p(UltraProcessed) = \Phi(\alpha + \beta_1 GI_i + \beta_2 organic_i + \beta_3 label\ rouge_i + \delta_c) \quad (2)$$

$$p(ContainsAdditives) = \Phi(\alpha + \beta_1 GI_i + \beta_2 organic_i + \beta_3 label\ rouge_i + \delta_c) \quad (3)$$

# 5. Results

## 5.1 Nutritional quality

Table 2 reports estimates of our OLS fixed effects regressions on *Nutri-Scores*. As expected, both *PDO* and *PGI* coefficients are positive and significant at the 1% level. Therefore, based on our sample we can confirm *H1* that *GIs* are indeed associated with higher *Nutri-Scores* (i.e. lower nutritional quality). In our full sample, this positive association with values of lower nutritional quality is more strongly pronounced for *PDOs*.

The differences of predicted *Nutri-Scores* of GI products compared to non-GI cheeses and prepared meats are not of a large magnitude since we focus on comparable products (see Figure 1). Nevertheless, the small but significant differences can lead GIs to fall in a worse category, i.e. from D (cut-off value 18) to E.

Note that there are no white hams with a PDO or goat and sheep cheeses with a PGI in our sample (see Table A2, appendix 3). Thus, the corresponding expected Nutri-Scores in Figure 1 represent an extrapolation, e.g. the expected Nutri-Score if a white ham would be a *PDO*. While there is a tendency to score higher for *PDOs* and *PGIs* across all products when controlling for food categories, the expected Nutri-Scores describing extrapolations for specific food categories should still be interpreted with caution. This also applies to extrapolations of predicted probabilities in Figure 2 estimated by our probit regression, which are described in the next section.

[5] In line with our hypotheses, our initial specifications are based on the *GI dummy*. Note that in our final model specifications we distinguish between *PDOs* and *PGIs* in a categorical variable called *GI label* with the reference group of *non-GI* products, to account for potential differences between the two EU GI labels.

On the whole, our results suggest that across the considered food categories PGIs and PDOs in particular tend to have on average higher Nutri-Scores, which translates into lower nutritional quality.

**Table 2** OLS regressions Nutri-Score (higher value = lower nutritional quality)

| **Regressor** | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *GI dummy* | 1.41*** | | | |
| | (0.12) | | | |
| *GI label (reference: non-GI)* | | | | |
| *PDO* | | 1.15*** | 1.57*** | 1.56*** |
| | | (0.12) | (0.08) | (0.08) |
| *PGI* | | 2.35*** | 0.43*** | 0.42*** |
| | | (0.29) | (0.13) | (0.13) |
| *Organic* | | | | -0.27** |
| | | | | (0.11) |
| *Label rouge* | | | | 0.08 |
| | | | | (0.26) |
| *Food category (reference: white ham)* | | | | |
| *Cured sausage* | | | 17.16*** | 17.14*** |
| | | | (0.15) | (0.15) |
| *Cured ham* | | | 10.65*** | 10.64*** |
| | | | (0.16) | (0.16) |
| *Cow cheese* | | | 7.68*** | 7.68*** |
| | | | (0.13) | (0.13) |
| *Goat cheese* | | | 6.54*** | 6.55*** |
| | | | (0.16) | (0.16) |
| *Sheep cheese* | | | 9.61*** | 9.64*** |
| | | | (0.19) | (0.19) |
| *Constant* | 14.73*** | 14.73*** | 6.27*** | 6.30*** |
| | (0.09) | (0.09) | (0.12) | (0.12) |
| **Summary Statistics** | | | | |
| N | 6,088 | 6,088 | 6,088 | 6,088 |
| Adj. $R^2$ | 0.01 | 0.01 | 0.78 | 0.78 |
| AIC | 38811.82 | 38805.03 | 29572.84 | 29570.88 |

***Notes:*** *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$. Robust standard errors in parentheses.

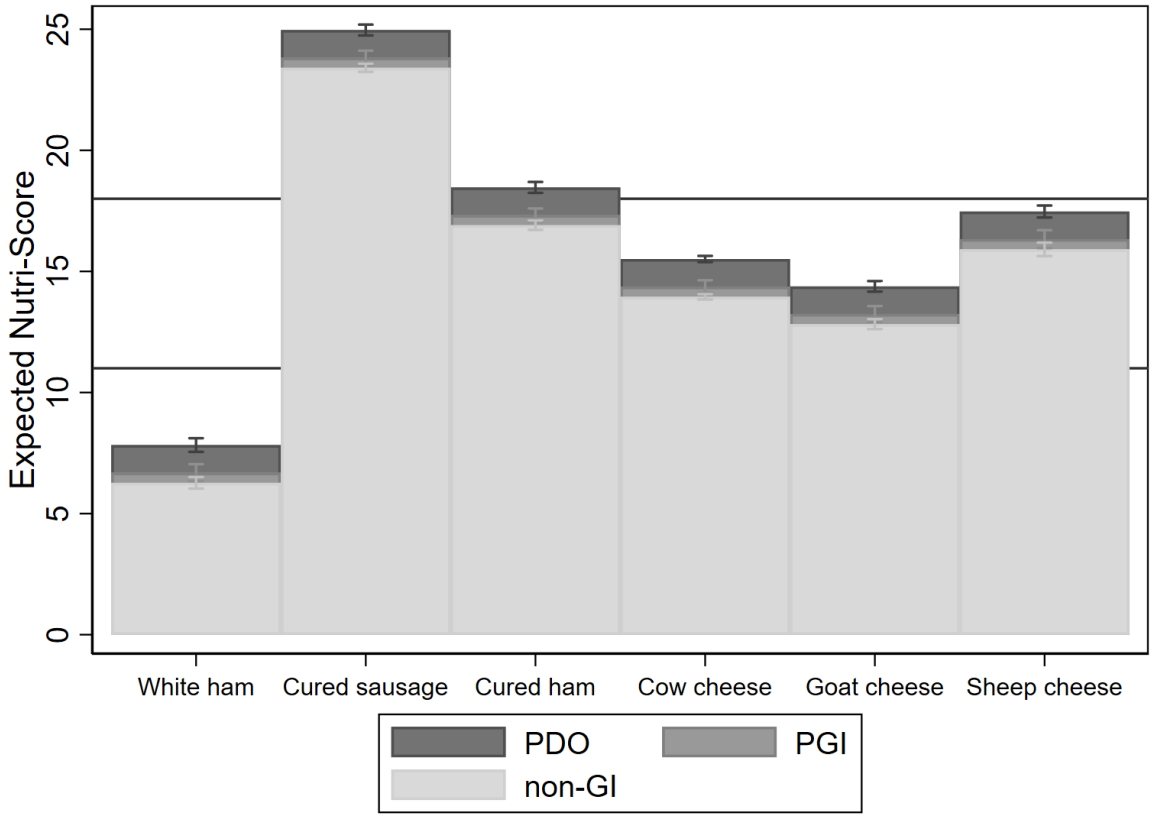


**Figure 1:** Plot of predictive margins of *GI label* on expected *Nutri-Scores* (model 4, Table 2). Lines represent the cut-off points from Nutri-Score C to D and D to E (higher is worse).

### 5.2 Ultra-processing and presence of additives

Table 3 reports results concerning our hypotheses *H2* and *H3*. Model 5 and 7 confirm our hypothesis that *GIs* are less likely to be ultra-processed and to contain additives. However, model 6 and 8 reveal that these lower likelihoods of GIs are only statistically significant for *PDOs* with typically stricter rules than *PGIs*.

Again, the differences between GIs and non-GIs are not particularly large. The predicted probability of *PDOs* to be ultra-processed is about three percentage points lower than for *non-GIs*. Also, in some categories such as white hams the vast majority of products is predicted to be ultra-processed (> 90%), while it is the opposite for sheep cheeses (< 20%). These results are in line with our descriptive statistics in Table A3 (appendix 3) and underscore again the importance of controlling for food categories.

Moreover, Figure 2 shows that the predicted probabilities to contain additives are around 90% for *non-GI* white hams and sausages, but also lower again for *PDOs* with about 87% and 83% respectively. The cheese categories have substantially lower predicted probabilities to include additives. But yet again, *PDOs* are expected to have a significantly

lower likelihood to contain additives. All predicted probabilities are also in line with the descriptive findings in Chazelas et al. (2020) where 82% of processed meats and 30% of cheeses include additives.

**Table 3** Probit regressions of being ultra-processed and containing food additives

| **Regressor** | *NOVA-group* (5) | *NOVA-group* (6) | *Additives* (7) | *Additives* (8) |
|---|---|---|---|---|
| *GI dummy* | -0.10** | | -0.23*** | |
| | (0.05) | | (0.05) | |
| *GI label (reference non-GI)* | | | | |
| *PDO* | | -0.11** | | -0.29*** |
| | | (0.06) | | (0.06) |
| *PGI* | | -0.06 | | -0.04 |
| | | (0.10) | | (0.09) |
| *Organic* | -1.00*** | -1.00*** | -0.87*** | -0.87*** |
| | (0.08) | (0.08) | (0.07) | (0.07) |
| *Label Rouge* | -0.17 | -0.18 | 0.06 | 0.02 |
| | (0.16) | (0.16) | (0.14) | (0.14) |
| *Food category (reference white ham)* | | | | |
| *Cured sausage* | -0.05 | -0.05 | -0.18** | -0.19** |
| | (0.09) | (0.09) | (0.08) | (0.08) |
| *Cured ham* | -2.13*** | -2.14*** | -0.72*** | -0.74*** |
| | (0.09) | (0.09) | (0.09) | (0.09) |
| *Cow cheese* | -2.38*** | -2.38*** | -2.12*** | -2.12*** |
| | (0.08) | (0.08) | (0.07) | (0.07) |
| *Goat cheese* | -2.36*** | -2.36*** | -2.13*** | -2.12*** |
| | (0.09) | (0.09) | (0.09) | (0.09) |
| *Sheep cheese* | -2.66*** | -2.65*** | -2.55*** | -2.52*** |
| | (0.12) | (0.12) | (0.11) | (0.11) |
| *Constant* | 1.78*** | 1.78*** | 1.55*** | 1.55*** |
| | (0.07) | (0.07) | (0.06) | (0.06) |
| **Summary Statistics** | | | | |
| N | 5,680 | 5,680 | 6,088 | 6,088 |
| Pseudo $R^2$ | 0.40 | 0.40 | 0.37 | 0.37 |

***Notes:*** *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$. Robust standard errors in parentheses.

All in all, our findings indicate that GIs tend to be less likely to be ultra-processed and to contain food additives. However, this tendency is driven by PDOs with typically stricter production rules that in some cases even explicitly ban the use of additives. Also, note that organic products show a more pronounced tendency and thus, much lower likelihood to be ultra-processed and to contain additives.

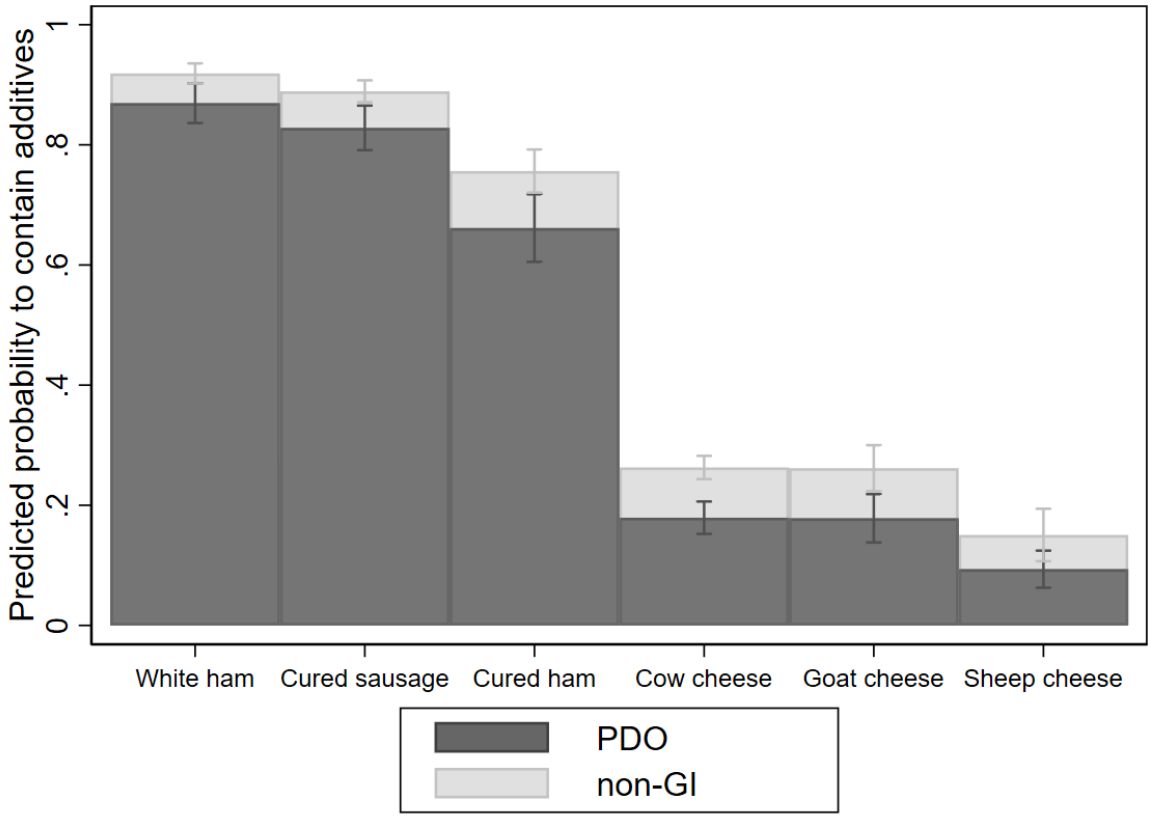


**Figure 2:** Predicted probabilities to contain additives of *PDO* per food category (model 8, Table 3).

## 6. Robustness checks

As mentioned earlier, our full-sample regression specifications with controls for food categories model an overall tendency of PDOs and PGIs across categories and not a category-specific one. There can be deviations in specific category contexts and not all categories contain PDOs or PGIs (see also Table A2 and A3 in appendix 3). Thus, we also run within category regressions to check whether our findings still hold. We consider the categories of cow cheeses and cured hams because each of these categories include a sufficient number of both PDOs and PGIs. Overall, the results of these regressions do not invalidate our main findings (see appendix 5).

A second robustness check considers additives. In terms of health many common food additives such as citric acid (E 330) are considered to be harmless (Chazelas et al., 2020). Therefore, we redefine our dependent variable in a robustness check to *contains adverse additives*. We code the variable as 1 if a product included at least one additive that is related in the literature to adverse health effects. Appendix 6 lists these additives and the corresponding results in Table A9. Actually, no PDO product in our sample includes additives related to adverse health effects. This of course confirms *H3*, but we cannot include PDOs in our model specifications due to this perfect prediction. In line with our previous findings, there is also no

statistically significant difference between PGIs and non-GI products regarding the use of adverse additives.

Finally, we run negative binomial regressions to analyse the count of additives (see appendix 7). In line with our expectations, PDOs and PGIs are more likely to contain less additives in general with statistical significance compared to non-GI products. Again, the overall tendency of PDOs is stronger than the one of PGIs. Nevertheless, both PDOs and PGIs tend to include less food additives.

## 7. Discussion and limitations

GI research suffers from a lack of comprehensive and readily available data (Török et al., 2020). One of our major contributions is that we base our analysis on a large number of observations and GIs from the Open Food Facts database. Despite its large coverage OFF does not provide information about all available products. Nonetheless, we compare more than 70 GIs to a large number of generic products, which represents a substantially larger scope compared to case studies of single GIs.

Another aspect concerns the generalizability of our results. It is difficult to make general conclusions in GI research due to the heterogeneity of registered products (Török et al., 2020). We focus on 79 cheeses and processed meats from 10 countries not only because many GIs fall in these categories, but also because additives are common in these categories. In contrast, GI products such as lemons from Sorrento or apples from South-Tyrol fall in NOVA-group 1 of unprocessed or minimally processed foods (Adams et al., 2020; Monteiro et al., 2019). Also, the Nutri-Score does not cover fresh fruits and vegetables, raw meat or honey (FOD, 2022). This is another reason why we focus on processed GI products such as cheeses and prepared meats, which are also controversially discussed in health debates. Consequently, our analysis covers the most relevant GI categories with regard to our research questions.

Moreover, there is not only heterogeneity among GIs, but also generally in the OFF food categories that we consider. Higher Nutri-Scores of PDOs in a cheese category could be due to the fact that GIs may tend to be more ripened and hardened cheeses (e.g. Parmesan cheese) rather than fresh cheeses. While it is important to be aware of within category variation, these differences do not nullify our overall findings. The OFF categories still represent categories in which consumers search for products.

To continue, food naturalness is a crucial aspect for consumers (Román et al., 2017). Consumers become ever more aware of issues concerning food additives and classifications like the NOVA system or the Food Naturalness Index of Sanchez-Siles et al. (2019) explicitly

account for additive use. This greater awareness also reflects itself in general ambitions to reformulate processed products under the F2F strategy (European Commission, 2020). While consumers may perceive traditional processes and the related GI labels as positive, this positive aspect of GIs may be undermined by the deliberate use of food additives. Therefore, the PGI label may lose reputation in particular, especially if additives are used that were publicly debated regarding health hazards. Even worse, the perception of foods can influence the gustatory experience of a product as Siegrist and Cousin (2009) showed for wines.

One limitation of our study is that we cannot control for the dosage of additives. However, the standard paradigm in toxicology "the dose makes the poison" is being scrutinised by recent studies. The intake of certain additives itself may be harmful despite a low dosage in food (Chazelas et al., 2020, 2021). Therefore, it is already important to investigate the general presence of additives (Chazelas et al., 2020) as we have done in models 6 and 8. This importance seems to be especially true for GI products that allegedly represent less processed and more natural alternatives (FAO, 2021; Glogoveţan et al., 2022).

Regarding nutritional quality, processed meats and cheeses are generally prone to score low in overall nutritional quality, giving producers incentives to improve their nutritional quality. While major supermarkets such as Delhaize in Belgium praise reformulations of hams and cheeses resulting in better Nutri-Scores, GIs are bound to stricter rules that can also stipulate minimum salt or fat contents. Thus, the currently rather small difference in Nutri-Scores between GIs and non-GIs in our regressions may increase in the future to the potential disadvantage of GIs. Non-GI producers could strategically reformulate to reach a cut-off value to fall in a better Nutri-Score category, i.e. from E to D. While certain GI specifications may ensure superior sensory characteristics (Huysmans & van Noord, 2021), this might come at the expense of better Nutri-Scores.

The association of GIs with bad Nutri-Scores may be concerning for GI producers. The current GI regulation does not comprehensively cover nutritional aspects and other sustainability related standards (FAO, 2021; Wirth, 2016). While certain individual products may have the potential to offer the healthier or more environmentally friendly alternative (Belletti et al., 2015; FAO, 2021; Glogoveţan et al., 2022; Vandecandelaere et al., 2021) this is mainly based on the respective product specifications and not the overall GI regulation. Thus, EU policy-makers need to carefully contemplate about making the GI label more inclusive by accounting for eco- and health-related issues in the regulation.

Finally, the Nutri-Score does not consider the use of food additives as well as the content of vitamins, calcium, iron or other minerals. However, case studies on GIs as well as producer

information highlight that GIs are richer in these latter favourable ingredients compared to their generic counterparts (FAO, 2021). Higher contents of conjugated linoleic acid in Portuguese GI cheeses and meat suggest better health-related characteristics (Alfaia et al., 2006; Partidário et al., 2008) and Spanish GI hams show higher percentages of healthier unsaturated fatty acids (Fernández et al., 2007). In our study, we could not control for all these various aspects that often require laboratory tests. However, we do account for the use of food additives, which grants primarily PDOs a better standing in terms of health compared to non-GI products. Overall, PDOs tend to avoid additives and do not include additives related to adverse health effects at all in our sample. Future research may investigate on a broader basis the prevalence of other beneficial and/or unfavourable ingredients in GIs compared to non-GIs.

## 8. Policy implications

In our analysis, we focus on cheeses and prepared meats, which remain prominent GI products in the media regarding health and labelling debates. Consequently, we formulate food policy recommendations applicable to these specific types of products. However, some may argue that we should not consume these GIs of animal origin at all due to comparatively high carbon-footprints, health concerns or animal welfare considerations (Willett et al., 2019). Thus, before we provide our policy implications concerning cheeses and prepared meats, we suggest that fruit and vegetable GIs such as clementine from Calabria or sweet onions from the Cevennes should receive more attention in terms of agri-food promotion campaigns compared to processed GI products.

Moreover, the sales value for GI fruits, vegetables and cereals is increasing. The sales value grew by 97% from 2010 to 2017 and represented 8% of the total sales value of agri-food GIs in 2017. In comparison, cheeses and prepared meat products had a joint share of more than 50% (AND-International, 2019). Thus, policy-makers should stimulate new applications of fruit and vegetable GIs and support producers in marketing their products. 41% of new GI registrations since 2020 were fruits, vegetables and cereals compared to 12% of cheeses and prepared meats. A continuously growing number of registrations of fruit and vegetable GIs may enable the GI sector as a whole to contribute more to healthier diets.

In what follows, we suggest concrete starting points for policy proposals concerning cheese and prepared meat GIs as well as related nutritional labelling that could be considered in the upcoming regulatory revisions under the EU Green Deal initiatives. Also, individual GI product specifications can already be amended under article 53 of the current GI regulation 1151/2012. For example, Mozzarella changed its maximum curd temperature from 36°C to

39°C (Huysmans & van Noord, 2021). As a matter of fact, about one fifth of all food GIs have undergone at least one amendment and processed GI products were amended about 40% more often compared to unprocessed ones (Quiñones Ruiz et al., 2018).

First, we suggest that current GI product specifications should become more flexible in terms of e.g. minimum salt or fat contents. Authors of the FAO (2021) report also advocate for GI amendments and suggest that in specific contexts such as Chinese "furu" (fermented tofu) GIs with lower salt content may be allowed to account for better nutritional quality. Our findings on the association of GIs with lower Nutri-Scores strengthen this point. While for traditionalists this may represent a sacrilege, GI producer organisations should consider allowing less salt and fat in their GIs. Several non-GI producers already started reformulating their products, which also results in better Nutri-Scores.

A perfect example of GI reformulation is the application for an amendment of the famous Italian ham "Prosciutto di San Daniele" which has been published in March 2022.[6] With explicit reference to the WHO (World Health Organization) health goals the consortium of San Daniele ham intends to allow its producers to lower salt contents. Moreover, the consortium emphasises that this lower salt content does not jeopardise the authentic organoleptic characteristics, which is what purists could fear. The amendment has not been implemented yet because the reformulation was classified as a major amendment by the European Commission. To allow for easier and faster reformulation, a practical policy implication would be to treat such health-related amendments as minor. Minor amendments can be processed much faster because they do not require an official opposition procedure.

Second, our results indicate that overall, PDOs tend to be less likely to contain additives as well as to be ultra-processed in general. In order to strengthen consistency across different GIs, harmonised rules on additive use should be considered. Restrictions regarding additives should not compromise GIs, but underscore one of the major goals of the regulation which is to preserve traditional production techniques. Also, systematically avoiding the use of additives would strengthen the natural character of GIs, which sometimes struggle in finding the right balance between artisanal and industrialised production (Gangjee, 2017). More and more consumers demand transparency and more natural products that contain fewer and preferably no food additives (Sanchez-siles et al., 2019). In that respect, GIs should not leave the field clear for e.g. organic non-GI products and non-GI producers that already started marketing campaigns praising their additive-free products (see e.g. Fleury Michon, 2022).

[6] In the Official Journal of the European Union, C 139, 29 March 2022.

In addition, GI amendments that concern the restriction of certain food additives to make the final product more natural should also be classified as minor. A recent example is the amendment to the specification of PGI "Mortadella di Bologna", which was intended to guarantee a simpler and more natural recipe. The minor amendment was approved in June 2022 and added an explicit ban on polyphosphates as well as processing aids and other substances that affect the product's colour. Moreover, natural flavourings are now restricted to a maximum of 0.3%.

Finally, the Nutri-Score seems likely to become the Commission's proposal for harmonised labelling, but its ultimate success remains uncertain. While the European Food Safety Authority (EFSA) emphasised the need for healthier food choices, it did not give a clear label recommendation, leaving policy-makers with a lot of uncertainty (Turck et al., 2022). Therefore, a possible adjustment of the Nutri-Score could be to reward products that are free from (adverse) additives, which may be a step towards current opponents. For example, the Italian EU official Roberto Berutti fears that with the Nutri-Score also ultra-processed foods will be labelled as the green A-/B-label i.e. healthy choices (Fortuna, 2021). The NOVA system already considers additives and the use of additives must be clearly stated in every product's ingredient list. Thus, a revised Nutri-Score may account for additives as well with relatively little effort compared to current labelling.

In July 2022, the steering committee of the Nutri-Score, which consists of competent authorities of seven countries, approved future changes to the Nutri-Score metric (MSP, 2022). These changes are likely to improve the scores of certain hard cheeses with limited amounts of salt, which can be seen as a step towards several GI producers. However, while the Nutri-Score algorithm may improve, it still does not account for the presence of additives or vitamin levels. Nevertheless, the recent decision underscores that the Nutri-Score metric is still developing and may be revised even further as suggested above.

## 9. Conclusion

For the first time, we examined quantitatively nutritional quality and food composition of EU GIs with the help of extensive data on Nutri-Scores, NOVA-groups and additive presence derived from the French Open Food Facts database.

Our OLS fixed effects regressions indicate that both PGIs and PDOs are currently associated with higher (i.e. worse) Nutri-Scores. In the future, rigid traditional product specifications may impede reformulations, which could advantage non-GI products further.

Next, our probit results affirm previous indications in the literature that GIs are less likely to be ultra-processed (i.e. to fall in NOVA-group 4) as well as to contain additives. However, these findings are driven by PDOs. Overall, less strict PGIs do not show a significant difference concerning ultra-processing and additive use compared to non-GI products. Hence, the general heterogeneity of GI products (Török et al., 2020) also reflects itself in our differing results regarding PDOs and PGIs.

Our findings have several policy implications concerning GI cheeses and prepared meats. First, corresponding GI specifications should become more flexible in terms of reformulations concerning e.g. minimum salt and fat contents. Second, harmonised rules on food additive use could be considered in the GI regulation. Third, the Nutri-Score remains one of the EU's preferred options for a new mandatory EU-wide nutrition label. However, its highly-debated limitations in assessing nutritional quality complicate decision-making. In order to bring proponents and opponents of the Nutri-Score closer, the underlying metric may be enhanced by accounting for the use of food additives and/or the content of vitamins as well as other beneficial nutrients.

All in all, whether GIs can actually contribute to healthier diets remains ambiguous. Our findings suggest a potential of some GIs regarding food processing and additive use, but not in terms of nutritional quality based on the Nutri-Score metric. Therefore, we hope to provide new starting points for researchers and practitioners to scrutinise further the policies and possibilities of GIs to contribute to a healthier future.

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# Appendix

## Appendix 1: Open Food Facts (OFF) data

People can add products to the OFF database by scanning the barcode and adding pictures of the packaging. The information is then automatically processed. Consequently, products are uniquely identified by their Global Trade Item Number (GTIN) that is embedded in the barcode. As the data is crowd-sourced we cannot eliminate the possibility that there are errors in our data. However, Open Food Facts systematically controls its data with the help of random sampling and also updates information regularly in case of e.g. reformulations. In addition, more and more producers are aware of the fact that their products are shown on the website and also double-check their entries (Chazelas et al., 2020).

We deleted observations with insufficient information in terms of nutritional aspects. If this basic data is missing, the corresponding observation is more prone to errors in other aspects as well. Our iterative data cleaning process also allowed us to detect faulty data (e.g. honey in cheese category). Thus, our sample remains insightful in spite of some caveats.

We only consider products that are sold in France to ensure consistency and avoid duplicates of the same product just being sold in different countries. To continue, we deleted duplicates of the exact same product of the same brand being sold in a different package size. We systematically identified potential duplicates with the help of a "hash key" that we generated by summing up the values of nutrients. This method was used after consultation with the OFF team. As mentioned before, observations with incomplete information about the nutrition facts were removed accordingly.

Also, the meat categories are predominantly including pork products. To achieve higher comparability of products within the meat categories, we systematically removed products that are not made from pork (e.g. "ham" made from turkey). In addition, we do not consider obvious combinations of products such as "*assiettes* (platters)" selling hams together with e.g. cheeses or sausages sold in a loaf of bread.

All in all, the iterative data cleaning process to reduce errors in the original OFF data resulted in 6,088 final observations.

## Appendix 2: Correlation matrix

**Table A1** Correlation matrix of independent variables

| **Variables** | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) *GI dummy* | 1.000 | | | | | | | | | | | |
| (2) *PDO* | 0.860 | 1.000 | | | | | | | | | | |
| (3) *PGI* | 0.428 | -0.093 | 1.000 | | | | | | | | | |
| (4) *Non-GI* | -1.000 | -0.860 | -0.428 | 1.000 | | | | | | | | |
| (5) *Organic* | -0.019 | -0.004 | -0.032 | 0.019 | 1.000 | | | | | | | |
| (6) *Label rouge* | -0.009 | -0.060 | 0.088 | 0.009 | -0.044 | 1.000 | | | | | | |
| (7) *Cured ham* | 0.042 | -0.058 | 0.184 | -0.042 | -0.040 | -0.004 | 1.000 | | | | | |
| (8) *Goat cheese* | 0.011 | 0.050 | -0.067 | -0.011 | 0.030 | -0.043 | -0.097 | 1.000 | | | | |
| (9) *Cow cheese* | 0.192 | 0.202 | 0.019 | -0.192 | 0.013 | -0.080 | -0.263 | -0.265 | 1.000 | | | |
| (10) *Sheep cheese* | 0.192 | 0.240 | -0.051 | -0.192 | 0.080 | -0.033 | -0.074 | -0.074 | -0.202 | 1.000 | | |
| (11) *White ham* | -0.217 | -0.191 | -0.086 | 0.217 | 0.023 | 0.064 | -0.137 | -0.137 | -0.373 | -0.105 | 1.000 | |
| (12) *Cured sausage* | -0.187 | -0.208 | 0.003 | 0.187 | -0.077 | 0.094 | -0.150 | -0.150 | -0.409 | -0.115 | -0.212 | 1.000 |

## Appendix 3: Descriptive statistics

**Table A2** Number of GIs per category

| *GI label* | Cow cheese | Goat cheese | Sheep cheese | Cured sausage | White ham | Cured ham | Total |
|---|---|---|---|---|---|---|---|
| *PDO* | 622 | 117 | 172 | 1 | 0 | 48 | 960 |
| *PGI* | 124 | 0 | 0 | 52 | 4 | 89 | 269 |
| *Non-GI* | 1,800 | 423 | 156 | 1,096 | 985 | 399 | 4,859 |
| Total | 2,546 | 540 | 328 | 1,149 | 989 | 536 | 6,088 |

**Table A3** Averages of dependent variables per category and GI label

| *GI label* | Cow cheese | Goat cheese | Sheep cheese | Cured sausage | White ham | Cured ham | Total |
|---|---|---|---|---|---|---|---|
| | | | *Nutri-Score* | | | | |
| *PDO* | 15.5 (1.8) | 13.6 (1.4) | 18.2 (1.6) | 25.0 (0.0) | - | 18.1 (1.1) | 15.9 (2.2) |
| *PGI* | 13.8 (2.3) | - | - | 24.3 (1.3) | 6.5 (3.0) | 17.9 (1.6) | 17.1 (4.6) |
| *Non-GI* | 14.0 (2.6) | 13.0 (2.5) | 15.1 (2.7) | 23.4 (2.9) | 6.3 (3.8) | 16.8 (2.3) | 14.7 (6.4) |
| Total | 14.4 (2.5) | 13.2 (2.3) | 16.7 (2.7) | 23.4 (2.9) | 6.3 (3.8) | 17.1 (2.2) | 15.0 (5.9) |
| | | | *NOVA-group 4 rather than 3* | | | | |
| *PDO* | 0.21 | 0.49 | 0.06 | 1.00 | - | 0.00 | 0.21 |
| *PGI* | 0.17 | - | - | 0.98 | 1.00 | 0.36 | 0.42 |
| *Non-GI* | 0.25 | 0.17 | 0.23 | 0.94 | 0.94 | 0.37 | 0.55 |
| Total | 0.24 | 0.24 | 0.15 | 0.94 | 0.94 | 0.33 | 0.50 |
| | | | *Contains additives* | | | | |
| *PDO* | 0.20 | 0.44 | 0.05 | 0.00 | - | 0.00 | 0.19 |
| *PGI* | 0.16 | - | - | 0.90 | 0.75 | 0.90 | 0.56 |
| *Non-GI* | 0.26 | 0.18 | 0.19 | 0.90 | 0.92 | 0.81 | 0.57 |
| Total | 0.24 | 0.23 | 0.11 | 0.90 | 0.92 | 0.76 | 0.51 |

***Note*:** Standard deviations for continuous variables in parentheses.

## Appendix 4: Correctly predicted observations

The predictions below were made using the estimates of model 6 (*NOVA-group*) and model 8 (*Additives*) presented in Table 3.

In model 6, a product was predicted to fall into NOVA category 4 if the predicted probability exceeds 50%. Note that out of 5,680 observations, 2,852 are in NOVA group 3 and 2,828 in NOVA group 4, i.e. are classified as ultra-processed. An empty model would hence correctly predict 2,852 out of 5,680 observations, or 50%. The estimated model 6 correctly classifies 4,673 observations or 82%. The model reduces errors in the prediction of *NOVA-group* by 64%.

**Table A4** Correctly predicted observations based on model 6

| ***NOVA-group*** | **No. of observations** | **% of sample** |
|---|---|---|
| Correctly predicted NOVA-group 4 | 1,942 | 34% |
| Correctly predicted NOVA-group 3 | 2,731 | 48% |
| Incorrectly predicted NOVA-group 4 | 886 | 16% |
| Incorrectly predicted NOVA-group 3 | 121 | 2% |
| Total | 5,680 | 100% |
| Correctly predicted | 4,673 | 82% |

In model 8, a product was predicted to contain additives if the predicted probability exceeds 50%. Note that out of 6,088 observations, 3,121 contain at least one additive and 2,967 do not contain food additives. An empty model would hence correctly predict 3,121 out of 6,088 observations, or 51%. The estimated model 8 correctly classifies 4,994 observations or 82%. The model reduces errors in the prediction of *contains additives* by 63%.

**Table A5** Correctly predicted observations based on model 8

| ***Contains additives*** | **No. of observations** | **% of sample** |
|---|---|---|
| Correctly predicted to contain additives | 2,332 | 38% |
| Correctly predicted not to contain additives | 2,662 | 44% |
| Incorrectly predicted to contain additives | 789 | 13% |
| Incorrectly predicted not to contain additives | 305 | 5% |
| Total | 6,088 | 100% |
| Correctly predicted | 4,994 | 82% |

## Appendix 5: OLS and probit results of cured ham and cow cheese subsamples

**Table A6** Cured ham subsample regressions

| **Regressor** | *Nutri-Score* (1) | *NOVA-group* (2) | *Additives* (3) |
|---|---|---|---|
| *GI label (reference non-GI)* | | | |
| *PDO* | 1.23*** | Omitted as all | Omitted as all |
| | (0.21) | NOVA-group 3 | additive-free |
| *PGI* | 1.05*** | -0.01 | 0.41** |
| | (0.21) | (0.16) | (0.21) |
| *Organic* | 0.84** | -0.67** | -1.09*** |
| | (0.39) | (0.31) | (0.24) |
| *Label Rouge* | 0.78 | 0.18 | Omitted as all |
| | (0.70) | (0.42) | contain additives |
| *Constant* | 16.77*** | -0.32*** | 0.97*** |
| | (0.12) | (0.07) | (0.08) |
| **Summary statistics** | | | |
| N | 536 | 453 | 479 |
| Adj. $R^2$ / Pseudo $R^2$ | 0.06 | 0.01 | 0.05 |

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

**Table A7** Cow cheese subsample regressions

| **Regressor** | *Nutri-Score* (4) | *NOVA-group* (5) | *Additives* (6) |
|---|---|---|---|
| *GI label (reference non-GI)* | | | |
| *PDO* | 1.45*** | -0.16** | -0.25*** |
| | (0.10) | (0.07) | (0.07) |
| *PGI* | 0.03 | -0.22 | -0.31** |
| | (0.22) | (0.15) | (0.14) |
| *Organic* | -0.71*** | -0.87*** | -0.90*** |
| | (0.14) | (0.12) | (0.12) |
| *Label Rouge* | -2.65*** | Omitted as all | Omitted as all |
| | (0.39) | NOVA-group 3 | additive-free |
| *Constant* | 14.09*** | -0.59*** | -0.56*** |
| | (0.06) | (0.03) | (0.03) |
| **Summary statistics** | | | |
| N | 2,546 | 2,341 | 2,531 |
| Adj. $R^2$ / Pseudo $R^2$ | 0.08 | 0.03 | 0.03 |

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

**Appendix 6: Probit results with dependent variable *contains adverse additives***

Table A8 lists food additives that are related to adverse health effects (Chazelas et al., 2020) and included in our sample. The dependent variable *contains adverse additives* was coded as 1 if the product includes at least one adverse additive and 0 if not. The results of the corresponding probit regressions are reported in Table A9.

**Table A8** List of adverse additives included in sample

| **Name of food additive** | **E-number** |
|---|---|
| Sodium nitrite | E 250 |
| Potassium nitrate | E 252 |
| Diphosphates | E 450 |
| Triphosphates | E 451 |
| Polyphosphates | E 452 |
| Monosodium glutamate | E 621 |
| Carrageenan | E 407 |
| Sodium phosphates | E 339 |
| Calcium phosphates | E 341 |
| Potassium metabisulphite | E 224 |
| Carboxymethylcellulose | E 466 |
| Potassium phosphates | E 340 |

| **Table A9** Probit estimating probability to contain adverse additives | | | | |
|---|---|---|---|---|
| **Regressor** | (7) | (8) | (9) | (10) |
| *GI dummy* | -1.14***<br>(0.05) | | -0.67***<br>(0.07) | |
| *GI label*<br>*(reference non-GI)* | | | | |
| *PDO* | | Omitted as all free from adverse additives | | Omitted as all free from adverse additives |
| *PGI* | | 0.07<br>(0.08) | | 0.01<br>(0.10) |
| *Organic* | | | -0.80***<br>(0.09) | -0.79***<br>(0.09) |
| *Label rouge* | | | 0.26<br>(0.18) | 0.16<br>(0.16) |
| *Category*<br>*(reference white ham)* | | | | |
| *Cured sausage* | | | 0.07<br>(0.07) | 0.04<br>(0.07) |
| *Cured ham* | | | -0.28***<br>(0.08) | -0.23***<br>(0.09) |
| *Cow cheese* | | | -2.96***<br>(0.08) | -2.94***<br>(0.08) |
| *Goat cheese* | | | -3.28***<br>(0.16) | -3.25***<br>(0.16) |
| *Sheep cheese* | | | -3.26***<br>(0.23) | -3.18***<br>(0.24) |
| *Constant* | -0.12***<br>(0.02) | -0.12***<br>(0.02) | 1.19***<br>(0.05) | 1.18***<br>(0.05) |
| **Summary statistics** | | | | |
| N | 6,088 | 5,128 | 6,088 | 5,128 |
| Pseudo $R^2$ | 0.07 | 0.00 | 0.64 | 0.61 |

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

## Appendix 7: Results of additives count data regressions (negative binomial)

| **Table A10** Dependent variable: Number of included food additives | | | | |
|---|---|---|---|---|
| **Regressor** | (11) | (12) | (13) | (14) |
| *GI* | -1.33*** | | | |
| | (0.06) | | | |
| *GI label* | | | | |
| *(reference non-GI)* | | | | |
| *PDO* | | -1.80*** | -0.88*** | -0.90*** |
| | | (0.08) | (0.09) | (0.09) |
| *PGI* | | -0.48*** | -0.38*** | -0.39*** |
| | | (0.07) | (0.08) | (0.08) |
| *Organic* | | | | -0.83*** |
| | | | | (0.06) |
| *Label rouge* | | | | -0.19*** |
| | | | | (0.05) |
| *Category* | | | | |
| *(reference white ham)* | | | | |
| *Cured sausage* | | | 0.18*** | 0.13*** |
| | | | (0.03) | (0.03) |
| *Cured ham* | | | -0.33*** | -0.38*** |
| | | | (0.04) | (0.04) |
| *Cow cheese* | | | -1.45*** | -1.47*** |
| | | | (0.05) | (0.05) |
| *Goat cheese* | | | -1.64*** | -1.63*** |
| | | | (0.11) | (0.10) |
| *Sheep cheese* | | | -1.41*** | -1.37*** |
| | | | (0.18) | (0.18) |
| Constant | 0.24*** | 0.24*** | 0.69*** | 0.78*** |
| | (0.02) | (0.02) | (0.02) | (0.02) |
| **Summary statistics** | | | | |
| N | 6,015 | 6,015 | 6,015 | 6,015 |
| Pseudo $R^2$ | 0.03 | 0.04 | 0.16 | 0.17 |
| Log pseudolikelihood | -8379.47 | -8313.85 | -7291.67 | -7183.03 |

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

## Appendix 8: List of GIs included in our sample

1. Abondance (PDO, cheese, France)[7]
2. Banon (PDO, cheese, France)
3. Beaufort (PDO, cheese, France)
4. Bleu d'Auvergne (PDO, cheese, France)
5. Bleu de Causses (PDO, cheese, France)
6. Bleu de Gex Haut-Jura (PDO, cheese, France)
7. Blue Stilton Cheese (PDO, cheese, France)
8. Brie de Meaux (PDO, cheese, France)
9. Brie de Melun (PDO, cheese, France)
10. Brillat-Savarin (PGI, cheese, France)
11. Camembert de Normandie (PDO, cheese, France)
12. Cantal (PDO, cheese, France)
13. Chabichou du Poitou (PDO, cheese, France)
14. Chaource (PDO, cheese, France)
15. Charolais (PDO, cheese, France)
16. Chavignol (PDO, cheese, France)
17. Comté (PDO, cheese, France)
18. Coppa di Parma (PGI, meat, Italy)
19. Cotechino Modena (PGI, meat, Italy)
20. Culatello di Zibello (PDO, meat, Italy)
21. Edam Holland (PGI, cheese, the Netherlands)
22. Emmental de Savoie (PGI, cheese, France)
23. Époisses (PDO, cheese, France)
24. Feta (PDO, cheese, Greece)
25. Fourme d'Ambert (PDO, cheese, France)
26. Gorgonzola (PDO, cheese, Italy)
27. Gouda Holland (PGI, cheese, the Netherlands)
28. Grana Padano (PDO, cheese, Italy)
29. Gruyère (PGI, cheese, France)
30. Gruyère (PDO, cheese, Switzerland)[8]
31. Jambon d'Ardenne (PGI, meat, Belgium)
32. Jambon d'Auvergne (PGI, meat, France)
33. Jambon de Bayonne (PGI, meat, France)
34. Jambon de Vendée (PGI, meat, France)
35. Langres (PDO, cheese, France)
36. Livarot (PDO, cheese, France)
37. Mâconnais (PDO, cheese, France)
38. Maroilles (PDO, cheese, France)
39. Mont d'Or / Vacherin du Haut-Doubs (PDO, cheese, France)
40. Morbier (PDO, cheese, France)
41. Mozzarella di Bufala Campana (PDO, cheese, Italy)
42. Munster (PDO, cheese, France)

[7] Name of GI (GI label, type of product, country of origin)
[8] Switzerland is not part of the EU, but since 2011 the EU and Switzerland protect each other's GIs.

43. Neufchâtel (PDO, cheese, France)
44. Noord-Hollandse Gouda (PDO, cheese, the Netherlands)
45. Ossau-Iraty (PDO, cheese, France)
46. Parmigiano Reggiano (PDO, cheese, Italy)
47. Pecorino Romano (PDO, cheese, Italy)
48. Pélardon (PDO, cheese, France)
49. Picodon (PDO, cheese, France)
50. Pont l-Évêque (PDO, cheese, France)
51. Porc de Franche-Comté (PGI, meat, France)
52. Porc du Sud-Ouest (PGI, meat, France)
53. Porc noir de Bigorre (PDO, meat, France)
54. Pouligny-Saint-Pierre (PDO, cheese, France)
55. Prosciutto di Parma (PDO, meat, Italy)
56. Prosciutto di San Daniele (PDO, meat, Italy)
57. Queso Manchego (PDO, cheese, Spain)
58. Raclette de Savoie (PGI, cheese, France)
59. Reblochon (PDO, cheese, France)
60. Rigotte de Condrieu (PDO, cheese, France)
61. Rocamadaour (PDO, cheese, France)
62. Roquefort (PDO, cheese, France)
63. Sainte-Maure de Touraine (PDO, cheese, France)
64. Saint-Marcellin (PGI, cheese, France)
65. Saint-Nectaire (PDO, cheese, France)
66. Salam de Sibiu (PGI, meat, Romania)
67. Salame Felino (PGI, meat, Italy)
68. Salers (PDO, cheese, France)
69. Saucisson de l’Ardèche (PGI, meat, France)
70. Saucisson sec d'Auvergne / Saucisse sèche d'Auvergne (PGI, meat, France)
71. Schwarzwälder Schinken (PGI, meat, Germany)
72. Selles-sur-Cher (PDO, cheese, France)
73. Soumaintrain (PGI, cheese, France)
74. Südtiroler Speck (PGI, meat, Italy)
75. Tête de Moine (PDO, cheese, Switzerland)
76. Tome de Bauges (PDO, cheese, France)
77. Tomme de Pyrénées (PGI, cheese, France)
78. Tomme de Savoie (PGI, cheese, France)
79. Valençay (PDO, cheese, France)