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Viewpoint:

Regulating Meat Consumption to Improve Health, the Environment and Animal Welfare[1]

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Abstract: Meat consumption has increased significantly in the last 50 years. This trend raises various health and environmental issues, as well as moral concerns regarding farm animal welfare. In this paper, we discuss the regulation of meat consumption in developed countries. Specifically, we discuss possible justifications for this regulation in terms of environmental, health and animal welfare considerations, as well as the effect of fiscal, informational and behavioral regulatory instruments. Finally, we present a list of challenges that policy makers and food scholars may need to confront in the future.

Keywords: Meat consumption, regulation, health, environment, climate change, animal welfare.

JEL codes: Q11, Q52, H31.

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1 Introduction

Debates about meat production and consumption are often complex and controversial. Scholars and policy makers increasingly advocate for a reduction in meat consumption in developed countries for health, environmental or animal welfare considerations (Godfray et al., 2016; Willett et al., 2019). Although governments already act in various ways to sustain or control the production of meat, there is little agreement over the actions they should take to reduce the consumption of meat. The objective of this paper is to discuss the justification for and the effectiveness of possible regulatory actions to curb meat consumption in developed countries.

The consumption of animal products has significantly increased in the last 50 years (Terra Nova, 2017; FAO, 2018). In 1961, 52% of the per capita protein availability in the European Union (EU) came from plant-based products (Figure 1b). At that time, wheat products were the main source of protein availability (26g/capita/day), while meat represented 17g/capita/day (Figure 1c). The quantity of proteins from plant-based products has remained stable over time, while the protein availability from animal products has sharply increased, such that animal products now represent 58% of protein availability per capita/day. Today, animal products provide approximately 30% of the available calories in the EU (Figure 1a), and are an important source of nutrients. Meat is the major source of protein availability with 28g of protein/capita/day, followed by wheat products and dairy products. Other sources of protein—including other animal proteins (such as fish and seafood) or plant-based products (such as pulses)—have remained stable over time but are low in comparison.

The evolution in the EU of meat availability depends on the meat category (Figure 1d). Historically, bovine meat and pigmeat were the two main sources of meat protein. Pigmeat

quantities constantly increased from the 1960s to the 1990s and then remained relatively stable, while per capita protein quantity from bovine meat first increased up until the 1990s but sharply declined thereafter. On the contrary, the per capita availability of protein from poultry meat has increased constantly over time, such that it now largely exceeds the availability level of bovine meat and almost reaches the availability level of pigmeat. Different factors may explain this evolution. In particular, the relative price of different meats plays a role in the increasing share of poultry meat and the decreasing share of bovine meat.

The global nutritional transition over the last century—which includes a transition toward meat products—is also likely related to income changes (Drewnowski and Popkin, 1997). According to the meta-analysis of Gallet (2010a), the income elasticity of meat is about 1 for beef, 0.8 for poultry and pork and 0.7 for lamb. Yet, Vranken et al. (2014) show an inverted U-shaped relationship between meat consumption and income. Below the turning point, they estimate a positive income elasticity of 0.5 whereas above the turning point—that is, for higher levels of income—the income elasticity would be -1.2. The substitution between red and white meat is partly a consequence of the evolution of the relative price of white and red meat, with white meat significantly cheaper than red meat. Gallet (2010b) reports own-price elasticity in the range of -0.8 for poultry, and in the range of -1 for beef and lamb. However, changes in consumers' preferences with respect to intrinsic characteristics of meat products (such as taste, freshness) or external factors (such as environmental, health and animal welfare concerns), as well as changing consumer lifestyles, may also play a growing role in consumer food choice (Verbeke et al., 2010; Henchion et al., 2014).

The evolution in our diet toward more animal products generates important external costs. In developed countries, meat consumption may increase the risk of various chronic health

diseases (Nelson et al., 2016; Godfray et al., 2018). Meat, and particularly meat from ruminants, is also a significant source of greenhouse gas (GHG) emissions and a major driver of deforestation and worldwide biodiversity loss (IPCC 2019, IPBES 2019). It also contributes to the local pollution of water, soil and air (Dumont et al., 2016; Poore and Nemecek, 2018). Moreover, much of the land, energy and water used to grow feed crops for animals could be used more efficiently to grow plant-based food directly consumed by humans (Shepon et al., 2018). Meat also contributes indirectly (through animal rearing conditions) to global threats, such as antibiotics resistance and zoonosis (Dumont et al., 2016). In addition, society is more and more concerned by animal suffering and welfare in the farming industry, which is likely associated with the growing number of vegetarian and vegan consumers in rich countries (Ruby, 2012; The Economist, 2018).

Hence, several health, environmental and societal pressures may justify a more stringent regulation of meat consumption. Willet et al. (2019) argue that a transition toward more plant-based food is a major lever to enhance human health and environmental sustainability. Yet, the efforts to regulate meat consumption are, so far, limited in comparison to the regulation of other economic sectors. For instance, most polluting sectors are now regulated in order to mitigate climate change. In Europe, many countries have adopted a carbon tax on transport, and about half of European GHG emissions are covered by the EU Emission Trading System (involving energy, steel or cement industries, etc.).[2] However, the food sector—which represents a non-negligible part of total GHG emissions (15-28%)—is not concerned by these

[2] The EU emissions trading system defines a cap on the total amount of greenhouse gas emissions and within the cap it allows companies to trade emission allowances. For more information, cf. https://ec.europa.eu/clima/policies/ets_en.

climate regulatory schemes (Garnett, 2011).[3] In the domain of local air pollution (PM2.5), Tschofen et al. (2019) indicate that agriculture, and especially animal farming, has become the greatest contributor to air pollution damages in the US, emphasizing that much of the regulation so far has concerned the electricity sector but has overlooked (animal) agriculture.

The objective of this short viewpoint paper is not to present a comprehensive discussion of meat regulation. Our approach is selective, and we focus on demand-side regulation which we believe has not yet been sufficiently addressed. Therefore, we do not discuss supply-side regulation such as the Common Agricultural Policy (CAP) or animal health management. Instead, we mostly discuss regulation in developed countries, and essentially focus on Europe, with France as a typical example. Moreover, we do not discuss all types of impacts. For instance, we overlook important issues such as food security, amenities provision and rural development. Finally, we do not intend to present an exhaustive overview of the literature on meat consumption and regulation, but only a selection of studies. In particular, we refer mostly to the literature in economics.

The outline of the rest of the paper is as follows. In Section 2, we briefly discuss the three main domains of negative impacts associated with meat consumption—namely, health, environment and animal welfare—and discuss the justifications for regulation. In Section 3, we discuss fiscal, informational and behavioral instruments that can be used to regulate meat consumption. Finally, in Section 4, we present what we consider to be important future challenges in the regulation of meat consumption.

[3] The question of how to regulate agriculture and the meat industry is gaining prominence on the climate regulatory agenda. Various public national reports in Denmark, France, Sweden, or the UK discuss the possibility of introducing a carbon (or methane) tax on meat.

Figure 1: EU per capita availability of food and meat products

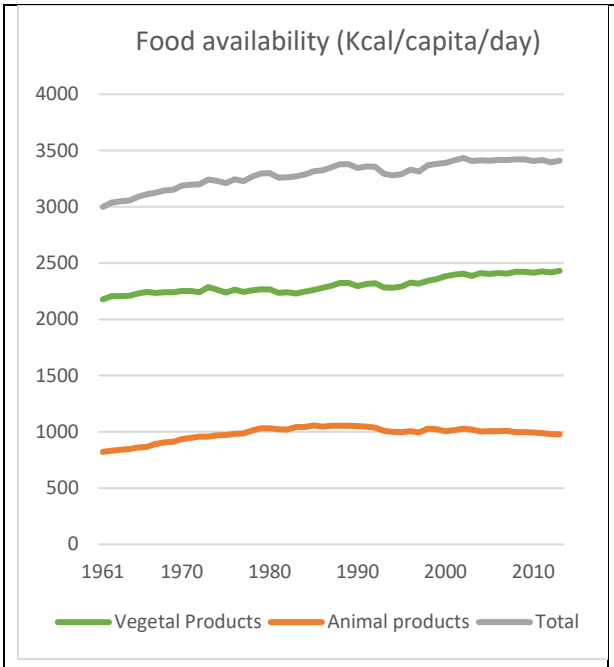

Figure 1-a

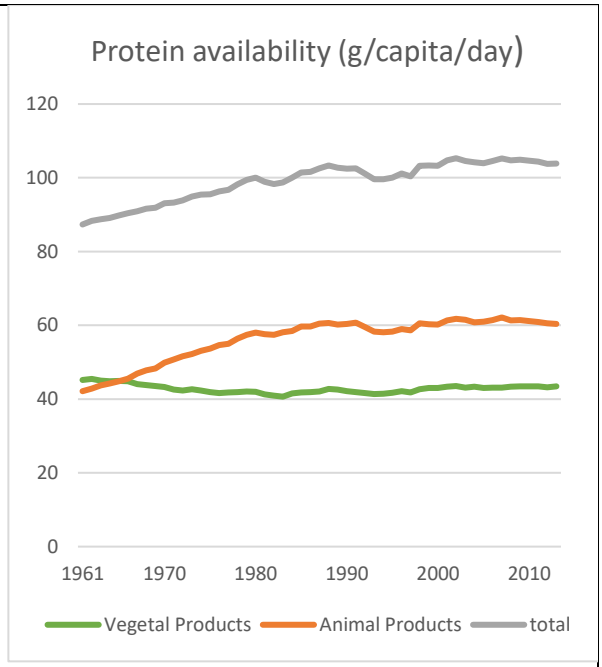

Figure 1-b

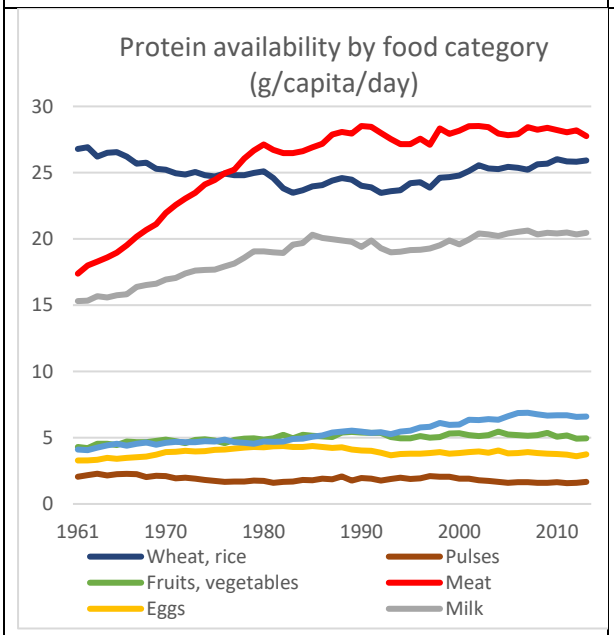

Figure 1-c

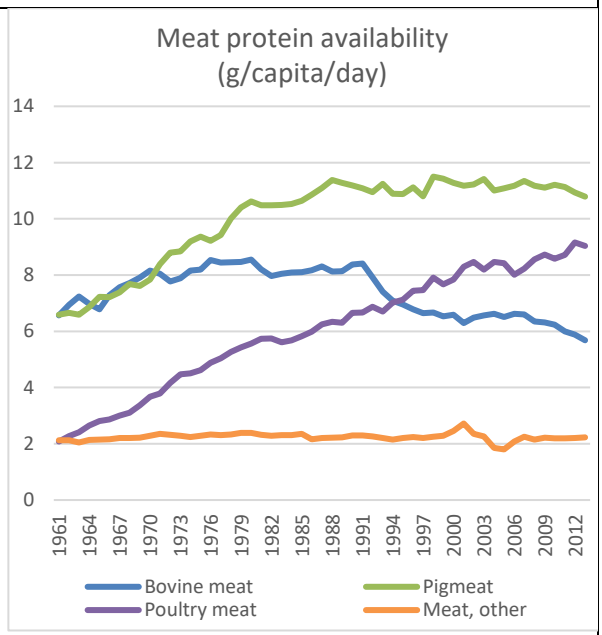

Figure 1-d

Own figures computed using the quantitative data from FAO food balance sheets (http://www.fao.org/faostat/en/#data/FBS) for the period currently available (1961–2013) for the EU region. They are calculated as national availabilities (production, import and stocks) net of exports, feed, non-food usage, usage input for food, wastage, and closing stocks. Therefore, they do not correspond to consumption quantities. However, since consumption evolution follows net supply availabilities, the figures provide an informative description of food consumption trends.

2 Justifications for meat regulation

2.1 Impacts on health, environment and animal welfare

The increase in meat consumption over the last five decades has not been without consequences for human health, the environment and animal welfare.

In terms of the health impacts, red and processed meat consumption is positively associated with all-cause mortality (Rohmann et al., 2013). The effect is most prevalent for cancers. The International Agency for Research on Cancer (IARC) considers red meat as (probably) carcinogenic to humans, particularly for colorectal cancer but also for pancreatic cancer and prostate cancer. In addition, each daily intake of a 50-gram portion of processed meat increases the relative risk of colorectal cancer by 18% (IARC, 2015). In addition, processed meat consumption is characterized by a high content of cholesterol and saturated fatty acids, which are both associated with coronary heart disease (Mozaffarian et al., 2010) and diabetes (Micha et al., 2010; Wolk, 2017).[4] Moreover, all meat intake is positively associated with weight gain (Vergnaud et al., 2010). Due to the high intake of red and processed meat in high-income countries, the World Health Organization thus recommends limiting their consumption. Finally, the widespread use of antibiotics in industrial animal food production increases the risk of the development of antibiotic-resistant bacteria. Regarding climate change, at the country level in Europe, food consumption contributes between 15% and 28% to overall GHG emissions (Garnett 2011). Given current consumption trends, the environmental impact of the food system could substantially increase. According to some

[4] In France, almost 70% of people consume red and processed meat. Actual red meat consumption fits the recommendation on average (no more than 70g/day according to ANSES) for those who consume it. However, there is a large heterogeneity in consumption as the standard deviation is 55g/day (INCA3), meaning that a significant proportion of red meat consumers eat more than the recommended level. Regarding processed meat, more than half of consumers eat more than the recommended maximal level (no more than 25g/day).

studies, in 2050, ruminant meat may be responsible for around two-thirds, and animal products for 80%, of global GHG emissions from agriculture (Hedenus and Wirsenius, 2014; Tilman and Clark, 2014). The recent special IPCC report on land use (IPCC 2019) states: "Balanced diets, featuring plant-based foods, such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds, and animal-sourced food produced in resilient, sustainable and low-GHG emission systems, present major opportunities for adaptation and mitigation while generating significant co-benefits in terms of human health (*high confidence*)." Furthermore, GHG emission levels depend on the type of meat. Ruminant meat leads to higher GHG emissions than pork or poultry, which have a similar carbon footprint. The type of production system could affect the environmental impact. Indeed, even if grazing helps carbon sequestration, extensive production systems may generate more GHG emissions than intensive production systems per unit of output (Nguyen et al., 2010).[5]

Animal consumption also has a significant impact on land and water use (Mekonnen and Hoekstra, 2012). The livestock sector uses 35% of total world cropland for animal feed and 20% of green water for feed production. In Europe, the share of croplands used for animal feed is even higher, with only 40% of cropland devoted to human consumption. Taken

[5] The argument that grazing can help reduce climate change due to carbon sequestration is still controversial. First, it seems that adequate management practices of grassland may increase carbon sequestration (e.g. Teague et al., 2016, in the North American context). However, in real life conditions, when following these practices, it is not granted. Second, even for livestock raised on grass, the net contribution to GHG emissions is specific to local conditions and is in general positive. As shown by Poore and Nemecek (2018), for any product there is a huge heterogeneity in the associated GHG emissions. In the case of beef production, they report a tenth-percentile of 20kg CO2-equivalent per 100g of protein and a ninetieth-percentile of 105kg. However, they argue that the ability (of producers) to reduce environmental impacts is limited. Third, if grazing levels decrease, the land for grazing could be replaced by forests which tend to generate more carbon sequestration. Generally, this calls for analyzing substitutions in land use and associated GHG emissions (or sequestration). Nevertheless, as shown by the "4 per 1000" initiative, changes in land management and use have a large potential for carbon sequestration, but at present this remains highly challenging and would necessitate important changes in the way we produce food. See Searchinger et al. (2018) for a recent method to properly account for the opportunity cost of land use with an application to the impact of changing diet.

together, croplands devoted to feed production, pasture and grazing lands represent around 75% of the world's agricultural land (Foley, 2011). Land devoted to animal production thus competes with the land used for vegetal products required for direct human consumption (Dumont et al., 2016; Shepon et al., 2018).[6] Meat production also leads to other indirect impacts on the environment: land degradation due to overgrazing, biodiversity loss (mainly brought about by land use and ecosystem pollution), water and land pollution from animal waste, and air pollution through the emissions of ammoniac from the intensive farming units for poultry and pigs (Godfray et al., 2018). Moreover, livestock production is an important driver of deforestation due to the rapid expansion of pastures but also to the increasing demand for high-quality protein feeds, such as soybean (Opio et al., 2012). For example, in South America, livestock is responsible for more than 85% of deforestation (71% for grazing and 14% for animal feed, according to De Sy et al., 2015). However, organic fertilizing from manure has positive impacts on soil fertility and soil biodiversity. With a high concentration of livestock in a given zone, these positive impacts are likely to be eliminated by the negative impacts due to the excessive use of fertilizers, leading to water pollution (Dumont el al., 2016).

In relation to animal welfare, Europe is often considered to be the most advanced region in the world in terms of animal welfare legislation (European Court of Auditors, 2018). Regulatory standards concern norms at the farm, during transport and in slaughterhouses. According to a European Parliament study (European Parliament, 2017), there are an

[6] This point is related to the food efficiency debate. Due to the loss in food conversion through animals, more food could be produced if crops were consumed directly by humans rather than produced to feed animals. Note that food efficiency can be redefined in order to consider that part of the food consumed by livestock is not in fact edible for humans, which in turn reduces the food inefficiency of animal production (Wilkinson, 2011). However, food efficiency should in principle also account for the "potential" production capability of land, namely the possibility of producing edible crops where non-edible crops are currently produced. More generally, following the logic of opportunity cost, it seems that the relative economic cost of producing different food on different land should be the major criterion in this debate.

estimated 4.5 billion chickens, egg-laying hens and turkeys in the EU, and 330 million cattle, pigs, goats, and sheep. In France alone, approximately one billion terrestrial animals (chickens, pigs, cows, etc.) are killed every year in slaughterhouses; that is, about three million per day. Most farm animals are raised in intensive farming conditions, namely in cages or in confined environments without outdoor access. For instance, more than half of the hens produced in Europe are raised in cages, and as many as 69% in France, for instance (ITAVI, 2017). Most animals are slaughtered after a few weeks or months; that is, they live for only 2 to 20% of their normal life span. In addition, males are coproducts in the egg or milk industry, and are killed at birth or whilst very young. Many painful practices within the industry, such as castration without anesthesia, dehorning, tail docking, teeth clipping, beak trimming, and slaughter without stunning are legal and widespread throughout European countries.

2.2 Regulatory justifications

The negative impacts of meat consumption on health, environment and animal welfare justify its regulation. However, the justifications for regulation in each of the three domains are different, and often quite subtle.

In the health domain, for instance, it may be argued that meat consumption is essentially a private choice, and that consumers should be free to decide if the benefits and the costs associated with their own choice increases their private utilities or not. This consumers' sovereignty argument—that may act against government intervention, however—suffers from two major limitations. First, the choice made by consumers also has implications for the rest of the society due to the collective nature of the health system. For instance, according to a recent study (Direction du Trésor, 2016), the social cost of obesity in France reached €20

billion in 2016, slightly less than tobacco (€26 billion) and more than alcohol consumption (€15 billion). Second, it may be argued that food choices are not always the "right" choices from the viewpoint of the consumers themselves, as consumers may, for instance, underestimate the negative long-term health consequences of meat consumption, misunderstand complex dietetic recommendations or suffer from self-control problems related to consumption (Griffith and O'Connell, 2010). In that case, a paternalistic intervention strategy to reduce meat consumption may be warranted.

The justification for meat regulation in the environmental domain seems more straightforward than in the health domain. It typically relies on a standard market failure; namely the negative externalities impacting the environment. However, the standard approach in economics recommends regulating pollution at the source, namely at the farm; yet, this is notoriously difficult in agriculture, as it requires detailed farm-level measurements of pollution (Springmann et al., 2016). Moreover, agricultural pollution, such as water pollution, is typically plagued by the nonpoint source issue, which makes it difficult to identify the polluters and thus to regulate efficiently. Using a large database and a life-cycle approach, Poore and Nemecek (2018) examine the environmental impacts of various food products on five dimensions: GHG emissions, the use of land, the use of water, eutrophication, and acidification. They unambiguously show that all animal products—not only beef—have the biggest impact on the environment. Moreover, given the heterogeneity of multiple impact pathways and outcomes, they recommend a comprehensive regulatory approach, and conclude that a "dietary change can deliver environmental benefits on a scale not achievable by producers". Finally, directly regulating consumption rather than production may avoid domestic animal products being penalized versus imports.

Concern for animal welfare justifies regulation for several reasons. First, consumers appear to care about animal welfare. Any regulation aimed at improving the information available on animal-friendly products must ensure that consumers may still make choices consistent with their moral preferences. Moreover, even though consumers may not be willing to pay individually for animal welfare because of the free-rider problem, they may still care about animal welfare; that is, animal welfare may be viewed as a public good. In that case, the justification for the government's intervention is clear, as improving animal welfare would generate a positive "moral externality" on all of those who care; see Lusk (2011) for a thorough discussion on regulation justified by public good considerations. As discussed in the previous paragraph on environmental regulation, there is the question of the regulatory choice between supply versus demand. As mentioned in the introduction, this paper focuses on demand regulation. An argument in favor of demand regulation regarding animal welfare is that supply regulation works imperfectly in particular because it is difficult and that it may be very costly to monitor production sites.[7] Indeed, there exists evidence of compliance issues with respect to animal welfare legislation (European Court of Auditors, 2018). More generally, a high level of meat consumption necessarily involves a high number of animals being slaughtered and goes hand in hand with industrial production, which arguably involves problematic rearing conditions due to, for example, high rates of confinement.[8] Therefore, directly targeting meat consumption may be efficient. Finally, there is a direct externality on animals, independent of how consumers feel about this externality. This requires considering

[7] This raises the question of the optimal rate of monitoring, and (e.g.) that of the fees that non-compliant producers would have to pay.

[8] However, as for the environment, the global impact of intensive farming on animal welfare is not clear (Robbins et al. 2016).

a non-anthropocentric welfare criterion, where animals' suffering and more generally animals' welfare counts per se.[9]

3 Regulatory instruments

3.1 Fiscal instruments

Until now in the EU, member states have not implemented any tax policy targeting meat products. However, several economic analyses have addressed the issue of the impact of carbon-based taxes on diet. The targeted market failure is the externality due to GHG emissions. In these analyses, taxation is generally based on the GHG emission content of the different food products.[10] Because animal products—and particularly meat products—have a high content in GHG emissions, meat products experience the highest level of taxes in these simulations. Table 1 provides an overview of the results of recent studies that evaluate the impact of carbon-based taxes on consumption, health and GHG emissions in the case of EU countries.[11]

[9] In utilitarian ethics, it is argued that no moral argument can justify ignoring the suffering of an animal (Singer 2011). Blackorby and Donaldson (1992) introduced a two-species (critical-level) utilitarian social welfare function and applied it in the context of meat eating. In that setting, regulation that would reduce farm animals' suffering improves such a welfare criterion even if humans' welfare does not change. Of course, the regulation can be based on moral notions different from utilitarianism (e.g., Regan, 1983). It is beyond the scope of the paper to discuss the extensive literature in philosophy and law about the moral status of animals (Sunstein and Nussbaum, 2004), and its implications for welfare economics and policy making (Carlier and Treich, 2020).

[10] As far as we know, no economic analysis exists on the regulation of other environmental impacts of meat consumption, such as eutrophication or acidification. It should be noticed that a tax policy based on the eutrophication effect, for instance, would change the relative amount of tax compared to a tax based on GHG emissions, at the expense of the consumption of chicken. This would, in turn, affect the consumption of other meat categories.

[11] There are a priori different ways to implement taxation. In some studies, the tax is an excise tax; the level of which depends on the GHG content of the taxed products. In other studies, the tax is an ad-valorem tax which impacts products with a GHG content higher than some thresholds. Alternatively, the ad-valorem tax may also be related to the GHG content of the products.

A direct comparison of the results from these studies is difficult as the studies use different designs of taxes (the implicit price of carbon differs, the set of products which are taxed varies and there are revenue-neutral versus non-neutral taxation scenarios). Some key results emerge, however. The consumption of red meat (beef and lamb) is the most impacted as it experiences the highest rate of taxation. On the other hand, the consumption of poultry is much less impacted due to a lower tax rate given its lower GHG emission level, and to the substitution effect following a rise in the price of red meat. Moreover, the impact on health may be positive or negative depending on the design of the tax. Globally, meat taxation is likely to have a positive health impact. However, in revenue-neutral scenarios that integrate subsidies to products with a low GHG emission content, the impact on health may be negative. This is because in such scenarios, energy dense products such as sugary products are subsidized. This means that a carbon-based taxation scheme should be designed to take into account the health impact of the scheme. Finally, these simulation studies suggest that GHG emissions are reduced but in a limited range. Even a high tax rate (high-level of carbon tax as 200€/t CO2-equivalent or a 20% price increase of meat products) does not allow more than a 10% reduction in GHG emissions from diet alone, which is far removed from the global objective of the EU of a 30% reduction in 2030, compared to 2005.

Concerning health objectives, while no tax policy currently directly targets meat products, Denmark introduced a tax on saturated fat in 2011. The tax rate was previously 16 DKK/kg (about €2.15) of saturated fat for selected product categories and only applied if the saturated fat content exceeded 2.3g per 100g of product. Given the saturated fat content of meat products, this tax impacted a large number of these products. Jensen and Smed (2013) show that the introduction of the tax on saturated fat in food products in Denmark led to a reduction in the level of consumption of fats by 10 to 15%. They also show that, for some types of

products, there were some shifts in demand from consumers moving from high-price supermarkets to low-price discount stores. However, the impacts of the tax were considered controversial (in particular, because of the impact on the food industry, as well as a possible increase in purchases made in neighbouring countries), and as a result, the tax was abandoned in 2013.

The convergence in health and climate objectives is not a given. Rather, such convergence strongly depends on the design of the scenario. In particular, Springmann et al. (2016) show that in order to achieve improvements in both climate and health dimensions in a revenue-neutral policy, products with a high GHG emission content (animal products) must be taxed and the revenues generated by the tax must be used to subsidize fruit and vegetables, while avoiding subsidizing energy-dense products. In addition, Bonnet et al. (2018) show that targeting beef, lamb and veal —rather than all meats—allows about a two-thirds reduction in GHG emissions at a much smaller cost for the consumer.

Table 1: Overview of recent studies assessing the impact of carbon-based taxes in the EU

Authors	Country	Scenarios	Impacts on :		
			Meat Consumption	Nutrient intakes / Health	GHGE
Abadie et al. (2016)	N	Ad valorem taxes and subsidies to minimize DWL s.t. isocaloric diet and lower GHGE (-10%).	Red meat: - 49%; Poultry: + 39% Milk: +28% ; Cheese: -28%	Decrease in fat (-2.3%) and SFA (-5.2%) Increase in carbohydrates (+0.9%) and proteins (+4.0%)	-10% (by construction)
Bonnet et al. (2018)	Fr	Tax based on GHG content. 56 or 200 €/t CO_{2e}. Products taxed: a) All animal products	Low / high CO_{2e} price Beef: -8.3% / -24.7%; Chicken: -5.4% / -17.2%; Dairy Products: -1.8% / -6.3%	Low / high CO_{2e} price Calories: -0.7% / -2.5% SFA: -1.6% / -5.5%	Low / high CO_{2e} price: -1.9% / - 6.1%
		b) Beef meat only	Beef: -10.9% / -31.4%; Chicken: +0.4% / +1.4%; Dairy Products: +0.4% / +1.2%	Calories: +0.1% / +0.2% SFA: +0.2% / +0.6%	-1.1% / -3.2%
Briggs et al. (2013)	UK	Tax based on GHG content (27 €/t CO2e). a) Products taxed: GHG content > 4.1 kg CO_{2e} /kg.	Beef: -14.2% [-17.9 – -10.6]: Poultry: -0.2% [-0.5 - +0.1]; Milk: -0.3% [-0.4 -0.1] ;Cheese: -0.2% [-0.3 -0.1]	-1.4% energy intake 7770 [7150-8390] deaths avoided	-7.5%
		b) Case a) and subsidies for products with GHG content < 4.1 kg CO_{2e} /kg. Tax revenue-neutral scenario	Beef: -13.7% [-17.4 – -10.1] ;Poultry: -0.3% [-0.1 - +0.7] ; Milk: +6.2% [+5.1 +7.3]; Cheese: +0.9% [0.5 1.3]	+ 1.0% energy intake 2685 [1966 – 3402] additional deaths	-6.1%
Caillavet et al. (2016)	Fr	Ad-valorem tax: 20% on a) All animal-based products	Not Reported	Decrease in calories (-8.1%), proteins, SFA, and cholesterol	-7.5%
		b) a) except fish, white meat and fresh dairy		Decrease in calories (-5.6%), proteins, SFA, and cholesterol	-7.0%
Edjabou and Smed (2013)	DK	Tax based on GHG content (29 $ /t CO2e) a) all products taxed	Beef: -12% (*); Poultry: +1% Milk= -1%; Cheese: -3%	Decrease in calories (-2 to -4%), SFA; increase in sugar	-4.0 to -7.9%
		b) a) + decrease in VAT (revenue-neutral scheme)	Not reported	Increase in calories (+1 to +2%), sugar. Decrease in SFA.	-0.7 to -3.4%
Garcia-Muros et al. (2017)	E	Tax based on GHG content (50 € /t CO2e) a) all products taxed	Beef: -15% (*);Poultry: -5.5% Milk: -6% ;Dairy products: -10%	Decrease in calories (-4%), and all nutrients (-3 to -9%)	-7.6%
		b) all products taxed except cereal, milk, F&V	Beef: -19%; Poultry: -4.5% Milk: +2% ;Dairy Products: -11%	Decrease in calories (-2.5%), and all nutrients but fiber	Not reported

Note: We provide results for selected scenarios. In general, more scenarios are analyzed by the authors. All models consider the whole diet, except Bonnet et al., who focus on animal products consumption. (*) Changes in consumption are extrapolated from the figures.

3.2 Informational instruments

Informational instruments are typically used to reduce the information asymmetry between producers and consumers, and to better match food products' characteristics with heterogeneous consumers' preferences. Information can drive meat purchases towards (meat or non-meat) products with healthier, more environmental- or animal welfare-friendly characteristics. A qualitative switch towards such products can be achieved only if consumers have the necessary information about those characteristics and are willing to pay for such products, which are generally more expensive.

Many willingness-to-pay (WTP) studies show that consumers are concerned with attributes, such as price and quality and, to a lesser extent, food safety and health characteristics (Koistinen et al., 2013). For instance, Van Loo et al. (2014), Koistinen et al. (2013) and Gracia et de Magistris (2016) show using choice experiments that the WTP for nutritional attributes and origin of the meat products receive the highest consideration, followed by animal welfare attributes. Other environmental attributes, such as water footprint or reduced carbon emission, lead to no or smaller WTP values. Interestingly, Panzone et al. (2018) show that being required to recall past environmentally-friendly behavior before shopping increases consumers' WTP for environmental attributes. WTP values are usually highly heterogeneous and depend on the demographic and psychometric characteristics of consumers, on the product category (beef versus pork, for instance, in Koistinen et al., 2013) and on the regions or countries (Germany versus Canada in Peschel et al., 2016). Although some consumers are very concerned by animal welfare, the average WTP for this attribute is often low (see Janssen et al., 2016 for a review of the literature and for a meta-analysis see Clark et al., 2017). Along similar lines, Griffith and Nesheim (2010) examine WTP for organic products, showing that

quality comes first in relation to consumers' concerns, with health concerns second, and environmental concerns lagging some distance behind.[12]

Labels have been introduced in many countries to provide comprehensive information on food nutritional attributes. Some countries have implemented voluntary front-of-pack nutritional labelling. Such labels are designed to facilitate the understanding of complex and multidimensional attributes of food products for consumers. For instance, many supermarkets and food manufacturers in the UK display a traffic light label on the front-of-pack of food products, indicating a high, medium or low content of fat, saturated fat, salt, and sugars. Nowadays, in several countries in Europe, some private operators use of a similar color-based coding labelling system, called Nutri-Score. This has an index (coded from capital letters A for the highest nutritional quality level, to capital letter E for the lowest) that summarizes the content in nutrients and food that consumers should favor in their diet (fibers, proteins, fruits, and vegetables), and those that should be limited (energy, saturated fat, sugars, and salt). While nutritional labels affect diet, the impact is limited, with a higher impact only for higher income consumers (Drichoutis et al., 2012). A recent experimental study shows that mandatory front-of-pack food labels with simplified information on environmental characteristics may lead consumers to switch to food baskets with better environmental quality (Muller et al., 2019). For environmental and animal welfare attributes, only a few

[12] There is an obvious economic rationale behind these observations that the WTP for environmental and animal welfare attributes is limited. These attributes can indeed be viewed as public goods. Even if a consumer personally cares about these attributes, she has little incentive to pay the additional premium for better products given the minimal global impact of her actions. This observation may partly explain why label initiatives on environmental attributes are rarely used in the food industry. There have been a few attempts to do so, such as the retailer Tesco in the UK developing a carbon label on some retailing items, though this was not pursued. Indeed, Tesco's carbon label resulted in little or no effect on purchases (Hornibrook et al., 2013). Kortelainen et al. (2016) also show no effect of the introduction of a carbon reduction label on prices and demand for detergents in a UK retail chain.

mandatory labels exist and they often target a particular food product (such as table eggs based on the EU, or organic products).

In most EU countries, the majority of information campaigns are part of nutritional policies. Information campaigns such as the well-known 'Eat 5 a day' (to increase fruit and vegetable consumption) have a modest but positive impact (Capacci and Mazzochi, 2011). In France, the Plan National Nutrition Santé (PNNS) includes a recommendation on meat consumption (no more than 70g/day for red meat and 25g/day for processed meat). Interestingly, the recommendations vary significantly between one country and another (Tukker et al., 2011; RISE, 2018). Some simulation studies conclude that such information campaigns are likely to be welfare improving—but only if consumers do, in fact, integrate them into their consumption habits—and as such should be much more highly developed (Irz et al., 2016). An open question concerns the respective impact of using positive versus negative messages. Recent studies show that providing information on the negative environmental impact of meat production has no significant effect on meat consumption (Cordts el al., 2014; Marette and Millet, 2016).

Finally, we discuss the more long-term policy impacts, such as educational policies. It seems likely that more knowledge about the negative impact of meat production and consumption has a significant impact on food choices. Several studies show that meat consumption decreases with general education level (Rimal, 2002; Pfeiler and Eigloff, 2018). Willett et al. (2019) emphasize the need to develop educational policies in the food domain. While most policies target adults, targeting the young may be more effective. To a large extent, food tastes and eating habits develop at a young age and tend to be persistent. Young people have more plasticity and a greater freedom to make significant behavioral choices that may influence the rest of their lives. Wynes and Nicholas (2017) emphasize that adolescents are an important

target group for the promotion of high-impact environmental actions, such as a shift towards plant-based diets but they find that educational tools, such as high school science textbooks largely fail to stress the importance of these actions. Several initiatives, such as meat-free days in school canteens, have been developed around the world with the objective of educating the young through their active participation.

3.3 Behavioral instruments

The eating of meat is not only a physical action but also a largely psychological phenomenon affected by cognition, culture, history, emotions, personality, and morality. The public generally displays a low level of awareness as to the negative impacts of meat production (Wellesley et al., 2015), and may form self-serving beliefs in order to reduce the feeling of guilt associated with the death and the suffering of farm animals (Loughnan et al., 2010). Meat consumption is largely perceived as "nice, necessary, natural, and normal" (Piazza et al., 2015). People often prefer to continue eating the food they know and like and to follow the norm, as a primary motive may be to share and enjoy together common traditional meals. Social feedback causes beliefs to be self-reinforcing and the meat-eating norm is thus stable (Nyborg et al., 2016). Consumption habits are therefore difficult to change; but persistent social norms, such as smoking in public places or fertility standards, have changed, and this change can be stimulated by public policies. Eker et al. (2019) links a behavioral diet model to an integrated assessment model, and identify social norms as a key driver of global diet change. Food habits depend on unconscious and automatic responses to specific and subtle external cues. Policies that inform the population and implement well-designed behavioral interventions may thus help to reduce meat consumption and progressively challenge the status quo.

An example of behavioral intervention applied to meat consumption is the Meatless Monday campaign launched in 2003 at the John Hopkins School of Public Health, to promote healthier decisions at the start of every week. Meatless days have gained popularity worldwide, as they have been implemented in more than 40 countries to date (Meatless Monday, 2016).[13] By providing a simple prescriptive recommendation to consumers, the meatless day campaign is easily understood by all. Peer pressure and a public commitment to follow the campaign may help mitigate self-control problems for meat-eating consumers. Using a "foot-in-the-door" psychological technique, it encourages consumers to initially adopt a small commitment only (that is, by eliminating meat consumption only once a week to start with), with the possibility that a desire to adopt a greater commitment will develop later. It favors learning about alternatives to meat-based meals and helps consumers to challenge persisting beliefs, dietary habits and routines. It may also address coordination problems among consumers, as well as problems with the supply side, as it helps food retailers and restaurants to anticipate changing demands on a specific day.

Various nudges can also affect choice habits. There is empirical evidence on the efficiency of nudges in the health environment, as well as in the food choice domains (Thaler and Sunstein, 2008). However, a recent meta-analysis (Cadario and Chandon, 2018) shows that the average effect of "eating nudges" in field settings is small and varies depending on whether nudges are cognitively-oriented or affectively-oriented, for instance. Kurz (2018) conducts a field experiment in two restaurants; changing the menu order and enhancing the visibility of the vegetarian dish in one restaurant, with the other restaurant serving as a control. She shows that the share of vegetarian lunches sold increases by a modest 6 percentage points, however

[13] An influential report in France (Terra Nova, 2017) recommends implementing meatless days in school canteens, and this is now implemented through an experimental law in France (i.e., the Cazebonne law).

this effect is fairly persistent over time. Relatedly, Hansen et al. (2019) show that presenting the vegetarian option as a default may be particularly effective. These first results raise the broader and more complex question as to the effect of various and possibly competing nudges, since the food industry already uses a wide range of marketing tactics to emphasize the positive health, environmental and moral impacts of the meat products they sell.

Another instrument studied extensively in psychology (but not much in economics) is "tailored communication"; namely communication such that information about receivers is used by senders to reach better message efficiency. It is widely recognized that messages may be more efficient if they are individualized based on the receivers' socio-demographics, such as age, gender or cultural factors. Tailored communication may also improve the precognitive conditions favoring attention, understanding, memorization, or acceptance of the message. It has been used with success in tobacco and weight control campaigns, as well as changes towards more sustainable diets and meat consumption reduction (Bech-Larson and Grønhøj, 2013; Delichatsios et al., 2001).[14] The use of tailored communication may be facilitated with the development of information technologies (for example, emails, SMS and web applications), but it also raises some issues; such as the cost of implementation, privacy concerns, senders' long-term credibility, receivers' welfare impacts, equity, and the risk of unethical manipulation.

4 Challenges

[14] One strategy consists of providing comparative feedback, such as "compared to other women from this health center, you eat fewer servings of fruits and vegetables per day" or evaluative feedback such as "your fruit and vegetable intake is well below the recommended level of 5–9 servings per day" (Hawkins et al., 2008).

The regulation of meat consumption is one of the major challenges that developed countries must face in the coming decades (Willett et al., 2019). In this section, we briefly discuss some of the key challenges that we believe are most important and that should concern food scholars and policy makers in the future.[15]

i) Convergence of impacts. We emphasize the trio of impacts of meat consumption on the environment, health and animal welfare. Most policies have various, complex and sometimes opposing impacts on these categories. We illustrate this complexity with one example; that of a carbon tax. We have already discussed that the existence of health and environmental co-benefits due to climate regulation is not a given. Moreover, the picture is more complex when the broader impacts are also considered. If a carbon tax is implemented, beef consumption should decrease, normally leading to—for example—a reduction in GHG emissions, and in both land and water use, the prevalence of colorectal cancers and the number of cattle slaughtered. However, this tax may also typically increase pork, chicken and milk consumption if the substitution effect following a decrease in beef consumption dominates the price effect on those animal products. This would, in turn, increase the intake of saturated fats from mostly pork delicatessen and dairy products, which raises additional health issues (Westhoek et al., 2011), and generate water and air pollution. Moreover, several pigs and hundreds of broilers are needed to obtain the level of meat and protein provided by a single cow. Since pigs and broilers are most often raised intensively, the ratios of animals/meat and suffering/meat may increase as a result. Hence, a carbon tax may have both positive and negative impacts depending on the type of impact and of the animal product we consider.

[15] We emphasize that this discussion about future challenges is very preliminary and incomplete. Our objective in this section is simply to point out some interesting and stimulating ideas, without proposing a thorough elaboration of these ideas.

Policy makers will thus face the considerable challenge of designing comprehensive policies to account for all these subtle sets of impacts, and to find ways to evaluate and make tradeoffs across these various impacts.

ii) Quality-quantity tradeoff. In this paper, we advocate for a decrease in meat consumption. For the most part, we analyze the meat quantity issue rather than the meat quality issue, except in the section on informational instruments (see Section 3.2). Yet, consumers may often jointly consider the choices around the quantity and quality of meat products. Typically, the decrease in quantity may be accompanied by an increase in the quality of the consumed products. This idea is not new, as illustrated by occurrences in the wine industry. Consumption in Southern Europe (particularly in France) has sharply decreased over the last 30 years but this change has been accompanied by an increase in the quality of wine, such that many producers have benefited from a structural evolution in the wine sector. In the case of the meat industry, there already exist different quality levels signaled to consumers by means of labeling (label rouge, geographical indications, organic, etc.). According to consumer surveys, a share of consumers is willing to adopt “less but better” meat consumption (for example, de Boer et al., 2014). Relatedly, many polls indicate that a significant part of the European population is becoming “flexitarian” (that is, consuming meat only occasionally, such as once a week). Hence, it is crucial to better understand the substitution effects within the category of animal products, but also outside of this category. A possible “rebound effect” of a (more) vegetarian diet (Grabs, 2015) should then be considered, as the reduction in meat consumption may help save money and in turn further affect food and non-food choices. Recent studies on the consumers of organic products shows that these consumers have a higher food expenditure than the rest of the population, but also that the increase in unit price is partly compensated for by a quantity effect and a structure effect; that is, the composition

of the food basket differs with more products from cheaper food product categories (Kesse et al., 2018).

iii) Upstream impacts. Demand regulation, whatever it is, will impact upstream agents, and typically producers. First, due to substitutions between food products, demand for all different food products will change and therefore prices will also change. Producers will be impacted, but the magnitude as well as the direction of the impacts still need to be evaluated. Lusk and Norwood (2009) argue that plant-based products are less expensive to produce than animal products, in particular because they require less land or more generally less inputs. They conclude that a shift away from animal products and towards plant-based products correspond to an overall decrease in the aggregate demand for agricultural products. This shift is likely to have negative impacts on agricultural producers. But price changes also affect trade. Lehtonen and Irz (2013) analysed the impact of a 20% decrease in the decrease in red meat consumption in Finland and concluded that national producers' income is almost not affected while trade is significantly impacted with a decrease in imports and an increase in exports. Tukker et al (2011) found similar effects on trade with a decrease in red meat consumption. These results also suggest that when evaluating the GHG impact of meat regulation, one must consider these subtle trade effects, and sources of carbon leakage. Producers facing a decrease in the domestic demand could also react by modifying the characteristics of their products and could engage in some quality/quantity trade-off (cf. challenge ii). Overall, all the food industry will be impacted by the change in the demand. Lusk and Norwood (2009) argued that the food industry as a whole may gain from such a change as on average plant-based products are more processed than animal products.

iv) Instruments' synergies. In the previous section, we discuss fiscal, informational and behavioral instruments separately. However, it is also important to consider instruments comparatively; that is, to examine which instrument is more effective and in which context. The extensive economic literature on climate policy about whether or not to use tax versus permits illustrates that question. Moreover, it is important to study the synergies among these instruments. There is a large literature in public economics studying several market failures (for example, externalities, information asymmetry or market power) and how to combine several instruments (see, for instance, Goulder and Parry, 2008). There is also an emerging literature about the interactions between economic and behavioral incentives. It is well known, for instance, that a fiscal incentive may undermine moral motivation (Benabou and Tirole, 2003). To illustrate this, taxing meat may or may not exacerbate consumers' moral intrinsic motivation to reduce meat consumption beyond the financial impact. For instance, Hestermann et al. (2018) exhibit a "crowding-in" effect: cognitive dissonance amplifies consumers' (negative) responses to a meat tax. The issue of social norms is also quite complex, since the policy to regulate meat may affect consumers' behavior and in turn progressively change the norm in terms of meat-eating in society, which can further impact behavior, and so on (Dasgupta et al., 2016). This raises challenging questions for policy evaluation, as preferences are endogenous and affected by the policy itself (Bowles, 1999). More fundamentally, characterizing and measuring welfare when consumers have bounded rationality or bounded self-interest is notoriously difficult.

v) Animal welfare evaluation. Another challenge concerns the definition and characterization of animal welfare. While accounting for the environmental and health impacts is standard in academic and policy literature, accounting for the impact on animal welfare is not. And while we can usually determine with some confidence when health or the environment

deteriorates, this is less clear for animal welfare. The literature on animal sciences has long used various indicators for welfare, such as the rate of mortality or injuries, impaired growth, the reproduction or immune system, measures of stereotypes and self-narcotization, stress hormone levels, space allotment, and transport time (Broom, 2014). All these measures are useful but imperfect. They face the inescapable issue of anthropocentric interpretations, and they may go against the basic intuitions of consumers: for instance, free range access favors the expression of animals' natural behavior but may increase aggressive behavior, and in turn animals' injuries or death, for instance. Interestingly, an emerging literature in animal sciences uses—also used in economics—a revealed preferences approach, where animals' preferences are inferred from their choices (Dawkins, 2004). Finally, we must acknowledge the immense difficulty of welfare comparisons between humans and animals. Indeed, while economists still disagree about how to compare the welfare among different humans, the fundamental question of how to compare the welfare of animals with other animals (for example, that of a cow versus a hen), as well as between animals and humans, may be the subject of intense academic and policy debate in the future. In any case, the immense challenge of evaluating animal welfare does not provide a good enough reason to ignore animal welfare, and may instead warrant a precautionary approach.

vi) Political economy. When addressing meat regulation, the question of political feasibility is central. We must therefore also discuss political economy issues. The animal farming sector will likely be harmed globally by a decrease in meat consumption. The sector is currently in economic crisis, and farmers' income is often very low. However, the sector is also economically and politically powerful. For historical reasons, the rural population is often over-represented compared to its population share in political institutions of most developed countries, such as in the Senate in France. The production sector may often try to "capture"

regulation, and thus supply-side regulatory measures (such as the greening of CAP or animal welfare improvement) may fail to achieve their objectives. In this political context, a policy targeting consumption may be a powerful alternative way in which to reach societal objectives. However, this policy will likely face strong resistance from the production sector, and perhaps also from consumers. Indeed, it is not clear that policy makers currently have a societal license to regulate meat consumption. Governments appear to be trapped in a cycle of inertia: they fear the repercussions of intervention, and the public may underestimate the problem because of the lack of government intervention (Wellesley et al., 2015). Most people want to consume cheap meat, without feeling guilty for the environment or for the animals they eat. However, as discussed above, norms progressively change, and it is possible that the regulation of meat will be increasingly accepted by society, in turn changing beliefs and improving the acceptance of changes in dietary habits and associated policies.

vii) Developing countries. The policy discussion regarding the health, environmental and moral impacts of meat consumption mostly concern the developed countries. However, in our globalized world, it must also concern developing countries. Meat is an essential source of nutrients for hundreds of millions of people in developing countries. Population growth and possible dietary changes towards animal products in developing countries is expected to increase the GHG emissions from food and agriculture by up to 80% by mid-century (Springmann et al., 2016). In Asia, over the last 50 years, meat consumption has been multiplied by 15, so that Asia now represents almost half of the total consumption of meat worldwide. Hence, the developing world already has a primary impact on meat consumption trends. As the developing world becomes richer, and if the dietary pattern follows the path of developed countries during the nutritional transition, meat consumption will drastically increase worldwide during this century. Health and environmental issues will increase at both

a local and global level, and meat regulation in developing countries will become necessary. However, one cannot exclude the possibility that the increasing global awareness of the detrimental effects of meat production in developed countries may also mitigate the likely future increase in consumption in developing countries.

viii) Food innovations. We conclude with a brief and tentative discussion of innovations in meat substitutes. Nowadays there exist several vegetal meat products (such as the Beyond Meat or Impossible Foods burgers) already sold in retail markets, which have a similar organoleptic as standard meat product. Moreover, it is technically possible to produce a steak from animals' muscle cells; the so-called cultured (or in vitro or clean) meat. This innovation may become affordable in some years hence, with its regulation currently under discussion in the US. Other meat substitutes include mycoprotein, alga and insects. These alternatives to meat may induce less environmental externalities (Tuomisto and Teixeira de Matos, 2011; World Economic Forum, 2019). Debates about the health and environmental impacts of these innovations will likely emerge, as well as issues regarding consumers' acceptability of these products. Meat substitutes are already facing some opposition from the traditional farming sector, and are stimulating regulatory debates about labelling these products as "meat" while they have not been culled from a live animal (The Guardian 2019). To date, these alternatives have been mostly developed by the private sector through small startups. However, given the global benefit potential, regulators should look to more proactively encourage the research and development of these alternatives. It is possible that in some decades to come, the population will progressively move away from standard meat products to favor these protein alternatives. The implications of this scenario are fundamentally apposite for the food and farming industry, for the management of rural areas and more generally for the human-animal relationship in our societies.

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