Is Meat Too Cheap? Towards Optimal Meat Taxation

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Abstract

Advances in environmental science and economics permit us to conclude that meat is significantly underpriced. While livestock plays a significant role in climate change and negatively impacts global nitrogen cycles and ecosystem biodiversity, economically efficient policies for regulating meat production and consumption are under-researched. In the absence of first-best policy instruments for the livestock sector, meat taxes can address multiple environmental externalities simultaneously, while improving diet-related public health. We review the empirical basis for the 'social costs of meat' and study several elements from public, behavioural and welfare economics, which could motivate regulatory efforts to tax meat in high-income countries: (i) multiple environmental externalities, (ii) adverse effects on one's own health, (iii) animal welfare, (iv) learning curves for 'alternative protein technologies', and (v) distributional effects. We identify several directions for future research towards optimal meat taxation: First, assessment and economic valuation of environmental externalities from livestock have to be extended to biodiversity loss, taking proper account of indirect land-use effects. Second, second-best modelling of meat taxes could elucidate the interplay of regulating multiple environmental externalities from livestock farming. Third, normative viewpoints on accounting for health benefits, distributional impacts and animal welfare are significant factors of the right tax on meat.

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1. Introduction

Throughout human history, livestock farming and meat consumption have brought welfare to communities by bringing people together around culinary experiences and traditions. Today, livestock farming supports many livelihoods, and meat is regarded as an important source of protein and micronutrients in many parts of the world. Despite these benefits, there is a growing consensus that the recent global trajectory of meat production and consumption is unsustainable. Livestock farming plays a significant role in many of the most pressing environmental challenges of our time, including climate change, biodiversity loss, and nitrogen pollution (see *Figure 1*).

A failure to mitigate emissions from the agricultural sector, where livestock is a leading source of pollution, could preclude meeting the 1.5 degrees climate objective, and complicate the path to limiting climate change to well below two degrees of warming (Springmann et al., 2018; Clark et al., 2020). High levels of meat consumption also pose significant risks for public health in high-income countries. The cancer agency of the World Health Organization has declared processed meat carcinogenic and unprocessed red meat likely carcinogenic to humans based on strong mechanistic evidence (Bouvard et al, 2015), and there is moderate to high evidence from meta-analyses of epidemiological cohort studies that red and processed meat increases risks for coronary heart disease, stroke, and type-2 diabetes (Schwingshackl et al, 2017; Bechthold et al, 2019). In its current form, livestock is also a risk factor for potentially large public health threats from zoonotic diseases and antimicrobial resistance (Espinosa et al., 2020; O'Neill et al., 2016).

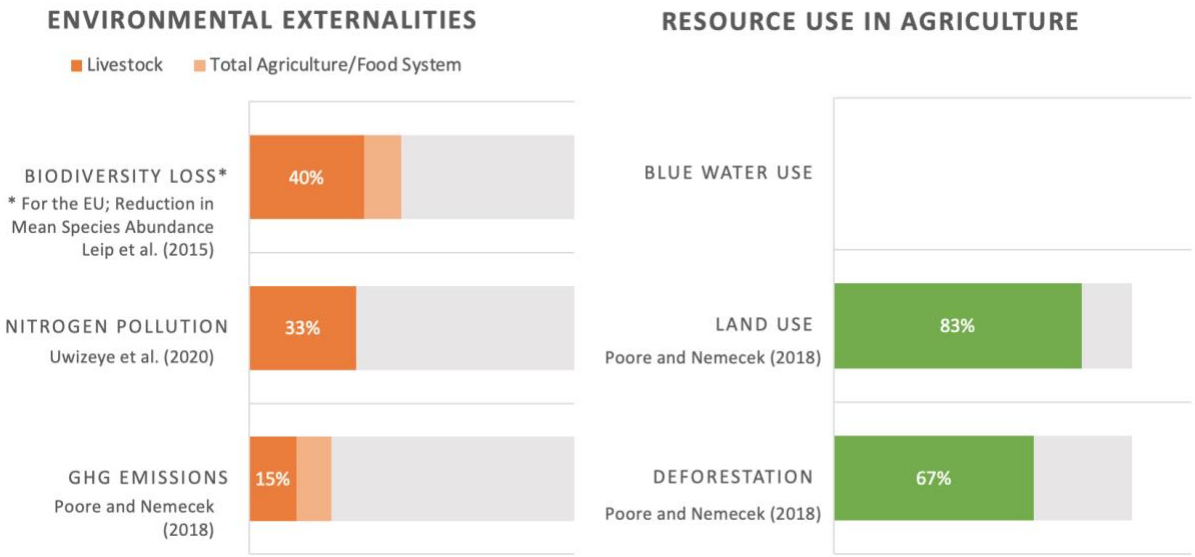

Figure 1: *The share of livestock in major environmental challenges.*

The negative externalities of meat are currently not reflected in retail prices and have remained largely unaddressed by policymakers. The lack of regulatory attention that meat has been receiving appears especially pronounced when compared to regulatory progress in other major polluting sectors, such as electricity and transportation. For example, even though roughly 15% of global GHG emissions can be attributed to livestock farming (Gerber et al., 2013), the sector is not covered by the vast majority of carbon pricing policies. There are several factors that may explain why meat has been largely ignored by regulators: Economic entities are much smaller and more scattered than in other sectors, which makes policies hard to implement due to high monitoring and transaction costs. For the most relevant externalities, cost-effective production-side abatement options are currently limited, with potential break-through solutions like alternative protein technologies only in the very early stages of development and deployment. That implies a stronger role for demand-side abatement, likely to be

met with strong opposition by those invested in the incumbent sector. Finally, meat regulation may have been perceived too politically risky for regulators, who fear that consumers will perceive measures with impacts on their private meal choices as too coercive.

More recently, however, the requirements of a net-zero carbon transition, and calls for 'building back better' after the Covid-19 pandemic, have raised not only the need, but also the prospects of more stringent regulation of meat in developed countries. From the perspective of environmental economics, it is clear that appropriate pricing of meat, which reflects the social costs from environmental and public health damages, should be at the core of such regulation. Indeed, regulators seem increasingly open to the idea of raising meat prices: The European Commissions' Farm-to-Fork Strategy (European Commission, 2020) under the European Green Deal, for example, foresees that "EU tax systems should also aim to ensure that the price of different foods reflects their real costs in terms of use of finite natural resources, pollution, GHG emissions and other environmental externalities."

This article investigates the potential of meat taxation in high-income countries for addressing a multitude of externalities and advancing the necessary transformations in livestock production and meat consumption. The environmental impacts attributable to most animal products are several orders of magnitude higher than those of plant-based products (Poore and Nemecek, 2018), and new research indicates that carbon taxes on plant-based foods would be close to zero (Pieper et al., 2020). When targeted externality-correcting policy instruments across the whole agricultural sector are unavailable, meat taxes are an attractive instrument.[9] An adjusted tax on meat can make progress on multiple regulatory objectives, for which livestock farming and meat consumption are first-order issues. In environmental economics, this logic is reminiscent of taxing transportation fuel, which similarly addresses many externalities at once, including air and noise pollution, climate change, and congestion (Parry and Small, 2005). In contrast to optimal fuel pricing, however, economically efficient policies for regulating meat in a second-best context are under-researched[10]. Previous work in public economics has predominantly focussed on single categories of externalities (Espinosa et al., 2020; Kehlbacher et al., 2016; Wirsenius et al., 2011), with the recent exception of Katare et al. (2020).

Our review of the current state of research in environmental economics on the social cost of meat indicates that meat is currently significantly underpriced. When adding up all environmental externalities for which economic valuations are currently feasible, environment-related social costs are on average between 62–89% of current retail prices for beef in the United States (pork: +32%, poultry (broilers only):+52%), and thus significantly higher than the social cost of carbon. While no inference can be made on the optimal second-best tax rate for meat products, these results can inform future economic modelling studies. Our review further indicates that taking a normative viewpoint on accounting for health benefits is imperative for the optimal regulation of meat, as health costs from eating meat can be two orders of magnitude higher than the known environmental damages.

We proceed as follows: The next section reviews the empirical basis for the 'social costs of meat'. . The subsequent section applies this knowledge to state-of-the art theoretical thinking about environmental taxation, assessing several elements from public, behavioural and welfare economics, which could motivate regulatory efforts to tax meat: (i) multiple environmental externalities, (ii) health

[9] For simplicity, we omit dairy products from our analysis. We note that appropriate dairy pricing is another important venue for research. Some of our theoretical conclusions seem transferable to this context.

[10] In a systematic literature review, we classified only six articles as studying the matter from a public economics perspective. We assessed peer-reviewed publications for existing research on optimal Pigouvian meat taxation, searching for "(meat OR animal OR livestock OR beef OR pork OR poultry) AND (tax* OR pric*) AND (social cost* OR Pigou* OR optimal* OR efficien*)" across RePEC IDEAS and Google Scholar (first 100 entries).

'internality' (i.e., adverse effects on one's own health), (iii) animal welfare, (iv) learning curves for 'alternative protein technologies', and (v) distributional effects.In the final section, we contextualise the theoretical lessons with political economy considerations.

2. The social cost of meat

Appropriate meat pricing requires taking stock of the magnitude of environmental externalities and health effects associated with livestock farming and meat consumption. This section highlights empirical evidence and progress in the economic valuation of environmental externalities and diet-related health impacts.

2.1. Evidence on environmental externalities

With farm-to-fork environmental impact assessments through life-cycle analysis, there is now a robust empirical basis for linking meat products to environmental outcomes, such as greenhouse gas emissions, pollution from phosphor and nitrogen, land use and water use (c.f. Poore and Nemecek, 2018). At a global scale, the main environmental externalities from livestock are (1) climate change, (2) nutrient pollution and (3) biodiversity loss. Intensive livestock production systems have also been linked to the risk of zoonotic disease emergence (Espinosa et al., 2020; Jones et al., 2019) and antimicrobial resistance (O'Neill, 2016; Lhermi et al., 2019). While these large-scale threats bolster the case for more stringent livestock regulation, we focus on more tractable externalities in this article. Meat production contributes to climate change through the emission of methane (from enteric fermentation in ruminants and manure storage), nitrous oxide (from fertilizer application and manure processing) and carbon dioxide (from feed-related direct land-use changes and energy use) (Gerber et al., 2013). Nutrient pollution, in the form of ammonia (NH3), nitrogen oxides (NOx), nitrates (NO3−) and organic N, results in soil acidification, eutrophication of oceans and freshwater pollution (Uwizeye et al., 2021; Brink et al., 2011). Through ammonia emissions and particulate matter from animal manure, livestock is also a significant contributor to local air pollution, causing respiratory health issues in agricultural workers, local residents and the general population (Lavaine et al., 2020). Biodiversity loss from livestock farming is largely driven by land use change (FAO, 2019).[11]

Figure 2 combines life-cycle assessments for meat products with social cost estimates to quantify the economic value of environmental damages from different meat types in USD-per-kilogram terms. While decades of climate science have provided increasingly robust global estimates on the social cost of carbon, economic valuations are much scarcer and more uncertain for other impacts, such as nutrient pollution (Brink et al., 2011). This is, among other factors, due to the spatial variation in the dose-response relationship of pollutants and the difficulty of assessing the counterfactual condition of natural ecosystems.

[11] Under certain rearing conditions, animal farming can have positive externalities, for example through carbon sequestration from grazing. Globally, however, these effects are outweighed by negative impacts (Godfray et al., 2018).

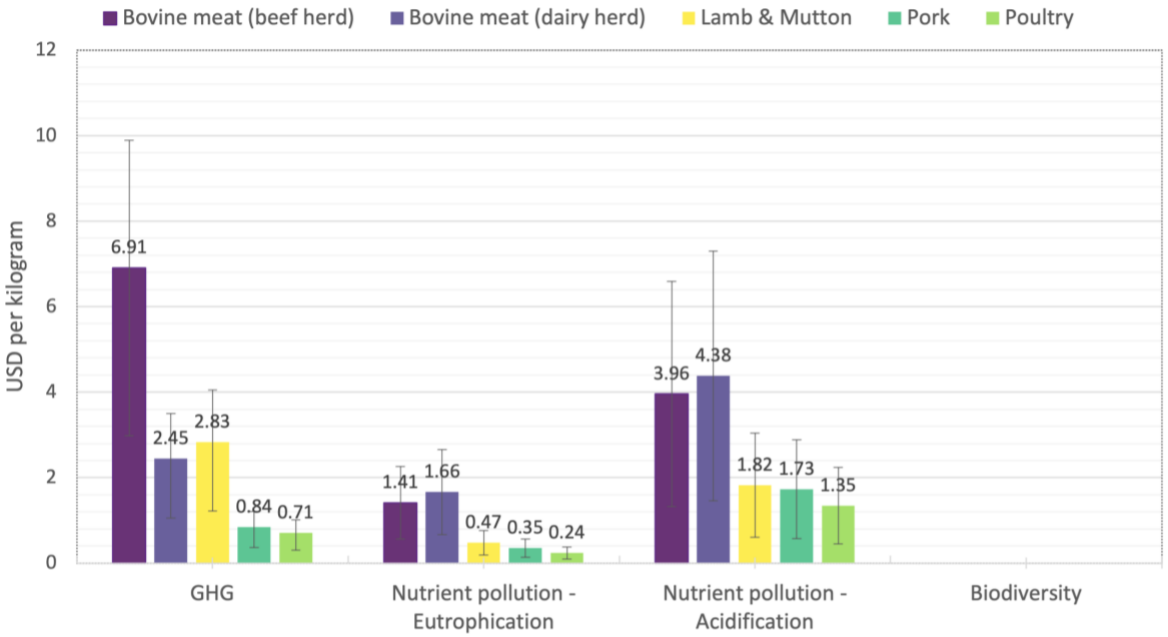

***Figure 2**: Environment-related social costs for selected meat types. Life-cycle environmental impacts from Poore and Nemecek (2018), who include other food categories. Social Cost of Nitrogen for the EU from Brink et al. (2011) and global social costs of carbon from IPCC (2018, p.265).*

The social costs of biodiversity loss have not been quantified to date. Notwithstanding, a growing body of research within economics and environmental science asserts the immense economic value of natural ecosystems and the role of transforming or reducing livestock farming in maintaining biodiversity (c.f. Dasgupta, 2021; Benton et al., 2021). Studying the optimal expansion of agricultural land in a quantitative two-sector growth model of the global economy, Lanz, Dietz and Swanson (2018) find that the negative effect of biodiversity loss on agricultural productivity alone could justify a moratorium on further land conversion socially optimal. The associated social costs of biodiversity loss for agricultural productivity alone are hence significant, even without approximating the total economic damage from destroyed ecosystems, including decline in additional regulating, supporting and cultural ecosystem services. Global modelling studies on land-use and biodiversity further indicate that reducing agricultural land expansion will play an important role for reversing the trend of biodiversity loss (Williams et al., 2020). Leclère et al. (2020) find that maintaining global terrestrial biodiversity without negative impacts on food security requires significant transformation of the global food system, including more plant-based diets. Eventually, linking global estimates on the social cost of biodiversity loss to livestock farming will require robust and comparable impact assessments. While there are inherent difficulties with reducing biodiversity impacts to a single metric, new measures, such as Mean Species Abundance (MSA) or Potentially Disappeared Fraction (PDF) could make biodiversity assessments more comparable in the future, and allow, at least in approximation, for global impact assessments (FAO, 2019).

2.2. Evidence on diet-related health impacts

In high-income countries, the detrimental health impacts of some meats, in particular of red meat (which includes beef, lamb, and pork) and of processed meat (which, among others, includes bacon, and sausages of any kind), are now well established. In 2015, the cancer agency of the World Health Organization declared processed meat as carcinogenic and unprocessed red meat as likely carcinogenic to humans based on strong mechanistic evidence (Bouvard et al, 2015). In addition, there is consistent evidence from meta-analyses of epidemiological cohort studies that red and processed

meat increases risks for coronary heart disease, stroke, and type-2 diabetes (Schwingshackl et al, 2017; Bechthold et al, 2019). The effects of unhealthy diets on the health of an individual are a form of self-inflicted harm and therefore not an externality. Health impacts can, however, also affect macroeconomic outcomes: the diet-related health consequences from meat consumption can indirectly lead to productivity losses, which can be included in social cost estimates. In addition, in countries with universal health-care coverage where health-care costs are collectivized, such health risks increase the cost of such a policy instrument. .

Figure 3 illustrates the costs associated with diet-related health impacts in high-income countries and for the global average, based on an increase of meat consumption of one additional serving per day. The valuation based on statistical life (VSL, left) can be understood as a measure of the privately incurred harms from meat consumption (Springmann et al., 2016; Springmann, 2020), based on the willingness to pay for a mortality risk reduction in a defined time period (OECD, 2012). In contrast, the cost-of-illness approach (right) captures the direct and indirect costs associated with treating a specific disease, including medical and health-care costs (direct), and costs of informal care and from lost working days (indirect) ((Springmann et al., 2018; c.f. Leal et al., 2006).

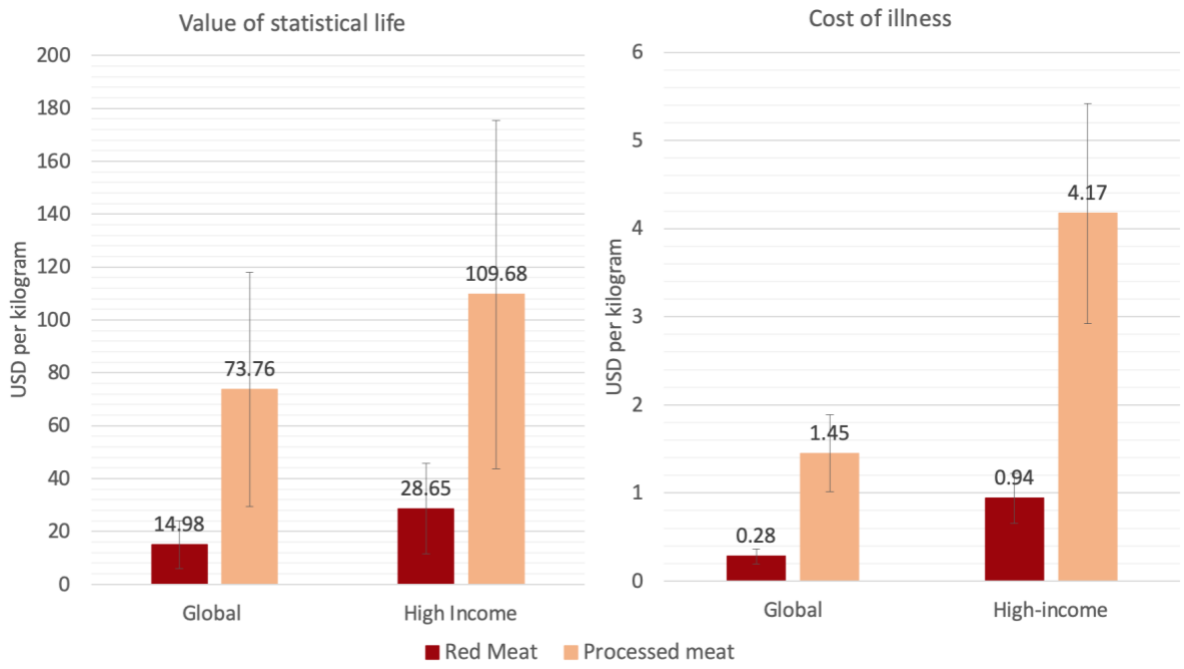

Figure 3: *Diet-related health damages and health costs from one additional serving of meat per day, based on Springmann et al. (2016, 2018, 2020). Privately incurred harms from meat consumption (left) are valued two orders of magnitude over costs-associated with specific resulting diseases (right).*

3. The public economics of meat: modelling taxes in the second-best

Although the social costs from livestock-related environmental damages and health effects are significant, they have remained largely unaddressed. In most countries, the only taxes on meat are currently value-added taxes, often at reduced rates. What the 'optimal' tax level on meat should be, depends on which externalities, and other regulatory objectives are to be addressed by this instrument. For example, optimal consumption taxes should generally contain a Ramsey taxation element which optimizes revenue generation. Policymakers also have to navigate specific normative positions, such as on animal welfare and 'health-based taxation', and their consequences for taxing

meat. The other upshot is that, in the words of Avinash Dixit, we live in a world that is second-best, at best: In imperfectly regulated markets, meat taxes have to be designed with any remaining uncorrected distortions in mind. In a first-best setting, livestock farming and meat consumption, as any other form of agricultural production and food consumption, should be subject to targeted externality-correcting instruments that get at the root of the problem: optimal carbon pricing, nitrogen regulation and ecosystem valuation. In the absence of these options, however, meat taxes can be an attractive second-best instrument to make progress on many regulatory objectives at once, for which livestock production and meat consumption are first-order issues.

This section casts light on some of the most important challenges, both for modelling an optimal second-best tax on meat, and for policymakers, who have to weigh in on which objectives they want to address and how these objectives might complement or counteract each other. *Figure 4* summarizes potential components of taxing meat and different factors of second-best tax levels.

***Figure 4**: Summary of potential meat tax components and factors that may influence second-best tax levels, relative to the sum of external costs*

Tax component	**Factors that may increase [+] or lower [–] the tax component**
Environmental externalities (climate change, nutrient pollution, biodiversity)	[–] Synergies between mitigating environmental externalities [+] Magnitude of indirect land-use and water-use effects on suboptimally regulated resource markets
Health internality	[+] High magnitude and pervasiveness of health internalities [–] Consumers substitute towards other unhealthy products
Animal welfare	[+] Higher meat prices lower returns to self-deception with respect to animal welfare, crowding in social preferences [–] Additional animal lives may be worth living
Indirect support for 'alternative protein' (AP) technologies	[+] Pervasiveness of uncorrected innovation-related market failures for alternative protein technologies
Distributional concern	[–] Tax incidence falls disproportionately on poorer households [+] Progressive revenue recycling [+] Health benefits from taxing meat fall on poor households
Ramsey tax component	[+] Fiscal revenue generation

3.1. Interaction of multiple environmental externalities

When regulating a set of simultaneously occurring, overlapping distortions and inefficiencies, economic theory has asserted that the optimal policy response is generally different from the sum of its parts. Lipsey and Lancaster (1956) assert that in the presence of at least one persistent uncorrected distortion, any attempt to combine 'regular' first-best policies has no guarantee to increase welfare. Instead, a second-best policy mix might involve policies that would seem distorting in a perfectly competitive setting. Practically, this means that social costs from multiple inefficiencies (see Figures 2

and 3) cannot simply be added up, but that their interaction needs to be carefully considered: a second-best optimal meat tax under multiple externalities may be more, or less, than the sum of its parts. This point generally holds for multiple market failures and inefficiencies (see also Section 3.2-6), here we discuss its application to multiple environmental externalities of meat consumption initially.

As a simple illustrating example take two prominent environmental externalities of livestock farming, greenhouse gas emissions and nutrient pollution: A fully externality-correcting tax on GHG emissions from livestock will likely have the co-benefit of reducing local nutrient pollution. As has been demonstrated in other contexts (c.f. Parry and Small 2005 for optimal fuel taxes), a tax that simply adds up the Pigouvian tax levels for both local pollution and GHG emissions will be sub-optimally high, as it did not account for the synergistic effect that one tax component has on the other. Despite much quantitative work on co-benefits of climate change mitigation, research on second-best interactions between carbon emissions and local environmental pollution from livestock farming seem to be lacking.

Furthermore, what environmental science has called an 'indirect land-use' effect might pose a greater challenge and potential for environmental economics research into meat regulation: Take the case of the global land market. Livestock farming relates to 82 % of global use of arable land (Poore and Nemecek, 2018). Increasing or decreasing meat consumption will therefore lead to a `general equilibrium effect' on the land market. This effect will increase or decrease pressure on other forms of land use (including via exports, see Schwerhoff and Wehkamp, 2018), which are significant drivers of deforestation and biodiversity loss (IPBES, 2019). This is a second-best consideration because the above effect would need not be taken into account if there was a complete, optimally regulated land market[12], where appropriate scarcity-weighted prices can unlock unrealised conservation opportunities (e.g. Xie et al., 2020). In the absence of optimal regulation, however, livestock farming excessively contributes to deforestation, biodiversity loss and water scarcity in some parts of the world.

3.2. Health internalities

A growing body of literature in behavioural economics indicates that consumers do not adequately account for the risks to their own health when eating meat, resulting in long-term 'internalities' from diet-related disease. Correcting these uninternalized costs on the self is another potential rationale for higher taxes on meat. Corrective taxes on health-related internalities have several precedents in real-world policy: Governments around the world have imposed taxes on products that are widely accepted to be corrosive for public health, including tobacco, alcohol and sugary beverages. The closest real-world example to a meat tax, Denmark introduced, and later repealed, a tax on saturated fats in 2011, leading to significant demand reductions for selected meat products as shown by econometric ex-post analysis (Jensen and Smed 2013, Jensen et al., 2015). Nutritional studies have found that the health outcomes of such taxes critically depend on cross-price elasticities of demand (Mytton et al., 2007), indicating that health-motivated meat taxes need to be carefully targeted to avoid consumers substituting red and processed meat for similarly unhealthy products.

Treating the corrosive health effects of meat-heavy diets as an internality (an adverse effect on one's own health) that merits governmental intervention is a distinct normative standpoint that requires careful justification. In specific, this position is based on the premise that dietary choices do not maximize individual welfare. This is the case when the risk of diet-related disease is not sufficiently

[12] Existing instruments on these markets, such as the international REDD(+) scheme for forest protection are insufficient in both ambition and coverage.

known to consumers (incomplete information), or not sufficiently deliberately chosen by meat eaters at the point of consumption (non-standard preferences, beliefs or economic decision-making, c.f. DellaVigna, 2009). As for the latter, people's diet-related choices can be subject to a multitude of behavioural effects, including lack of willpower, projection bias and time-inconsistent preferences (Loewenstein, O'Donoghue and Rabin, 2003; O'Donoghue and Rabin, 2000, c.f. Griffith, 2018). A crucial question for policy design is thus, whether such 'behavioural failures', similarly to market failures, should entail governmental correction. This requires, if not a breach, at least a selective relaxation of the standard conception of welfare as utility maximization based on revealed preferences, i.e., the notion that people are best off with what they choose (Bernheim and Rangel, 2009). Conversely, some policymakers may actively choose to embrace alternative notions of welfare, such as long-run subjective well-being ("happiness"), or context-specific regulatory objectives for public health, which could justify regulating internalities from meat (over)consumption (c.f. Fleurbaey and Blanchet, 2013).

Within public economics, several propositions have been made on the optimal design of corrective taxes in the presence of health internalities (Allcott et al., 2019; Griffith et al., 2018, 2019; van den Bijgaart et al., 2020). As far as these results are transferable to the case of meat taxation, we can expect that the second-best tax rate on meat increases with the magnitude and pervasiveness of internalities in the population and the responsiveness of consumers to meat price changes. Depending on distributive considerations, the optimal internality tax may increase if low-income households display stronger diet-related behavioural failures and are more elastic to price changes compared to the rest of the population, priming them for great benefits from internality correction.

Irrespective of where one stands on the normative question of internality correction, systematic biases in dietary behaviour complicate the regulation of meat. For example, behavioural effects may constrain the degree to which taxation will be successful in changing dietary behaviour, creating space for additional non-market-based interventions. The simultaneous failure of markets and consumer behaviour, therefore, renders meat consumption another example in a line of several 'environmental-behavioural second-best problems' in environmental economics[13] (c.f. Shogren and Taylor, 2008).

3.3. Animal welfare

Animal farming, especially in its widespread intensive forms, raises various moral concerns. These concerns are commonly advanced as a primary individual reason to reduce or ban the consumption of meat (Ruby, 2012). They also seem to gain political prominence, as illustrated by frequent protests against food retailers and referenda about animal welfare. Increasingly, animal sciences recognize the emotional and cognitive abilities of animals, including those of farm animals (Broom 2014, Marino 2017). Animal welfare is thus another possible (moral) motivation for regulating meat production and consumption by increasing the price of meat. However, research in economics about animal welfare is almost non-existent (Carlier and Treich, 2020, exceptions include McInerney, 2004 and Johansson-Stenman, 2018). How to account for animal welfare when designing meat taxes, is thus a largely open question.

Many people seem to care about animal welfare and are willing to pay a premium for more animal-friendly food products (Lagerkvist and Hess, 2011). A starting point is therefore to maintain an anthropocentric view of evaluating economic outcomes, but to recognize that animal welfare, like the

[13] Other examples concern residential energy efficiency, where behavioural failures to conserve energy interact with energy-related externalities (Lindén et al., 2006), and transportation, where the externalities of motorised transport are aggravated by behavioural failures in transport mode choice, resulting in unhealthy low levels of physical activity (van den Bijgaart et al., 2020; Mattauch et al., 2016).

environment, is a public good (Norwood and Lusk, 2011). Standard principles of environmental policy should thus apply. For instance, informational instruments such as labels may help but are imperfect due to free-riding. At a basic level, public intervention should encourage food products with high animal welfare standards. However, there is evidence of a 'preference gap' between subjects' elicited willingness to pay for animal welfare in lab or survey studies and the consumers' real purchase decisions in food markets (Norwood and Lusk, 2011, Grethe, 2017). Various behavioral considerations may matter to explain consumers' behaviour, such as warm glow, saliency, anthropomorphism, as well as (non)familiarity with certain animals. It has been shown that compassion and empathy decrease with genetic distance (Miralles et al., 2019). The psychological literature on the 'meat paradox' emphasizes that meat-eating, like other forms of morally troublesome behaviour, conflicts with deeply held moral principles and generates a cognitive dissonance (Barkan et al., 2015, Bastian and Loughnan, 2017).

These behavioral considerations regarding pro-animal concerns complicate regulation. To illustrate, Hestermann et al. (2020) explore the effect of the price of meat in the presence of cognitive dissonance. Consumers form self-serving beliefs about the suffering of animals in order to alleviate the guilt associated with meat eating. The price of meat has a causal effect on consumers' beliefs: High prices stimulate realism by lowering the returns to self-deception. As a result, cognitive dissonance magnifies the price elasticity of meat consumption. This finding raises the question of the regulator's objective when setting a meat tax. If consumers resort to self-deception to undermine animal suffering, they hold unrealistic beliefs. Following the merit goods literature, there is thus a role for regulatory intervention to correct such beliefs by using appropriate taxes (Besley, 1988).

The previous discussion adopts an anthropocentric view of animal welfare, in the sense that animals are accounted for in the social objective only through consumers' preferences and beliefs. However, a long tradition in philosophy has advanced that animal welfare should matter intrinsically (Bentham 1780, Singer 1975). Johansson-Stenman (2018) discusses established normative positions of environmental ethics and provides evidence supporting the direct inclusion of animal welfare into a utilitarian social welfare function but notes difficulties of properly measuring animal welfare. In practice, current approaches evaluate the provision of basic needs such as food and shelter, and health indicators such as injuries, diseases or stress hormone levels. Animal science experts recognize the need to better integrate positive experiences and properly account for cognition, emotions and the motivation of animals (Dawkins, 2012; Broom, 2014). Blackorby and Donaldson (1992) consider a two-species model where humans derive utility from eating animals in which the social planner cares about the welfare of both humans and of animals. They show that Pareto-efficient allocations cannot be decentralized, and that the second-best solution involves a tax on meat as well as direct control of farm animal welfare standards.[14] Building on Blackorby and Donaldson (1992), Espinosa and Treich (2020) discuss optimal policy regarding animal welfare and emphasize the importance of the notion of "life worth living".

In sum, it is hard to deny that animal welfare matters for regulation of meat consumption. But what follows for regulation? We tentatively conclude that for taxing meat: first, anthropocentric perspectives offer an additional rationale for taxing meat if taxation contributes to animal welfare by ensuring better rearing conditions,and helps mitigate behavioral limitations. Second, non-anthropocentric perspectives raise challenging questions when a life is worth living and how this can be ascertained. Rather than studying those implications for optimal taxation, an agreed minimum level of animal welfare might, however, bypass those complications. Norms of animal welfare that no one would disagree with should be enforced by regulation, that is, there are norms we as a society require,

[14] Beyond utilitarianism, various moral theories (e.g., deontology, virtue ethics) address the issue of meat consumption (Carlier and Treich 2020). They usually conclude that it is morally problematic to exploit animals and to consume meat, and recommend veganism (Regan 1983, Kymlicka and Donaldson 2011).

their production can be viewed as a merit good and rewarded from the public purse. Beyond that minimum level of welfare, the individual consumers may choose to buy better animal welfare at a premium. To help farmers meet such a minimum standard, redistributing some of the revenue of a meat tax towards enhanced rearing conditions ("animal welfare levy") could be a policy that addresses these concerns, but is so far unexamined.

3.4. Development and adoption of 'alternative protein' products

A reduction in the consumption of meat will be accompanied by a shift to meat substitutes, which are generally known to have a (much) lower environmental impact, although questions around upscaling remain (for an overview see World Economic Forum, 2019). There is a large variety of such substitutes, ranging from unprocessed foods such as beans or lentils, to more processed plant-based products (meat analogues) such as tofu and Quorn, to novel products such as lab-based, or 'cultured' meat (c.f. World Economic Forum, 2019; Tuomisto and Teixeira de Mattos, 2011)[15]. Over the past decade, continued innovation has allowed for the commercialization of a larger variety of meat analogues, many with a close semblance to meat, such as the 'Beyond' and 'Impossible' burgers. Likewise, the first 'proof of concept' of cultured meat was showcased in 2013. While past cost decreases have been substantial, much uncertainty remains around anticipating the effect of mass production (Rubio et al. 2020, Specht 2020, Treich, 2021).

By further encouraging the uptake of meat substitutes, the introduction of a meat tax could accelerate the development and commercialization of cultured meat and meat analogues. This indirect effect of meat taxes on innovation in substitutes may even justify higher present-day taxes on meat consumption. There are several reasons for this. First, evidence from other domains suggests that innovation spillovers are particularly high for novel products (Dechezlepretre et al., 2017) and in R&D-intensive industries (Bloom et al, 2013). Second, the development of cultured meat and meat analogues makes a durable shift away from meat a more likely future. As such, support for innovation in meat substitutes can act as a commitment device for policymakers (see Harstad (2020) and Dengler et al (2018) for this argument in the context of climate policy), as it lowers the cost of future taxes or restrictions on meat consumption. Such auxiliary benefits provide a rationale for additional support for research and development activities particularly for cultured meat products. This support may be direct, through higher R&D subsidies, or indirect, via higher meat taxes.

Vice versa, in the absence of an 'appropriate' price for meat, there exists a rationale to either subsidize consumption of meat substitutes, or set subsidies on meat substitute R&D in excess of the Pigouvian level. The rationale for this is that increased development and commercialization of such substitutes mitigates the underpriced externality of meat consumption. This argument is reminiscent of the rationale for (temporary) renewables second-best subsidy in the absence of adequate carbon pricing ten years ago (Fisher and Newell, 2008; Gerlagh et al., 2009; Kalkuhl et al., 2012). Importantly, optimal environmental regulation should always use both an input tax to control environmental damages, and research subsidies to influence the direction of clean innovation (Acemoglu et al. 2012).

Meat taxes can encourage the uptake of alternative protein products by decreasing their relative price and thereby making them more competitive with conventional meat products. The success of meat alternatives, however, will to a large extent depend on the degree of substitutability between meat

[15] The terminology around these innovations is still in flux, and depends on the narratives and motives of different stakeholders. While some producers in the field of cellular agriculture pushed for 'clean meat', suggestive of a not further defined set of positive properties, the academic discourse largely converges on the more neutral and broad term 'alternative proteins', which we use alongside 'meat substitutes' (c.f. Sexton, Garnett and Lorimer, 2019).

and alternative protein products, with taste-like and cheaper substitutes more likely gaining a large market share (Carlsson et al., 2021). This substitutability will be shaped in part by the physical characteristics of such meat alternatives, such as the nutritional content and likeness to meat in flavor and texture. An important factor will however also be the public perception of meat alternatives. Important considerations here are that alternative protein products may not be perceived as 'good' as the real thing and the fact that the consumption of meat has a strong cultural component which alternative proteins may not be able to replace (World Economic Forum, 2019).

3.5. Distributional effects

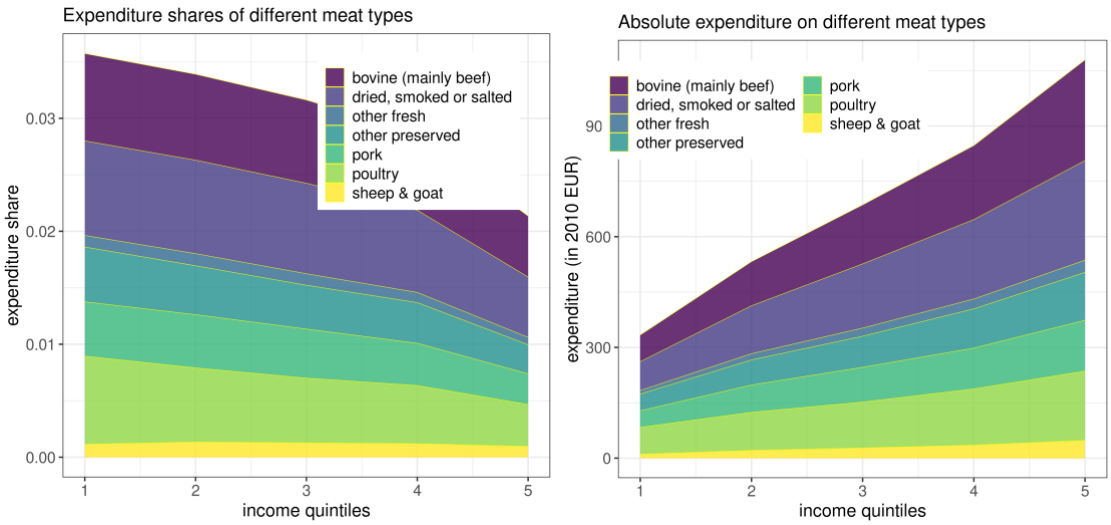

Figure 4: *Relative and absolute expenditure shares on different types of meat across income quintiles for the European Union (country-weighted EU-aggregate). (Source: Klenert et al. 2021)*

A frequent concern against meat taxes is that the tax burden would fall disproportionately on low-income households, as these spend a larger share of their income on food products. This raises the question whether a meat tax should be adjusted for such distributional effects.

The fact that relative spending on food falls with rising income is one of the most empirically verified laws in economics. This effect is called Engel (1857)'s Law and is the argument behind reduced VAT rates for foodstuffs and other basic necessities in many countries. It is also at the basis of distributional arguments against carbon taxation (Grainger and Kolstad, 2010). Empirical studies have shown that, in most European countries, for the weighted EU-average and for the US, the curve of relative meat expenditure by income does indeed follow the characteristic Engel's Law shape (exceptions are France and Portugal, which have more of a mild inverted U-shape; Klenert, et al. 2021, see Figure 3; Bureau of Labor Statistics, 2020).

When tax rates are not flat, but differentiated, which would be the case for a tax based on carbon content, the concrete incidence of meat taxes also depends on how households allocate their expenditure across different meat types. The tax burden can be expected to be high especially for those groups in society that predominantly consume meat types with high social costs (e.g. beef). For EU countries, Klenert et al. (2021) show that relative expenditure patterns on different meat types vary significantly. For instance, due to the peculiar inverted U-shape of the relative meat expenditure curve in France, a GHG-intensity-based tax would affect the three middle quintiles most, as they spend a larger part of their expenditure on beef than the lowest and the highest quintile. By comparison, a tax on poultry would likely be strongly regressive in France as relative poultry expenditure in these countries follows the typical Engel's Law shape.

Beyond initial (partial equilibrium) distributional impacts, a complete assessment of the distributional consequences of meat taxes also takes into account the different reactions of households, long-term effects and the use of the meat tax revenue. A tax on meat differs in its impact on consumption from, for instance, an environmentally-motivated tax on fuel, in the sense that consumers can immediately substitute away from the taxed good, without major investments or suffering objective adverse effects. This implies a stronger demand reaction to meat taxes compared to, for example, fuel taxes[16], particularly for low-income households and hence a higher price elasticity (see Wadud et al. 2009). Due to their stronger reaction to price increases, low-income households might over-proportionately benefit from long-run health effects from reduced meat consumption. According to Alcott et al. (2019) this might justify increasing the tax on unhealthy products such as meat, the more health benefits are skewed toward low-income consumers.

In optimal environmental taxation models that feature heterogeneous households, a frequent outcome is that externality taxes should not be corrected for their distributional impact, as it can be offset by adjusting the tax and transfer system optimally (Jacobs and de Mooij, 2015). This result depends on the level of the marginal cost of public funds (MCPF), i.e. the marginal social value of government vs. private funds. Only if the MCPF equals one, income and environmental taxes can be set independently. Apart from the optimality of the tax system, whether or not the MCPF equals one, depends on several assumptions, such as the policy instruments available for redistribution and the shape of the utility function (Cremer et al. 1998; Jacobs and van der Ploeg, 2019), which need to be ascertained for the various ways of representing meat taxes we suggest. However, when policy instruments such as income taxes are not at their optimum, the MCPF can be greater or smaller than one (Jacobs, 2018). In this case, the separability between externality and income taxes does not hold anymore (Sandmo, 1975), which might justify corrections to optimal externality taxes for distributional reasons or additional policies aimed at offsetting the potential regressive effect of the tax.

Further work in environmental taxation has studied the distributional outcome of combined tax and specific revenue recycling policies, especially the incidence of specific revenue recycling options. Applying the conclusions of such work to meat taxes suggests that the use of the tax revenue can help make meat taxation packages more progressive. It is known that if the relative spending on a good decreases with income, but the absolute spending increases, taxing this good and returning the revenue lump-sum on a per-capita basis is progressive (Klenert and Mattauch, 2016). Hence, the simplest way of balancing the potentially regressive initial distributional effects of a meat tax would be uniform lump-sum redistribution of the revenue (Caron et al., 2018; Rausch et al., 2011; Williams III et al., 2014). If that is politically infeasible, using the revenue to further cut the reduced VAT rate on food would also be progressive, however additional analysis would be required to determine whether this fully offsets the initial regressive impact of the tax.

Finally, meat taxation in high-income countries may have overall positive effects on global food security. At present, livestock farming is associated with high opportunity food losses, as it competes with other, less resource-intensive forms of crop farming for human use. For the United States, Shepon et al. (2018) have found that replacing animal-based food products with plant-based products by far exceeds the potential of eliminating supply chain food waste for increasing food availability. While the global distribution of food items, and food security in poor nations in specific, is influenced by many more factors, among them global trade relations and the effectiveness of national institutions, these results highlight the role that reduction in the demand for meat products can play for securing food availability for a growing world population.

[16] As consumers tend to be more responsive to increases in the price of meat, compared to, for instance, gasoline, particularly in the short term (for the respective elasticities, see Gallet, 2010 and Brons et al., 2008).

4. Discussion

In a second-best setting, meat taxation is an attractive instrument because it advances many regulatory objectives at once, even if only partially. Nevertheless, meat taxes may need to be accompanied by complementary direct regulation and industrial policy. The role of meat taxes within the broader policy package towards sustainable meat further depends on their political feasibility.

4.1. Demand- or supply-side regulation?

While policymakers usually have a choice between taxing meat at the source or levying consumption taxes on final products, the second-best meat tax that we have been assessing is a downstream tax by design. One advantage is that consumption taxes can ease competitiveness concerns, as they would affect meat from all sources and reduce the risk of domestic producers being undercut by imports from countries with lower environmental regulations. Compared to other polluting industries, upstream entities (i.e. farms) in the livestock sector are also comparatively small and scattered, resulting in high monitoring costs for farm-specific pollution and rearing conditions.[17] In the presence of high monitoring costs, Schmutzler and Goulder (1997) have demonstrated that consumption taxes may be more efficient, if production-side abatement options are limited and the taxed goods can be easily substituted. For the climate externality in specific, there is evidence that potential efficiency gains on the production side are indeed very constrained, at least in developed countries (Wirsenius et al., 2011).[18] Given the scale of the regulatory issues and the potentially uncompromising constraints on input factors such as agricultural land expansion, it can more generally be assumed that per-capita meat demand needs to decline, justifying a strong emphasis on demand-side solutions.

A marked disadvantage of consumption taxes on meat is, nevertheless, that they neglect potential efficiency gains at the source. Where efficiency gains are significant (e.g. animal welfare and prevention of antimicrobial resistance) or highly localized (e.g. deforestation hotspots), complementary policies are needed to incentivize necessary transformations. Moreover, a second-best meat tax does not resolve trade-offs between different regulatory motives. For example, while extensive forms of livestock rearing will benefit animal welfare, they may aggravate certain environmental damages. Likewise, 'cultured meat' innovations may help consumers to substitute away from products which are environmentally harmful but may not alleviate the disease burden that comes with consuming large quantities of processed meat. Finally, the necessary transformations in the livestock sector cannot be achieved without adjusting existing supply-side policies, including reform of former subsidies, as for example under the European Union's Common Agricultural Policy.

4.2. Political economy considerations

The FAO (2020) estimates that the livestock industry contributes to 40% and 20% of agricultural output in developed and developing countries respectively, and globally provides livelihoods for 1.3 billion people. Attempts to change the fiscal status of livestock products will be resisted by major vested interests, and there is the potential for unintended consequences that affect the well-being of large numbers of people, especially those on low income. Understanding these political economy

[17] Along with leakage concerns and equity concerns on the production side, high transaction costs were identified as one of the main barriers to including agricultural emissions in the European Union Emissions Trading System (Grosjean et al., 2016)

[18] Smith et al. (2008) have estimated that the technological potential for reducing methane and nitrous oxide emissions from livestock is 12% and 5% respectively.

constraints, and avoiding or mitigating undesirable negative trade-offs, will increase the chances that interventions with net societal benefits are also politically feasible.

Though governments tend to dislike tax hypothecation, revenues generated from meat taxes could actually or notionally be assigned to correcting market failures in a way that both benefits current livestock producers and produces societal benefits. For example, farmland currently used for livestock might with lower stocking density or conversion to other uses provide a variety of provisioning, regulating or cultural ecosystem services whose greater provision would justify public payment. Rewarding farmers more generously for the public goods provided by their farm lands, while incentivizing more sustainable land uses, could be an effective and equitable way to ease opposition to more stringent regulation. Gren et al. (2021) demonstrate for Sweden that assigning the revenues of a climate tax on food products to farmers for selected ecosystem services, such as peatland restoration for enhanced carbon sequestration, can significantly enhance the environmental effectiveness of the tax policy, while also increasing the net income of farmers.

Consumer elasticities for food and other livestock products are personally and culturally derived. It may be that as the environmental and health externalities of meat consumption and production become more apparent, consumer behaviour and preferences evolve so that a new equilibrium is possible where individuals eat less but more expensive meat. The success of some niche premium brands marketed on both quality and environmental sustainability suggests a pathway to a more radical change in the meat sector, which might also provide a sustainable future to the livestock industry. This topic would reward more economic modelling to understand the feasibility of such a new equilibrium and what combination of fiscal and regulatory would most easily bring it about.

4.3. Public support and cultural dynamics of food choice

As meat consumption has a strong cultural connotation, and food choices are perceived as 'private matters', there is a concern that meat taxes would be met with strong public opposition. In the context of a survey on citizens' preferences for climate policy in France, Douenne and Fabre (2020) have indeed elicited that meat taxes are one of the most unpopular measures, with only 17% of French respondents supporting them. It is unclear whether that is because citizens are unaware of the mitigation potential of changing meat consumption patterns, sceptical of the 'Pigouvian' effectiveness of meat taxes, or oppose the measure because they perceive it as too coercive.

Nevertheless, the design of concrete meat taxation policies can be tweaked to harness public support. Work on public support for carbon pricing suggests that framing of the tax proposal and use of revenues are decisive determinants for getting citizens on board (Klenert et al., 2018). In a study with German, US American and Chinese citizens, Fesenfeld et al. (2020) demonstrate that policy packaging can enhance support of meat taxes. The public support for taxes has been highest when they were at a moderate level and combined with popular policies such as animal welfare standards, discounts on vegetarian meals and information campaigns. More ambitious meat taxes can also be made more appealing by simultaneously lowering agricultural subsidies to meat farmers, introducing more stringent farming standards, and using tax revenue to support low-income households.

Another concern is how meat taxes will influence social preferences for voluntary meat reduction. Early research on animal welfare behavioral motives in meat consumption choices suggests that meat taxes crowd in social preferences, by lowering the returns to self-deception (Hestermann et al., 2020). This suggests that even moderate meat taxes may have an outsized impact by making the uninternalized social costs embedded in meat products visible to consumers. After all, consumption (Holt and Goodwin 1997) habits matter in explaining meat demand. When dietary preferences are

endogenous, there is also a rationale to complement meat taxes with broader changes in the 'culinary infrastructure' to harness the dynamics of socio-cultural dietary choice and make meat-reduced diets more attractive to consumers (c.f. Hawkes et al., 2015; Mattauch, Hepburn & Stern, 2018).

5. Conclusion

Advances in environmental science and economics permit us to conclude that meat is significantly underpriced. By how much it is underpriced is currently unknown. We believe that there is high value in providing policymakers and society with a number, as we demonstrate, meat consumption is a highly important factor in the biggest environmental problems of our time from biodiversity loss via water pollution to climate change. While the contribution of the global livestock sector to climate change (15%) is significant, the role of livestock is of first-order importance for regulating global nitrogen cycles and maintaining ecosystem biodiversity. Meat taxes can, in addition, advance progress on both the environment and public health simultaneously, as high levels of meat consumption are associated with increased risk of a number of diseases.

Our review indicates that the global environmental social costs, when they are added up, are on average between 8.49–12.28 USD/kg for beef (depending on the production of dairy by-products), 2.92 USD/kg for pork and 2.30 USD/kg for poultry. This estimate is likely conservative as it does not include the social cost of attributable biodiversity loss and the health effects from livestock-related air pollution. In December 2020, the average US retail price for beef was 13.75 USD/kg (9.08 USD/kg for pork; 4.42 USD/kg for broilers) (US Department of Agriculture, 2020), suggesting the appropriate tax on beef, as a ballpark estimate (i.e. ignoring interaction effects), should at least double its retail price. Including the valuation of privately incurred harms would approximately quadruple it.

Our review further indicates that progress in environmental economics is needed especially along the following lines: Economic valuation of the extent to which biodiversity loss is driven by livestock farming is still scarce, both due to a lack of comprehensive and comparable impact assessments that can be extrapolated to a global scale, and due to lack of robust social cost estimates for the damages from biodiversity loss. We further assume that indirect land-use effects, borne out of the additional pressure that livestock puts on land expansion and deforestation in suboptimally regulated global land markets, will play a significant role in the extent of environmental damages from livestock production and consumption of animal-based products. Further, second-best modelling of policy instruments (including taxes) could elucidate the interplay of regulation of the multiple externalities, diet-related adverse health effects of meat consumption and distributional effects. A nascent literature in welfare economics, moreover, has explored the role of animal welfare in economic valuation, clarifying the impact of different normative possibilities and the interplay between meat taxes and improvements in animal welfare standards. We call for further research in public economics to disentangle and quantify the effects of related normative positions on animal welfare and diet-related health. Finally, technologies for alternative proteins and meat substitutes will impact the demand for meat this decade: while estimates of their expected cost-decreases exist, further research should examine how these alternatives to meat are best fostered by regulation, given livestock's first-order importance in multiple global environmental problems.

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