WORKING PAPERS

N° 1503

January 2024

"The Animal-Welfare Levy"

Romain Espinosa and Nicolas Treich

Toulouse School of Economics

The Animal-Welfare Levy*

Romain Espinosa† and Nicolas Treich‡

January 4, 2024

Abstract

We provide a non-anthropocentric rationale for implementing a levy on meat consumption due to animal-welfare considerations. It operates as a Pigouvian tax and addresses externalities on farmed animals. Under total utilitarianism, the levy is a subsidy when an animal's life is worth living, and a tax when it is not. Under average utilitarianism, it is always a tax when human welfare exceeds animal welfare. Even under conservative assumptions, calibrated tax levels are substantial and would make most-intensive animal farms unprofitable. Taxes are significantly higher for chickens and pigs than for cows, in contrast to the taxation of other meat externalities.

Keywords: Animal welfare, meat, Pigouvian taxation, utilitarianism, life worth living, quality-adjusted life years, population ethics.

JEL classification: Q18, Q50, H41, I31.

---

*The authors thank Matt Adler, Heather Browning, Mark Budoflson, Andrew Clark, Patrick Fève, Bob Fischer, Jim Hammitt, Christian Hellwig, Linus Mattauch, Marco Runkel and François Salanié, as well as seminar participants at the Universities of Amsterdam, Berlin, Fribourg, Geneva, Heidelberg, Montpellier, Nanterre, Toulouse, and at the Normative Economics & Economic Policy webinar series, SBCA conference, Oxford GPI workshop and EAAE congress for useful comments. Nicolas Treich acknowledges research funding from the ANR under grant ANR-17-EURE-0010 (Investissements d'Avenir program) and from the FDIR chair at TSE-Partnership. Romain Espinosa acknowledges research funding from the ANR under grant ANR-19-CE21-0005-01. Corresponding author: Nicolas Treich (nicolas.treich@inrae.fr).

†CIRED, CNRS, France.

‡Toulouse School of Economics, INRAE, France.

1 Introduction

In this paper, we provide a non-anthropocentric economic rationale for implementing a meat-consumption levy due to animal-welfare considerations. We consider a simple economic model of consumption externalities on animals, derive an analytical expression for this levy, examine how this expression changes under different assumptions regarding the economic environment or the normative setting, and finally calibrate the levy for most-commonly farmed animals (chickens, pigs and cows).

A variety of political bodies, reports and scholars have advocated for a meat tax, based primarily on the environmental impact of animal farming (FAIRR 2017, TAPPC 2020, Bonnet et al. 2020, Byrne 2022, Funke et al. 2022, Broadbent 2023). However, the possibility of taxing meat for animal-welfare reasons has also gained attention, as recently highlighted by the European Court of Auditors (ECA 2023). In Germany, an expert commission appointed by the Minister of Food and Agriculture has proposed the implementation of an animal-welfare levy, known as the *Tierwohlabgabe*. This levy would be applied to every kilogram of meat sold, and the revenue generated would be used to support farm-husbandry conditions. Perino and Schwickert (2023) recently conducted a survey that indicated some political support in Germany for this animal-welfare levy. Nonetheless, the current challenge lies in the lack of a conceptual foundation and a worked calculation for the levy.

This paper addresses both of these issues, as it provides an economic rationale for and an initial calculation of the animal-welfare levy. Our model makes the key assumption that animal welfare has intrinsic value, and is an integral component of social welfare. In other words, our approach is non-anthropocentric. The idea is then that meat consumption has social implications regarding animal welfare, as it requires that animals be born and bred. If the life of a farmed animal involves more suffering than pleasure, then choosing to consume meat may be viewed as morally problematic, as it requires the creation of an unpleasant life. In this case, the choice of meat consumption should be discouraged. On the contrary, if farmed animals live pleasant lives, then animal consumption should be encouraged. These social impacts provide a justification for the application of a levy (either a tax or a subsidy) on meat consumption. In our simple model, this levy should be a tax rather than a subsidy only if the animal's life is *not* worth living. Our benchmark result shows that this levy per animal is precisely equal to the opposite of the animal's utility level.

The concept of this proposed levy is obviously Pigouvian in nature (Pigou 1920, Baumol 1972, Bovenberg and Goulder 2002). By affecting the price of meat, and in turn the demand for it, the levy addresses the externality caused by the production of animals for meat. The levy is exactly equivalent in size to the marginal social damage or benefit resulting from the existence or non-existence of farmed animals. Note that the historical Coasian objection to Pigouvian taxation does not apply in our context. Unlike human agents, animals lack the capacity for private negotiations, and do not possess the freedom and awareness to relocate and avoid the externality. In an economy where the sole distortion is the externality associated with animal welfare, applying the proposed animal-welfare levy would lead to the non-anthropocentric first-best outcome.

Although the animal-welfare levy can be conceived as a classical Pigouvian fee, it is important to recognize its particularities. We have to face two major difficulties that arise when animal welfare matters intrinsically, which have not been addressed in the economic literature on Pigouvian taxation. First, conceptually, the levy affects the quantity of meat produced, and thus the number of farmed animals. This is thus a case of variable population (Blackorby et al. 2005), where life worth living emerges as a central concept for the design of optimal regulation. Second, in practical terms, the evaluation of the externality on animals requires the assessment of animal well-being. As our approach is non-anthropocentric, this assessment cannot in principle resort to the observation of market prices, as these are controlled by humans, nor to the standard human willingness to pay approach. We thus need to tackle the difficulty of measuring animal well-being and comparing it to human well-being.

Our benchmark analytical result assumes total utilitarianism, which is the sum of the utilities of both humans and animals. However, this normative setting is questionable under a variable population. As a result, we also consider the most-common alternative, average utilitarianism. We show that it is socially optimal to reduce animal consumption and impose a greater animal welfare levy under average utilitarianism than under total utilitarianism. We also find that the levy is always a tax under average utilitarianism when human welfare is greater than animal welfare. This is because applying a tax on meat reduces the number of individuals with the lowest welfare (i.e. animals), which in turn increases average welfare. We also explore critical-level utilitarianism, a theoretical framework often used in case of variable population, and find here again a greater animal welfare level than under total utilitarianism. Our benchmark result under total utilitarianism may therefore be viewed as a lower bound for the animal-welfare levy when it is a tax and an upper bound when it is a subsidy.

We then propose a method for the calibration of the animal-welfare levy, based on the benchmark result that the levy is the opposite of the animal's level of utility. To determine this latter, we introduce a model of animal utility which involves three essential parameters: the animal-welfare score, the utility potential, and the monetization parameter. The animal-welfare score measures the level of an animal's welfare given its living conditions at a specific time, and is calibrated using the Five-Freedoms approach (Brambell 1965) from Animal Sciences and the quality-adjusted-life-years (QALY) approach from Health. The utility potential, which captures the intensity of an animal's experience of the world, is calculated using the number of neurons (Wong 2016, Budolfson and Spears 2019, Espinosa 2023). Last, the monetization parameter is calibrated using the human WTP for a QALY, allowing us to transform animal utility levels into monetary units, namely the unit of the animal-welfare levy.

We then present three applications using data from France. We first calculate the animal-welfare levy for broilers in four different production systems. We show that the tax per chicken can be dozens of Euros for standard (intensive) systems but only a few Euros for organic systems, highlighting the significant impact of rearing conditions on animal welfare. Second, we calculate the levy per kg of meat for four types of animals in standard systems: broilers, pigs, cows from dairy herds, and cows from beef herds. We show that the levy can exceed 50 Euros per kg for broilers and pigs but acts as a subsidy for cows from beef herds. This result stands in contrast to the taxation of other meat externalities, which typically indicate a greater impact of beef and a lower impact of chickens and pigs. Third, we simulate the effect of a GHG tax on beef and conclude that although this tax reduces environmental externalities it also increases externalities on animals, and so results in lower rather than higher global welfare. Overall, our results suggest that animal-welfare impacts are of first-order importance and that implementing animal-welfare levies would have a drastic impact on food prices and food systems more generally. Furthermore, the impact of animal-welfare levies is shown to differ considerably from that of environmental taxes.

1.1 Related literature

Our paper is related to several strands of research. There is first a longstanding literature in philosophy on animal welfare. Famous utilitarians such as Bentham (1789), Sidgwick (1893) and Singer (2011) have argued that the well-being of sentient animals should be included in the social objective. Research in animal ethics, ethology, and cognitive sciences indicates in particular that all mammals and birds are sentient (Low et al. 2012, Broom 2014), and hence so are all common terrestrial farmed animals. In contrast, economic research to date has been based on anthropocentric/speciesist normative approaches (Johansson-Stenman 2018, Fleurbaey and Leppanen 2021), with only a few exceptions (Blackorby and Donaldson 1992, Clarke and Ng 2006, Eichner and Pethig 2006, Espinosa and Treich 2021, Kuruc and McFadden 2022). In this paper, we formally explore some implications of relaxing anthropocentrism by using a simple economic model of animal consumption and studying optimal regulation.

Our paper is part of the rapidly growing literature on food taxes. There is in particular an emerging body of research stressing the climate, environmental and health externalities of animal-based food, and justifying its taxation (Springmann et al. 2018, Bonnet et al. 2020, Funke et al. 2022, Mattauch and Tenkhoff 2023, Perino and Schwickert 2023). It builds on the longstanding literature on Pigouvian taxation (Pigou 1920, Baumol 1972, Bovenberg and Goulder 2002). Although externalities on animals are often colloquially evoked in this literature, they have not been formally or empirically incorporated as a justification for an additional tax on meat. We here fill this gap by proposing a simple conceptual framework for a tax on meat that is explicitly justified by animal-welfare considerations. Our model in Section 2 is formally similar to the standard one used in environmental economics and is also connected to the recent working paper by Eichner and Runkel (2022), who consider a much more general model with "moral consumers" and explore theoretically the optimal regulation of meat (for related work on environmental regulation with moral consumers, see Dasgupta et al. 2016 and Daube and Ulph 2016).

Our paper is also strongly related to the population-ethics literature, namely the study of the moral issues arising when decisions affect the number (and/or identity) of people who are born. See in particular Parfit (1984) in Philosophy and Blackorby et al. (2005) in Economics. This issue arises in our model as the policy choice affects the number of animals consumed, and these animals matter intrinsically: see the discussion and analysis in Section 3. The economic literature on population ethics has to date mostly been axiomatic or conceptual (for a recent contribution, see, e.g., De la Croix and Doepke 2021). There are only few economic analyses that have applied population-ethics principles. We here propose a simple application to the choice of the animal population, as in Blackorby and Donaldson (1992) and Espinosa and Treich (2021). However, none of these contributions has specifically considered meat taxation. Moreover, we will systematically compare the animal-welfare levy under a variety of normative settings.[1]

Last, our paper is related to the literature on animal-welfare measurement. See for example Broom (2014), Mellor (2016), Weathers et al. (2020) and Browning (2022) in Animal Sciences. The existing literature in Economics is based on humans' WTP for animal welfare (Lagerkvist and Hess 2011, Norwood and Lusk 2011), and is not directly relevant to our approach in which animal welfare matters intrinsically, and not only through a human lens. In Section 4, we instead use a calibration method that combines the well-known Five-Freedoms approach (Brambell 1965, Mellor 2016) from Animal Health, and the QALY literature from Health (Weinstein et al. 2009, Hammitt 2013, Espinosa 2023).

2 Theoretical basis

In this section, we first introduce a simple model of consumption externalities on animals. We then consider optimal non-anthropocentric regulation in this economy. This provides an economic foundation for the implementation of an animal-welfare levy on meat consumption; this levy can be conceived as a Pigouvian fee. We then discuss a number of generalizations of this simple model.

2.1 A simple model

We take the simplest possible model to analyse the implications of meat consumption for animal welfare. This model will be referred to as the benchmark model in the remainder of the article, and has three purposes. First, it provides a conceptual basis for the animal-welfare levy. Second, it allows us to derive a closed-form solution for the animal-welfare levy that we will use in the calibration below. Third, this solution serves as a benchmark to which we will compare to the solutions obtained from more-general or alternative models at the end of this section and in the next.

In this simple model, there is one representative human. Let n be the number of farmed animals consumed by this human, so that there are n animals consumed (and thus produced) in total. The human individual has the following individual objective:

$$u(n) - cn \tag{1}$$

where c is the cost of producing an animal and $u(.)$ is an increasing and concave human utility function. This leads to the following FOC:

$$u'(n_e) = c \tag{2}$$

where n_e is optimal individual meat consumption. This equality simply reflects that the marginal benefit of consuming an animal is equal to its marginal cost. The second-order condition is satisfied. In the following, we mostly focus on interior solutions. The

[1] Our paper is also formally related to the literature on endogenous fertility (Becker and Lewis 1973). A subset of this literature has focused on welfare implications and fiscal policies. However, the motivation for these policies is typically their impacts on growth (Barro and Becker 1989, Galor and Weil 1999), intergenerational inequality (Nerlove et al. 1986), the pension system (Groezen et al. 2003), environmental externalities (Golosov et al. 2007) and education (Baudin 2011). This literature has not usually considered whether lives are worth living, which is the subject of our work here.

conditions i) $u'(0) > c$ and ii) $u'(n) < c$ when n is sufficiently large, ensure that a unique solution exists and that it is interior.

We now analyse the social[2] problem that directly includes the welfare of farmed animals. Our normative setting is thus non-anthropocentric. In the benchmark model we consider total utilitarianism. Denoting by v the well-being of each living animal, the "social objective" of the sum of human and animal welfare becomes:

$$U(n) = u(n) - cn + nv \tag{3}$$

The novelty here is hence to include animal welfare in the social objective through the term nv. The social decision concerns n, i.e. the number of animals that are consumed and thus brought into existence. Note that the problem is fully characterized by the maximization of this social objective (3) as a function of n. This presentation of the social problem summarized in the social objective proves to be convenient, as it encapsulates all pertinent assumptions in one single formal expression. We will retain this presentation throughout the analysis, even when we consider more-general or alternative models.

Socially-optimal consumption n^* is thus given by the following FOC:

$$u'(n^*) = c - v \tag{4}$$

which simply reflects that the marginal utility of consuming an animal is equal to its marginal social cost. Compared to the FOC of the individual program above, there is an extra term, $-v$, representing the social impact of bringing an animal to life for human consumption.

The comparison between n_e and n^* is obvious: under total utilitarianism, it is socially optimal to consume fewer (resp. more) animals than under the individual case if $v < 0$ (resp. $v > 0$). Note that the comparison of the social and private decisions here requires the comparison of the utility of being alive to that of 0. We follow the convention, and assume that $v = 0$ corresponds to an animal life that is "morally neutral", namely a life that is exactly equivalent to nonexistence (Blackorby et al. 2005, Espinosa and Treich 2021). Hence, we compare life to nonexistence.[3] In other words, in the unregulated economy there is under-consumption of meat when animal life is better than nonexistence and over-consumption when it is worse than nonexistence.

Before turning to the analysis of optimal regulation, we briefly discuss corner solutions. Suppose that $u'(0) < c$, which implies vegetarianism ($n^* = 0$) in the laissez-faire economy. Then, if v is high enough (i.e. $v > c - u'(0)$), we have $n^* > 0$ and vegetarianism is not socially optimal. Conversely, vegetarianism may be optimal in a society of meat-eaters when v is low enough. We do not further explore these corner cases in the following.

2.2 Benchmark result: The animal-welfare levy

We have seen that the individual consumption level is not socially optimal in general (unless $v = 0$). We now explore the optimal taxation of the externality in this economy.

[2]Note that the term "social" here refers to the society composed of humans and animals.

[3]This undoubtedly raises a thorny philosophical issue. This is discussed in, e.g., Salt (1917), Dasgupta (2005), Golosov et al. (2007), Visak (2013) and De la Croix and Doepke (2021).

We call this the *animal-welfare levy*. Again, we consider the simplest-possible model of taxation. Applying a fiscal levy t to meat consumption, optimal individual animal consumption, denoted by $n(t)$, is simply given by the following FOC:

$$u'(n(t)) = c + t \tag{5}$$

The social problem then amounts to choosing t to maximize

$$u(n(t)) - cn(t) + n(t)v \tag{6}$$

where it is assumed that the product of the tax is fully returned to the consumer. This yields:

$$u'(n(t)) = c - v \tag{7}$$

By using the FOC of the individual problem above, i.e. (5), we can immediately infer the following:

Benchmark result: *Under total utilitarianism, the socially-optimal animal welfare levy is equal to the opposite of the level of animal utility:* $t^* = -v$.

The animal-welfare levy thus operates similarly to a Pigouvian tax by accounting for the externalities on animals that are produced for meat. It is equal to the marginal social value of consuming one additional animal, so that the externality on animals is fully internalized by the consumer. As there is no heterogeneity across consumers and no distortionary effects of taxation, it is immediate that this levy allows society to attain the non-anthropocentric first-best outcome.

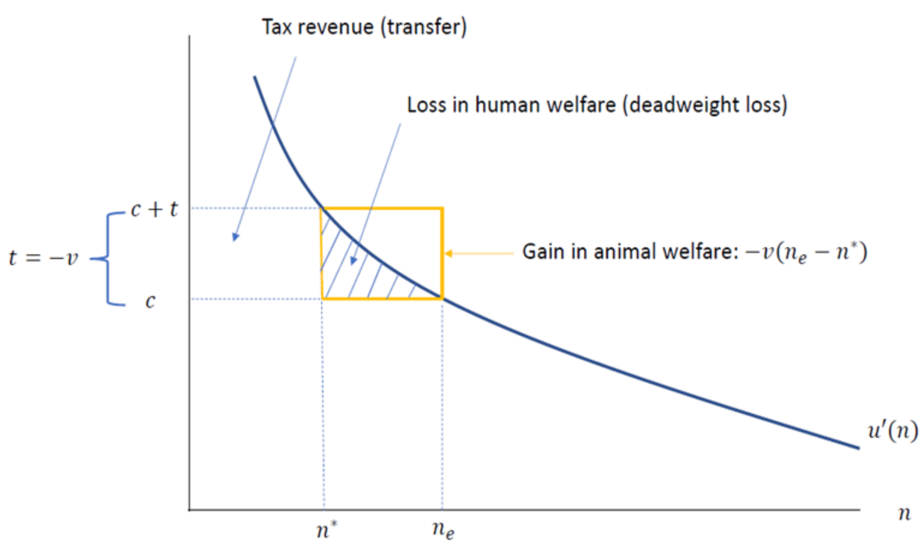

Figure 1: The welfare impact of the animal-welfare levy: $t^* = -v > 0$

Figure 1 represents the welfare impact of the levy when it is a tax, i.e. $t^* = -v > 0$. The hatched area represents the classic deadweight loss due to taxation, which corresponds to the loss in human welfare. The novelty in this Figure, as compared to the economic textbook presentation of Pigouvian taxation, is the interpretation of the yellow rectangle. This rectangle represents the gain in animal welfare: $-v(n_e - n^*) > 0$. This gain is due to the animal lives not worth living that are avoided as a result of lower meat consumption. As this figure illustrates, the animal-welfare levy induces a "shift" of welfare from humans to animals, and increases overall welfare in society.[4]

In the rest of this section and in the next, we explore theoretically how the animal-welfare levy varies in more-general or alternative settings. We thus carry out some comparative-static analysis with respect to the benchmark result. We consider one deviation from the benchmark model at a time. We say that the animal-welfare levy is greater when t increases, namely when either i) the tax is higher if the levy is a tax (i.e. $t > 0$), or ii) the subsidy is lower if it is a subsidy ($t < 0$).

2.3 Generalizations

We now generalize the above benchmark model. These generalizations encompass non-linear production costs, endogenous animal wellbeing, multispecies, and altruistic preferences. Each generalization is presented in turn, and the theoretical proofs are provided in the Appendix. These generalizations are relatively straightforward and consistently indicate that the benchmark result $t = -v$ continues to hold or represents a conservative estimate of the animal-welfare levy.

The benchmark model assumes a linear production cost. In Appendix A.1, we consider a straightforward extension of this model in the competitive economy. Let $c(n)$ be the nonlinear production-cost function and p be the price of meat. Producers choose n to maximize profits, i.e. $pn - c(n)$, while consumers choose n to maximize their utility, i.e. $u(n) - pn$. The standard competitive-equilibrium condition is: $u'(n_e) = c'(n_e) = p$. As is well known, we show that the animal-welfare levy is still equal to $t = -v$ in this economy. The main difference from the benchmark result above concerns its implications, as there is now a shift of welfare from both consumers and producers to farmed animals, as shown in Figure A.1.

In our benchmark model, the level of animal well-being is fixed. Hence, our model does not include any choice regarding the quality of animal lives. In other words, we assumed that the animal-production technology is fixed. Suppose now that the social planner can change the technology by imposing a mandatory "animal-welfare standard" d that affects animal well-being, denoted by $v(d)$. In Appendix A.2, we show that the benchmark result above continues to hold in the sense that the optimal animal-welfare levy is $t = -v(d)$, where d is the socially-optimal animal-welfare standard. As in Eichner and Runkel (2023), and consistent with the Pigovian tax literature (Bovenberg and Goulder 2002), we show that two instruments (i.e. the levy and the animal-welfare standard) may be required to attain the first-best outcome. This makes sense, as we need to regulate both the quantity and the quality of animal lives.

Relatedly, it can also be argued that the level of animal well-being may be affected by the number of animals produced, for example, because more animals increase confinement in animal farms. We can allow for this by expressing animal well-being as a function of n, i.e. $v(n)$. For brevity, we refer to this as a density effect. We show in

[4]Note that this is an unusual welfare "shift", since the beneficiaries are nonexisting animals that would have existed without the policy.

Appendix A.3 that the socially-optimal levy is now $t = -[v(n) + nv'(n)]$, where the second term in the square bracket captures the change in animal life quality due to the number of animals that are raised. Assuming that $v'(n) < 0$, i.e. animal well-being falls as more animals are produced, this additional density effect leads to a higher levy.

The benchmark model assumes that only one animal species is produced or consumed. We can easily generalize the model to s multiple species (such as chickens, pigs or cows), each with its own animal wellbeing level v_s and production cost c_s. We show in Appendix A.4 that the benchmark result above continues to hold for multi-species when a levy t_s can be applied to each animal product s: applying an animal-welfare levy to each species $t_s = -v_s$ yields the first-best outcome. This is unsurprising as it is an application of standard Pigouvian taxation in the context of multiple externalities (see, e.g., Dasgupta et al. 2016). Note that the label s may also be used to distinguish the animals in the same animal species produced under different production technologies (such as standard chicken vs. organic chicken).

In our benchmark model, the consumer does not care about animals. This assumption may be unrealistic, as there is a great deal of evidence that consumers are willing to pay a premium for products that are more animal-friendly (Lagerkvist and Hess 2011, Norwood and Lusk 2011). In Appendix A.5, we consider a simple extension in which the consumer is altruistic toward animals and show that the benchmark result remains if the social planner maximizes the welfare of the representative altruistic human plus that of animals. The optimal animal-welfare levy under altruism continues to be $t = -v$. See Daube and Ulph (2016) for a related result.

3 Population ethics

The choice of the optimal animal-welfare levy directly affects the number of living animals. This choice then amounts to the comparison of social situations, each with a different size of the animal population: we are thus in a variable-population scenario, which raises a series of normative issues (Blackorby et al. 2005). This section discusses a number of these issues. We begin by the pivotal concept of a life worth living. We subsequently explore different normative settings, such as average utilitarianism, and conclude by examining the indirect repercussions on wild animals.

3.1 A life (not) worth living

The above analysis shows that there is over-consumption of meat when an animal's life is considered as not worth living, and under-consumption when it is considered worth living. This last result is reminiscent of the "logic of the larder" (Salt 1917, Matheny and Chan 2005, Singer 2011) that humans do animals a favor by eating them since they would otherwise not exist. This logic requires that $v > 0$, and thereby justifies the consumption of meat as bringing an animal to life is socially desirable. However, as we will argue later in the calibration exercise, most farmed animals may not have lives worth living, so that $v < 0$ in most cases and meat consumption should rather be discouraged.

The emergence of the concept of life worth living in this analysis makes clear the real purpose of the animal-welfare levy. This is not intended to serve as compensation for animal suffering, nor as a way of collecting funds for the enhancement of their living conditions. Its objective is rather to encourage or discourage the consumption of animals based on whether their existence entails a life that is deemed worth living or not. The importance of the concept of a life worth living has already been informally discussed in the ethical literature on animal welfare (Singer 2011, Visak 2013, Gosseries and Meijers 2022).

It is crucial to understand, however, that this result depends critically on the normative setting considered. Under total utilitarianism, bringing an additional animal into existence only has social value if that animal's life is worth living. But, as we will see in the rest of this section, this result no longer holds under alternative normative settings. Specifically, the threshold value that makes an additional life socially beneficial is no longer the morally-neutral utility level $v = 0$. As such, life-worthiness alone will not determine whether the levy is a tax or a subsidy in these alternative settings.

It is also worth underlining that total utilitarianism has long been criticized in the population-ethics literature. Most famously, it yields the well-known repugnant conclusion (Parfit 1984). In our setting, this conclusion implies that it might be socially optimal to produce an enormous quantity of meat just to create very many farmed animals whose lives are only barely worth living. The intuition is that, if social welfare is defined as the sum of all utilities, adding any individuals whose lives are barely worth living will automatically increase social welfare. In our setting, total utilitarianism may thus encourage greater meat production than alternative normative settings. To investigate, we next consider the main alternatives to total utilitarianism that do not yield the repugnant conclusion, namely critical-level utilitarianism and average utilitarianism.[5]

We should also mention another relevant population-ethics principle: procreation asymmetry (McMahan 2009). This presents another normative challenge to total utilitarianism. It contends that not bringing an animal into existence due to its life not being worth living is not morally equivalent to bringing an animal into existence as its life will be worth living. Total utilitarianism, in its typical formulation, violates procreation asymmetry: the social value of bringing an animal with positive utility into existence or abstaining from doing so under opposing negative utility are exactly the same.

3.2 Critical-level and average utilitarianism

We first explore a common alternative to total utilitarianism: critical-level utilitarianism (CLU). Unlike total utilitarianism, CLU considers that an additional life increases social welfare if and only if this life is sufficiently good and not only barely worth living. It is robust to both the repugnant conclusion and procreation asymmetry. In its simple form, CLU is the sum of the excess of individual utilities above a critical level $\gamma \geq 0$ (Blackorby and Donaldson 1984). Under CLU, the problem of the social planner is to maximize over n the social objective:[6]

$$u(n) - cn + n(v - \gamma) \tag{8}$$

[5] For a discussion of various normative criteria under variable population, see, for instance, Ponthière (2003), Dasgupta (2005), Blackorby et al. (2005) and Greaves (2017).

[6] Note that we do not include a critical-value parameter for the human part of welfare, as this would not make any difference here.

implying the FOC:

$$u'(n) = c - v + \gamma \tag{9}$$

Optimal consumption under CLU is thus always lower than that under total utilitarianism, since $\gamma \geq 0$. It is easy to see that the optimal animal-welfare levy is then

$$t_{CLU} = -v + \gamma \tag{10}$$

The animal-welfare levy is thus higher under CLU than under total utilitarianism. Under CLU, the threshold value of v where the tax becomes a subsidy is the critical parameter γ. It is no longer where life becomes worth living, but when the value of life equals this threshold value.

Second, we consider average utilitarianism, the most-common alternative to total utilitarianism. Under average utilitarianism, a new life increases social welfare as long as it raises overall average welfare in society — meaning the utility of the new life exceeds the pre-existing average welfare figure. Formally, we have the following social objective:

$$\overline{U}(n) \equiv \frac{1}{1+n}(u(n) - cn + nv) \tag{11}$$

We can easily show that it is optimal to choose a lower n under average utilitarianism than under total utilitarianism. To see this, denote by $\overline{n}$ the maximum of $\overline{U}(n)$ so that $\frac{U(\overline{n})}{1+\overline{n}} \geq \frac{U(n^*)}{1+n^*}$. Assuming $U(n^*) \geq 0$,[7] this implies that $\frac{1+n^*}{1+\overline{n}} \geq \frac{U(n^*)}{U(\overline{n})} \geq 1$, where the last inequality comes from the definition of n^*. We hence have $n^* \geq \overline{n}$. This is a particular case of the more-general insight that the maximum of the average is always lower than the maximum of the sum (Nerlove et al. 1986).

It is also easy to see that the expression for the animal-welfare levy under average utilitarianism is:

$$\bar{t} = \frac{u(n(t)) - cn(t) + n(t)v}{1 + n(t)} - v \tag{12}$$

This expression is always greater than that under total utilitarianism, i.e. $\bar{t} \geq t^* = -v$. It is furthermore easy to see that this expression can also be written as:

$$\bar{t} = \frac{u(n(t)) - cn(t) - v}{1 + n(t)} \tag{13}$$

The optimal animal-welfare levy under average utilitarianism is then a tax (i.e. $\bar{t} \geq 0$) as long as human welfare is greater than animal welfare. The intuition is that taxing meat reduces the number of individuals with the lowest welfare in society (i.e. animals), which increases average welfare. Hence, under average utilitarianism, the threshold value of v where the tax becomes a subsidy is the welfare of humans.

Third, some authors have proposed weighting the social contribution of a new life according to population size. This approach, called number-dampened utilitarianism (NDU) (Ng 1986), consists in multiplying average utility by a positive value that is a function of population size. This "dampening" function is concave to reflect that adding

[7] This is a mild assumption, which is ensured under $u(0) \geq 0$. In words, this is ensured if we assume that human life remains worth living in a vegetarian society.

an extra individual has diminishing marginal value, namely that it generates a smaller gain when the number of pre-existing individuals is larger. We show in Appendix A.6 that the animal-welfare levy is always greater than $-v$ in this normative setting, as was the case for average utilitarianism and CLU. It is shown, in particular, that the optimal animal-welfare levies under NDU and CLU consist in adding a positive term to the optimal levy under total utilitarianism, i.e. $t^* = -v$. As such, even if the animal's life is worth living ($v > 0$), so that the levy is a subsidy rather than a tax under total utilitarianism, it is still possible that the levy be a tax under these two alternative normative criteria, as for average utilitarianism.

Finally, we make two related observations. First, we have not considered the equity-sensitive versions of utilitarian settings, such as prioritarianism (Blackorby et al. 2005, Adler 2019). Second, Zuber et al. (2023) recently proposed an axiomatic approach leading to representation theorems for a multispecies social welfare function. Building on their analysis, under their axioms of dominance, species-level separability and individual-level anonymity, the social objective in our simple setting would take the following form:

$$g(u(n) - cn) + ng(v) \tag{14}$$

assuming a continuous and increasing function $g(.)$ with $g(0) = 0$. We show in Appendix A.7 that the animal-welfare levy is always greater under the social objective (14) than that under total utilitarianism when life is not worth living $v < 0$. This holds true contingent on the concavity of the transformation function $g(\cdot)$, namely under prioritarianism (Adler 2019).

Overall, we conclude that the use of alternative normative settings may require significant adjustments to the animal-welfare levy. In particular, this shows that the Pigouvian principle of increasing the marginal private cost/benefit by the exact amount generated by the negative externality is no longer valid under alternative normative settings. This illustrates the importance of population-ethics issues for the pricing of externalities.

3.3 Wild-animal welfare

Humans as well as farmed and wild animals compete for resources, typically land and food. Humans and their livestock use a large part of the land on Earth, which involves the destruction of wild-animal habitats. Deforestation, mainly due to animal farming in a number of parts of the world such as South America (De Sy et al. 2005), is a case in point. Forests generally host a greater population of wild animals than do pastures and croplands.[8] This indirect impact of livestock production on wild-animals' habitats even threatens the very existence of some wild animal species, as emphasized in the literature on biodiversity loss. This in turn introduces another population-ethics dilemma associated with meat consumption, if we assume that wild animals also have intrinsic value.

We thus extend our initial model to include this indirect impact on wild-animal welfare. In Appendix A.8, we consider a model with both a resource constraint and a

[8] A comprehensive review of wild-bird densities suggests the following typical numbers of breeding birds per square kilometer: 300 on cropland, 375 on pasture, 450 on grassland, 800 in temperate mixed forest, and 1250 in warm mixed forest (Gaston et al. 2003).

calorie constraint. The resource constraint reflects that humans and farmed and wild animals consume a given amount of a resource, and the calorie constraint that humans require a certain number of calories and obtain these from the consumption of resources and animals.

This model produces a new expression for the animal-welfare levy:

$$t = -v - \lambda v_w \tag{15}$$

where v_w is wild-animal welfare and λ is a "technical factor" that captures how the number of wild animals changes with the number of farmed animals. This result thus underlines that what now matters for the animal-welfare levy is the relative well-being of farmed vs. wild animals weighted by this technical factor. We expect this factor to be negative in most instances, i.e. $\lambda < 0$. This simply reflects that the numbers of existing farmed and wild animals act as substitutes rather than complements, consistent with the competition for resources noted previously. Moreover, assuming that a wild-animal's life is worth living, i.e. $v_w > 0$, this additional term $-\lambda v_w$ in general increases the animal-welfare levy.[9]

Setting	Social objective	Animal-welfare levy
Total utilitarianism (TU)	$u(n) - cn - nv$	$t = -v$
Critical-level utilitarianism	$u(n) - cn + n(v - \gamma)$	$t = -v + \gamma$
Average utilitarianism	$\frac{u(n)-cn+nv}{1+n}$	$t = -v + \frac{u(n(t))-cn(t)+n(t)v}{1+n(t)}$
Number-dampened utilitarianism	$\frac{1}{1+n}(u(n) - cn + nv)f(1+n)$	$t = -v + [\frac{1}{1+n(t)} - \frac{f'(1+n(t))}{f(1+n(t))}][u(n(t)) - cn(t) + n(t)v]$
Prioritarianism	$g(u(n) - cn) + ng(v)$	$t = -\frac{g(v)}{g'(u(n(t))-cn(t))}$
TU with non-linear cost	$u(n) - c(n) - nv$	$t = -v$
TU with quality choice	$u(n) - (c + d)n + nv(d)$	$t = -v(d)$
TU with density effect	$u(n) - cn + nv(n)$	$t = -[v(n(t)) + n(t)v'(n(t))]$
TU with two animal species	$u(n) - cn + n_1v_1 + n_2v_2$	$t_1 = -v_1, t_2 = -v_2$
TU with altruism	$u(n) - cn + \alpha nv - nv$	$t = -v$
TU with wild animals	$u(n) - cn + nv + wv_w$	$t = -v - \lambda v_w$

Table 1: The animal-welfare levy under different theoretical settings

We summarize in Table 1 a number of the theoretical results above. The first panel presents the closed-form solution for the animal-welfare levy under the different normative possibilities of total, critical-level, average and number-dampened utilitarianism, as well as prioritarianism. The second panel presents this solution for different models: those with a non-linear production cost, a quality choice, a density effect, two species, altruism and wild animals. The detailed derivation of the results that are not presented in the main text appears in the Appendix. The general lesson from this table is that the benchmark result of the animal-welfare levy being the opposite of the farmed-animal utility level ($t = -v$) either continues to hold or provides a lower bound for the animal-welfare levy (in the case of taxation) or an upper bound (in the case of subsidy).

[9]This is not guaranteed, of course, as one may argue that at least some wild-animal lives (e.g., those from r-selected species) are not worth living (Horta 2010).

4 Calibration

The benchmark result above is that the optimal animal-welfare levy equals the opposite of the animal's utility level, i.e. $t = -v$. In this section, we attempt to estimate v, and thus the value of this levy. As discussed above, it is important to remember that this estimation is based on a number of assumptions, such as total utilitarianism, and is likely to be a conservative estimate.

Estimating the utility level v is challenging for a variety of reasons. First, it is not obvious how to value welfare (changes) in economic terms, as we do for humans using revealed or stated preferences methods in standard cost-benefit analyses (e.g., willingness-to-pay studies). Second, comparing the welfare of animals from different species is also difficult. Intuitively, some animals can experience the world more intensely than others. For instance, elephants are capable of much-more complex emotions (e.g., grieving) than are insects. In the literature, this issue has been referred to as the problem of interspecies comparison. Third, the above model considers that v can take positive or negative values. Our model of animal welfare then also has to include a reference point where $v = 0$. This threshold can be conceived as the tipping point at which life becomes no longer worth living as living conditions worsen.

4.1 Model for animal utility

We estimate the utility level v of an animal species s using the following general expression:

$$v = \phi_s m \int_{t=0}^{t=T} q(t)dt \tag{16}$$

where $q(t)$ is the animal-welfare score at any point in time t, ϕ_s the utility potential of species s, and m a monetization parameter that allows the transformation of utility points into monetary units.

In what follows, we explain the different steps taken to calibrate each parameter, and calculate the formula for each animal of interest: chickens, pigs and cows. We first define a model that estimates an animal's welfare as the extent to which its fundamental needs are fulfilled. Second, we calculate a score for animal utility based on the animal's welfare status. Third, we calculate a standardized welfare score that takes into account the heterogeneity in the intensity with which animals are expected to experience the world. Fourth, we calculate the animal's utility balance, i.e. the integral of the animal's utility over its entire life. Last, we calculate the monetary equivalent of the animal's utility. This overall approach allows us to express the utility level of an animal in terms of the unit of the levy (i.e. money), and thus to directly obtain its value by taking its opposite, consistent with our benchmark result: $t = -v$.

For the first step, as in Espinosa (2023), we evaluate animal welfare using the well-established Five-Freedoms framework (Brambell 1965). In this model, used by the World Organization for Animal Health, animal welfare is assessed through the achievement of five freedoms: (i) from hunger, malnutrition, and thirst; (ii) from fear and distress; (iii) from heat stress or physical discomfort; (iv) from pain, injury, and disease; and (iv) the freedom to express normal patterns of behavior.[10] We consider that these freedoms can be either attained or violated to different extents. We assume that the violations, if any, can be mild, moderate, severe, or very severe. Each violation level increases the number of violation points by one (i.e. no violation = 0, mild = 1, moderate = 2, severe = 3, and very severe = 4). We calculate the total number of violation points (W), which is akin to a *misery score* in the QALY literature for humans. An animal with all freedoms fulfilled has no violation points (noted $W = 0$) while an animal with all five freedoms very severely violated has 20 freedom violation points ($W = 20$).

Second, we define a threshold of violation points beyond which the utility of an animal becomes negative. Deciding at which point welfare is so bad that life becomes not worth living is somewhat arbitrary, for both humans and animals.[11] However, the existence of such a tipping point is globally accepted in the valuation of human life quality (e.g., QALY) and is also recognized in animal science (e.g., mercy killing). We denote by W_0 the number of freedom-violation points above which an animal's life is no longer worth living.

The score thus depends on the number of freedom-violation points. We normalize the score to 1 when all freedoms are attained, i.e. the animal's needs are all fulfilled. Furthermore, the utility of an animal is, by definition, equal to zero at the threshold W_0. We also want the score to fall continuously with the number of violation points. Following Espinosa (2023), we use the following parametric form for the animal-welfare score: $q(t) = \frac{W_0 - W(t)}{W_0}$. One property of this simple linear form is that each additional violation point reduces animal welfare by the same amount ($\frac{-1}{W_0}$). This is a rather conservative approach, as it assumes that severe violations of some fundamental needs can be compensated by improvements in other fundamental needs.

Third, we consider the issue of interspecies comparison. Building on Wong (2016), Budolfson and Spears (2019) and Espinosa (2023), we propose to express animal welfare from different species on a single standardized utility scale. This single species-neutral utility function aims to reflect interspecies differences in well-being potential (and can also be applied to intraspecies differences in well-being according to rearing conditions). This species-neutral utility function weights animal utilities by their *utility potential* (Buldolfson and Spears 2019), which accounts for the intensity with which different species of animals experience the world. Given that more-complex emotions require greater levels of cognition, utility potentials are estimated using a proxy for the latter. Following Espinosa (2023), the utility potential for species s is calculated as the ratio of the number of cortical / pallial neurons of species s over the number of cortical neurons for humans ($\phi_s = \frac{n_s^{\psi}}{n_h^{\psi}}$). This subset of neurons, found in the cerebral cortex for mammals and the pallium for birds, are part of the sensory-associative brain struc-

[10] Alternative models, like the Five Domains, can also be used. We have chosen the Five-Freedoms model as it is the most widely-recognized model of animal welfare. However, this model has been criticized by numerous researchers and activists as being too restrictive regarding the needs of animals. For instance, the Five-Freedoms framework overlooks the positive mental states that animals can experience and focuses only on reducing their negative experiences.

[11] Espinosa and Treich (2021) use survey data to show that various individuals (animal experts, students, activists) have heterogeneous views about when an animal life is worth living under the current farming systems. However, almost all believe that broilers in standard systems do not have a life worth living.

tures and are correlated with cognition measurements (Herculano-Houzel 2017). The parameter ψ reflects normative uncertainty about the connection between the number of cortical/pallial neurons and well-being capacity. We set $\psi = 1$.

Fourth, we calculate the utility balance of an animal's life by aggregating the instantaneous utilities over its lifespan. Animals endure $W(t)$ violations of freedoms at each moment t of their life. We define the utility balance as the sum of all instantaneous utilities from the birth of an animal ($t = 0$) up to its death ($t = T$).

Last, we express the utility balances in monetary equivalents. To do so, we define a monetization parameter m that multiplies the utility balance. Note that the monetary equivalent of losing one day of life for an animal from species s that has all its needs fulfilled would be $m \times \phi_s \times (1 - 0)$. As humans are also animals (for whom $\phi_h = 1$), m can be seen as the value of losing one day of human life in perfect health. In what follows, we consider $m = 402$ Euros, as m reflects the social cost of losing one year of human life equal to 147,000 Euros (Téhard et al. 2020). This is in line with common values used for the value-of-statistical life in benefit-cost analysis.[12] With the ϕ_s for pigs (about 1/44), this implies, for instance, that one additional day of the life of a pig with maximal animal welfare has a value of a little under 10 Euros.[13]

4.2 Application to chickens in intensive farms

We now apply the above model of animal-welfare valuation to broiler farming. Consider the case of a broiler that is raised in an intensive farm in France (indoor farming with no cages), which represents 66% of the French production (so-called "standard" chickens).[14] A chicken's life begins in a hatchery where fertilized eggs are settled. On the day of hatching, or a few days before,[15] the eggs/chicks are sent to the farms to begin the fattening phase. Chickens in intensive farms are raised for 35 days.[16] During this time period, they experience rapid growth due to genetic selection which

[12]Note that the way to combine the QALY approach with benefit-cost analysis is open to debate (Bleichrodt and Quiggin 1999, Hammitt 2013), but this issue is beyond the scope of this paper.

[13]Note that our method ensures the comparability of utilities. First, the animal welfare scores are directly comparable across animal species since we use the same evaluation method based on the Five Freedoms approach for all animals. The scores then translate into utilities through ϕ_s, so that animal utilities are thus comparable by construction. However, the comparability with humans is not obvious since we do not use the same method to assess human welfare. Yet, we implicitly rely on the "high/low scaling" method (Adler 2019; page 190). Under this method, the evaluator picks two scaling points, "high" and "low", and scales the various individuals' utility functions so that they assign equal utility to the high point, and equal utility to the low point. In our setting, the low scaling point corresponds to the zero-utility level, namely the level of utility equivalent to nonexistence or death. The high scaling point corresponds to the maximal possible instantaneous welfare, i.e., $q(t) = 1$ for animals and the maximal QALY (=1) for humans. The main difference compared to the practical implementation of this method (see, e.g., Decancq ad Neumann 2014) is that the utility levels under the high point varies across species due to the use of the utility potential parameter.

[14]Source: https://web.archive.org/web/20220725123440/https://www.agro-media.fr/analyse/les-forces-et-faiblesses-de-la-filiere-volaille-francaise-46372.html.

[15]Source: https://web.archive.org/web/20220725095634/https://www.paysan-breton.fr/2018/01/leclosion-a-la-ferme-offre-de-nombreux-avantages/.

[16]Source: https://web.archive.org/web/20220725102232/https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-volailles-de-chair.

can generate substantial suffering.[17] Chickens do not have outdoor access, and the density can be as high as 22 chickens/m2. The rearing conditions prevent the animals from exerting normal behavioral habits, such as spreading their wings or taking dust baths. Most farms debeak (the partial cutting of the chicken's beak) to limit aggressive behavior resulting from these difficult rearing conditions. During the rearing period, the litter is generally not changed, which makes it progressively damp and loaded with ammonia from animal excreta. This causes physical discomfort to animals (via skin inflammation).

After 40 days at the farms, chickens are sent to abattoirs. EU legislation provides limited protection for poultry transportation. Unlike mammals, there is no time limit for poultry transport, and access to water and food is mandatory only if transport exceeds 12 hours (Chapt. V, Article 2.1, 1/2005). The maximal density can be as high as 31 chickens/m2.[18] The capture of chickens for transport has been denounced by many animal-welfare NGOs. According to the largest French NGO for farmed-animal welfare, L214, capture is an extremely stressful event for chickens whatever the method (machinery or manual), and often leads to dislocations and broken bones.[19] At the abattoir, chickens are suspended by their legs before being electrocuted. The period of suspension is criticized for producing substantial distress and suffering (the dislocation of legs or wings, broken bones, and bleeding). For conventional meat, chickens are then stunned by electrocution and slaughtered.

Based on the above, we evaluate the freedom violations at each stage of the chicken's life. We consider that the chickens are relatively regularly fed, although not diversely (a mild violation). We assume that chickens are free from fear, but that the high density can cause major psychological distress (a severe violation). Animals also experience great physical discomfort at the farm due to high density (a very severe violation) and pain due to debeaking, rapid growth, high density (lack of nesting areas), and ammonia (very severe violation). Last, chickens cannot express their natural patterns of behavior (very severe violation). During transportation and slaughtering, we assume maximal freedom violations due to psychological distress and the lack of natural behaviors. We further consider that there are severe violations of the freedom from pain. There is some minimal protection during transportation (restrictions during heat waves, for instance), but many injuries are still reported. We assume very severe violations of physical comfort at both the transportation and slaughtering stages.

The process of calculating the economic cost of the chicken's welfare is summarized in Table 2. We use $\phi = 1/285$ for the utility potential parameter. We explore two cases: $W_0 = 7$ and $W_0 = 10$. These values correspond to the median opinion of a representative sample of the UK population. Participants were asked to express their views on the number of freedom-violation points based on two different framings: one stating that the overall welfare of an animal becomes negative ($W_0 = 7$), and the other stating that it renders the animal's life not worth living ($W_0 = 10$). The details of the

[17] Source: CIWF, animal-welfare NGO https://web.archive.org/web/20220725101002/https://www.ciwf.fr/animaux-delevage/poulets-de-chair/.

[18] When chickens weigh between 1.6kg and 3kg, the minimal surface is 160cm2/kg. Assuming that chickens weigh 2kg on average, the minimal surface is 320cm2 per chicken. In total, transporters can put up to 10000/320=31 chickens per square meter.

[19] Source: https://web.archive.org/web/20220725121155/https://www.l214.com/animaux/poulets/abattage-des-poulets-de-chair/.

	Farm	Transport	Abattoir
Freedom from hunger, malnutrition, and thirst	Mild (1)	Moderate (2)	Moderate (2)
Freedom from fear and distress	Severe (3)	Very severe (4)	Very severe (4)
Freedom from heat stress or physical discomfort	Very severe (4)	Very severe (4)	Very severe (4)
Freedom from pain, injury, and disease	Very severe (4)	Severe (3)	Severe (3)
Freedom to express normal patterns of behavior	Very severe (4)	Very severe (4)	Very severe (4)
Total number of violation points: W(t)	16	17	17
Number of days	38	1	1
$v = m\phi \int_0^T \frac{W_0 - W(t)}{W_0} dt$ If $W_0=7$		-€72.57	
If $W_0=10$		-€33.96	

Table 2: The economic valuation of chicken welfare in intensive farms in France

survey are presented in Appendix B1.

Our calculations indicate that the rearing conditions of chickens in intensive farms produces a negative utility balance. This is consistent with the assessment of animal experts (Espinosa and Treich 2021). The economic estimate of v is therefore negative, and the levy is tax and not a subsidy. When we consider $W_0 = 7$, the economic externality is estimated at about 73 Euros per chicken; lower standards of a life worth living ($W_0 = 10$) produce a lower value of 34 Euros per chicken. Given that the average price for a chicken is about 3 Euros,[20] the externality on chicken welfare largely outweighs the production costs. The animal-welfare externality is therefore eleven times the average market price with the more-conservative approach ($W_0 = 10$), and 24 times larger with the stricter evaluation ($W_0 = 7$). In other words, were we to tax the intensive chicken at $t = -v$, as theory suggests, market prices would rise by 1032% (if $W_0 = 10$) and 2319% (if $W_0 = 7$).

4.3 Intra-species taxation: application to chickens

We now explore the heterogeneity of intra-animal welfare taxation by looking at different production methods for the same animal species. There are four main production systems for broilers in France, which are subject to different legal requirements for the rearing conditions: 'standard' (described above), certified, *Label Rouge* and organic.

Certified chickens experience very similar rearing conditions to standard chickens except for their growth rate: they are from slower-growth strains and are slaughtered after 56 days. Due to this slower growth rate, we assume that chickens in certified farms only endure severe violations of the freedom from pain and injury and the freedom from physical discomfort.

Next, *Label Rouge* and organic chickens are raised in less-dense farms (up to 11 chicken/m2 for Label Rouge and 10 chicken/m2 for organic chickens). Chickens in both systems have access to perches (at least 10 cm per animal) and systematic mutilation is forbidden. They must have outdoor access after the first six weeks, with at least 2 m2/chicken for Label Rouge and 4 m2/chicken for organic production. The final confinement period cannot exceed 15 days. In addition, organic chickens must have outdoor access for at least one-third of their life. The farm size is restricted in both

[20]Source: France AgriMer, July 2022. https://web.archive.org/web/20220726084201/https://rnm.franceagrimer.fr/prix?POULET.

cases (up to 4400 chickens for Label Rouge and 4800 for organic chickens). Animals must have natural light in both methods, and are also from slower-growth strains than certified chickens (they are slaughtered after 81 days). The transportation of organic chicken is subject to the same legal constraints as for standard and certified chickens. *Label Rouge* chickens cannot be transported for more than 3 hours or 100 km. For organic chickens, the floor has to be at least one-third hard surface (no duckboards or grates).[21] In addition, organic chickens must have sufficient protection against rain, wind, sun and extreme temperatures, and have roughage.

Given the above, we consider that *Label Rouge* and organic chickens endure only moderate violations of the freedoms from physical discomfort and pain at the farm. We further consider that *Label Rouge* chickens have greater opportunities to express natural behavior, although this remains restricted as they probably only have outdoor access for one-third of their lives (a severe instead of a very-severe violation). We consider the violation of the freedom to express natural behavior for organic chickens to be moderate, as outdoor access is richer and wider. The freedom violations are similar for transport, except for the freedom from physical discomfort which is lower in *Label Rouge* due to the distance / duration restriction (severe instead of very severe). Last, we assume similar conditions at the abattoir.

Production System	**Economic valuation of v (in €)**	
	W_0=7	**W_0=10**
Standard	-72.57	-33.96
Certified	-82.59	-33.40
Label Rouge	-68.76	-13.19
Organic	-52.72	-1.96

Table 3: The economic valuation of chicken welfare by production system

The values for the different production systems appear in Table 3. Taking the more-conservative value for the threshold ($W_0 = 10$), the taxes range between 1.96 (Organic) and 33.40 Euros (certified) per chicken. With the less-conservative value ($W_0 = 7$), these are between 82.59 and 52.72 Euros per chicken. The taxes are the lowest for the production system that provides the highest animal welfare (organic). However, taxation for certified chickens can be higher than that for standard chickens. This reflects that certified broilers live significantly longer than standard chickens (56 vs. 38 days) but still live in poor conditions. Overall, the negative utility driven by a longer life in poor conditions outweighs the worse rearing conditions.

4.4 Meat prices

We now calculate animal-welfare levies as a levy per kg of meat for a number of animal species. The model above can be extended to multiple animal species, in which case the benchmark result continues to hold in the sense that the socially-optimal levies for each meat category are the opposite of the utility level of the different animals species, as shown in the theoretical Appendix A.4. We also discuss in the Appendix how we

[21]Source: `https://welfarm.fr/pdf/labels/fiche_poulets.pdf`.

estimate the animal-welfare score for pigs, and cows from dairy herds and beef herds. Figure 2 summarizes the key differences across these four animal species: chickens (standard), pigs (standard), cows (dairy herd) and cows (beef herd) for the threshold $W_0 = 10$. The average welfare scores, life durations, utility potentials and ratios of meat per animal are obviously very different across species. For instance, dairy cows live more than 70 times longer than chickens, but weigh more than 100 times more, and their utility potential is over 10 times greater.

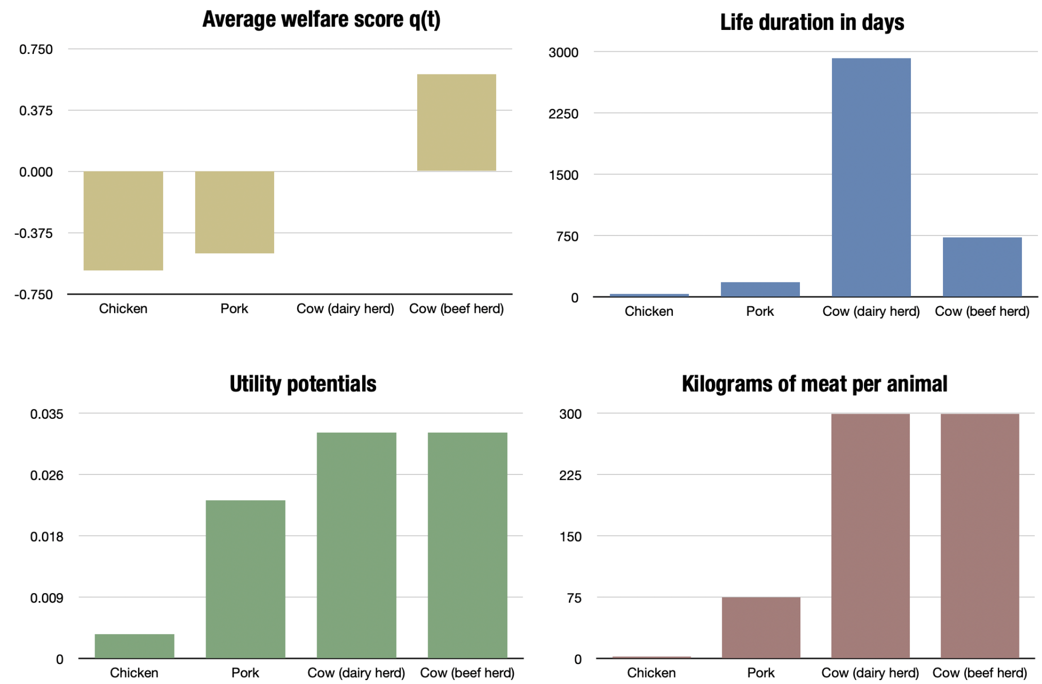

Figure 2: The key differences across animal species (with $W_0 = 10$)

Figure 3 shows the animal-welfare levies for the two thresholds of $W_0 = 10$ (left panel) and $W_0 = 7$ (right panel), together with the meat retail price and environmental taxes per kg of meat for chicken, pork and beef (from dairy or suckler cows).[22] This allows us to estimate the final meat prices given the different externalities. Based only on the retail price, beef is more expensive than chicken or pork. We consider here three environmental taxes: fine particle pollution, climate change and nutrient pollution (acidification, and water and marine eutrophication). Consistent with previous results (e.g., Funke et al. 2022), the price gap between different types of meat is increased when environmental taxes are applied. This reflects that the production of cows generates relatively more pollution than that of chickens and pigs per kg of meat (Poore and Nemecek 2018, CE Delft 2023).

[22]The data for the environmental externalities are taken from CE Deflt (2023), which calculates the cost per kilogram of meat for several environmental externalities. https://cedelft.eu/wp-content/uploads/sites/2/2023/03/CE_Delft_220109_Pay_as_you_eat_dairy_eggs_and_meat_Def_2.pdf The retail prices are taken from FranceAgrimer: https://observatoire-prixmarges.franceagrimer.fr/resultats-par-domaine/ (Summer 2022).

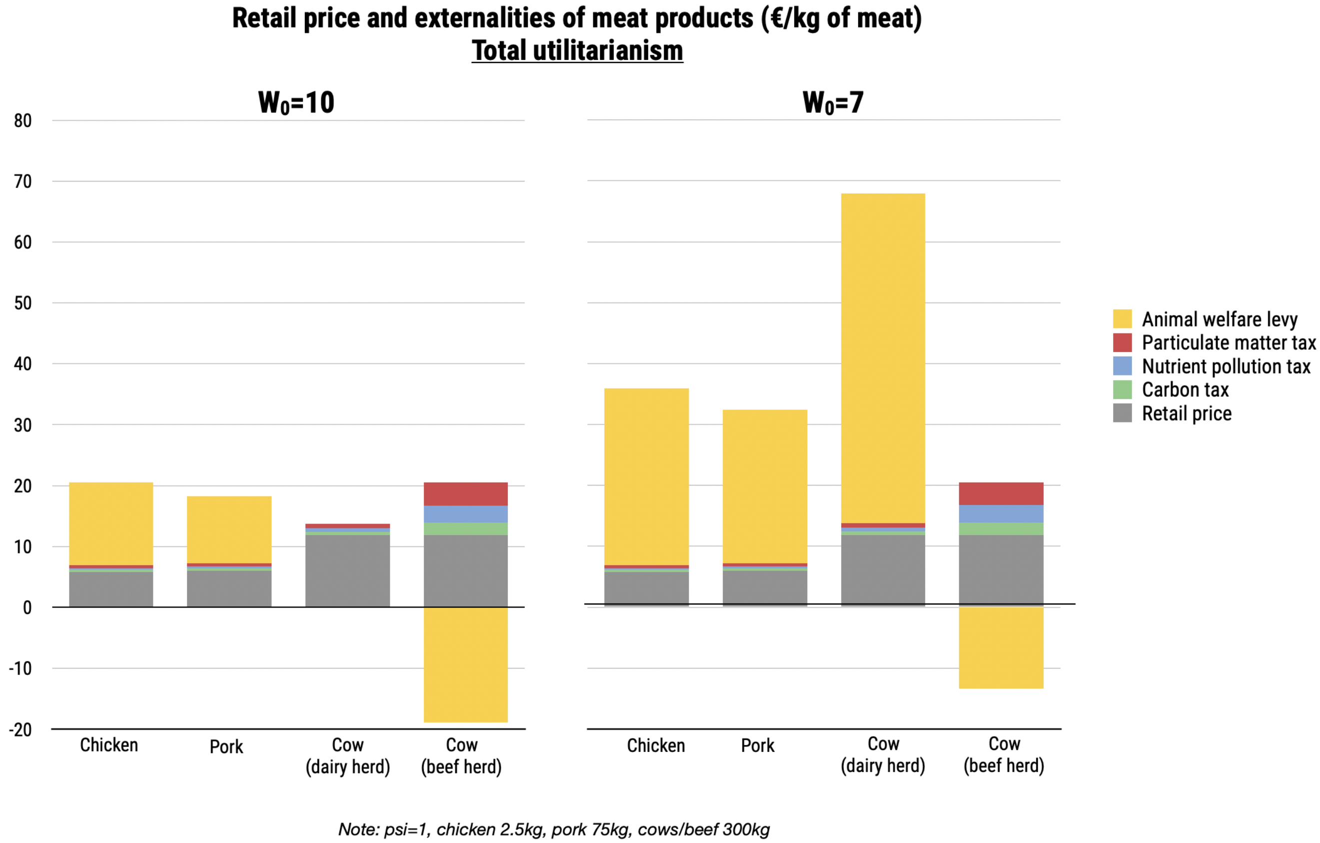

Figure 3: Animal-welfare levies per kg of meat

However, this picture becomes very different when the animal-welfare levy is included. First, when $W_0 = 10$ the levy is almost zero for beef from dairy herds and becomes a subsidy for beef from beef herds. Chicken and pork thus now become much more expensive compared to beef, even accounting for the environmental externalities. The impact of the animal-welfare levy is much larger than that of environmental taxes, even under our fairly-conservative assumptions. This result is related to that in Kuruc and McFadden (2022), whose numerical analysis finds that the animal-welfare impacts of dietary decisions are much larger than those from climate effects. Figure 3 also illustrates the considerable difference in the estimated animal-welfare levies across different types of meat. This follows from the remarks above regarding the differences across animal species in Figure 2. We note also the sensitivity to the threshold, especially for dairy cows, comparing $W_0 = 10$ to $W_0 = 7$. This is mainly because dairy cows live for a relatively long time (about 8 years) as compared to the other animals. The results for dairy cows are thus very sensitive to the assessment of day-to-day welfare at the farm, as they accumulate over longer periods of time and may change substantially according to the threshold W_0.

Taxation also depends on the weight of animal welfare relative to human welfare. The figures above are utility potentials ($\phi_s = (n_s/n_h)^{\psi}$), based on (cortical/pallial) neurons with $\psi = 1$. Espinosa (2023) discusses the normative premises of choosing ψ, and underlines that $\psi = 1$ is equivalent to assuming a constant return to neurons on welfare capacity. Espinosa (2023) assumes $\psi = 0.9$, in line with decreasing returns as sentience is easily attained with a small number of neurons (e.g., insects). Table 4 shows how taxes increase when we instead assume $\psi = 0.9$. In the case of total utilitarianism with $W_0 = 10$, the tax per kilogram of meat rises from 13.58 to 23.92 Euros for chicken (+76%), from 11.07 to 16.17 Euros for pork (+46%), and from -18.86 to -26.58 Euros for beef from beef herds (+41%). The size of the taxes and subsidies reflects that a smaller ψ corresponds to larger utility potentials for animals (relative to humans) and thus assigns greater economic importance to their welfare.

Utility potentials are weights to compare animal welfare with human welfare. We here use cortical/pallial neurons to determine these, but alternative measures are available. Progress in Science may help better capture the welfare potential of animals from different species, so that other measures can be used to determine utility potentials. One recent example comes from the *Moral Weight Project* of the *Rethink Priorities* research institute, which calculated utility potentials for a dozen animals using the hedonistic and cognitive capacities found in the Animal-Science literature. The resulting taxes using these utility potential values[23] can be calculated for chickens ($\phi = 0.368$) and pigs ($\phi = 0.548$), and are much larger than those from the cortical/pallial neuron ratios above: see Table 4. In the conservative scenario with $W_0 = 10$, taxes increase to 1432.02 Euros per kilogram of chicken and 267.47 Euros per kilogram of pork.

Threshold W_0	Utility potential	Tax in Euros per kg of meat			
		Chicken	Pork	Cow (dairy)	Cow (beef)
$W_0 = 10$	Neuron ratio with $\psi = 1$	13.58	11.07	0.06	-18.86
$W_0 = 10$	Neuron ratio with $\psi = 0.9$	23.92	16.17	0.09	-26.58
$W_0 = 10$	Moral weight	1432.02	268.47	.	.
$W_0 = 7$	Neuron ratio with $\psi = 1$	29.03	25.25	54.17	-13.39
$W_0 = 7$	Neuron ratio with $\psi = 0.9$	51.11	36.89	76.37	-18.87
$W_0 = 7$	Moral weight	3060.16	612.63	.	.

Table 4: Taxation levels with varying weights on animal welfare

4.5 The impact of a GHG tax on beef

While taxing animal-based products for the sake of animal welfare is a relatively new issue in the public debate, a number of bodies have recommended a GHG tax on meat products. However, when a product generates multiple externalities, taxing it on one dimension only may not increase social welfare. A key concern for public policies is in particular the substitution effects induced by the introduction of a tax, and the quantification of the effect on any externalities that are not targeted by the tax.

In this section, we calculate the monetized environmental externalities as well as the animal externalities associated with a GHG tax on beef. We focus on beef as this generates by far the highest GHG emissions, and might plausibly be the first policy target. As above, we use CE Delft (2023) to calculate the environmental externalities and Bonnet et al. (2018) for the meat price-elasticities in France. We consider here a tax of 1.7 Euros per kilogram of beef, assuming on average 30kg of CO2-eq per kilogram

[23]We use here their results on the probability-of-sentience-adjusted welfare ranges without neurons. Source: Welfare Range and Probability of Sentience Distributions, by Laura Duffy, 2022.

of beef and a price of 0.05664 Euros per kg of CO2-eq.: the details appear in Appendix C. Our estimates indicate that this tax would reduce beef consumption by 19.2%. Due to substitution effects, this tax would however increase chicken consumption by 0.8% and pork consumption by 0.9%.

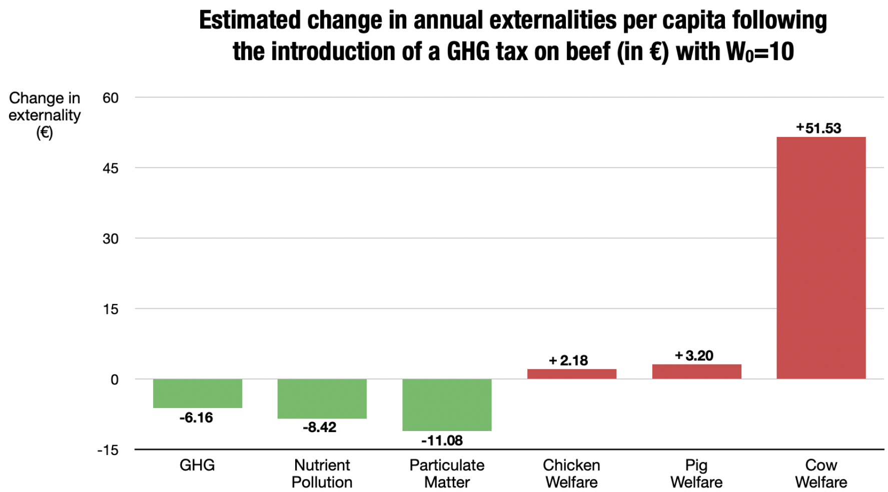

Figure 4: The estimated change in annual externalities per capita following the introduction of a GHG tax on beef (in Euros) with $W_0 = 10$

Figure 4 depicts the impact of a GHG tax on beef on the monetized externalities per human when $W_0 = 10$. Unsurprisingly, this tax significantly reduces environmental externalities. The largest impact is on nutrient and air pollution, which can be seen as co-benefits to the reduction in climate externalities. However, this GHG tax also increases the negative externalities on animals: this is due to the increased consumption of meat with negative animal externalities, namely chicken and pigs, and the reduced consumption of meat with positive animal externalities, namely cows from beef herds. Overall, Figure 4 shows that the GHG tax on beef has a negative social impact due to its externalities on animals. The main driver is by far the reduction of the positive externalities due to fewer cows in beef herds.

5 Discussion

5.1 Policy implications

This paper makes three contributions. First, it proposes a theoretical foundation for applying a tax (or a subsidy) on meat for animal-welfare considerations. Second, it studies the population-ethics problem raised by the implementation of such a tax. Third, it calibrates the tax, building on recent developments in Animal Sciences and Economics. Importantly, this paper yields a number of policy implications.

First, animal-welfare regulations in most countries currently rely on legislative tools such as norms and guidelines. These measures aim to establish a minimum level of animal welfare that is practical and not overly burdensome for the meat industry. However, our research highlights the importance of considering meat taxation as part of broader animal-welfare regulation. The levy on meat helps to mitigate externalities on farmed animals by affecting their numbers. Policymakers should therefore consider incorporating meat taxation into animal-welfare regulations in order to improve the overall welfare of animals.

A second policy-relevant finding is that our research often indicates high taxation levels. Our calibration exercises suggest that the animal-welfare levy could reach significant levels of dozens or even thousands of Euros per animal. In practice, these tax levels would likely shut down the most-intensive forms of animal Agriculture. It is worth noting that this conclusion holds even in our utilitarian setting, which is often criticized for not guaranteeing fundamental animal rights (Francione 1997). This suggests that both the deontological (Regan 1983) and utilitarian approaches to animal welfare may converge on the issue of industrial farming. At its core, this utilitarian reasoning recognizes that the pleasure of consuming meat is "relatively trivial by comparison with the interests of, say, a pig in being able to move freely, mingle with other animals, and generally avoid the boredom and confinement of factory farm life" (Singer 1980).[24]

Our third key message highlights the importance of animal-rearing conditions. The calibration exercise reveals substantial differences in the value of the levy according to these conditions. For example, the levy for standard (intensive) farming of chickens can be several dozen Euros per animal, but only around 2 Euros per animal under organic farming, making the product relatively affordable. Certain types of farming, such as extensive farming for cows, may even merit significant subsidies. It is however important to note that under average utilitarianism the levy will never be a subsidy as long as farmed-animal welfare remains below human welfare. Additionally, the impact on wild animals may reverse this result, as extensive animal Agriculture uses up a great deal of resources (especially beef production via pastures), and has a considerable impact on biodiversity.

The fourth key takeaway from our work is the significant difference in the tax burden across different types of farmed animals. Compared to beef, the tax per kg of meat is much higher for chickens and pigs, primarily because they are raised under more-intensive conditions and produce less meat per animal. This result is in contrast to other meat externalities, such as those from climate change, as shown in Figure 3. Our calibration exercise also indicates that the externalities on animal welfare are much larger than those on the environment. The implementation of a GHG tax on beef may not therefore be optimal, as this would encourage the consumption of animals raised under more-intensive conditions, such as chickens and pigs, over those raised under more extensive conditions, such as ruminants like cows that emit methane, as shown in Figure 4. Applying a uniform tax on all meat may instead be a better way of addressing both animal welfare and environmental externalities.

Overall, our research has far-reaching implications for animal-farming practices and highlights the need for significant changes in food production and consumption. This emphasizes the importance of protein alternatives, such as plant-based alternatives or cultured meat, which aim to replicate the taste of meat while avoiding the externalities

[24] It is also worth noting that we likely calculate very-conservative tax estimates. For instance, the utility potentials we used are very low compared to Fischer (2023; see Table 4), the animal-welfare score does not capture the absence of positive experiences and is linear (not convex), the monetization parameter considers "maximal health" (while the loss of a day of life with "maximal happiness" should be even higher), and we consider total utilitarianism (see Table 1).

on animals. Were these innovations become widely-adopted, they could significantly reduce the number of farmed animals raised for food. However, the social impact of these innovations will depend on which conventional meat they replace.

5.2 Limitations and further research

The model we have analysed is basic, and could be expanded in a number of directions (see the Appendix for a first range of extensions). It assumes a quasi-linear utility function and homogeneous individuals, and does not account for market power, pre-existing tax distortions, or the budgetary impacts of the regulation. As our benchmark model largely corresponds to the textbook model of externality regulation, existing research in Public and Environmental Economics (e.g., Bovenberg and Goulder 2002) is directly relevant for the extensions. One interesting area of research in the industrial organization of food markets pertains to the impact of animal-welfare levies on the decision-making of meat producers in a more-complex economy.

In Social Choice and Welfare Theory, existing research on normative criteria such as total, critical-level and average utilitarianism usually focuses on human welfare, and is thus anthropocentric. Recent research by Fleurbaey and Leppanen (2021) and Zuber et al. (2022) offers important insights into their extension to non-human welfare. In Section 3.2, we briefly addressed this topic with one result from Zuber et al. (2022), but this leaves open the fundamental question of the appropriate social welfare function in a multispecies setting. Note also that our model accounts for animal welfare directly in the social objective. However, a more-common anthropocentric approach is to consider animal welfare indirectly via human altruism (Norwood and Lusk 2011, Fleurbaey and van der Linden 2021). The Appendix shows that the main insights of our analysis continue to hold under altruism. Nevertheless, it is important to consider alternative forms of other-regarding preferences that could affect the design and implementation of animal-welfare policies.

The method behind the calibration exercise will likely improve in the future. First, more-encompassing models of animal welfare may also account for positive experiences. This would likely increase the levy for animals living in intensive farming conditions, as they experience limited positive experiences, and could also increase the subsidy for animals living outdoors. Second, animal-welfare assessment could be carried out by animal-welfare experts. Third, the determination of the utility potentials will improve in the coming years, switching for instance from biological measures (such as neuron counts) to behavioral observations of species capacities (as in Fischer 2023). Overall, the economic evaluation of animal welfare represents an exciting new field of research, with significant potential for advancing animal-welfare policies and improving food-production systems.

Note that we calibrated the animal-welfare levy only for the benchmark model: calibration under other theoretical settings (see Table 1) is more difficult and raises a number of questions. For instance, which value should we take for γ under critical-level utilitarianism, and should we choose a different value for each species (Williamson 2021)? And which $g(.)$ function to apply under prioritarianism? Note also that the calibration of the levy under average utilitarianism requires estimates of human welfare and the number of farmed animals consumed. Another challenge, already discussed briefly above, concerns calibration accounting for indirect effects on wild-animal welfare.

This requires an estimate of wild-animal wellbeing and the technical factor λ.[25] While this may appear to be a daunting task, it could potentially be applied for a limited set of wild animals and in a specific area.

Our analysis focused on four main types of animal-based products: meat from chicken, pork and cows (from either dairy or beef herds). The analysis should be extended to other types of animal-based products such as eggs and milk. In this case, an important question concerns the allocation of the externality on animal welfare across different end-products. For instance, the farming externality on the welfare of egg-laying hens should be divided between the meat of the hen and the eggs it produces. Similarly, the externality on the welfare of dairy cows could be split between beef and milk.[26] Relatedly, we have here omitted the issue of veal. Male calves born to dairy cows are killed after a few months for their meat and suffer from adverse living conditions. The production of veal is inseparable from milk production. Taxing veal meat at the welfare-externality level could lead to prohibitively-high prices, ending the sale of veal. But how would the externality from veal then be accounted if it is no longer sold and becomes an unsold waste product in the industry?

Overall, our paper suggests that it is possible to directly incorporate the well-being of animals into economic analysis (Johansson-Stenmann 2018, Carlier and Treich 2020). This underscores the significant implications of animal welfare for economic outcomes, as we have shown that this can drastically affect the prices of meat. Furthermore, it highlights that it is feasible to move beyond anthropocentrism without discarding traditional economic analysis. By incorporating animal welfare, economics can play a vital role in shaping public policy towards more-ethical production and consumption.

A Appendix: Theory

A.1 Non-linear production costs

In this Appendix, we analyze a trivial extension to the benchmark model. We consider the competitive equilibrium and allow the production cost $c(n)$ to be non-linear. Let p be the price of meat. The producer maximizes profits $pn - c(n)$ over n, and the consumer maximizes utility $u(n) - pn$. This gives the standard equilibrium condition:

$$u'(n_e) = c'(n_e) = p \tag{17}$$

As before, suppose that the social planner applies a levy to meat consumption in order to account for the externality on animals. Following the analysis above, the condition characterizing the consumer and producer choices when there is a meat-consumption levy of t is:

$$u'(n(t)) = c'(n(t)) + t \tag{18}$$

[25] Matheny and Chan (2005), using data from Gaston et al. (2003), provide some of the elements for the estimation of λ. They show that chicken consumption generates very few wild-animal life-years lost, over five times fewer than pork consumption, and over fifteen times fewer than beef consumption.

[26] Note that similar questions arise with respect to the environmental externalities (when the emissions from the cow are allocated between the meat and the milk), reflecting that the products are produced jointly and the externality emerges at the production level.

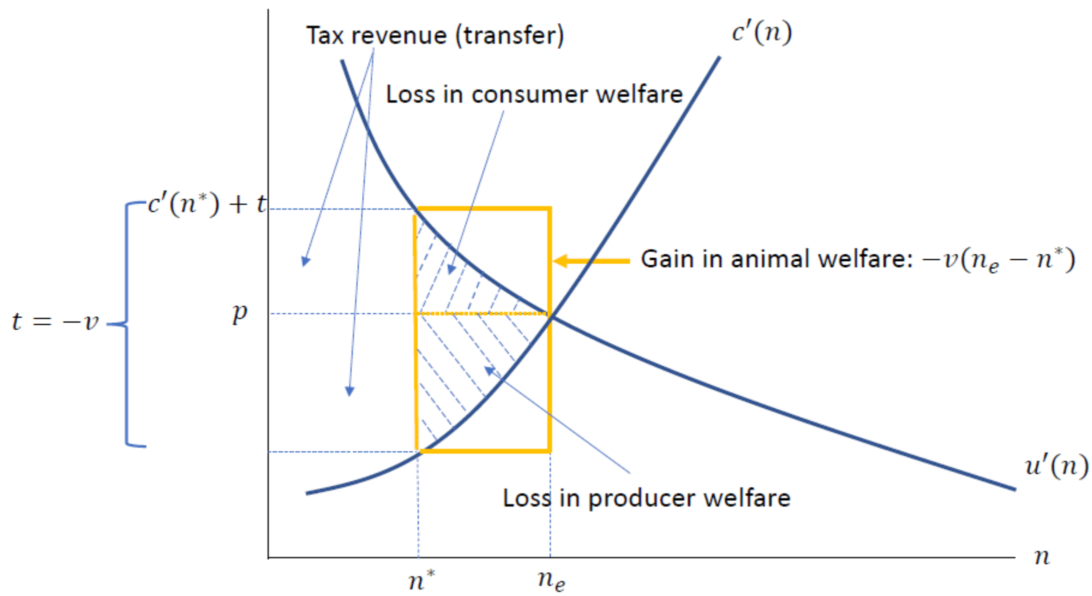

Figure A1: The welfare impact of the animal-welfare levy in the competitive equilibrium

The problem of the social planner is then to maximize over t the sum of the welfare of the consumer, the producer and animals, namely $u(n(t)) - c(n(t)) + n(t)v$, leading to the following FOC:

$$u'(n(t)) = c'(n(t)) - v \tag{19}$$

Combining the two last FOCs simply gives $t^* = -v$. Hence, the benchmark result continues to hold. This is a standard result in the Pigouvian taxation literature. Figure 5 shows the welfare impact of the levy when it is a tax, i.e. $t^* = -v > 0$. As in Figure 1, the hatched areas represent the deadweight loss, i.e. the loss in human welfare resulting from the reduction in the consumer and producer surpluses.

A.2 Quality choice: Animal-welfare standards

The benchmark model considers the optimal quantity choices, namely the number of farmed animals. It does not however address the choice of the quality of animal lives. In this Appendix, we assume that the social planner can choose the level of a mandatory "animal-welfare standard" $d \geq 0$ that affects animal wellbeing, now denoted by a function $v(d)$ that is assumed to be increasing and concave. We also assume that the production cost per animal equals the baseline cost of production plus the cost of the improvement in animal welfare, i.e. $c + d$.

We wish to analyze the socially-optimal level of animal consumption in this economy. Summing up human and animal welfare, social welfare is given by $u(n) - (c+d)n + nv(d)$ and yields the following optimality conditions:

$$v'(d^*) = 1 \tag{20}$$

$$u'(n^*) = c + d^* - v(d^*) \tag{21}$$

We next turn to the consumer's problem. She maximizes over n her individual objective: $u(n)-(c+d)n$. As before, the consumer does not internalize the impact of her consumption on animal well-being. The consumption of meat is therefore suboptimal, with the immediate corollary that the non-anthropocentric first-best outcome can be implemented if a tax of $-v(d^*)$ is applied to meat consumption. The value of the socially-optimal levy is thus, again, the opposite of the utility level, as in the benchmark case above where v was exogenous.

We now show that both a quantity instrument, t, and a quality instrument, d, are required in this economy to attain the non-anthropocentric first best. To show this, we consider sequentially the cases where only one instrument is available to the social planner. We first assume that only the quality instrument is available. Define $n(d)$ as the optimal level of meat consumption for a given animal-welfare standard. This is given by rewriting the FOC above as follows: $u'(n(d)) = c + d$. The social planner then optimizes over d :

$$u(n(d)) - (c + d)n(d) + n(d)v(d) \tag{22}$$

which, using the FOC, yields the optimality condition:

$$\frac{n'(d)v(d)}{n(d)} + (v'(d) - 1) = 0 \tag{23}$$

Given that $n'(d) < 0$ under $u'' < 0$, it is optimal to adjust the animal-welfare standard d compared to the above situation if and only if $v(d)$ is not equal to zero. Under $v(d) < 0$ for instance, there is less animal consumption at the social optimum compared to the individual case. Hence, when the animal's life is not worth living, the regulatory authority "over-invests" in animal welfare in order to push down the number of animals consumed. This is because this over-investment mechanically increases the price of meat.

The non-anthropocentric first-best outcome can be attained only if the decisions n and d in the second-best are the same as in the first-best. From the conditions above, this is the case if and only if $v(d) = 0$ when $v'(d) - 1 = 0$, namely if it turns out that the optimal animal-welfare standard is exactly such that the life of an animal is morally neutral. Note that this depends only on the shape of animal utility as a function of the technological choice, $v(d)$, and thus not on human preferences or other model parameters. Functions such as $v(d) = \log(d - k)$ or $v(d) = 1 - e^{k-d}$ with $k \geq 0$ satisfy this property. In these special cases, no animal-welfare levy is needed and social welfare is maximized by simply choosing the optimal animal-welfare standard. But in general an animal-welfare levy is required to maximize social welfare.

We now consider the case where only a quantity instrument is available to the social planner. If the consumer can choose quality d, she will set it to zero since d produces an additional private cost for the consumer without any benefit. The social-planner's problem is then to maximize over n the objective $u(n) - cn + nv(0)$. This can never attain the first best except when it is socially optimal to choose $d = 0$, that is $v'(0) = 1$. A function such as $v(d) = 1 - e^{-d}$ satisfies this property, but this is again a very special case. We conclude that, in general, both quantity (the animal-welfare levy) and quality (the animal-welfare standard) instruments are required for efficiency. This observation about the need for both quantity and quality instruments is similar to those made in models of environmental regulation (Bovenberg and Goulder 2002), and recently by

Eichner and Runkel (2023) for animal-welfare regulation. Our model can be viewed as a special case of these general models.

A.3 Density effect

In this Appendix, we assume that the number of farmed animals n can affect animal wellbeing, now denoted $v(n)$. This is another case where animal wellbeing is not fixed but rather endogenous. The socially-efficient outcome is defined by the maximization over n of the social objective $u(n) - cn + nv(n)$, leading to the following FOC:[27]

$$u'(n^*) - c + [v(n^*) + n^* v'(n^*)] = 0 \tag{24}$$

The problem of the consumer is the same as that in the simple model, leading to the individual consumption level n_e given by $u'(n_e) = c$. Hence, by the same reasoning as in the benchmark model, it can easily be seen that the optimal animal-welfare levy is now $t = -[v(n(t)) + n(t)v'(n(t)]$. This is a direct generalization of the benchmark result. The second term in the brackets captures the change in animal life quality due to the change in the number of animals raised.

A.4 Multiple species

We here consider multiple animal species, s. Let v_s denote the utility level of an animal of species s and n_s the number of animals of species s. We show that the benchmark result in the multiple species case, i.e. $t_s^* = -v_s$, holds. For simplicity, we only consider two species in the proof below: the extension to more species is straightforward. We also consider a two-attribute utility function, and assume that the properties of this function are such that the second-order conditions continue to hold.

Using obvious notation, the objective of the representative consumer is now

$$u(n_1, n_2) - c_1 n_1 - c_2 n_2 \tag{25}$$

where $u(n_1, n_2)$ is the two-attribute utility function of the consumer associated with the two types of meat. Introducing the animal-welfare levies, the FOCs of this problem are simply

$$u_1(n_1(t_1, t_2), n_2(t_1, t_2)) - (c_1 + t_1) = 0 \tag{26}$$

$$u_2(n_1(t_1, t_2), n_2(t_1, t_2)) - (c_2 + t_2) = 0 \tag{27}$$

where $n_1(t_1, t_2)$ and $n_2(t_1, t_2)$ denote respectively the optimal consumption of animals of species 1 and 2 as a function of the levies $t_1$and t_2, and u_s denotes the derivative of the utility function with respect to attribute $s = 1, 2$.

The social planner then maximizes the sum of consumer and animal welfare over t_1 and t_2

$$\max_{t_1,t_2} u(n_1(t_1, t_2), n_2(t_1, t_2)) - c_1 n_1(t_1, t_2) - c_2 n_2(t_1, t_2) + n_1(t_1, t_2)v_1 + n_2(t_1, t_2)v_2 \tag{28}$$

[27]For simplicity, we assume that $v(n) + nv'(n)$ is decreasing in n, so that the SOC is satisfied. A sufficient condition is that $v(.)$ be decreasing and concave: increasing the number of animals reduces animal wellbeing at an increasing rate.

leading to the following FOCs:

$$\frac{\partial n_1(t_1,t_2)}{\partial t_1}\{u_1(n_1(t_1,t_2),n_2(t_1,t_2))-c_1+v_1\}+\frac{\partial n_2(t_1,t_2)}{\partial t_1}\{u_2(n_1(t_1,t_2),n_2(t_1,t_2))-c_2+v_2\}=0 \tag{29}$$

$$\frac{n_2(t_1,t_2)}{\partial t_2}\{u_2(n_1(t_1,t_2),n_2(t_1,t_2))-c_2+v_2\}+\frac{n_1(t_1,t_2)}{\partial t_2}\{u_1(n_1(t_1,t_2),n_2(t_1,t_2))-c_1+v_1\}=0 \tag{30}$$

Note that the second terms of the left-hand sides above capture the cross effects of the taxes. Using the FOCs of the consumer problem in Equations (26) and (27) above, these FOCs then simplify to:

$$\frac{\partial n_1(t_1,t_2)}{\partial t_1}\{t_1+v_1\}+\frac{\partial n_2(t_1,t_2)}{\partial t_1}\{t_2+v_2\}=0 \tag{31}$$

$$\frac{n_2(t_1,t_2)}{\partial t_2}\{t_2+v_2\}+\frac{n_1(t_1,t_2)}{\partial t_2}\{t_1+v_1\}=0 \tag{32}$$

It is then obvious that $t_s^*=-v_s$, $s=1,2$, are the solutions to this problem.

Note finally that the model in this Appendix can be interpreted as one with different animal-rearing conditions s for animals of the same species (e.g., chickens from conventional and organic farming). These different rearing conditions may well affect the production cost c_s and the utility level v_s. This Appendix is thus relevant for both intra- and inter-species taxation.

A.5 Altruism

In this Appendix, we show that the benchmark result $t^*=-v$ also holds when the consumer displays is altruistic towards animals. Under (pure) altruism, the objective of the representative consumer is now

$$u(n)-cn+\alpha nv \tag{33}$$

where α is the degree of altruism towards animals. Following the same logic as in the benchmark model, an animal-welfare levy t can be introduced. The consumer problem's FOC is

$$u'(n(t))=c+t-\alpha v \tag{34}$$

The social-planner's objective is to maximize the sum of consumer and animal welfare over t:

$$\max_t u(n(t))-cn(t)+\alpha n(t)v+n(t)v \tag{35}$$

leading to the following FOC

$$u'(n(t))=c-\alpha v-v \tag{36}$$

Combining the two previous FOCs thus implies

$$t^*=-v \tag{37}$$

Consumer altruism therefore does not change the optimal animal-welfare levy. This is because the levy reflects the gap between private and social harm, which is independent of altruism. Note that this result holds no matter the sign of α, so that it also applies under malevolence. See Daube and Ulph (2016) for a related result.

One limitation of the previous analysis is that it considers only one representative consumer, and thus does not capture any free-riding incentives associated with the public-good nature of animal welfare in a model with many altruistic consumers (Espinosa and Treich 2023). It is easy to show that introducing this public-good dimension exacerbates the inefficiency, and that the levy becomes $t = -\alpha(N-1)v - v$, where N is the number of (identical) consumers. Hence, if life is not worth living, the tax is higher due to the extra term $-\alpha(N-1)v$ when $N > 1$.

A.6 Number-dampened utilitarianism

In this Appendix, we consider number-dampened utilitarianism (NDU). In its simple form, NDU is equal to average utility multiplied by a positive-value function of the population size (Ng, 1986). Formally, this leads to the following social objective:

$$D(n) \equiv \frac{1}{1+n}(u(n) - cn + nv)f(1+n) \tag{38}$$

with a "dampening" function $f(.) > 0$ that is assumed to be increasing and concave.

We now show that it is optimal to choose a lower n under NDU than under total utilitarianism. Denote by $\widetilde{n}$ the maximum of $D(n)$, so that $\frac{f(\widetilde{n})}{l+\widetilde{n}}U(\widetilde{n}) \geq \frac{f(n^*)}{1+n^*}U(n^*)$. Assuming $U(n^*) \geq 0$ (which holds under $u(0) \geq 0$), this implies $\frac{f(1+\widetilde{n})/(1+\widetilde{n})}{f(1+n^*)/(1+n^*)} \geq \frac{U(n^*)}{U(\widetilde{n})} \geq 1$, where the last inequality comes from the definition of n^*. We therefore have $\frac{f(l+\widetilde{n})}{1+\widetilde{n}} \geq \frac{f(1+n^*)}{1+n^*}$. This implies $\widetilde{n} \leq n^*$, since $\frac{f(1+n)}{l+n}$ is decreasing in n. With f concave, we have $\frac{f(n)-f(0)}{n} \geq f'(n)$; since $f(0) > 0$, this implies $\frac{f(n)}{n} \geq f'(n)$ and, in turn, $\frac{f(n)}{n}$ decreasing.

It is then easy to see that the expression for the optimal levy under NDU is

$$t_{NDU} = [\frac{1}{1+n(t)} - \frac{f'(1+n(t))}{f(1+n(t))}][u(n(t)) - cn(t) + n(t)v] - v \tag{39}$$

which is thus greater than the optimal levy under total utilitarianism (of $-v$) under f concave, since the first term of the right-hand side is positive.

A.7 Prioritarianism

In this Appendix, we show that equity-sensitive motives lead to a higher tax when $v < 0$. We consider the following social objective: $g(u(n) - cn) + ng(v)$. The function g in this objective captures the sensitivity to the distribution of human and animal utilities. We assume $g''(.) < 0 < g'(.)$ and $g(0) = 0$. Since g is concave, a mean-preserving reduction in the spread of utilities (i.e. a Pigou-Dalton transfer) increases social welfare. This setting is often coined prioritarianism (Adler, 2019), or generalized utilitarianism.

Recall that optimal meat consumption under a tax t, $n(t)$, is given by the individual consumer's FOC: $u'(n(t)) = c + t$. The social-planner's objective consists in maximizing over t as below:

$$\max_t g(u(n(t)) - cn(t)) + n(t)g(v) \tag{40}$$

leading to the following FOC

$$g'(u(n(t)) - cn(t))(u'(n(t)) - c) + g(v) = 0 \tag{41}$$

Combining the two previous FOCs implies

$$t = -\frac{g(v)}{g'(u(n(t)) - cn(t))} \tag{42}$$

Now, assuming $u(n(t)) - cn(t) \geq 0$ (which holds under $u(0) \geq 0$), we have $t \geq -\frac{g(v)}{g'(0)}$ under $v < 0$ (and $-g(v) > 0$). Since g is concave and $g(0) = 0$, we have $g(v) < vg'(0)$, or $-g(v) > -vg'(0)$. We hence have $t > -v$ when $v < 0$.

A.8 Wild animals

The model in this extension is based on the competition for resources, say "grain". The total grain available G is given by the following "grain constraint":

$$G = g + ng_a + wg_w \tag{43}$$

where g, g_a and g_w are respectively the consumption of grain per human, per farmed animal and per wild animal, and where n and w are respectively the numbers of farmed and wild animals per human. Note that g_a and g_w are assumed to be fixed, and can be interpreted as the amount of grain per farmed and wild animal necessary for subsistence. Note also that the resource constraint is binding in the sense that all of the grain is consumed. The intuition is that the social planner has no direct control over the population of wild animals, which then consume all of the grain that is left by humans and farmed animals by growing in size.

In this model, farmed and wild animals only consume grain, of g_a and g_w respectively, while humans consume both animals n and grain g. We further assume that humans require a certain number of calories C, given by the following "calory constraint":

$$C = nz + g \tag{44}$$

where the parameter z determines the conversion factor from animals into calories for human consumption (this factor is normalized to 1 for grain). This calory constraint thus implies that the choice of animal consumption n automatically determines the amount of grain consumed per human, g.

We now explore the normative implications of this simple model. We denote by v_w the well-being of a representative wild animal. As in the benchmark case, we consider total utilitarianism. By summing human, farmed-animal and wild-animal well-being, we obtain the following simple extension of the social objective:

$$u(n) - cn + nv + wv_w \tag{45}$$

Substituting both the grain and calory constraints above into this objective and maximizing over n leads to the following FOC:

$$u'(n) = c - v - \lambda v_w \tag{46}$$

where λ is a "technical factor" capturing how the number of wild animals w varies with the number of farmed animals consumed n, and is equal to

$$\lambda = \frac{z - g_a}{g_w} \tag{47}$$

Moreover, by the same reasoning as above, the animal-welfare levy is then

$$t^* = -v - \lambda v_w \tag{48}$$

This extension shows that what matters for determining whether meat consumption should be taxed or subsidized is the well-being of farmed animals compared to the technical factor $\lambda times$ that of wild animals.

The sign of λ is determined by that of $z - g_a$, which shows the extent to which the production of an additional farmed animal reduces ($\lambda < 0$) or increases ($\lambda > 0$) the number of wild animals. Note that λ falls as the conversion factor of farmed animals into calories for humans (z) rises, and as the amount of grain needed per farmed animal (g_a) falls. These two parameters measure how efficient meat consumption is in terms of converting grain into calories through animals for human consumption. Note also that when g_w is larger λ is smaller, so that taking wild-animal well-being into account becomes less important for the choice of n. If wild animals require more grain to survive, the impact in terms of the number of wild animals from consuming more farmed animals becomes more muted.

B Appendix: Calibration

B.1 Calibration of W_0

We estimate the utility level v by computing an animal-welfare score $q(.)$. We propose above a parametrization of the function $q(.)$ which is a linear function of the number of violation points of the Five Freedoms. More precisely, we define $q(.)$ as $q(t) = \frac{W_0 - W(t)}{W_0}$, where $W(t)$ is the total number of violation points at time t and W_0 is the threshold value such that $q(.) = 0$ if $W(t) = W_0$. If an animal endures more than W_0 freedom violation points, we have $q(.) < 0$.

To calibrate W_0, we designed a survey and collected data from a representative sample of the UK population[28] using the online survey platform Prolific. The survey consisted of three screens (see the instructions in the Online Appendix). On the first screen, we introduced the participants to our model of animal welfare: We described the Five Freedoms framework, the range of possible violation points for each freedom, and an indicator that sums up the violation points across freedoms. On the second screen, we displayed two hypothetical examples of an animal that either was in perfect welfare (zero violation points) or in the worst welfare (twenty violation points). Last, we randomized participants regarding the third screen with equal probability. Given that it is not clear how to communicate the notion of a life worth living, or negative utility, we considered two framings. Half of the participants saw a screen where we presented W_0 as the threshold value above which the negative experiences of the animal become

[28]We used a UK representative sample as Prolific has solely UK or US representative samples.

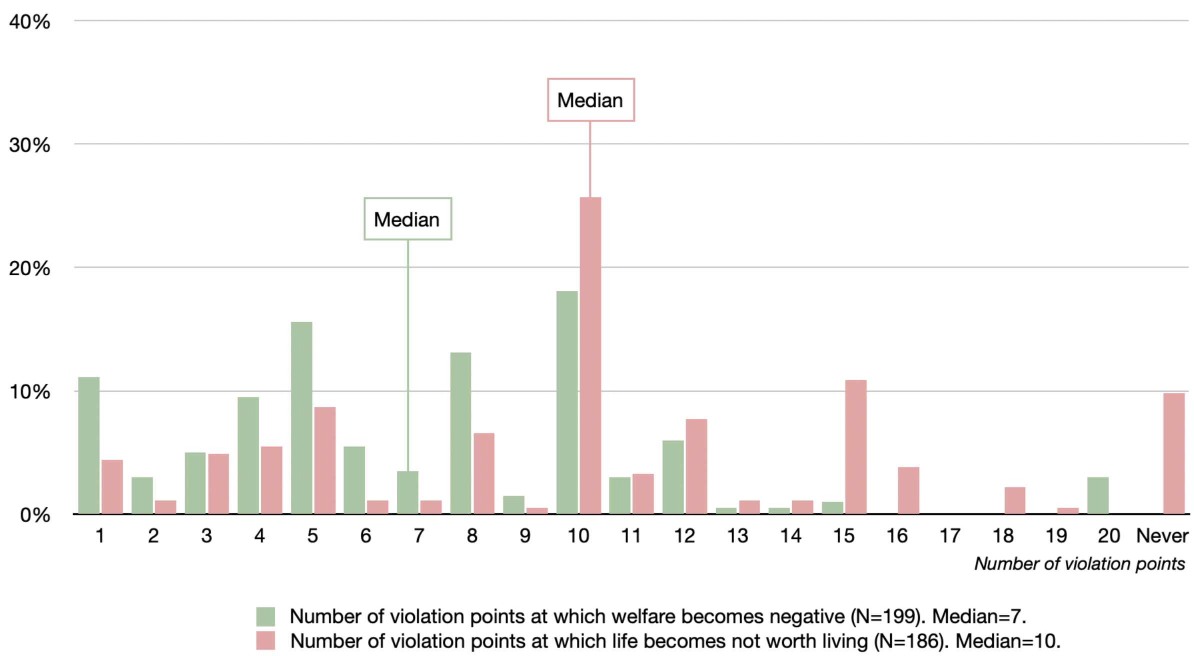

Figure B1: The distribution of respondents' views about W_0

so important that "its life is no longer worth living". The other half of the participants saw the same question, but with W_0 presented as the threshold value above which the animal has "a negative welfare overall". On this third screen, participants were asked to report this threshold value.

The survey was run on November 30th 2023. In total, 501 participants completed the survey, and 385 successfully passed the attention checks on the first screen. Of these, 186 faced the "life not worth living" framing and 186 the "negative welfare" framing. The participants were on average 45 years old, 50.4% female, and 60.3% employed.

Figure B1 shows the survey results. The median W_0 is 10 in the "life-worth-living" framing and 7 in the "overall negative-welfare" framing. The mode of each distribution is 10, but the negative-welfare distribution is more right-skewed than the life-worth-living distribution. The second most-frequent value for W_0 in the negative-welfare framing is $W_0 = 5$, reflecting some heterogeneity in participants' views. For our calibration purpose, we will retain the two median values $W_0 = \{7, 10\}$.

B.2 Animal-welfare score: Application to pigs

Similarly to chickens, pigs in France are raised on four types of farms: standard, Label Rouge, Label Rouge "Fermier" and organic. We will focus here on the standard rearing system, as 95% of pigs are raised on this type of farm. According to the French Ministry of Agriculture, the density in the standard system is about 1 pig per square meter.[29] There is no obligation for outdoor access or natural light. Most of the pigs are castrated without anesthesia between 2 and 4 days after birth to prevent the meat from developing a bad taste. In addition, due to the high density of animals, most pigs have their tails

[29] https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-porcs.

cut to avoid tail biting between animals. Most of pigs are raised above ground on grating (90% of all pigs) or on litter (5% of all pigs).[30] Pigs are usually prematurely separated from the sow after a few weeks, and are killed after 6 months of farming.

The rearing conditions of pigs in France have regularly been criticized by animal-welfare NGOs. Activists argue that these poor living conditions lead to high mortality rates (about 20% of the pigs die on the farm according to 2015 industry data). Animal advocates also point out the consequences of high animal density in farms, which leads to numerous injuries from aggressive behavior, and which also leads farmers to mutilate the animals (tail and teeth cutting). They also highlight that pigs are not able to express their natural behavior in these confined rearing conditions.

Based on the above, we consider the following freedom violations at the farm. First, we presume that pigs are well-fed and have access to water, so there is no violation of the first freedom. Second, we assume however a severe violation of the freedom from stress (high density leading to aggression from other pigs, and the separation of the piglets from the sow at an early age). Third, we consider that animals experience very-severe physical discomfort (grating, high density, and cage confinement for sows) and significant pain (injuries from the attacks, and mutilation without anesthesia) leading to very-severe violations of the third and fourth freedoms. Fourth, pigs in these farms cannot express their natural behaviors, such as digging, leading to a very-severe violation of their last freedom. Last, we assume similar conditions for transportation and slaughter, but further consider a moderate violation of the first freedom as pigs can be transported for 24 hours without food or rest.[31]

B.3 Animal-welfare score: Application to cows

Beef comes essentially from two sources, dairy herds and beef herds, representing 32% and 68% of French beef production respectively.[32] Dairy cows are on two types of farms (standard or organic), with the standard system representing 97.6% of milk production. The standard system covers different farming conditions with respect to outdoor access, going from no or limited outdoor access to extensive access. In France, only a small number of animals have no outdoor access (8% in 2016) or limited access (12% had access to 100 square meters or less per cow).[33] Water and food such as fodder are freely available. When inside, cows usually are free to move, but in some farms cows stay tethered to their stall at the neck.[34]

Dairy cows are inseminated every year from around two years old, and separated from their calf usually one or two days after birth. This separation has been recognized as stressful for both cow and calf, as the cow-calf relationship can last for a number of months in the absence of separation (about 9 months for female and 11 to 12 months for male calves).[35] Over the past decades, the increasing productivity of milk production (from 4726L per cow in 1988 to 6734L per cow in 2018) has led to intensive lactation,

[30] https://www.la-viande.fr/animal-elevage/porc/organisation-elevage-porcin-france.

[31] https://agriculture.gouv.fr/la-protection-des-animaux-delevage-pendant-le-transport.

[32] https://web.archive.org/web/20220920073750/https://www.la-viande.fr/economie-metiers/economie/chiffres-cles-viande-bovine/cheptel-bovin-production-viande-bovine.

[33] https://web.archive.org/web/20220920075156/https://www.reussir.fr/lait/80-des-vaches-laitieres-francaises-paturent-plus-de-10-ares-mais.

[34] https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-vaches-laitieres.

[35] Source: FIBL, Fiche technique, 2020, N°2520.

which has contributed to the development of various health problems such as lameness and mastitis.[36] To limit the consequences of aggressive behavior at the farm, most cows are dehorned (87%), which generates intense suffering usually for a limited time period but with the possibility of chronic pain lasting for several months.[37] Once they become insufficiently productive, cows are fattened for a short period of time, and then sent to abattoirs (at an average age of 8).[38] About one third of cows are slaughtered without stunning (for religious reasons), which is considered to be very painful. Although the welfare of calves is not explicitly accounted for here, we note that male calves in the dairy industry are not useful for milk production. They are usually placed in small stalls after birth and then fattened in intensive farms abroad, and finally transported to the abattoir by truck or boat, which is associated with severe animal-welfare issues.[39] Overall, there are significant problems regarding the raising of dairy cows, and the European Food and Safety Authority (EFSA) recently released a report underlining a number of these: locomotory disorders (including lameness), mastitis, restriction of movement and resting problems, inability to perform comfort behaviour, and metabolic disorders.[40]

Given these figures, we assume no violation of the first freedom for dairy cows but moderate violations of the freedom from distress, as separation from the calves generates considerable distress for the cows. We further assume severe physical discomfort due to repeated pregnancies and intensive lactation, and moderate violation of the freedom from pain and injury given dehorning and the injuries that follow from intensive milking. Last, we consider severe violation of natural behavior, associated with the separation from calves and limited outdoor access for many dairy cows.

Beef herds, also called suckler cows, consist of breeds selected for their meat. The French Ministry of Agriculture distinguishes three main production systems (standard, Label Rouge and organic), but 96% of production takes place on 'standard' farms. Calves generally stay under their mother for the six first months. About two-thirds of calves are then fattened to produce meat, and are slaughtered between the ages of one to three. About one-quarter of the calves are used to renew the herd, and 6% are rapidly slaughtered for their meat. In France, almost all cows from beef herds stay at least six months per year on pasture.[41] This form of farming is often viewed as the most animal-friendly, and is usually not the target of animal-advocacy NGOs. However, most suckler cows are dehorned (61%) which still generates substantial pain for the animals. Issues regarding transport and slaughter are similar for dairy and suckler cows. We consider that there is no violation of the first freedom for beef herds, and only mild violations for the remaining freedoms.

---

[36] Data from Agreste, *Réseau d'information comptable agricole : 1988-2018 (France métropolitaine) - CPS 2007* .

[37] See: https://www.sciencedirect.com/science/article/pii/S0031938418305547.

[38] The average age of slaughter differs across breeds ranging between 71 months (Prim'holstein) to 116 months (Salers). Source: https://web.archive.org/web/20220920083122/https://www.reussir.fr/bovins-viande/large-panel-de-poids-et-dages-pour-les-vaches-de-reforme.

[39] https://www.ciwf.fr/animaux-delevage/vaches-laitieres/.

[40] https://www.efsa.europa.eu/en/efsajournal/pub/7993.

[41] https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-vaches-viande.

C Appendix: Simulation of a GHG tax on red meat

In this section, we describe the method that we use to simulate the impact of a GHG tax on red meat. We here focus on the change in demand, assuming constant retail prices from producers. Following Säll and Gren (2015), we calculate the change in quantities as follows:

$$\frac{\Delta Q_j}{Q_j} = \sum_k \frac{\Delta P_k}{P_k} \epsilon_{j,k} \tag{49}$$

where Q_j is the pre-tax demand for product j, P_k the price of product k, and $\epsilon_{j,k}$ the cross-price elasticity of products j and k (the own-price elasticity when $j = k$).

The vector of products contains white meat (chicken), pork and beef. The corresponding average pre-tax retail prices are 5.8, 5.98, and 11.85 per kilogram respectively. We here consider a GHG tax on beef of 1.7 Euros per kilogram of meat (average CO2-eq emissions for 1kg of beef = 30 kg, and the price of CO2-eq = 0.05664 Euro/kg).

As we do not have information on the elasticities between products of the same type of meat with different farming methods, we assume constant market shares for a given type of meat before and after the tax. The externalities are calculated using the single products (e.g., standard chicken) while the change in consumption is estimated at the more-aggregate product category (e.g., white meat). The market shares for chicken are 71.7% for standard, 8.7% for certified, 17.4% for Label Rouge, and 2.2% for organic. The market shares for beef are 68% for beef herds and 32% for dairy herds.

We consider the following matrix of elasticities (E), in which the values are taken from Bonnet et al. (2018):

$$E = \begin{bmatrix} -1.4517 & 0.0493 & 0.0510 \\ 0.1649 & -1.1238 & 0.1991 \\ 0.0558 & 0.0630 & -1.3358 \end{bmatrix} \tag{50}$$

Using this information, we estimate the change in overall consumption and calculate the change in externalities using the externality data from Section 3.

References

Adler, M.D. (2019) Measuring Social Welfare: An Introduction. Oxford University Press, USA.

Barro, R.J. & Becker G.S. (1989) Fertility choice in a model of economic growth, Econometrica, 57(2), 481-501.

Baudin, T. (2011) Family policies: What does the standard endogenous fertility model tell us?, Journal of Public Economic Theory, 13(4), 555-593.

Baumol, W.J. (1972) On taxation and the control of externalities. American Economic Review, 62(3), 307-322.

Becker, G.S. & Lewis H.G. (1973) On the interaction between the quantity and quality of children, Journal of Political Economy, 81(2) Part 2 , 279-288.

Bentham, J. (1789) An Introduction to the Principles of Morals and Legislation, Oxford: Clarendon Press.

Blackorby, C. & Donaldson, D. (1984) Social criteria for evaluating population change. Journal of Public Economics, 25, 13-33.

Blackorby, C. & Donaldson, D. (1992) Pigs and guinea pigs: A note on the ethics of animal exploitation. Economic Journal, 102, 1345-69.

Blackorby, C., Bossert, W., & Donaldson, D. (2005) Population Issues in Social Choice Theory, Welfare Economics, and Ethics. Cambridge University Press.

Bleichrodt, H., Quiggin J. (1999) Life-cycle preferences over consumption and health: when is cost-effectiveness analysis equivalent to cost–benefit analysis?. Journal of Health Economics, 18(6), 681-708.

BMEL (Empfehlungen des Kompetenznetzwerks Nutztierhaltung) (2020).

Bonnet, C., Bouamra-Mechemache, Z., Corre, T. (2018) An environmental tax towards more sustainable food: Empirical evidence of the consumption of animal products in France, Ecological Economics, 147, 48-61,

Bonnet, C., Bouamra-Mechemache, Z., Réquillart, V, & Treich, N. (2020) Regulating meat consumption: how to improve health, the environment and animal welfare. Food Policy 97, 101847.

Bovenberg, A.L., & Goulder, L.H. (2002) Environmental taxation and regulation. In Handbook of Public Economics (Vol. 3, pp. 1471-1545). Elsevier.

Brambell, F.W.R. (1965) Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems: Presented to Parliament by the Secretary of State for Scotland and the Minister of Agriculture, Fisheries and Food by Command of Her Majesty, December, 1965. HM Stationery Office.

Broadbent, J. (2023) Farming emissions tax of US$107 per tonne needed to meet climate targets, says Danish climate agency. https://www.just-food.com/news/farming-emissions-tax-of-dkk750-per-tonne-needed-to-meet-climate-targets-says-danish-climate-agency/

Broom, D.M. (2014) Sentience and Animal Welfare. CABI publisher.

Browning, H. (2022) Assessing measures of animal welfare. Biology and Philosophy 37(36), 1-24.

Budolfson, M. & Spears, D. (2019) Quantifying animal well-being and overcoming the challenge of interspecies comparisons. In The Routledge Handbook of Animal Ethics, pages 92–101. Routledge.

Byrne, J. (2022), Is a Dutch meat tax on the card? www.feednavigator.com/Article/2022/07/05/Is-a-Dutch-meat-tax-on-the-cards.

Carlier, A. & Treich, N. (2020) Directly valuing animal welfare in (environmental) economics, International Review of Environmental and Resource Economics, 14(1), 113-152. http://dx.doi.org/10.1561/101.00000115

CE Delft (2023) Pay as you eat dairy, eggs and meat: Internalising external costs of animal food products in France, Germany and the EU27.

Clarke, M. & Ng, Y.K. (2006). Population dynamics and animal welfare: issues raised by the culling of kangaroos in Puckapunyal. Social Choice and Welfare, 27, 407-422.

Cline, W. (2020) Carbon-equivalent taxes on US meat. Mimeo.

Dasgupta, P. (2005) Regarding optimal population. Journal of Political Philosophy 13(4), 414.

Dasgupta, P., Southerton, D., Ulph, A. & Ulph, D. (2016) Consumer behaviour with environmental and social externalities: Implications for analysis and policy. Environmental and Resource Economics 65, 191–226.

Daube, M., & Ulph, D. (2016). Moral behaviour, altruism and environmental policy. Environmental and resource economics, 63(2), 505-522.

Decancq, K., & Neumann, D. (2014). Does the choice of well-being measure matter empirically? An illustration with German data.

De la Croix, D., & Doepke, M. (2021) A soul's view of the optimal population problem. Mathematical Social Sciences, 112, 98-108.

De Sy, V., Herold, M., Achard, F., Beuchle, R., Clevers, J. G. P. W., Lindquist, E., & Verchot, L. (2015) Land use patterns and related carbon losses following deforestation in South America. Environmental Research Letters, 10(12), 124004.

ECA (European Court of Auditors) 2023 Transport of live animals in the EU: challenges and opportunities.

Eichner, T., & Pethig, R. (2006) Efficient nonanthropocentric nature protection. Social Choice and Welfare, 26, 47-74.

Eichner, T. & Runkel, M. (2022) Animal welfare, moral consumers and the regulation of animal food production, Cesifo working paper.

Espinosa, R. (2022) Animals and social welfare. Social Choice and Welfare, forthcoming.

Espinosa, R. & Treich, N. (2021) Animal welfare: Antispeciesism, veganism and a "life worth living". Social Choice and Welfare, 56(3), 531-548.

Espinosa, R. & Treich, N. (2023) Animal welfare as a public good. Ecological Economics, forthcoming.

FAIRR (2017) The Livestock Levy. https://www.fairr.org/article/livestock-levy-regulators-considering-meat-taxes/

Feinberg, J. (1974) The rights of animals and unborn generations, in Blackstone, ed., Philosophy and the Environmental Crisis 4.

Fischer, B. (2023) The welfare range table: https://rethinkpriorities.org/publications/the-welfare-range-table

Fleurbaey, M., & Leppanen, C. (2021) Toward a theory of ecosystem well-being. Journal of Bioeconomics 23, 257–295.

Fleurbaey, M., & Van der Linden, M. (2021) Fair social ordering, egalitarianism, and animal welfare. American Economic Journal: Microeconomics, 13 (4), 466-91.

Francione, G.L. (1997) Animal rights theory and utilitarianism: Relative normative guidance. Animal Law, 3, 75.

Funke, F., Mattauch, L., van den Bijgaart, I., Godfray, H.C.J., Hepburn, C., Klenert, D., Springmann, M. & Treich, N. (2022) Toward optimal meat pricing: Is it time to tax meat consumption? Review of Environmental Economics and Policy, 16(2), 219-240

Galor O. & Weil D.N (1999) From Malthusian stagnation to modern growth, American Economic Review, 89, 150-154.

Gaston, K.J., Blackburn, T.M., & Goldewijk, K.K. (2003) Habitat conversion and global avian biodiversity loss. Proceedings of the Royal Society of London. Series B: Biological Sciences, 270(1521), 1293-1300.

Golosov M., Jones L.E. & Tertilt M. (2007) Efficiency with endogenous population growth, Econometrica, 75(4), 1039-1071.

Gosseries, A., & Meijers T. (2022) Animal Population Ethics, in Gustaf Arrhenius, and others (eds), The Oxford Handbook of Population Ethics, Oxford Handbooks

Greaves, H. (2017) Population axiology. Philosophy Compass, 12(11), e12442.

Groezen B.V., Leers T. & Meijdam L. (2003) Social security and endogenous fertility: pensions and child allowances as siamese twins, Journal of Public Economics, 87(2), 233-251.

Hammitt, J.K. (2013) Admissible utility functions for health, longevity, and wealth: integrating monetary and life-year measures. Journal of Risk and Uncertainty, 47, 311-325.

Herculano-Houzel, S. (2017) Numbers of neurons as biological correlates of cognitive capability. Current Opinion in Behavioral Sciences, 16, 1–7.

Horta, O. (2010) Debunking the idyllic view of natural processes: Population dynamics and suffering in the wild. Télos, 17(1).

Johansson-Stenman, O. (2018) Animal welfare and social decisions: Is it time to take Bentham seriously? Ecological Economics, 145, 90–103.

Kuruc, K. & McFadden, J. (2022) Monetizing the externalities of animal agriculture: Insights from an inclusive welfare function, forthcoming. Social Choice and Welfare.

Lagerkvist, C.J. & Hess, S. (2011) A meta-analysis of consumer willingness to pay for farm animal welfare. European Review of Agricultural Economics, 38(1), 55–78.

Low, P., Panksepp, J., Reiss, D., Edelman, D., van Swinderen, B., & Koch, C. (2012) The Cambridge declaration on consciousness. Presented at the Francis Crick Memorial Conference, Cambridge, England.

Matheny, G. & Chan, K.M.A. (2005) Human diets and animal welfare: The illogic of the larder, Journal of Agricultural and Environmental Ethics, 18, 579-94.

Mattauch, L. & Tenkhoff, L. (2023) High 'steaks': Building support for reducing agricultural emissions. PLOS Climate, 2(10), e0000291.

McMahan, J. (2009) Asymmetries in the morality of causing people to exist. Harming future persons: Ethics, genetics and the nonidentity problem, 49-68.

Mellor, D. J. (2016) Moving beyond the "five freedoms" by updating the "five provisions" and introducing aligned "animal welfare aims". Animals, 6(10):59.

Nerlove, M., Razin, A. & Sadka, E. (1986) Some welfare theoretic implications of endogenous fertility, International Economic Review, 27(1), 3-31.

Ng, Y-K. (1986) Social criteria for evaluating population change: An alternative to the Blackorby-Donaldson criterion, Journal of Public Economics, 29, 375-381.

Norwood, F. B., & Lusk, J. L. (2011). Compassion, by the Pound: The Economics of Farm Animal Welfare. Oxford: Oxford University Press.

Parfit, D. (1984). Reasons and Persons. Oxford University Press.

Perino G., Schwickert, H. (2023) Animal welfare is a stronger determinant of public support for meat taxation than climate change mitigation in Germany. Nature Food 160–169.

Pigou, A. (1920) The Economics of Welfare. Macmillan.

Ponthière, G. (2003) Utilitarian population ethics: A survey.

Poore, J. & Nemecek, T. (2018) Reducing food's environmental impacts through producers and consumers, Science 360, 987-92.

Regan, T. (1983) The Case for Animal Rights, University of California Press.

Sidgwick, H. (1893) The Methods of Ethics, 5th Edn. Macmillan and co, New York.

Säll, S., & Gren, M. (2015). Effects of an environmental tax on meat and dairy consumption in Sweden. Food Policy, 55, 41-53.

Salt, H.S. (1917) The logic of the larder.

Singer, P. (1980) Utilitarianism and vegetarianism. Philosophy and Public Affairs, 9(4), 325-37.

Singer, P. (2011) Practical Ethics. Third edition. Cambridge University Press.

Springmann, M., Mason-D'Croz, Robinson, S., Wiebe, K., Godfray, H.C.J., Rayner, M., et al. (2018) Health-motivated taxes on red and processed meat: A modelling study on optimal tax levels and associated health impacts. PLoS ONE, 13(11), e0204139.

TAPPC (2020) Aligning food pricing policies with the European Green Deal.

Téhard, B., Detournay, B., Borget, I., Roze, S., and De Pouvourville, G. (2020). Value of a QALY for France: A new approach to propose acceptable reference values. Value in Health, 23(8), 985–993.

Visak, T. (2013) Killing Happy Animals: Explorations in Utilitarian Ethics. Palgrave Macmillan.

Weathers, S.T., Caviola, L., Scherer, L., Pfister, S., Fischer, B., Bump, J.B., & Jaacks, L.M. (2020) Quantifying the valuation of animal welfare among Americans. Journal of Agricultural and Environmental Ethics, 33(2), 261–282.

Weinstein, M.C., Torrance, G., & McGuire, A. (2009) QALYs: the basics. Value in health 12.

Williamson, P. (2021) A new argument against critical-level utilitarianism. Utilitas, 33(4), 399-416.

Wong, K. (2016). Counting animals: On effective altruism and the prospect of interspecies commensurability. PhD thesis, BA thesis, Princeton University, Princeton, NJ.

Zuber, S., Spears, D. & Budolfson M. (2022) Separable social evaluation for multispecies population, mimeo.

The Animal-Welfare Levy - Online Appendix

Instructions of the online survey used for the calibration of W_0

Screen 1 In this short questionnaire, we will show you a framework for animal welfare for farmed animals. This model was developed by animal welfare experts and focuses on the "Five Freedoms" that are considered essential to the welfare of the animal.

The Five Freedoms include:

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury, or disease
4. Freedom from fear and distress
5. Freedom to express normal behavior

To evaluate the welfare of animals on this scale, recent work has proposed to assess the level of violation of these freedoms, i.e., the extent to which each freedom is actually limited by the farming conditions the animal experiences.

The violation levels can take the following values for each of the Five Freedoms:

- No violation (0 point)
- Mild violation (1 point)
- Moderate violation (2 points)
- Severe violation (3 points)
- Very severe violation (4 points)

Researchers propose to compute an indicator of the animal's welfare by summing the violation points. The sum can take values ranging from 0 (no violation point at all) to 20 (all freedoms have very severe violations).

How many Freedoms are considered in the above model?
[1 2 3 4 5 No answer]

How many violation points can be assigned to a specific Freedom in the above framework?
[1 2 3 4 5 No answer]

Check all the Freedoms of animal welfare that the model contains:

- Freedom from hunger and thirst
- Freedom from discomfort
- Freedom from pain, injury, or disease
- Freedom from fear and distress
- Freedom to express normal behavior

Screen 2 We show you below two examples of how the violation point scheme can be used to assess the welfare of animals.

Imagine that a farmed animal has restricted access to food and water and that the very small amounts of food it has access to are of poor quality and low variety. It lives indoors with many other animals in a confined space that is overcrowded and noisy, without an appropriate place to rest. The ground is covered in animal waste, which releases chemicals such as ammonia. The space lacks appropriate ventilation and control of light and temperature, such that the animal suffers from aversive odours, light intensity, and temperatures. The routine is well-established and there are no unpredictable events. The animal belongs to a rapid-growth strain. The animal lives in an area where there are very limited risks of disease or poisoning. However, because of its rapid growth, the animal suffers from functional impairments, obesity, and poor fitness within its environment. Obesity is also a source of chronic injuries in the form of broken bones. The stall is not enriched, such that the animal has no opportunities to interact with the environment. The harsh living conditions (e.g. unrestricted breeding, resource limitations, lack of refuges) give rise to exclusively negative interactions with other animals, such as aggression without the possibility of escape.

The animal-welfare expert could assign the following grades:

- Freedom from hunger and thirst: very severe violations (4 pts)
- Freedom from discomfort: very severe violations (4 pts)
- Freedom from pain, injury, or disease: very severe violations (4 pts)
- Freedom from fear and distress: very severe violations (4 pts)
- Freedom to express normal behavior: very severe violations (4 pts)

The sum of violations would be 20/20.

Choose one of the following answers:

- The example is very clear
- The example is rather clear
- The example is rather unclear
- The example is unclear

Imagine that a farmed animal has free access to fresh water and drinks in appropriate amounts. It also has free access to food, and the diet is nutritionally well-balanced and contains a variety of food items of diverse texture and taste. The animal lives indoors with outdoor access and has plenty of space to move about freely. The ground is clean and the space contains some relatively comfortable resting areas. The space is well-ventilated and dissipates most odours and air contaminants. The noise, temperature, and light levels are well-controlled throughout the day and night to the levels preferred by the animal. The animal lives in an area where there are very limited risks of diseases or poisoning. The animal has good fitness within its environment and suffers from no functional impairment. Due to the well-adapted environment and provision of health treatments, the animal faces very little risk of injury or disease. The environment is enriched with various opportunities to explore, move around, and make choices. There are a few other animals of the same sex living on the site, with whom the animal can play. There are limited threats or risks of predation, and the animal can retreat into the shelter to rest safely when needed.

The animal-welfare expert could assign the following grades:

- Freedom from hunger and thirst: no violation (0 pts)
- Freedom from discomfort: no violation (0 pts)
- Freedom from pain, injury, or disease: no violation (0 pts)
- Freedom from fear and distress: no violation (0 pts)
- Freedom to express normal behavior: no violation (0 pts)

The sum of violations would be 0/20.

Choose one of the following answers:

- The example is very clear
- The example is rather clear
- The example is rather unclear
- The example is unclear

Screen 3 - Life not worth living framing. We have shown you before two examples of an animal's welfare with extreme violations. The sum of violation points was either at the minimum (0/20) or at the maximum (20/20).

Some people consider that once a given number of violation points is reached, the negative experiences of the animal tend to outweigh the positive experiences such that one could say that its life is no longer worth living.

This threshold value is particularly important because it might justify some intervention to ensure that the animal's life is worth living.

In your eyes, above which number of violation points do you think that the negative experiences of the animal become so important that one would say its life is no longer worth living?

- Life becomes not worth living at 1 violation point and above
- Life becomes not worth living at 2 violation points and above

...

- Life becomes not worth living at 20 violation points and above
- Life is never not worth living

Screen 3 - Negative welfare framing. We have shown you before two examples of an animal's welfare with extreme violations. The sum of violation points was either at the minimum (0/20) or at the maximum (20/20).

Some people consider that once a given number of violation points is reached, the negative experiences of the animal tend to outweigh the positive experiences such that one could say that the overall welfare tends to be negative.

This threshold value is particularly important because it might justify some intervention to ensure that the animal's welfare is positive.

In your eyes, above which number of violation points do you think that the negative experiences of the animal become so important that you would say that the animal has a negative welfare overall?

- Welfare becomes negative at 1 violation point and above
- Welfare becomes negative at 2 violation points and above

...

- Welfare becomes negative at 20 violation points and above
- It is never negative