Animals and Social Welfare

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Abstract

I propose a framework to evaluate the social gains from policies regarding animals. The model considers both the welfare of animals and humans. The gains in animal welfare are estimated by considering the violations of the animals' fundamental freedoms weighted for each species. I apply this framework to twenty policy proposals targeting wild, domestic, farmed, and laboratory animals. Although the policies benefit from widespread popular support in France (the annual willingnesses-to-pay range between 15 and 39 Euros per person per year), I show that they have very heterogeneous impacts on animal welfare (valued at between 0.013 and 3,618 Euros per person per year). I further show that humans' willingness-to-pay for policies improving animal welfare is a poor predictor of the effective impact on animal welfare of these policies. I conclude that it is essential to value animal welfare *per se* in cost-benefit analyses in order to determine the set of welfare-increasing policies.

Keywords: Social welfare, animals, animal welfare, human welfare, public policies, utility potentials, willingness-to-pay, contingent valuation methods.

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1 Introduction

Animal welfare has become a major political concern in Western societies. In the European Union, more than 86% of citizens in each member state consider that it is important to protect the welfare of farmed animals,[1] and the European Commission recently announced a ban on cage farming by 2027.[2] Similar concerns can be seen in the US, where about one in three Americans believes that animals should have the same rights as humans.[3] A recent survey indicates that 40% of the UK adult population considers that animal and human lives are worth the same.[4] The growing attention devoted to animal welfare goes beyond the well-being of farmed animals or pets, and questions our use of animals in numerous areas (e.g., circuses, animal experimentation, hunting, dissection at schools, and dolphin shows and zoos).

However, policymakers who wish to satisfy the aspirations of their citizens face a problem: How can animal welfare be economically valued? Cost-benefit analyses are essential to determine welfare-improving policies and, in a world of scarce resources, prioritize policies. Measures targeting animals therefore compete with other types of policies, and policy makers need a framework with which to value the social gains from improving animal welfare.

A growing number of economists have discussed how animal welfare should be taken into account in social choices. Work in ethology and neuroscience has indeed shown that a wide range of animals, starting with mammals and birds, and more recently reptiles and fish, are sentient, i.e. capable of feelings (Broom, 2019), and some economists therefore recommend considering their well-being when drafting policies. Johansson-Stenman (2018) recently noted that animal welfare has formed part of utilitarian philosophy since its very beginning starting with Bentham (1780) and Mill (1852), and more recently with Singer (1975). Given the considerable influence of the utilitarian framework in economic theory, an increasing number of economists have proposed the introduction of animal welfare into normative economics (e.g., Fleurbaey and Van Der Linden (2021); Carlier and Treich (2020); Kuruc and McFadden (2020)), and therefore into cost-benefit analyses. Although many contributions in Agricultural Economics have estimated the altruistic gains of improving animal welfare via willingness-to-pay (Lagerkvist and Hess, 2011; Clark et al., 2017), conventional cost-benefit analyses still lack the appropriate tools with which to consider the welfare impact on animals themselves. The last major obstacle economic theory faces in including animal welfare in the social welfare function is therefore empirical, i.e. how to define an appropriate method of empirically assessing animal welfare and valuing it economically.

In this paper, I propose a framework to quantify the welfare impact of policies affecting animals. The model takes into account the changes in human utilities following the implementation of a policy, and its impact on animals. The core contribution is to propose a method to economically value improvements in animal welfare in terms that are comparable to human utilities. The valuation of

[1] Source: Eurobarometer, 2016.

[2] `https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_3298`.

[3] `https://www.theguardian.com/world/2015/may/19/americans-animals-human-rights-poll`.

[4] `https://yougov.co.uk/topics/philosophy/survey-results/daily/2021/08/27/efc5e/1`.

human utilities is established from standard willingness-to-pay analyses. The welfare gains for animals are estimated in two steps. I first define a multi-species well-being framework that is inspired by the QALY model for humans. This framework, called the Five-Freedom Fulfillment Index (5FFI), relies on the five fundamental freedoms defining animal welfare recognized by the World Organisation for Animal Health (freedom from hunger/thirst/malnutrition, from fear/distress, from physical discomfort, from pain/injury/disease, and the freedom to express normal patterns of behavior) and evaluates the violations of these that would be prevented by the policies under consideration. Second, I use the recent discussion of *utility potentials* by Budolfson and Spears (2019) to transform the gains in animal welfare into monetary equivalents, using estimates of the number of cortical or pallial neurons for each species.

I then illustrate how this framework can be applied. I review twenty policies aimed at improving animal welfare that were discussed in France in 2020. Using a willingness-to-pay (WTP) study on a representative sample (N=1,485), I estimate the welfare gains for humans from improving animal well-being. I show that, as found in accumulating evidence from surveys, individuals are willing to pay substantial amounts to improve animal welfare (between 15.1 to 39.3 Euros per year per person). I next evaluate the welfare gains for animals using the 5FFI framework and the calibrated utility potentials. The results show a great deal of heterogeneity in the impact on animal welfare between policies, ranging from 0.013 to 3,618 Euros per year per person. Most importantly, I find no correlation between the impact on animal welfare and the WTPs of humans for animal welfare, so that WTP studies fail to capture the overall impact of policies on animal welfare from the animals' perspective.

The proposed model of social welfare offers some flexibility, as it can be adapted to the preferences of policy-makers or updated with new advances in animal science. First, animal welfare can be introduced at different levels of intensity, ranging from zero consideration to equal consideration of human welfare (or even greater consideration). Second, the list of criteria for animal welfare can easily be extended using more comprehensive views of animal well-being. In what follows, I take a conservative approach using the Five-Freedom framework, but future work can expand the definition of animal welfare to other criteria such as positive mental states. Third, new advances in animal sentience and cognition can easily be included by changing the metric used to determine the utility potential, i.e. the relative weight of a species compared to humankind. Similarly, researchers can easily introduce data on animal emotions rather than animal cognition, which is used as a proxy here, to define this potential once large cross-species datasets on emotions become available.

The remainder of the paper is organized as follows. Section 2 sets out the theoretical framework. Section 3 then introduces the application to the twenty policies discussed in France in 2020, and presents the main estimates. Section 4 shows how to apply the theoretical framework based on these estimates and comments on the results, and Section 5 discusses the model. Last, Section 6 concludes.

2 The social welfare of animal-welfare policies

2.1 Defining social welfare

In a recent contribution, Johansson-Stenman (2018) proposes several ways to include animals' interests in social welfare. At one extreme, social welfare is limited to human well-being, and so excludes both animal welfare and the animal-regarding preferences of the human population as in all economic theory to date with the exception of Blackorby and Donaldson (1992). Second, animal well-being can be indirectly taken into account in the social welfare function (SWF), i.e. through the animal-regarding preferences of human beings. Whether the SWF should only include altruistic preferences and exclude prejudicial preferences against animals (i.e. positive utility from animal suffering or being killed) is an open question. Johansson-Stenman (2018) argues that anti-social preferences are usually excluded from SWF when considering human-to-human relationships (Harsanyi, 1977; Sen, 1979; Goodin, 1986). In addition to these altruistic concerns, animals can also be considered in terms of their own well-being and enter the SWF directly, as argued in classic utilitarian philosophy. In this case, the interests of animals may be assigned lesser, equal or greater consideration in the SWF than humans' equivalent interests.

Espinosa and Treich (2021) present a characterization of the SWF in the critical utilitarian framework that includes animal welfare, with social welfare being an additive function of the utility of a representative human agent and a population of animals from a single species. In this setting, the social planner maximizes social welfare by choosing the number of animals raised and killed for human consumption and their rearing conditions. A key element of the SWF is the level of anti-speciesism of the social planner. Depending on the calibration, the social planner could assign a smaller, similar or larger weight to the interests of animals than to the human representative agent.

In what follows, I propose to analyze how a policy improving animal well-being can contribute to social welfare. I adopt a SWF that takes into account the utilities of all humans and all (non-human) animals. Following Espinosa and Treich (2021), I consider the utility of a representative human agent (U) in the population and the overall utility of animals per representative human agent (V).

$$\mathrm{SW}(\alpha) = U + \alpha V \tag{1}$$

where $\alpha \in \mathbb{R}_{\geq 0}$ is the degree of anti-speciesism of the social planner. Anti-speciesism refers here to

the propensity of the social planner to include the welfare of all sentient beings in the SWF.

In this setting, social welfare captures the changes in human utility following the implementation of the policy, which can be either positive, null, or negative (see below). In addition, this SWF allows us to take into account the welfare of animals *per se*, depending on the preferences of the social planner. When the social planner is fully speciest ($\alpha = 0$), the SWF includes animal welfare only through the changes in utility resulting from animal-regarding human preferences. As α increases and the social planner adopts a more pro-animal view of social welfare, animal interests appear in social welfare both indirectly (through human animal-regarding preferences) and directly (through changes in V). When $\alpha = 1$, the social planner is fully anti-speciest: in terms of the metric comparing utility across species, one point of human utility has the same impact as one point of animal utility. Different values of α correspond to normative propositions 2 to 5 in Johansson-Stenman (2018).

2.2 Human utilities

I consider here standard utility functions for humans. The utility function can include self-interest, human-regarding, and animal-regarding preferences. We can express the utility function of the representative agent as follows:

$$U(\omega) = u(c, \pi(\omega), h(\omega), a(\omega)) \tag{2}$$

where c is private consumption, ω is the policy affecting animal welfare, $\pi(\omega)$ is the benefits that the human agent derives from the use of animals, $h(\omega)$ is the human-regarding preferences of the agent, and $a(\omega)$ is her animal-regarding preferences.

In general, self-interested preferences are expected to induce a decrease in utility when the policy becomes more protective of the animals. People might indeed have fewer opportunities to use animals when the policy limits interactions damaging animal welfare. For instance, a policy that restricts intensive farming might lead to a lower amount of consumed meat or might increase prices, which leads to a decrease in $\pi(\omega)$. However, we can also imagine cases where $\pi(\omega)$ is increasing with ω. For instance, intensive farming might contribute to air pollution leading to health externality (Lavaine et al., 2020). In this case, consumers might selfishly benefit from restrictions on intensive farming.

I distinguish two types of other-regarding preferences. First, humans might care about other humans (positively or negatively), which is taken into account by the term $h(\omega)$.[5] For instance, people might anticipate that banning dolphin shows might put some people out of work. If they care about the welfare of other humans (i.e., altruism towards humans), people might then experience a

[5] I assume here that term $h(\omega)$ focuses on the selfish part of the utility of other humans to avoid interdependent utilities (see for instance the Love and Spaghetti puzzle (Bergstrom, 1989)).

decrease in human-regarding utility with the improvement of animal welfare. Alternatively, people could consider that the policy might improve both human and animal welfare (e.g., they think that banning intensive farming would also help workers that have hard working conditions), or they could also show negative preferences for humans (e.g., they dislike hunters and enjoy when hunters' selfish utility is reduced). Second, humans might also have animal-regarding preferences, which are reflected by $a(\omega)$. These preferences can be positive (i.e., altruism for animals) but could possibly be negative (i.e., sadism against animals).

Let us now consider the change of utility associated with a change of policy from ω_0 to ω_1. I note t the change in private consumption that makes the agent indifferent between the original policy (ω_0) and the new policy (ω_1). It can be interpreted as the willingness-to-pay for a change in policy from ω_0 to ω_1. It is defined by:

$$u(c-t, \pi_1, h_1, a_1) = u(c, \pi_0, h_0, a_0) \tag{3}$$

with $\pi_i = \pi(\omega_i), h_i = h(\omega_i), a_i = a(\omega_i)$, for $i \in \{0, 1\}$.

A first-order Taylor approximation of the left-hand side of equation (3) around the original point (c, π_0, h_0, a_0) gives:

$$u(.) - tu_c(.) + (\pi_1 - \pi_0)u_\pi(.) + (h_1 - h_0)u_h(.) + (a_1 - a_0)u_a(.) \simeq u(.) \tag{4}$$

It follows:

$$t \simeq (\pi_1 - \pi_0)\frac{u_\pi(.)}{u_c(.)} + (h_1 - h_0)\frac{u_h(.)}{u_c(.)} + (a_1 - a_0)\frac{u_a(.)}{u_c(.)} \tag{5}$$

In the empirical part below, I use a contingent valuation method survey to estimate the willingness-to-pay for a series of policies. For each policy, I consider the empirical WTP as an estimate of t. It is then clear that the WTPs do not reflect only preferences for animal welfare but net marginal changes in utility where the agent takes into account her private consumption, her use of animals, and her altruistic concerns for other humans and for animals.

For instance, let us consider the case of banning force-feeding in the production of *foie gras*. First, if the policy is implemented, the agent will lose some benefits that she derives from the consumption of *foie gras* (e.g., increase in production costs, contraction of supply). The decrease in benefits is expressed by $\pi_1 - \pi_0 < 0$. The impact on the agent's utility is given by the product of the change in benefits and the marginal impact of π on $u(.)$, i.e. $(\pi_1 - \pi_0)u_\pi(.)$. Next, the impact on the willingness-to-pay is determined by taking into account the marginal rate of substitution between the benefits of animal use (π) and private consumption (c), which yields $(\pi_1 - \pi_0)\frac{u_\pi}{u_c}$. If the agent enjoys the consumption of foie gras, this term will be negative and will thus negatively affect the WTP. Second, the agent might also be affected by the change in the (selfish) utility of other humans (altruistic concerns for other humans). The agent might anticipate for instance that

the ban will put numerous workers out of work, which is reflected by $h_1 - h_0 < 0$. The impact on the WTP is given by $(h_1 - h_0)\frac{u_h(.)}{u_c(.)}$. If the agent is altruistic towards other humans ($u_h > 0$), it will negatively affect the WTP. Last, the agent can anticipate a positive effect of the new policy on the welfare of animals, i.e., $a_1 - a_0 > 0$. The change in the agent's utility is expressed by the last term of the equation, i.e., $(a_1 - a_0)\frac{u_a(.)}{u_c(.)}$. If the agent is altruistic toward the animals $u_a > 0$, it will positively contribute to the agent's WTP.

In what follows, I consider that individuals who expect an increase in their utility ($t > 0$) will support the implementation of the policy. Individuals who have a negative expected change in their utility are assumed to oppose the reform ($t < 0$), and those who expect no change in their utility ($t = 0$) are assumed to be indifferent.

2.3 Animal utilities

In order to discuss animal welfare we require a good estimate of V. Fleurbaey and Leppanen (2021) discuss two possibilities for the evaluation of V. The first is to take the common approach in welfare economics and treat V as a single collection of individual utilities. We here need to calculate the welfare change of each individual affected by a policy and then aggregate them. The second option is closer to the approach used in community biology, and considers *communities* rather than *individuals*. Fleurbaey and Leppanen (2021) explain that there might be different views about whether the individual organism or the collective should be the focus of normative value.

I here propose to use the first approach, which follows the utilitarian tradition as animal welfare is individual-centered. In Public Economics, economists usually consider the utilities of individuals and do not place normative values on the existence of some specific groups. I proceed in a similar way, and consider that individuals, not communities, are able to have positive and negative experiences of the world. However, even in this case Fleurbaey and Leppanen (2021) underline that it might be difficult to evaluate the individual welfare of animals as we cannot rely on prices or WTPs,[6] and animals might have a different balance between mental and non-mental capacities as compared to humans.[7] More generally, it is extremely difficult to establish inter-species comparisons given that biological systems are specific to each species (or groups of species), and behavioral responses and needs are also species-dependent. This issue is known as the *problem of interspecies comparisons* (Budolfson and Spears, 2019).

One development in this problem of interspecies comparison has been proposed by Wong (2016), who considers that interspecies cost-effectiveness analyses should be conducted using a single species-neutral *Standard Welfare Unit* (SWU). The SWU should reflect the interspecies difference in well-being potential and the intraspecies changes in well-being.[8] Budolfson and Spears (2019) build on

[6] Fleurbaey and Leppanen (2021) also criticize the use of price mechanisms to elicit individual welfare in the case of human well-being. They invoke the argument of circularity: prices are both used as a variable to reach an equilibrium and as a valuation tool for utility. So, prices are both used to reflect utilities and to solve a market with conflicting utilities.

[7] Fleurbaey and Leppanen (2021) further distinguish between the two concepts of harm and suffering. I here focus only on the inclusion of animal welfare in the SWF, and do not discuss the potential harm to non-sentient beings.

[8] Wong (2016) further considers the duration of life as an element of the SWU. However, my framework here

this contribution and propose the calculation of a so-called *utility potential* (or well-being potential) that can be used as a weight in aggregating individual utilities to determine social welfare. Utility potentials are defined as a scaling factor that transforms the utility of each species into human-equivalent utilities by taking into account the potential for positive and negative experiences of the World, at both the positive and negative margins. The authors propose a metric n that would be correlated with the well-being potential, and the use of the ratio between the score of a species s (n_s) and the score of humans (n_h). In their framework, the *utility potential*, which I denote by ϕ_s, is given by $\frac{n_s^\psi}{n_h^\psi}$. The parameter ψ is said to reflect normative uncertainty about the connection between the empirical proxies and well-being capacity. Empirically, when humans have larger scores ($n_h > n_s$), a larger ψ is associated with a greater value placed on humans than on animals. By default, the utility potential of humans is standardized to 1. I discuss below the calibration of ψ and the choice of the metric n.

In what follows, I decompose the change in animal well-being that follows from the implementation of a policy (ΔV) into the sum of the changes in the (standardized) animal utility of all species weighted by the utility potential factor ϕ_s. This yields:

$$\Delta V = \sum_s \phi_s \sum_i \Delta v_i^s \tag{6}$$

where Δv_i^s is the change in standardized utility of animal i from species s resulting from the implementation of the policy. Note that ΔV is expressed in monetary units.

2.3.1 The Five-Freedoms Fulfillment Index

The estimation of a policy's impact on animal welfare therefore requires two elements: the individual changes in standardized utility among animals (Δv_i^s) and the utility potential of each species (ϕ_s). Setting out a unique criterion (or set of criteria) for the comparison of the changes in well-being for individuals of different species is complex, as the biological needs (and thus utility) of each individual depend on its species. However, it is possible to define a general framework to help evaluate the suffering of animals that policy makers or researchers can apply to specific situations, taking into account the particularity of the species under consideration.

To this end, I propose to bring together two approaches that are regularly used to assess welfare: the QALY, used for humans, and the Five Freedoms, used for animals. QALYs were developed in cost-benefit analysis to evaluate the welfare impact of health impediments for humans (Weinstein et al., 2009; Nord et al., 2009; Anderson and Phillips, 2009; Whitehead and Ali, 2010). The quality-adjusted life-year (QALY) is used to measure the quantity and quality of life, and assigns weights to different health states that reflect the quality of human life. A year in perfect health is assigned a score of 1, while death has a score of 0. Intermediate scores reflect health problems, and negative

focuses on yearly costs and benefits, so that I will mostly overlook this part of the SWU function. I will briefly discuss longevity in Section 5.5 below.

scores are associated with health states that are worse than death. One QALY unit is therefore a year of (human) life in perfect health.

The Five Freedoms is the best-established framework for the evaluation of animal welfare across species. Developed in 1965 (Brambell, 1965), the Five Freedoms are a list of freedoms that are considered to be essential for the respect of animal welfare. These Freedoms are recognized by the World Organization for Animal Health, which has 182 member States.[9] This list includes: (i) freedom from hunger, malnutrition, and thirst; (ii) freedom from fear and distress; (iii) freedom from heat stress or physical discomfort; (iv) freedom from pain, injury, and disease; and (iv) the freedom to express normal patterns of behavior. The Five Freedoms are sometimes perceived as too narrow,[10] and some researchers propose considering animal welfare in terms of whether the associated life is worth living (Mellor, 2016a; Espinosa and Treich, 2021). Even so, the Five Freedoms are generally considered as providing the necessary (although perhaps not sufficient) conditions to ensure animal welfare (McCulloch, 2013). While these freedoms may be somewhat restrictive, many of the actors involved recognize them as a relevant measure of animal welfare, either as an upper bound (farmers and policy-makers) or a lower bound (activists and ethologists).

I therefore propose to define a method similar to the QALY based on the Five Freedoms. Inspired by the EQ-5D method for QALY, I define levels of violation of each of the Five Freedoms: None (0), Mild (1), Moderate (2), Severe (3), and Very Severe (4). Similarly to the QALY approach, I calculate a score called the Five-Freedoms Fulfillment Index (5FFI) that is standardized to 1 when all freedoms are satisfied and 0 for death. An animal's welfare status is then expressed as a series of five digits (the 5FFI status) that we then map onto a numerical value (the 5FFI score). The satisfaction of all freedoms produces a welfare status of "00000" and a 5FFI score of 1.

The main advantage of this approach is that it allows us to compare the changes in animal welfare for different species based on the universal Five-Freedoms criteria but still leaves room for the interpretation of what constitutes mild, moderate or severe violations in the light of the biological needs of each species. This leeway may produce somewhat arbitrary outcomes, but is necessary for an approach that is sufficiently flexible to account for a variety of biological identities.

This approach aims to offer an improvement compared to models previously developed in the literature. First, previous work has attempted to define animal-welfare metrics but it has either focused on a single specific health condition (e.g., Freeman et al. (2005); Lynch et al. (2011); Freeman et al. (2012); Iliopoulou et al. (2013); Noli et al. (2016)) or on one species only (e.g., Bijsmans et al. (2016) for cats, and Schneider et al. (2010); Teng et al. (2018) for dogs). These models cannot easily be generalized for a large set of animals and for a wide range of situations and environments as they were developed for specific diseases or species.[11] On the contrary, the 5FFI is thought to be

[9] `http://web.archive.org/web/20210622075306/https://www.oie.int/en/what-we-do/animal-health-and-welfare/animal-welfare/`.

[10] See below for a discussion of the limitations of the Five Freedoms framework.

[11] An important contribution is Teng et al. (2018) who use the Five Domain framework that I discuss in the Discussion section below. However, the model is developed for canine diseases only. The main issue for generalization is that the paper trade off quality and quantity of life, which is an important point, but which necessitates taking into account the lifespan of each species under consideration. It is however a major question for future works in the

applied to a wide range of species (taking into account particularities associated with each need) and for a wide range of situations (e.g., pets, farmed or wild animals). Second, Weathers et al. (2020) propose one of the most elaborate attempts to measure changes in animal welfare across different species and different conditions. The authors develop a species-adjusted measure of suffering-years (SAMYs), which is an analog of disability-adjusted life years. They then use their method to estimate the social cost of animal farming practices in the US. The main innovation of this work is to provide an estimate of the change in animal suffering. However, an important limitation is that this model does not consider the needs of the animals (unlike the other works cited above) but relies on lay people's expectations of the changes in animal suffering, which might be more sensitive to anthropocentrism, anthropomorphism, and, more globally, limited knowledge about what matters for animals of different species.[12] On the contrary, the 5FFI starts from models developed in animal science that defines the elements that matter for the welfare of animals. Altogether, the 5FFI model that I develop here aims at combining the advantages of the two streams of models by estimating the level of welfare for a wide range of species in a large set of situations taking into account the needs of the animals identified by animal experts.

Two choices have to be made for the model's implementation. First, the QALY approach estimates the impact of each health restriction on welfare empirically (e.g., via surveys). This is not possible for the 5FFI, as animals cannot report their welfare. The 5FFI model instead allows each expert to decide what constitutes mild, moderate, severe, and very severe violations for each species. For simplicity, I will assume that each additional unit of violation has the same impact on the 5FFI score. This can be relaxed in future work to allow for different weights, but the assumption does not affect the general approach here. This has a useful property: it allows assessors (policymakers, researchers, practitioners) to calculate changes in the 5FFI score as the change in the number of violation points but does not require them to agree on the initial or final welfare status of the animals under consideration.[13] This approach is similar to the *misery score* that is sometimes used in the QALY literature to summarize the welfare status of an individual. Empirically, we tend to observe a linear relationship between the QALY utilities and the misery score (Pickard et al., 2019).

Second, as in the QALY approach, I define death as corresponding to a 5FFI score of 0. However, to make the model implementable we require an equivalence between death and other violations: At which point is death preferable to suffering? I here assume that animals are indifferent between death and the severe violation of all of their freedoms ("33333"),[14] so that animal lives with at least

field.

[12] Another limitation of Weathers et al. (2020) concerns the possible cognitive biases that might affect the answers to the survey. For instance, scope insensitivity can lead respondents to undervalue the welfare gains in situations with a large number of animals. For instance, the report welfare gains of saving 2,000 animals would not be equal to twice the welfare gains of saving 1,000 animals. It is therefore important to value animal welfare at the individual level.

[13] For instance, two people may agree that the violation score is two points lower, but not on initial and final welfare. One may think that we have moved from moderate to no violation (2 violation points avoided), while the other that we have moved from severe to mild violation (again, 2 violation points avoided).

[14] Assuming that death is equivalent to all violations being severe allows for welfare statuses to which death is

severe violations of all freedoms and very severe violations in at least one are not worth living.

The 5FFI index is then:

$$5\text{FFI} = \frac{15 - \sum_j w_j}{15} \tag{7}$$

where the w_j's are the violation scores for each of the Five Freedoms so that the 5FFI takes on values between 1 (no violations) and $-\frac{1}{3}$ (all violations are very severe), as depicted in Figure 1.

In what follows, I decompose the changes in standardized utility Δv into two parts: $\Delta v = q\Delta\zeta$. Here $\Delta\zeta_i$ is the gain in the 5FFI score for animal i from the implementation of the policy, which from the above takes on values from 0 to $\frac{4}{3}$.[15] The scaling parameter q allows us to monetize the reduction in harm, $\Delta\zeta$. To calibrate q, I propose the following equivalence, assuming that we evaluate policies on an annual basis (and so calculate the yearly gains). When the avoided harm is death, we set by definition $\Delta\zeta = 1$, so that the value of one year of living in good health for an animal compared to death is q before normalization. When converted into human-equivalent utility, the value of one year of life in perfect health for an animal is $\phi_s q$. When the animal at stake is a human, we have $\phi_s = 1$, so that q is the monetary value of losing a year of life in perfect human health, and by definition is one unit of QALY. We can therefore use estimates of a QALY unit to calibrate q.

2.3.2 Utility potentials

We next need to determine the ϕ parameters that account for the utility potential of each species. We first note that the notion of *utility potential* proposed by Budolfson and Spears (2019), or the equivalent concept of *hedonistic capacity* in Wong (2016), differs from the issue of sentience commonly used by animal and ethics experts regarding animal welfare. The general idea of sentience is the capacity to have feelings (Broom, 2019). More particularly, it encompasses the ability "to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risks and benefits, to have some feelings, and to have some degree of awareness" (Broom, 2016, p.2). Sentience can be seen as a binary concept that "requires a level of awareness and cognitive ability" (Broom, 2019, p.1). Numerous animals have been found to be sentient, including mammals, birds, fish, molluscs, and decapod crustaceans (Broom, 2007).

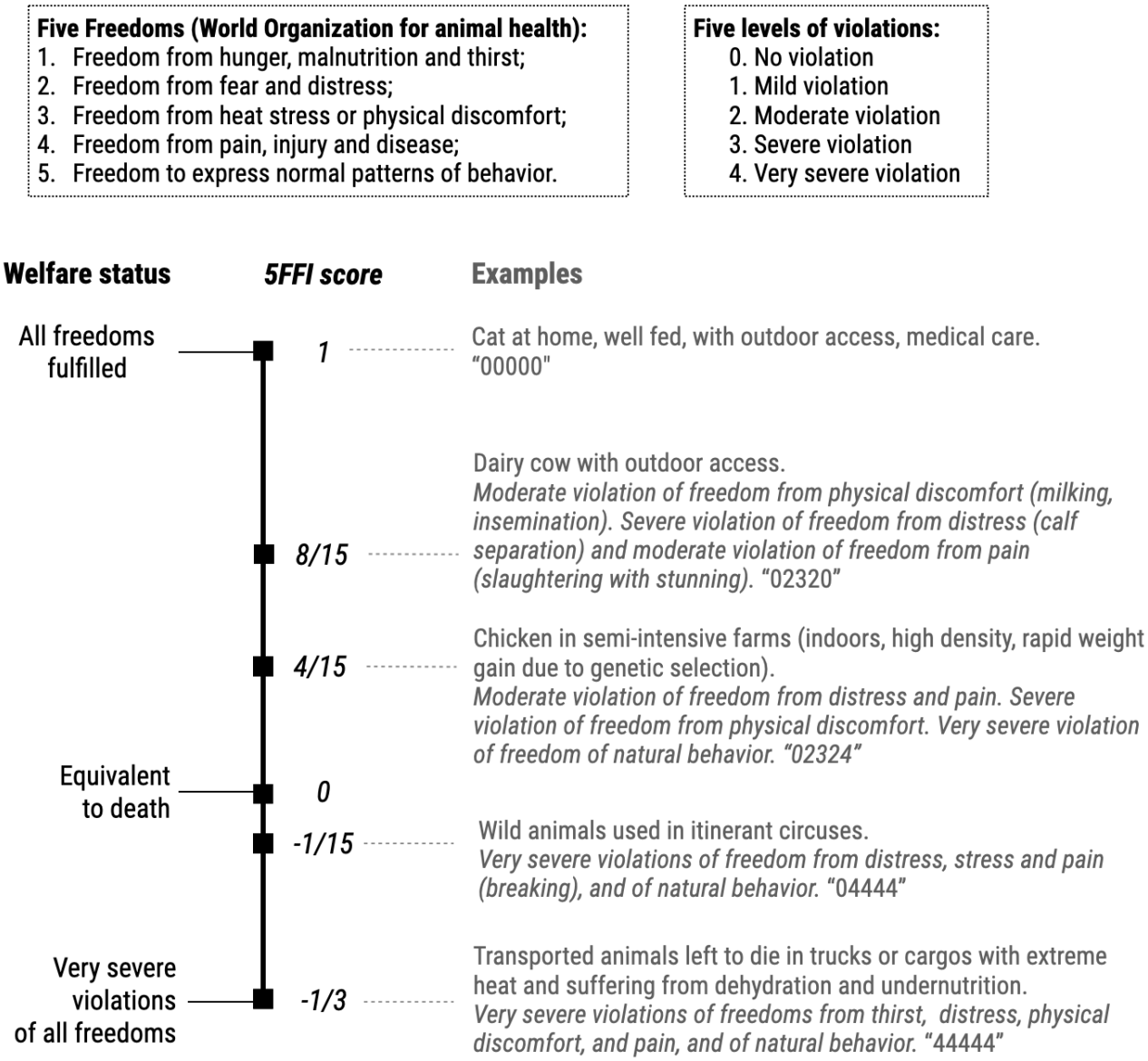
Utility potential differs from sentience insofar as sentience refers to the *capacity* to have subjective experiences of the World (a binary construct[16]), while utility potential refers to the "difference between species' varying abilities to realize both pleasures and pains" (Wong, 2016, p.14). In other words, I see sentience as an extensive concept (*whether* an animal can experience the World sub-

preferable. This is also the case for QALYs. In Espinosa and Treich (2021), a majority of people consider that death is preferable to industrial farming for some animals.

[15] Note that the lower bound depends on the specification of the equivalence of death, as this determines the reference point 0.

[16] The question of sentience as a binary construct has recently been discussed in Birch (2018) and Lee (2020).

Figure 1: The Five-Freedoms Fulfillment Index.



jectively), whereas utility potential is intensive (the extent to which individuals from a species can experience the World subjectively). Utilitarian philosophers like Peter Singer argue that the interests of all sentient beings should be taken into account in moral decisions (i.e. in the social-welfare function) and that equal interests should receive equal consideration. Utilitarians would therefore be interested in Standardized Welfare Units, which are more closely related to the question of *utility potential* than sentience.

The objective here is to find a good metric that is correlated with utility potentials. Research on animal sentience has mainly sought to determine whether an animal is sentient, i.e. whether we detect a minimal level of sentience in a given species. The binary outcome here does not allow for interspecies comparisons, as it does not represent the intensity or range of subjective experiences of which sentient beings are capable.

One way to measure utility potential is to find a variable that is correlated with it, i.e. a proxy. A first approach in Budolfson and Spears (2019) is the number of neurons. Given that more-complex emotions require greater levels of cognition, a cognition proxy will likely be correlated with utility potentials. However, recent work in cognition has shown that neurons in the sensory-associative structure are a better predictor of the capacity to have a subjective experience of the World. This subset of neurons, found in the cerebral cortex for mammals and in the pallium for birds, has been shown to correlate with cognition measurements (Herculano-Houzel, 2017). Cortical and pallial neurons are also associated with greater longevity via postponed aging (later sexual maturity) and higher survival rates due to increased cognitive capabilities (Herculano-Houzel, 2019). In what follows, I consider the number of cortical / pallial neurons in animals, denoted by n, as a cognition proxy in order to calculate the ϕ utility potentials. The sources of data on cortical/pallium neurons are presented in Supplementary Materials 1, and Table 1 presents a summary of the data that I consider.

Table 1: Estimates of the number of cortical / pallial neurons by species.

Animals and number of cortical/pallial neurons (10^6)			
Human: 24526	Elephant: 5508	Killer whale: 4729	Baboon: 2990
Giraffe: 2440	Dolphin: 2366	Macaque: 1441	Hippo: 1318
Tiger: 1182	Parrot: 1129	Lion: 1081	Bison: 831
Bovine: 790	Horse: 790	Zebra: 790	Hyena: 782
Panther: 686	Emu: 619	Wolf: 584	Pig: 554
Fox: 528	Dog: 528	Fox: 528	Lemur: 517
Sheep: 504	Wallaby: 287	Cat: 198	Badger: 198
Rabbit: 101	Hen: 86	Duck: 86	Goose: 86
Turkey: 86	Mink: 75	Rat: 44	Mouse: 19

Following Budolfson and Spears (2019), I use the following transformation function to map the number of cortical / pallium neurons to utility potentials: $\phi_s = \frac{n_s^\psi}{n_h^\psi}$. This poses two challenges: the parametric assumption of the transformation function and the calibration of the parameter ψ.

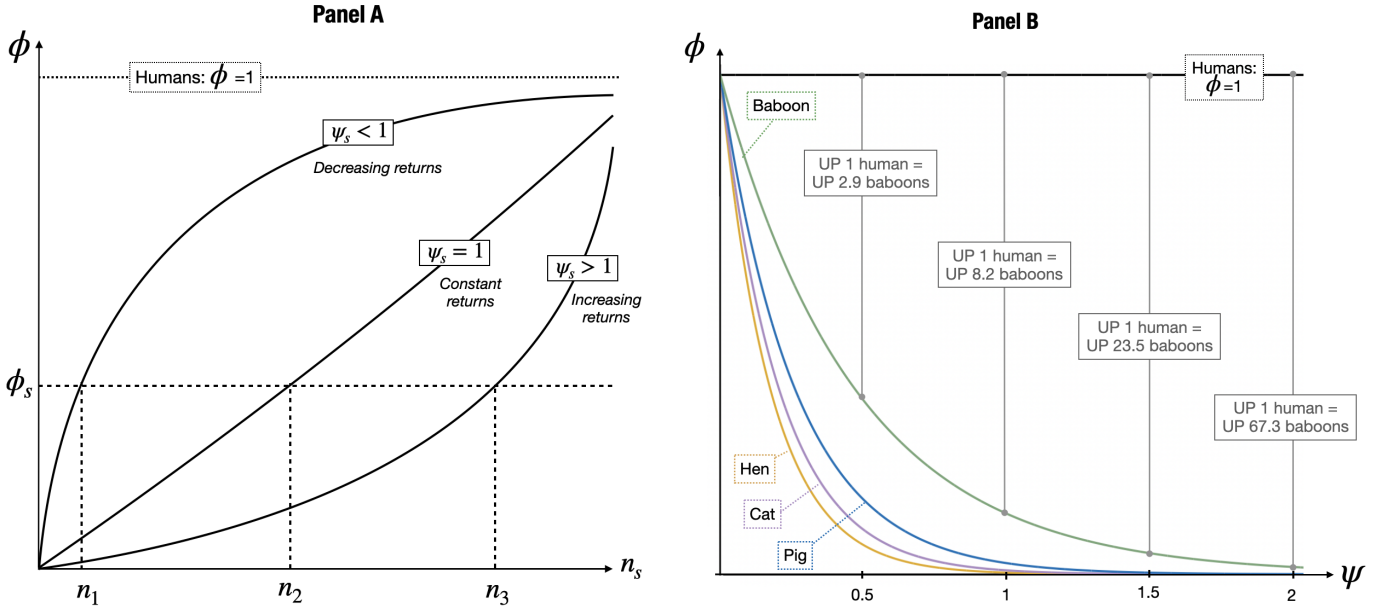
First, note that this transformation function makes parametric assumptions about the relationship between our measure and the utility potential. This has no justification from a neuroscience or ethology perspective, as we are not (and maybe will never be) able to directly assess utility potential, and so do not have evidence in favor of one type of association over another. The proposal in Budolfson and Spears (2019), although arbitrary and imperfect, is a starting point from which economic theory can build and that can be improved on in the future.

Second, we face the highly-complex (and sensitive) question of calibrating ψ. I suggest doing so by considering the resulting implications for the relationship between cortical / pallial neurons and utility potentials. The first derivative of the transformation function is $\frac{\partial \phi_s}{\partial n_s} = \frac{\psi n_s^{\psi-1}}{n_h^{\psi}}$. For all values of $\psi > 0$, this function assigns larger utility potentials to animals with more neurons, which conforms to what we observe in reality: more-complex emotions require greater cognition. Second, the second derivative ($\frac{\partial^2 \phi_s}{\partial n_s^2} = \frac{\psi(\psi-1) n_s^{\psi-2}}{n_h^{\psi}}$) reflects the increasing, constant, or decreasing returns to the number of neurons on sentience. $\psi > 1$ corresponds to increasing returns to scale: the more cortical / pallial neurons (n_s), the greater the gain in utility potential from an additional neuron ($\frac{\partial^2 \phi_s}{\partial n_s^2} > 0$). On the contrary, with $\psi < 1$ ($\psi = 1$), there are decreasing (constant) returns to scale. The latter implies that an additional cortical / pallium neuron has the same effect on utility potential as the preceding neuron, while decreasing returns to scale imply that the effect of an additional neuron is less than that of the preceding one. Panel A of Figure 2 provides a graphical representation of the impact of ψ on utility potentials, with a given level of utility potential being more rapidly achieved with lower values of ψ.

Choosing ψ is therefore equivalent to choosing the concavity of the potential utility function. Animal-science research tends to show that sentience is rapidly obtained in taxa with a relatively small number of neurons. For instance, sentience has been detected in fish and, recently, insects. Basic emotions are thus found in animals with a limited number of neurons, while complex emotions such as grieving can be found only among mammals with large numbers of neurons (e.g., primates and elephants). This suggests that fundamental levels of utility potentials (e.g., basic emotions) may only require relatively few neurons, while higher levels of utility potentials (e.g., complex emotions) are much more costly to acquire (in terms of neurons), supporting $\psi < 1$. In the application below, I assume $\psi = 0.9$ and discuss the robustness of the framework concerning this assumption.

Last, we can note that the parameter ψ affects the human-to-animals comparisons by changing the relative utility potentials of animals compared to humans. However, this impact is different from how α affects the consideration of animals in the social-welfare function. The parameter α accounts for the fact that, *for similar interests*, one might give priority to humans compared to non-humans, which defines *speciesism*. The parameter ψ accounts for the unknown relationship between the retained metric (here the number of cortical / pallial neurons) and the utility potential, i.e. *what can be considered as similar interests* across species.

Figure 2: Illustrations of utility potentials as a function of the value of the metric n (Panel A) and the ψ parameter (Panel B).



3 Application: Twenty Policies for Animals

3.1 Background

Animal welfare has received growing attention in French politics in recent years. A 2016 report from Parliament pointed out the violations of animal-welfare standards in abattoirs.[17] A 2018 Law subsequently increased the protection of farmed animals in transport and abattoirs and prohibited the construction of new cage-farming facilities.[18] In early 2020, the French Prime Minister commissioned an advisory report on the welfare of pets in France. Later the same year, a group of NGOs and activists proposed a referendum containing six policies targeting animal farming, hunting, animal experimentation and animal use in shows (circuses and dolphinariums). A large majority of French citizens (73%) supported the organization of this referendum.[19] In Fall 2021, the French Parliament passed a bill to fight against animal abuse which targeted domestic, farmed, and wild animals kept in captivity.

At the same time, a research project was jointly launched by the largest French University covering public affairs (SciencesPo) and the French National Institute for Scientific Research (CNRS) to evaluate the legislative opportunities to improve animal welfare in France. This project, which I led, aimed to identify the most-effective and consensual policies on animal welfare that were proposed by French NGOs.

The project, entitled *Twenty Policies for Animals*, was published in July 2020 and proposed

[17] Falorni Report, 2016. `https://www.assemblee-nationale.fr/14/rapports/r4312.asp`.

[18] Loi EGALIM. `http://web.archive.org/web/20210803063816/https://agriculture.gouv.fr/egalim-des-mesures-pour-lutter-contre-la-maltraitance-animale`.

[19] Survey by the polling institute IFOP on a representative sample of the French population, July 29th 2020.

a list of twenty policies that could be implemented by the State to improve animal welfare (see Table 2). These were grouped into ten categories: animal experimentation, child education, pets, trade, shows, hunting, farms and abattoirs, cattle, poultry, and swine. The bundle of measures was supported by 13 Members of Parliament from different parties (from extreme-Left to Right-wing) and 22 animal-welfare NGOs.

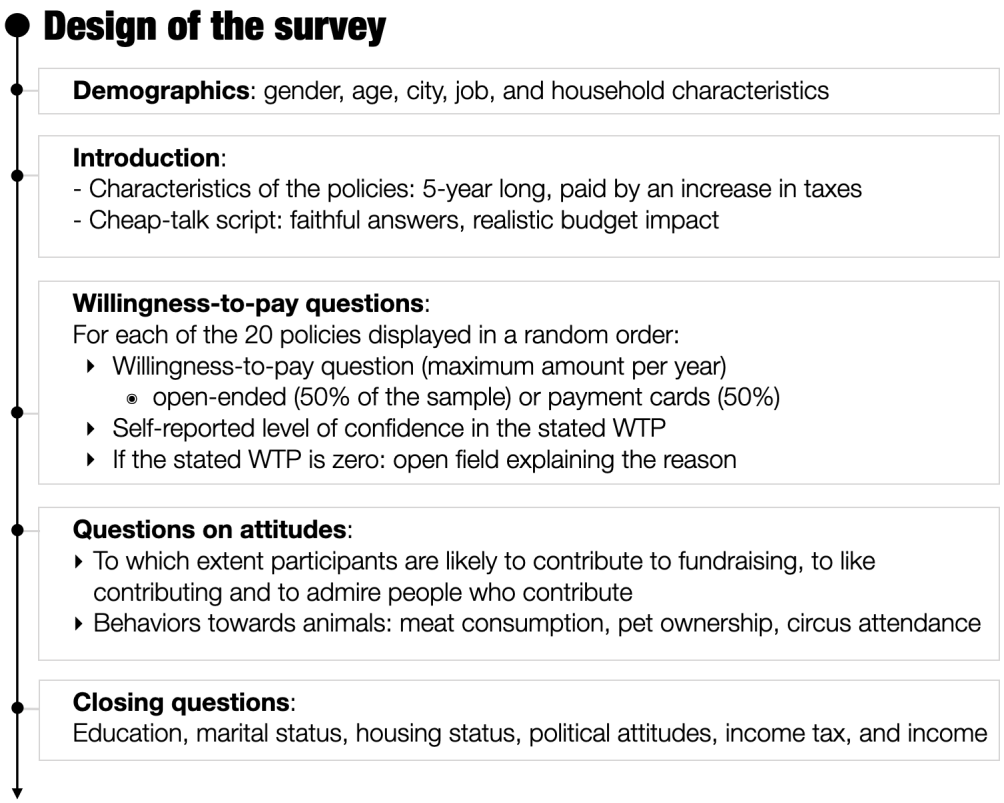
Table 2: List of policies proposed by the project *Twenty policies for the animals*

Category	Policy
Experimentation	Involve specialists in animal-free experimentation methods in all animal experimentation ethics committees
Experimentation	Prohibit the dissection of animals in primary and secondary education
Education	Introduce a daily plant-based menu in all school canteens
Education	Set up an animal ethics course in school curricula
Pets	Conduct sterilization campaigns for stray cats
Pets	Make the first visit to veterinary clinics free and compulsory to identify pets
Trade	Establish mandatory labeling of egg products according to the system already in place for eggs
Trade	Ban the production and sale of fur in France
Shows	Subsidize circuses for their conversion into shows without animals
Shows	Prohibit the reproduction and acquisition of dolphins and killer whales in dolphinariums
Farms and abattoirs	Prohibit industrial farming of the "farm-factory" type
Farms and abattoirs	Prohibit slaughter without stunning
Cattle	Improving the share of fibers in calves' diet to fight against deficiencies
Cattle	Improve calf bedding by introducing edible elements
Hunting	Prohibit the digging up of badgers and foxes
Hunting	Prohibit any form of hunting of animals kept in captivity
Poultry	Prohibit the breeding of laying hens in cages
Poultry	Prohibit force-feeding in the production of foie gras
Swine	Ban the use of carbon dioxide to stun and kill pigs in favor of other alternatives
Swine	Ban on tooth cutting in piglets and replacement by tooth grinding

3.2 Survey design

The willingnesses-to-pay (WTPs) of the French population for the 20 policies were evaluated via a survey (using the contingent evaluation method) in March 2020. The survey consisted of the five parts summarized in Figure 3. Participants first reported demographic information (gender, age, city, job, and household characteristics). Second, the survey displayed the instructions for the WTP questions. Respondents were told that they were going to see a list of policies, and that they should state how much at most they would be ready to pay per year to implement each policy. The yearly payment was said to last for five years via higher taxes. I also introduced a cheap-talk script to

Figure 3: Summary of the survey



reduce the impact of a possible hypothetical bias, as is standard practice in the literature (Carlsson et al., 2005).[20] In the script, I asked participants to answer as truthfully as possible, and to consider the impact the policies would have on their budget.

The survey next presented a series of 20 screens for the 20 policies in turn, including a short statement explaining each one. To avoid order effects, these policies appear in random order at the individual level. Participants reported their WTP on each screen. Half of the participants were randomly assigned to an open-ended questionnaire (for the entire survey) and entered a numeric value; the other half reported their WTP using payment cards (0 Euros, 0.01-0.99 Euros, 1-1.99 Euros, 2-2.99 Euros, ..., 9-9.99 Euros, over 10 Euros).[21] All participants with zero WTP for a given

[20]Previous work has discussed how the hypothetical nature of WTP surveys may lead participants to overstate their WTP (Carlsson et al., 2007). While the literature has shown mixed evidence of this hypothetical bias (Carlsson and Martinsson, 2001; Cameron et al., 2002; Johansson-Stenman and Svedsäter, 2012; Lusk and Hudson, 2004; Alfnes and Steine, 2005), Clark et al. (2017) find in their meta-analysis that cheap-talk scripts help reduce stated WTPs, so that they can mitigate this potential bias.

[21]The survey contained two elicitation formats (random assignment). More generally, the literature on contingent valuation method distinguishes four types of elicitation methods (Fonta et al., 2010). The open-ended approach, the bidding-game technique, the payment card approach, and the dichotomous choice format. The dichotomous choice format conveys very little information about the respondents' WTP as they only answer whether they are willing to pay a given amount of money. The bidding-game technique is a succession of dichotomous choices. It yields more information but it is not implementable for a significant number of policies as we have here. The payment card approach allows participants to choose the preferred option in a list of choices. It has the advantage of helping participants choose by offering more context but it is sensitive to range bias, i.e., the cards that the researcher

policy were asked to explain their decision using an open-ended question.

Participants were finally asked a series of questions on attitudes and socio-economic characteristics. Respondents indicated the extent to which they usually contribute to fundraising campaigns to which they feel close they admire people who contribute to fundraising campaigns for environmental programs and animals, and whether they are happy when they contribute financially to fundraising campaigns. Participants also reported their frequency of eating meat, whether they own a cat or dog, and whether they had gone to a circus or a park with dolphins the previous year. The socio-economic variables covered education, marital status, income, housing status, and whether the respondent pays income taxes. The entire survey is reproduced in Supplementary Materials 2.

3.3 Sample

Data collection was carried out by the private French polling institute *Opinionway*. This is one of the leading companies for polls in France and runs web-based surveys only. The survey was computerized using the firm's dedicated application. The company was asked to recruit 1,500 survey participants randomized over the two versions of the survey (payment cards vs. open-ended). A total of 1,485 exploitable questionnaires were completed. The polling institute supplied sample weights with the dataset to produce a representative sample of the French population.

The weighted representative-sample characteristics appear in Table 3. There are 52.6% women and 47.4% men, and all age categories over 18 are represented. Low-income individuals do not pay income tax in France, and only 56.3% of the weighted sample do so. About half of the (weighted) participants live in large cities (over 100,000 inhabitants), and 23.8% in small towns (under 2,000 inhabitants). One quarter of the sample did not finish High School (25.4%), another quarter stopped after High School (24.4%), 31.7% have two or three years of Higher Education, and 18.4% attended University for 4 years or more. Most of the respondents are either single (22.4%) or married (43.4%), and two-person households are the most common (38.7%). A majority of participants are homeowners (61.2%) and have no children aged under 18 in the household (62.8%).

As far as animals are concerned, a majority of respondents in the weighted sample have pets (52.7%), consistent with previous figures.[22] A large majority of respondents (90.3%) did not attend any shows involving animals (circuses or dolphinariums) in the year preceding the survey. 6.3% of the weighted sample is vegetarian, in the sense that they eat meat less than once a month, which is also consistent with previous surveys finding 5.2% vegetarians and vegans in France.[23] About one-third of participants eat meat every meal or every two meals (37.9%), while most eat meat between one and four times a week (51.8%).

proposed (Heinzen and Bridges, 2008). The open-ended technique does not influence respondents but gives less context to the participants. Some works find that the open-ended technique leads to more conservative estimates (Johannesson et al., 1991; Whynes et al., 2004) while others find the contrary (Heinzen and Bridges, 2008).

[22] https://www.ifop.com/publication/tel-maitre-tel-chien-ou-chat-les-francais-et-leurs-animaux-de-compagnie/.

[23] https://www.franceagrimer.fr/fam/content/download/62309/document/11_Synth%C3%A8se%20Panorama%20v%C3%A9g%C3%A9tarisme%20en%20Europe.pdf?version=1.

Table 3: Descriptive statistics of the survey sample (weighted)

Description	Values
Sample size	1,485
Gender	Female (52.6%) Male (47.4%)
Age distribution	18-24 (9.3%), 25-34 (15.5%), 35-49 (25.7%), 50-64 (25.3%), 64+ (24%)
Pay income tax	No (43.7%), Yes (56.3%)
City size	Fewer than 2000 inhabitants (23.8%), 2000-20,000 (16.6%), 20,000-100,000 (12.4%), 100,000+ (30.5%), Paris (16.8%)
Education	No High-School diploma (25.4%), High-School diploma (24.4%), Bachelor (2 or 3 years) (31.7%), Masters degree (4 or 5 years) or Ph.D. (18.4%)
Marital status	Single (26.1%), Married (43.4%), Partnership (13.5%), Civil partnership (6.1%), Divorced (8.4%), Widowed (2.5%)
Size of household	1 (22.4%), 2 (38.7%), 3 (18.1%), 4 (13.8%), 5 (5.6%), 6+ (1.4%)
Home-ownership	Owner (61.2%), tenant (31.0%), free accommodation (7.8%)
Children at home	None (62.8%), 1 (18.4%), 2 (13.8%), 3 (18.4%), 4+ (8.1%)
Pet owner	Yes (52.7%), No (47.3%)
Visited circus or dolphinarium last year	Yes (9.7%), No (90.3%)
Meat consumption	Every meal (10%), every two meals (27.9%), two to four times a week (40.6%), once a week (11.2%), two to three times per month (3.9%), once a month or less (6.3%)

3.4 Estimation and inference

I take a number of approaches to estimate average WTPs. I first assume a zero-inflated log-normal WTP distribution, as is standard in the contingent valuation literature (e.g., Bennett et al. (2019)). In this sample, the empirical distribution of the WTPs is close to (winsorized) log-normal (see for instance Appendix Figure B2).

Second, WTP measurement is sensitive to the elicitation method in the survey. The questionnaire applies two methods: open-ended questions and payment cards. Both have pros and cons: open-ended WTP questionnaires do not influence respondents, but the latter may become confused and declare unrealistic WTPs; payment cards may help participants to report more realistic WTPs but the set of intervals available might bias their answers, as it conveys information on the researcher's expectations. Survey participants were randomly assigned to one of the two treatments. In the rest of the analysis, I estimate the WTPs in the pooled dataset assuming the same distribution of WTPs under the two treatments. This approach is similar to the "hybrid" model used in the QALY literature (e.g., Andrade et al. (2020)) in which researchers estimate a single utility function by combining the data from two elicitation methods. [24] To further limit the influence of

[24]The general motivation for the hybrid method is that several elicitation methods might aim to assess the same underlying phenomenon but might yield different results. When there is no objective way of discriminating which method yields the most accurate estimates, combining the results of different elicitation methods is expected to limit the risks associated with one specific method. In our case, while the payment card approach is likely to influence participants, the open-ended questionnaire leaves them unbiased. However, while the open-ended questionnaire gives little context to help participants report a WTP, the payment card system gives them a more structured framework.

unrealistic WTPs in the open-ended questionnaire, I winsorize the data above 10 Euros.[25]

I estimate WTPs via maximum likelihood. Let y_i be the reported WTP, ω_i the sampling weight of individual i, and X_i the vector of variables associated with individual i. I denote by $h(.)$ the probability density function (PDF) of the log-normal distribution, and $H(.)$ the associated cumulative distribution function (CDF). Moreover, I denote by Z_i the variable accounting for zero inflation (i.e. that equals 1 if observation i results from zero inflation and zero otherwise). I assume that the zero-inflation process follows a normal distribution (probit), where $f(.)$ and $F(.)$ denote respectively the PDF and CDF. Last, Q_i denotes a dummy with value 1 for the individual i answering the open-ended questionnaire and 0 if she answered the payment-card survey.

The contribution to the likelihood function of the zero reported WTPs is the (weighted) probability of having a zero-inflated observation or a WTP below 0.01 Euros: $L_i = Pr(Z_i = 1|X_i) + Pr(Z_i = 0|X_i)Pr(y_i < 0.01|X_i)$. For strictly-positive reported WTPs under 10 Euros, the likelihood contribution depends on the elicitation method. For the payment cards, the reported WTPs lie in an interval. Denoting by $\overline{y}_i$ and $\underline{y}_i$ the upper and lower bounds of the interval for observation i, the contribution to the likelihood is: $L_i = Pr(Z_i = 0|X_i)[Pr(y_i \leq \overline{y}_i|X_i) - Pr(y_i > \underline{y}_i|X_i)]$. On the other hand, the likelihood contribution from the open-ended questionnaire is: $L_i = Pr(Z_i = 0|X_i)Pr(y_i|X_i)$. Last, the contribution to the likelihood for reported WTPs over 10 Euros is: $L_i = Pr(Z_i = 0|X_i)Pr(y_i > 10|X_i)$.

The overall likelihood function is then:

$$\begin{aligned} LL = \sum_i \omega_i \{ & \mathbb{1}_{\{y_i \leq 0.01\}} \ln[F(\gamma X_i) + (1 - F(\gamma X_i))H(0.01|\theta X_i)] \\ & + \mathbb{1}_{\{0.01 \leq y_i \leq 10\}} \ln[(1 - F(\gamma X_i))\{Q_i h(y_i|\theta X_i) + (1 - Q_i)(H(\overline{y}_i|\theta X_i) - H(\underline{y}_i|\theta X_i)\}] \\ & + \mathbb{1}_{\{y_i \geq 10\}} \ln[(1 - F(\gamma X_i))(1 - H(10|\theta X_i))]\} \end{aligned} \tag{8}$$

where γ is the vector of coefficients (including a constant term) associated with X for the zero-inflation stage, θ is the vector of coefficients (including a constant term) for the log-normal distribution, and $\mathbb{1}$ are dummy variables for the outcome y_i satisfying the associated condition.

3.5 Average WTPs for individual policies

I first estimate the average WTPs of individual policies using an intercept-only regression model.[26] Given that the observations are weighted to produce a representative sample, the results are estimates of the average WTPs in the French population. These WTPs are estimated as the product

[25] I winsorize here data above 10 Euros to limit the influence of extreme values in the answers. For instance, some participants report indeed being willing to pay 1,000 Euros yearly to have a single policy implemented. Overall, between 22.7% and 33.6% of the answers in the open-ended questionnaire are winsorized. I show below a robustness check in which I change the winsorizing threshold to 20 and 30 Euros. In the 30-Euro case, the shares of winsorized observations range from 13.5% to 21.5%.

[26] I estimate a model with demographics and controls in the Supplementary Materials: see below.

of the estimated probability of having a non-zero observation (i.e. $1 - F(\hat{\gamma_0})$) and the mean of the lognormal distribution ($exp(\hat{\theta}_0 + \frac{\hat{\sigma}^2}{2})$). The standard errors for the 95% confidence intervals are calculated using the delta method. The results are depicted in Figure 4 and the detailed results appear in Appendix Table A1.

The average annual WTPs are large for the twenty policies under consideration: the French are ready to pay between 17.19 and 39.30 Euros per year for their implementation. The introduction of mandatory stunning before slaughter for cattle has the largest WTP. This result is unsurprising as 74% of the French oppose the exemption of stunning for religious slaughtering.[27] In addition, the average annual WTP is over 30 Euros for the free but mandatory identification of pets (31.73 Euros) and a ban on fur (33.11 Euros). We also find considerable support for the introduction of alternative-methods experts in animal-experimentation ethics committees (28.94 Euros), a ban on badger and fox hunting (29.41 Euros), and the reconversion of circuses to end wild-animal shows (27.09 Euros).

The less-popular policies still attract relatively-large annual WTPs (over 15 Euros per citizen per year). The ban on force-feeding in *foie gras* production produces the lowest WTP (15.96 Euros). This may reflect the lack of alternatives to produce the same quantities of foie gras as the current force-feeding techniques. In general, less-coercive interventions tend to receive less support, with average annual WTPs of below 20 Euros: the labeling of egg products (17.19 Euros), animal-ethics classes (18.08 Euros) and plant-based menus in schools (18.10 Euros).

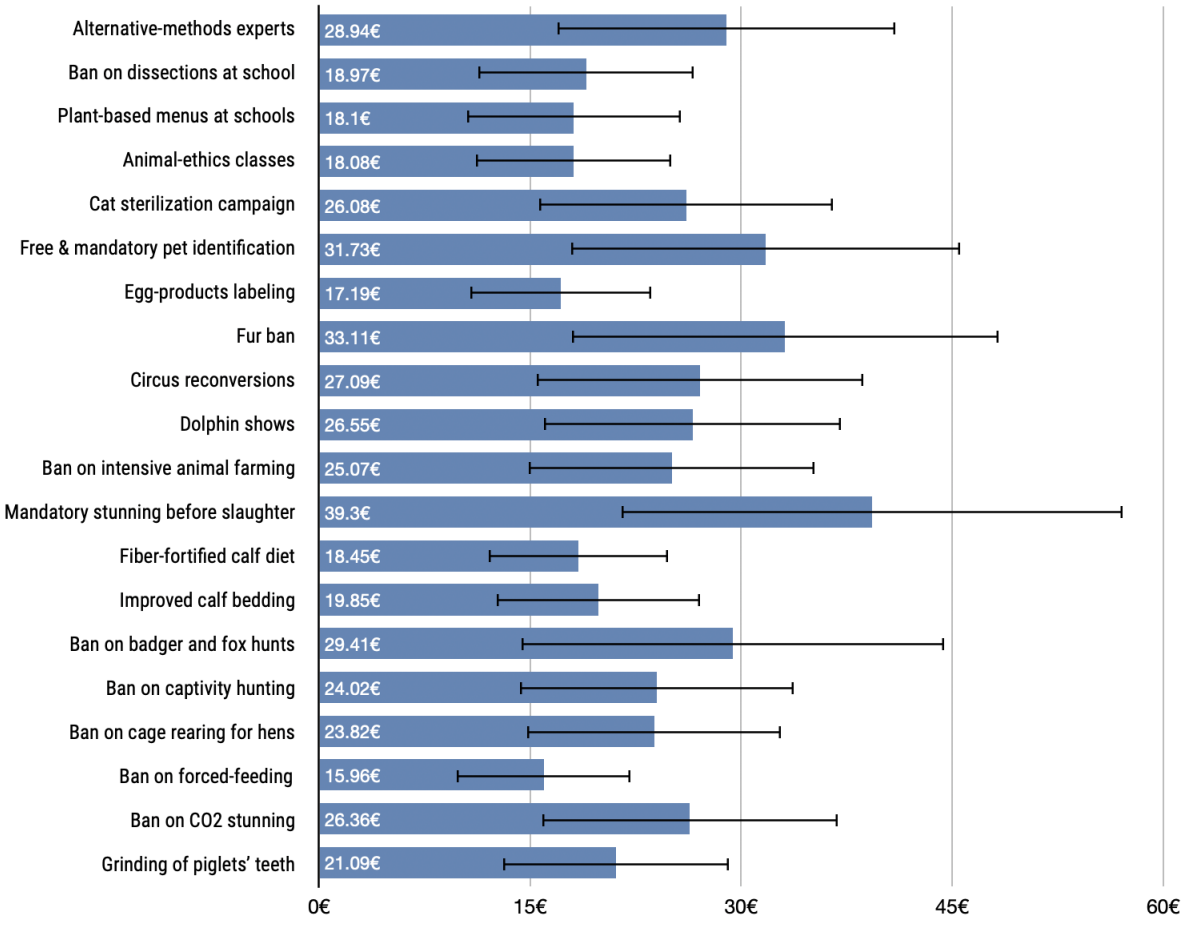
Overall, we do not see any clear pattern in terms of the WTPs between categories of policies. For example, policies relating to animal experimentation have an average WTP of 24 Euros, as against 26 Euros for policies regulating hunting and 24 Euros for pork-product policies. One exception concerns policies relating to farms and abattoirs that have high WTPs, mostly driven by the issue of mandatory stunning. Most measures propose banning the worst practices. Less-strict interventions receive relatively low WTPs, but the ban on force-feeding produces the lowest WTP figure.

I run a number of additional analyses, the findings of which appear in the Supplementary Materials. First, I consider heterogeneity in the WTPs by analyzing their individual determinants (Supplementary Material 3). Women are more likely to contribute, as well as those who attended a circus the previous year. On the contrary, the older and daily meat eaters are less likely to pay for animal-welfare policies. Second, I investigate the robustness of these estimates with respect to the degree of confidence respondents have in their answers (Supplementary Material 4). Weighting participants by their confidence produces lower average WTP figures, although the average drop is only small (between 0% and -6.7%). Third, I explore the extent to which reported WTPs are affected by warm-glow considerations, which would prevent us from adding up the WTPs to determine the WTP of a bundle of policies (Supplementary Material 5). A warm glow refers to individuals deriving a (large) emotional reward for doing something good themselves, which can be expected to be the case for animal welfare. In this case, warm-glow can produce a WTP for a bundle of policies that

[27] Source: 2020 - IFOP poll for OABA.

is lower than the sum of the WTPs for the single policies in the bundle, as the emotional reward is only received once. Cold WTPs, which we can approximate by controlling for the tendency to experience warm glow, are then more appropriate when considering policy bundles. I show that cold WTPs range from 42% to 60.5% of the warm WTPs presented above. Last, I explore whether the estimated WTPs are sensitive to the winsorizing threshold used in the open-ended questionnaire. I run the above estimation using two alternative thresholds, i.e., 20 and 30 Euros respectively. Results displayed in Table A2 show that they might be affected (higher thresholds yield lower WTPs) but that it does not affect much the ordering of the policies.

Figure 4: Average WTPs for the twenty policies (Model: intercept-only)



Note: Spikes represent 95% confidence intervals.

4 Contributions to social welfare

I now show how to apply the above theoretical framework to the social welfare of both humans and animals. I then discuss how the two welfare dimensions complement each other.

4.1 Human welfare

As mentioned in the theoretical section, the average WTPs can be seen as the monetary equivalents of the expected changes in the utility of the representative agent due to the implementation of the policies. Let us note however that there might be several reasons why these WTPs can differ from the expected change in utility. First, our questionnaire allowed participants to report positive WTPs only, such that negative WTPs were reported as 0. We might thus overestimate the utility gains associated with the implementation of the policies (Kriström, 1997). Second, previous work showed that people might report a null WTP not because they oppose the policy in general but because they oppose some specific dimensions, such as the payment vehicle. The presence of so-called 'protest zeros' might lead to underestimating the utility gains: some people would enjoy the implementation of the policy but they report a null WTP.

To investigate these two issues, we can analyze the reasons participants reported when they indicated a zero WTP. In the survey, participants who reported zero WTP were asked to explain their choice. The answers to these open-ended questions contain information about participants who do not wish to contribute to the policies. Screening these answers allows us to identify three zero-WTP types: (i) indifference (people who do not feel concerned or have no opinion), (ii) negative utilities (against the policy), and (iii) positive utilities. In the latter category, I include participants who say they are in favor of the policy but introduced in a different way, who support the measure but believe that they should not pay for its implementation, and who are in favor but do not have enough money to pay for it. I say that these participants have "hidden" positive utility. Protest zeros and free-riding participants are part of this category.

Figure 5 shows the distribution of utilities applying the above classification. The proportion of zeros is relatively large for all policies, and exceeds 50% of the (weighted) observations for three policies (plant-based menus, a ban on badger and fox hunting, and a ban on force-feeding). Most of these zero WTPs can however be considered to hide positive utilities (between 18.3% and 30.8% of all reported WTPs). For each of the 20 policies, about one in ten participants (between 7.8% and 12.5%) report a zero WTP and therefore seem to have zero utility gain from the policy's implementation. A relatively small proportion of participants would experience negative utility from the policies. This negative-utility figure is over 15% for three policies only, the same as those with a majority of zero WTPs (plant-based menus, a ban on badger and fox hunting, and a ban on force-feeding).

The above estimations considered all zeros to be real zeros. However, the share of real zero utilities among the zero reported WTPs is relatively small. On average, real zero utilities represent only 24% of reported zero WTPs, with negative and hidden positive utilities accounting respectively

for 21% and 55% of zero WTPs. On the extensive margin, estimations that take zero WTPs as real zeros could then underestimate the rise in social welfare resulting from the policies. However, we do not know the intensity of the utility drop that negative-utility participants would experience.

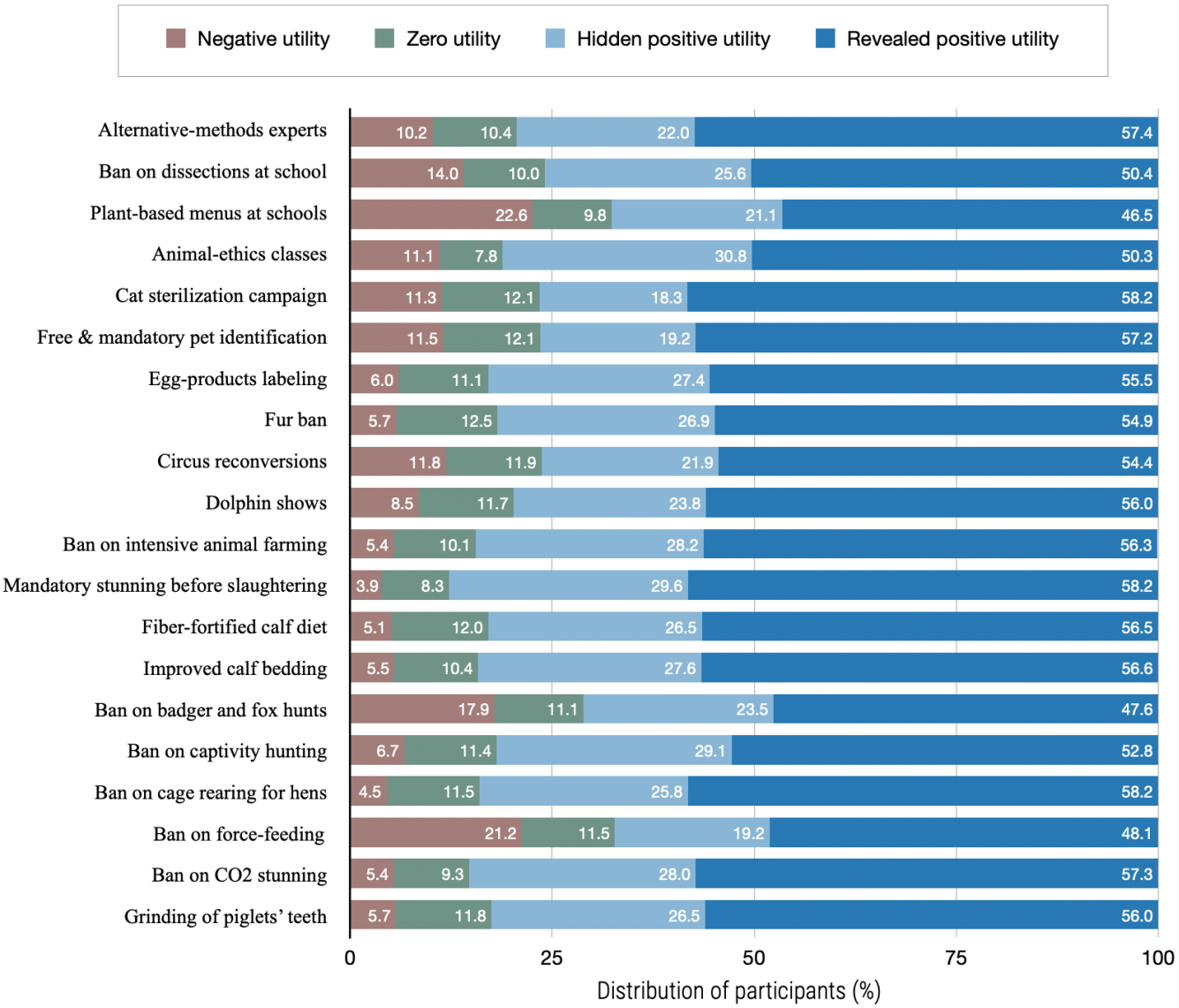
To assess the sensitivity of the results on the presence of negative WTPs, I select 6 of the 20 policies discussed above and elicit positive and negative WTPs on a (non-representative) sample of participants using Prolific. I compare two versions of the questionnaire. The first replicates the above framework with only positive WTPs using the same questions and response categories. The second, inspired by Clinch and Murphy (2001), first asks participants whether they support or oppose the reform or whether they are indifferent; they then report their WTP to support (oppose) the reform conditional on the fact that they support (oppose) it. The experiment is explained in detail in Supplementary Material 8. The experiment took place online with 361 French participants in October 2021. The results are displayed in Supplementary Materials 8 and show that negative WTPs are very limited compared to positive WTPs.

Next, the reported WTPs might differ from the monetary equivalents of the expected changes in utility because the survey is not incentive compatible, i.e., the dominant strategy for respondents might not be to truthfully reveal the maximum amount they are willing to pay for the implementation of the policy (Carson et al., 2014). This could generate a large share of unrealistically high or zero WTP responses in open-ended questionnaires (Johnston et al., 2017). An important element regarding incentives is whether the survey can be seen as consequentialist, i.e., as potentially influencing an agency's actions (Carson and Groves, 2007). In the survey, respondents are asked to answer as faithfully as possible, by indicating that the results will be used to inform the public debate (consequentiality). To limit the influence of unrealistically high WTP responses that could arise in the open-ended questionnaire, I winsorize answers above 10 Euros per year. The risk of zero WTP response inflation seems limited given that the density of zero WTPs is lower in the open-ended questionnaire than in the payment card approach.

Last, we can note that the above results might depart from the true WTP in the population for at least two reasons. First, we observe important differences between the open-ended and the payment-card surveys. The share of reported WTPs above 7 Euros is larger in the open-ended questionnaire than in the payment-card survey for all policies. It is unclear which elicitation method yields the most accurate estimates but the open-ended questionnaire might leave the respondents more uncertain. Second, we observe that the estimated average WTPs are larger than the maximum amount participants can report in the payment-card questionnaire (10 Euros and more). Relatedly, Table A1 shows that the average WTPs are significantly larger than the median WTPs. These two issues might either be due to a flaw in the design (i.e., the payment cards did not sufficiently well cover the spectrum of the participants' WTPs), or to an incorrect parametric assumption (i.e., log-normal distribution), or to the presence of extremely large WTPs in the population (in which case the parametric assumption might hold but it would be difficult to capture the extreme values with a payment-card scheme).

Given these limitations, the results of the average WTPs suggest that there is room for im-

Figure 5: The distribution of utilities for the twenty policies (weighted).



plementing policies aimed to improve animal welfare. Some of the above policies would induce very limited implementation costs. This is the case for instance of policies that concern a small number of animals (dolphin shows, circuses), those for which everything necessary for the implementation is in place (e.g., egg-products labeling), or those whose expected costs are very limited (e.g., animal-ethics classes, plant-based menus at schools). In addition, the economic costs of these policies might have already been partially taken into account by the respondents themselves (e.g., expected increase in prices, expected reduction in supply).

4.2 Animal welfare

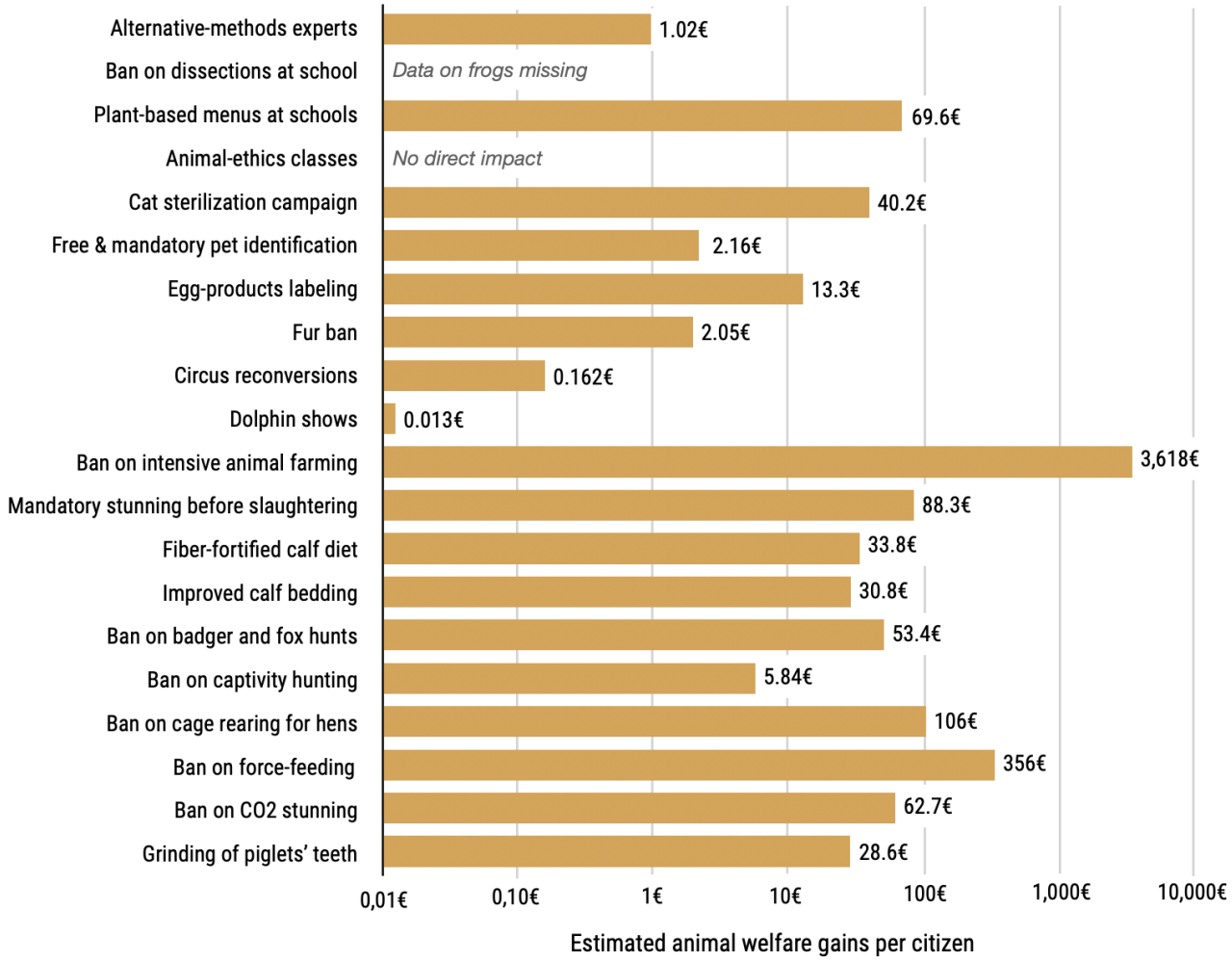
I now discuss the impact of policies on animal welfare. Figure 6 shows the monetary equivalents of the rises in animal welfare normalized by the number of people (i.e., the overall utility of animals per representative human) obtained from the 5FFI framework and utility-potential functions presented above. The implementation of the framework is described in the Supplementary Materials: I discuss for each policy the number and type of animals that are affected and the freedom violations that the policies would avoid. I consider only the direct effects of the policies. I was not able to determine the animal-welfare gains for two policies: the ban on dissection at school (due to missing data on frog brains to determine the utility potentials) and the introduction of animal-ethics classes (no direct impact on animals). I take one unit of QALY to be worth 147,000 Euros in France.[28]

To estimate the gain in animal welfare from each policy, I first determine the types and numbers of animals involved, and the number of freedom violation points that the policy avoids. I then express the welfare gains in monetary terms using the utility potentials. For instance, introducing edible elements in calf bedding (Policy 14) is expected to improve the physical comfort of the 91% of the two million calves in France that are raised on slatted floors (i.e. 1,820,000 calves per year). I assume that this policy will reduce the violation of the freedom from physical discomfort by two violation points, yielding $\Delta\zeta = \frac{2}{15}$ per calf. Bovines are estimated to have about 790 million cortical neurons, as against a figure of 24,526 million for humans. Last, there were about 52.6 million adults in France in 2020, $q = 147,093$, and $\psi = 0.9$. The per-person animal-welfare benefits of the reform are then: $1,820,000 \times \frac{2}{15} \times \frac{790^{0.9}}{24,526^{0.9}} \times 52,600,000^{-1} \times 147,093 = 30.8$ Euros per person.

Figure 6 displays the animal-welfare gains per person on a logarithmic scale, due to the considerable heterogeneity in the figures. Some policies have only a very limited impact on animal welfare. For instance, banning dolphin shows has an estimated welfare gain from animals of 0.013 Euros per person per year. This small figure mainly reflects the very few animals involved (27 dolphins and 4 killer whales). However, the economic costs of this policy would also then be small, and we cannot necessarily conclude that this policy is not welfare-improving. The largest welfare gains come from the ban on intensive farming: 3,618 Euros per person per year. This figure is driven by the very poor living conditions of animals that are raised in intensive farms, often in cages, producing significant violations of the freedoms from pain/injury, physical discomfort, and distress, and the freedom to

[28] I use the French QALY figures as this is the country of application. Téhard et al. (2020) estimate a QALY to be worth between 147,093 and 201,398 Euros. I take a conservative value of 147,000 Euros.

Figure 6: The estimated animal-welfare gains per person for the twenty policies using the 5FFI method of harm categorization and cortical/pallial neurons in the utility potential function.



express normal patterns of behavior.

Overall, only two policies produce animal-welfare gains of below 1 Euro per person per year, four between 1 and 10 Euros (alternative-method experts, pet identification, a fur ban, and a ban on captive hunting), and nine between 10 and 100 Euros (plant-based menus at schools, cat sterilization, egg-product labeling, mandatory stunning, fiber-fortified diet for calves, improved calf bedding, a ban on badger and fox hunting, a ban on CO2 stunning, and the grinding of piglets' teeth). Last, three policies yield gains of over 100 Euros per person: the bans on cage rearing for hens (106 Euros), force-feeding (356 Euros), and intensive animal farming (3,618 Euros).

4.3 Comparing human WTPs and animal utility changes

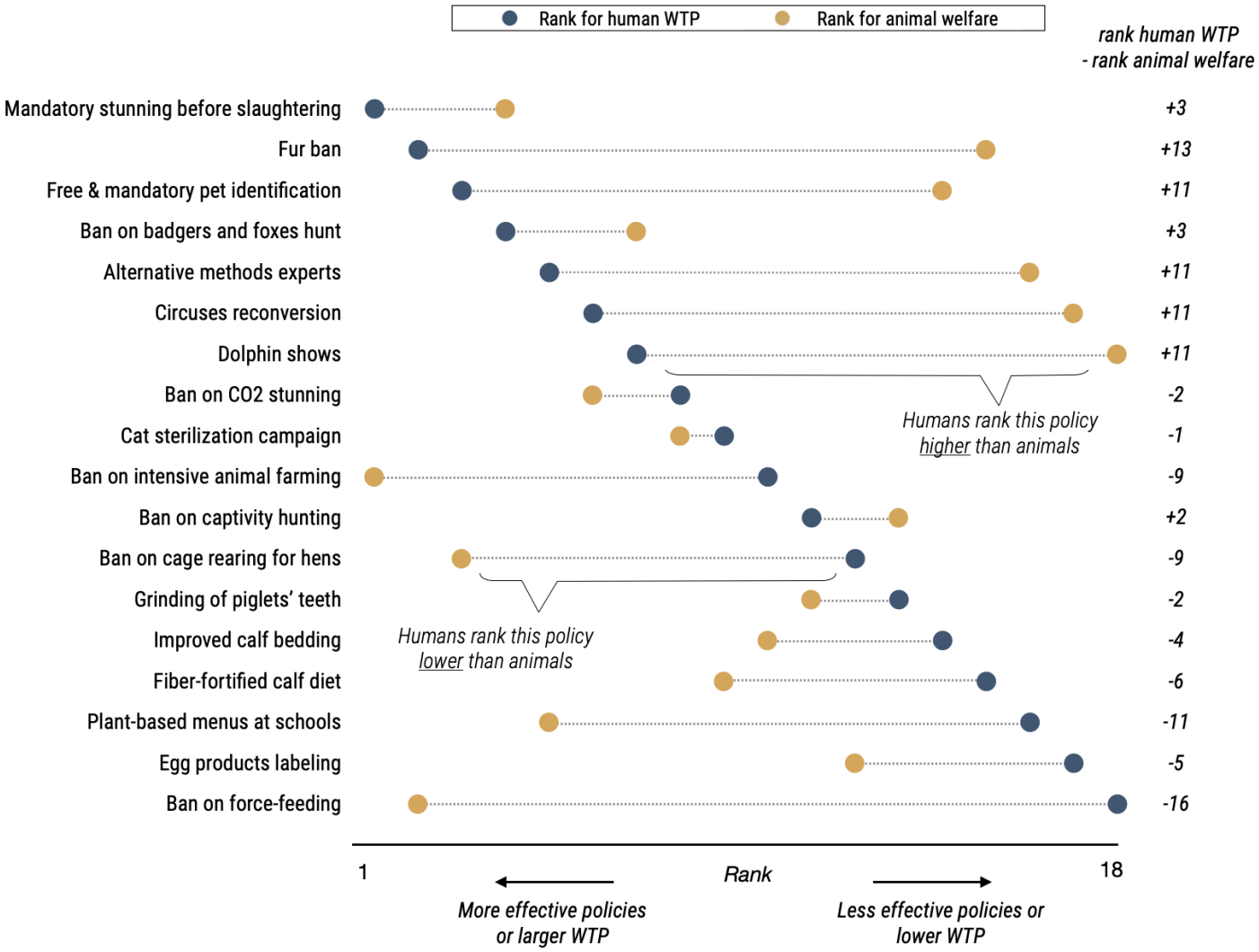
Policy-makers and researchers might seek to determine which policies are welfare-enhancing. Often, they might look at the citizens' willingness-to-pay for a policy to determine whether it can improve

overall welfare. If the sum of willingness-to-pays is larger than the costs of the implementation of the policy (that were not taken into account by the citizens in their answers to the WTP questionnaire), there is some room for implementing a Pareto-improving policy, assuming some form of redistribution among humans. As we saw, animal-welfare policies are widely supported by humans as about three quarters of French people are expected to support the policies under scrutiny and the average WTPs range between 16.95 Euros and 39.30 Euros per year. This important human support for animal-welfare policies leaves some room for policies improving both human and animal welfare.

However, considering the policy gains for animal welfare might substantially change the priority of the policies to be implemented. In a world of scarce resources, policymakers might indeed focus on the most welfare-enhancing policies. However, the above results show that the most impactful policies for the animals are not necessarily the policies with the largest human WTPs. For instance, banning dolphin shows is a popular strategy among French people who are ready to pay on average 26.55 Euros per year per person to implement it. However, the impact on animals is very limited (0.013 Euro per year per citizen) given the small number of animals involved. On the contrary, banning force-feeding is the least popular policy among humans, while one of the most impactful policies for animals.

Overall, the policies with the largest WTPs are not necessarily those that would improve animal welfare the most. This is illustrated in Figure 7 via the policy ranking for human and animal welfare (for the 18 policies for which I was able to estimate a direct impact on animal welfare). The ordering of policies based on human WTPs significantly differs from the ordering of policies based on the estimated impact on animal welfare. Right-hand-side and left-hand-side deviations show that there is no general pattern in the orderings, implying that we cannot infer the animal-welfare impact from human WTPs. There is if anything a negative correlation between the ranks ($\rho = -0.34$, $p = 0.165$), with human WTPs being larger for policies that have a smaller impact on animal welfare.

Figure 7: Policy ranks for animal and human welfare.



5 Discussion

I have here proposed a (first) general and implementable framework to evaluate the social gains of policies improving animal welfare. The complexity of the issue of valuing animal well-being in the social-welfare function has been circumvented by decomposing the issues into smaller parts (animal interests, 5FFI, and utility potentials). However, this implies significant normative choices at each step, leaving room for discussion and improvement.

5.1 Five-Freedoms Fulfillment Index

The paper evaluates the standardized utility of animals across species via the Five-Freedoms Fulfillment Index (5FFI). This is a first and important step to facilitate interspecies comparisons in cost-benefit analyses. However, its use can be challenged in a number of ways. The Five Freedoms may first be too restrictive for evaluating animal welfare. For instance, they do not consider positive experiences that could increase welfare and only focus on negative experiences i.e. problems (Mellor, 2016a,b). For example, playing or receiving affection increase the utility of both humans and many animals: these do not appear in the 5F but could be included were we to consider positive mental states.

Second, the assumption of equal weights for each violation is likely too restrictive. It is currently assumed that going from a mild to a moderate violation has the same impact as going from a moderate to a severe violation. We also assume that the violations of all freedoms are equally important. This might not be true, although finding a better specification is a substantial empirical challenge. The empirical estimation of WTPs for animals would help to weight violation points (Mason et al., 2001), but require species-specific weights. We can however note that one advantage of the equal-weight specification is that it facilitates discussions of the rise in animal welfare. Equal weights mean that we do not require agreement on initial and final animal welfare pre- and post-policy, but only on the number of violation points that the policy avoids. It is easier to agree that freedom violations fall by two points than on where animal welfare is currently and where it would end up after policy implementation.

Last, the results are sensitive to the choice of death equivalence in the 5FFI framework. I have taken a relatively conservative approach by assuming that death is equivalent to the severe violation of all Five Freedoms. If we consider that death is strictly preferable even before all freedoms are severely violated, we would have a less-conservative criterion for death equivalence. This in turn would increase the economic costs of animal suffering.

5.2 Utility potentials

Mapping the number of cortical / pallial neurons, or any other metric, into utility potentials requires some form of calibration. Budolfson and Spears (2019) assume a specific parametrization of the utility-potential function that has to be calibrated via the ψ parameter. In the theoretical model, I calibrated ψ by discussing the implications of the second-order derivatives. By doing so, I defined

a range of satisfactory values: $\psi \in (0, 1)$. However, the estimation of the animal-welfare benefits is very sensitive to the choice of ψ, even within this range. For example, Figure B3 shows the changes in the estimated animal welfare benefits for ψ 0.05 points higher and lower than the baseline scenario ($\psi = 0.9$) used in the above application. This produces substantial variations, ranging from -28% to -10.4% when $\psi = 0.95$, and from +12% to +38.2% when $\psi = 0.85$.

5.3 Cortical and pallial neurons

The number of neurons in the cerebral cortex or the pallium is used as a proxy for the level of cognition leading to utility potential. This proxy is currently the best metric available covering a large set of species that is correlated with animals' cognitive abilities. It is however not perfect and may be replaced in the future when better measures become available. The number of cortical/pallial neurons is likely an improvement over the total number of neurons, as in Budolfson and Spears (2019). Brain size, as an alternative, is also a poorer predictor of cognitive capacities, given that animals have very different neuronal densities: the brains of some birds pack similar numbers of neurons as monkeys due to the relatively high neuronal densities of avian brains (Olkowicz et al., 2016). However, the number of cortical / pallial neurons remains only imperfectly correlated with animal behavior and cognition, as some species with very small brains function very well (Broom, 2007). Future measures derived from new approaches (e.g., Logan et al. (2018)) could yield a better metric for the calculation of utility potentials.

One limitation in the use of cortical / pallial data here is that I was not able to calculate utility potentials for certain animals. For some animals, like frogs or some mammals, data were missing but could become available in future work. A greater challenge is the potential inclusion of fish or even insects. It is now recognized that fish are sentient (Broom, 2007; Franks et al., 2018) and that insects have subjective experiences of the World (Barron and Klein, 2016).

5.4 Interspecies and intraspecies comparisons

Another issue concerns the use of utility potentials to determine the weight a certain individual's interests should attract in social welfare. I here only considered *inter*-species variations, determining the utility potentials of each species by the average number of cortical / pallial neurons per species. It can however be claimed that utility potential should be defined at the individual and not the species level. Broom (2019) notes that sentience is acquired over time (very young fetuses are not sentient) and can be lost (in the case of accidents, for example). These *intra-species* variations in sentience arguments have already been raised by Singer in utilitarian philosophy. While this proposition may have theoretical merit, I assume that most people would strongly oppose individual welfare weights that depend on the number of cortical neurons. This would go against the principles of equality of rights between individuals that are largely accepted in democracies. The principle of equality of rights within each species does however violate the principle of the equal consideration of equal interests if there exist variations of sentience within each species. If we wish to maintain the

principle of the equality of rights within each species, we must thus partially violate the principle of the equal consideration of equal interests.

5.5 Longevity

The approach above considers annual costs and benefits. The Five-Freedom Fulfillment Index (5FFI) in particular defines animal welfare in a similar way to the QALY model, and measures animal-welfare violations that occur during a year. However, animal life expectancy varies across species. In the QALY framework, individuals are expected to have similar, or at least the same order of magnitude, life expectancies, so that one year of life is comparable across individuals. Life expectancy varies interspecies, which adds an additional layer of complexity. The key question is then whether we should weigh one year of welfare differently between species that have different life expectancies. In other words, should we consider years of life or shares of life expectancy? For instance, should one year of suffering of a hen, which can live for up to 20 years, be weighted less, equally, or more than a year of suffering of an elephant that can live for up to 80 years?

This question remains open, as one can argue for both positions (years-of-life or share-of-life-expectancy weighting). However, we can note that the well-being potential is likely to be correlated with life expectancy, which places a greater weight on animals with longer life expectancies. Herculano-Houzel (2019) shows that the number of cortical / pallial neurons is positively correlated with longevity. In other words, animals with more complex cognitive skills tend to live longer. Given that we have used cortical / pallial neurons to estimate utility potentials, we already have a positive correlation between longevity and utility potential.

5.6 The indirect consequences on animal welfare

One of the challenges in evaluating a policy's welfare gains is the scope of interests at stake. The consequences of some policies are easily defined. For instance, prohibiting the use of wild animals in circuses affects those animals in circuses, the employees, and the audience. However, the overall impact of some other policies is more complicated. A good example is a ban on fox hunting. Limiting fox hunting will improve animal welfare (the direct impact) but will also affect the animals that are eaten by foxes (the indirect effect). The increase in foxes will lead to more rodent deaths, but will also in turn reduce the crop damage caused by rodents.

This difficulty in defining the scope of analysis is not new in economic theory. It is also found in policy analyses that focus on partial equilibria that neglect general-equilibrium effects. However, the animal-ethics literature has addressed the importance of the welfare of wild animals (e.g., Sebo (2021)), and the RWAS (Reducing Wild Animal Suffering) movement argues that the effects of improving the welfare of predators on prey should be taken into account (Horta, 2017). Discussing the merits of RWAS is beyond the scope of the current paper, but we can note that some policies can be easily evaluated via their first-order impacts on animals, while others may produce more complex considerations about the range of interests that should be taken into account in social welfare.

5.7 Double counting of policy costs

An additional important issue for cost-benefit analyses is the risk of double counting. In the WTP study presented above, participants might have taken into account part of the economic impact of the implementation of the policies. For example, some consumers might imagine higher meat prices were cage-rearing to be banned, and so report negative WTPs. However, the welfare loss due to higher prices also appears in k, the policy's economic costs. There is thus a risk of counting the costs twice, once in consumers' (negative) WTPs and once in the policy costs.

One (partial) remedy is to ask respondents to report their WTPs holding prices constant. This strategy is apt for policies that may raise prices. Other policies such as bans on hunting or animal shows do not affect prices. Negative WTPs here can reflect lower utility from the loss of output derived from animal use (e.g., the pleasure of seeing dolphins) or anti-animal preferences (e.g., the pleasure of killing animals when hunting).

5.8 Adaptation of the model to scientific advances

The model that I introduced here should not be seen as fixed and is expected to be adapted to new findings in animal science. For instance, the use of cortical or pallial neurons serves only as a proxy for cognition, which, in turn, correlates with more-complex emotions. Future work should integrate advances in the field of animal sentience. For instance, undergoing projects such as the *Moral Weights* project of the *Rethink Priorities* Institute could yield more refined species weights. In the general model presented here, one should only use updated species weights as utility potentials instead of using the ratio formula proposed by Budolfson and Spears (2019).

Advances in science can not only contribute to a better determination of utility potentials but will also help better define *what* constitutes the welfare of animals. As we know more about the welfare of animals, we will be able to better identify the dimensions that matter. The 5 Domains framework is an improvement to the 5 Freedoms for instance, and as it becomes more and more recognized, the scope of dimensions considered for the determination of animal welfare will expand. Another possibility for improvement would be to compute weights associated with violation points. The general model proposed in the paper could be easily adapted by either replacing the Five Freedoms with the Five Dimensions or/and by putting unequal weights to different violations.

To facilitate the use and improvement of the model, I put the R code of the implementation of the model in the Supplementary Materials.

6 Conclusion

Animal welfare has become an important policy domain. Less-anthropocentric approaches require the assessment of animal welfare in policy analysis. However, while animal science has made considerable advances in documenting animal sentience and well-being potentials, economic theory has lacked a framework for interspecies welfare comparisons and an effective aggregation method of potentially-competing interests.

This paper has aimed to fill this gap by proposing a social-welfare framework accounting for both human preferences regarding animal welfare and animal well-being itself. The inclusion of animal welfare in social welfare is carried out in two steps: first by evaluating the freedom violations that are avoided by the implementation of new policies, and second by converting these welfare gains into monetary equivalents using utility potentials.

The application of this framework to 20 policies discussed in France in 2020 confirms that animal welfare is an important topic. Individuals are ready to pay significant amounts of money to improve animal welfare, between 15 and 39 Euros per person per year. In addition, the application showed that these policies can produce large but heterogeneous welfare gains for animals (between 0.013 and 3,618 Euros per person per year). The most important result for policymakers is that the animal and human welfare gains are not necessarily correlated, which can either result from impure altruism such as warm-glow or the misperception of the policy implications.

While this work opens the door to the empirical valuation of animal welfare, we have shown that these assessments involve numerous normative and calibration choices. These include the consideration of anti-animal preferences among humans, the definition of the determinants of animal welfare, and the metrics and parameters used to recover utility potentials. The calibration choices made here are first attempts to evaluate animal welfare and are open to discussion. However, even conservative calibration choices are preferable to the current status quo in which animal welfare is neglected.

Last but not least, this paper is a first attempt to economically value animal welfare from a non-anthropocentric perspective. Because we, humans, evaluate the world with our perception, our evaluation of animal welfare might inevitably be anthropocentric. In this respect, the economic valuation of animal welfare faces similar challenges as the evaluation of ecosystem services and biodiversity (Atkinson et al., 2012). For instance, the costs of the (mis)use of animals or the degradation of the ecosystems have not been integrated by the market yet. Similarly, the question of the altruistic concerns for animals that we have discussed in the paper might overlap with the issue of non-use values developed in the valuation of biodiversity. On the other hand, the literature on animal welfare valuation might also share some characteristics with the valuation of human welfare as both kinds of literature focus on sentient beings capable of welfare. The emerging field of animal welfare economics is likely in the future to draw from these two fields of research.

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A Additional tables

Table A1: Average WTPs in Euros for the twenty policies (intercept only)

Policy	Average WTP	(Std. Error)	[95% CI]	Estimated Median
Alternative-methods experts	28.94	(6.13)	[16.93 ; 40.95]	3.66
Ban on dissections at school	18.97	(3.89)	[11.35 ; 26.59]	1.34
Plant-based menus at schools	18.10	(3.87)	[10.51 ; 25.69]	0
Animal ethics classes	18.08	(3.54)	[11.14 ; 25.02]	1.46
Cat sterilization campaign	26.08	(5.33)	[15.63 ; 36.53]	3.39
Free and mandatory pet identification	31.73	(7.05)	[17.91 ; 45.55]	3.59
Egg products labeling	17.19	(3.28)	[10.76 ; 23.62]	2.19
Fur ban	33.11	(7.73)	[17.96 ; 48.26]	3.22
Circus reconversions	27.09	(5.92)	[15.49 ; 38.69]	2.95
Dolphin shows	26.55	(5.38)	[16.01 ; 37.09]	3.78
Ban on intensive animal farming	25.07	(5.18)	[14.92 ; 35.22]	3.05
Mandatory stunning	39.30	(9.09)	[21.48 ; 57.12]	4.50
Fiber-fortified calf diet	18.45	(3.25)	[12.08 ; 24.82]	3.15
Improved calf bedding	19.85	(3.68)	[12.64 ; 27.06]	3.02
Ban on badger and fox hunting	29.41	(7.65)	[14.42 ; 44.40]	0
Ban on captivity hunting	24.02	(4.96)	[14.3 ; 33.74]	2.86
Ban on cage rearing for hens	23.82	(4.60)	[14.8 ; 32.84]	3.49
Ban on force-feeding	15.96	(3.15)	[9.79 ; 22.13]	0
Ban on CO2 stunning	26.36	(5.35)	[15.87 ; 36.85]	3.62
Grinding of piglets' teeth	21.09	(4.09)	[13.07 ; 29.11]	2.85
N			1,473	

Table A2: Robustness analysis: changes in the estimated average WTPs and ranks following changes in the winsorizing threshold.

Policy	Winsorizing threshold					
	10 Euros (Original)		20 Euros		30 Euros	
	WTP	Rank	WTP	Rank	WTP	Rank
Alternative-methods experts	28.39	5	25.32	4	23.96	5
Ban on dissections at school	18.22	15	16.19	17	15.87	17
Plant-based menus at schools	17.86	18	16.17	18	15.67	18
Animal ethics classes	17.89	17	16.91	15	17.43	13
Cat sterilization campaign	25.74	8	22.74	5	19.62	10
Free and mandatory pet identification	31.12	3	25.34	3	24.88	3
Egg products labeling	16.90	19	14.56	19	13.96	19
Fur ban	33.08	2	25.92	2	25.59	2
Circus conversions	26.45	6	17.87	13	20.06	9
Dolphin shows	25.72	9	22.11	7	21.78	6
Ban on intensive animal farming	24.21	10	18.73	11	17.54	12
Mandatory stunning	37.95	1	33.49	1	33.00	1
Fiber-fortified calf diet	18.08	16	17.04	14	16.64	15
Improved calf bedding	19.46	14	17.99	12	16.91	14
Ban on badger and fox hunting	29.13	4	21.84	8	20.23	8
Ban on captivity hunting	23.87	11	21.63	9	24.19	4
Ban on cage rearing for hens	23.06	12	20.31	10	18.27	11
Ban on force-feeding	15.65	20	13.68	20	13.91	20
Ban on CO2 stunning	25.78	7	22.47	6	20.94	7
Grinding of piglets' teeth	21.10	13	16.78	16	16.11	16

Estimations are based on the entire sample, i.e. 1,473 observations.

Table A3: Robustness analysis: changes in the estimated average WTPs in the uncertainty-weighted model relative to the unweighted model.

	Changes (in Euros) in the WTP			
Policy	Mean	Min	Median	Max
Alternative-methods experts	-1.29	-2.73	-1.26	-0.09
Ban on dissections at school	-0.83	-2.21	-0.72	-0.27
Plant-based menus at schools	-1.02	-3.07	-0.87	-0.13
Animal ethics classes	-1.20	-3.60	-1.07	-0.05
Cat sterilization campaign	-0.91	-2.26	-0.87	0.10
Free and mandatory pet identification	-0.76	-1.93	-0.74	0.19
Egg products labeling	-0.33	-0.84	-0.32	0.04
Fur ban	-0.82	-1.06	-0.82	-0.49
Circus conversions	0.64	-1.54	-0.55	-0.26
Dolphin shows	0.00	-0.76	-0.12	1.85
Ban on intensive animal farming	-0.98	-3.60	-0.84	0.44
Mandatory stunning	-0.82	-2.06	-0.74	-0.01
Fiber-fortified calf diet	-0.83	-2.54	-0.80	0.54
Improved calf bedding	-0.63	-1.85	-0.60	0.12
Ban on badger and fox hunting	-0.72	-2.64	-0.62	0.52
Ban on captivity hunting	-0.10	-0.59	-0.22	1.43
Ban on cage rearing for hens	-1.35	-4.06	-1.11	-0.35
Ban on force-feeding	-0.38	-1.14	-0.33	0.00
Ban on CO2 stunning	-0.38	-1.30	-0.35	0.21
Grinding of piglets' teeth	-0.69	-3.05	-0.60	0.74

Estimations are based on the entire sample, i.e. 1,473 observations.

B Additional figures

Figure B1: The relationship between cortical / pallial neurons and performance to cognitive tasks from Herculano-Houzel (2017)

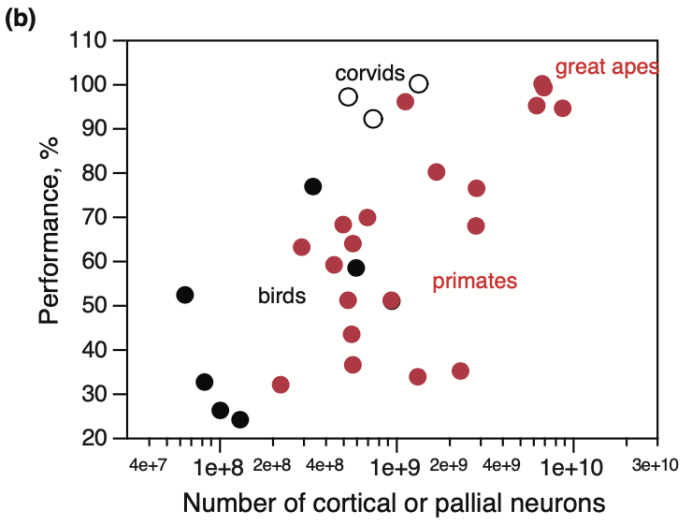


Figure B2: The distribution of the WTPs for alternative-methods experts in ethics committees (payment cards)

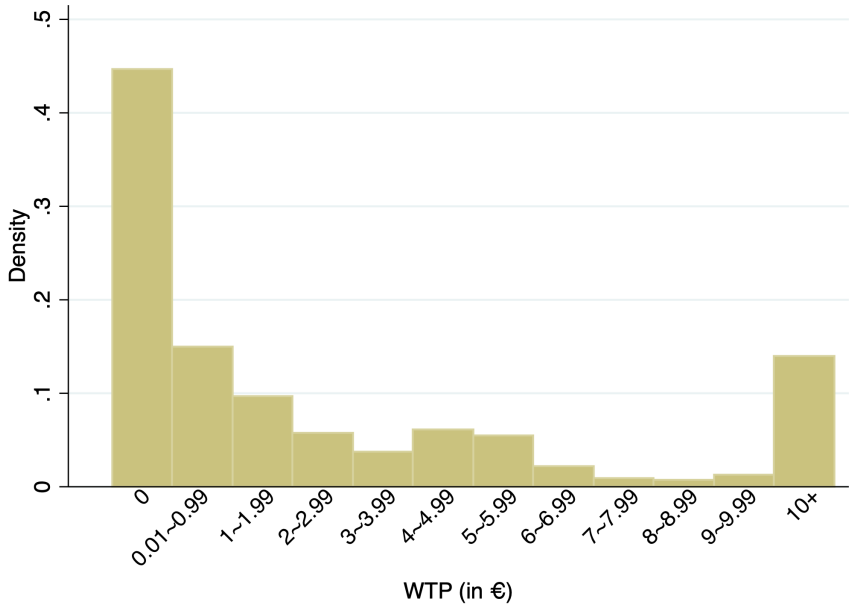


Figure B3: Changes in estimated animal welfare with two alternative calibrations of ψ in the utility-potential functions.

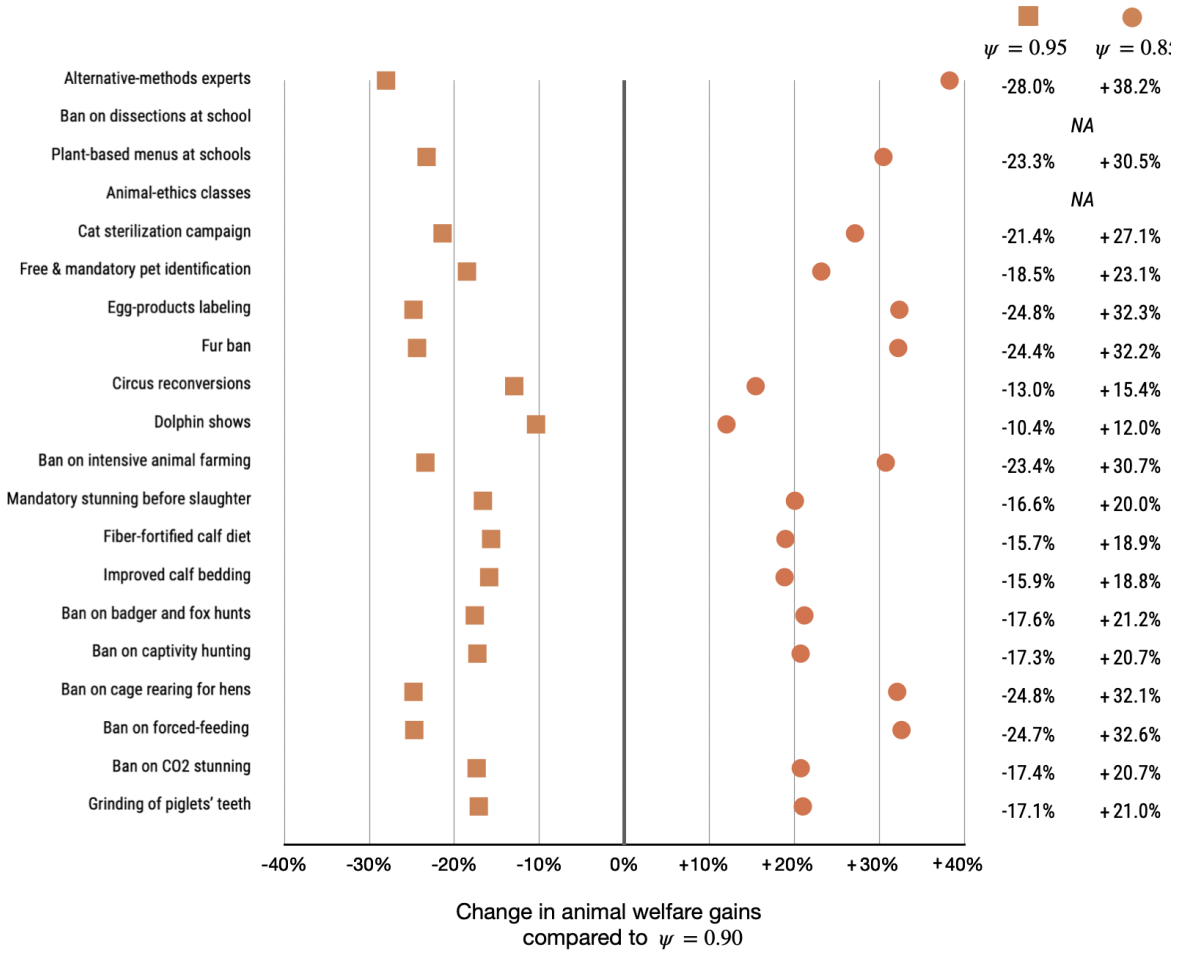
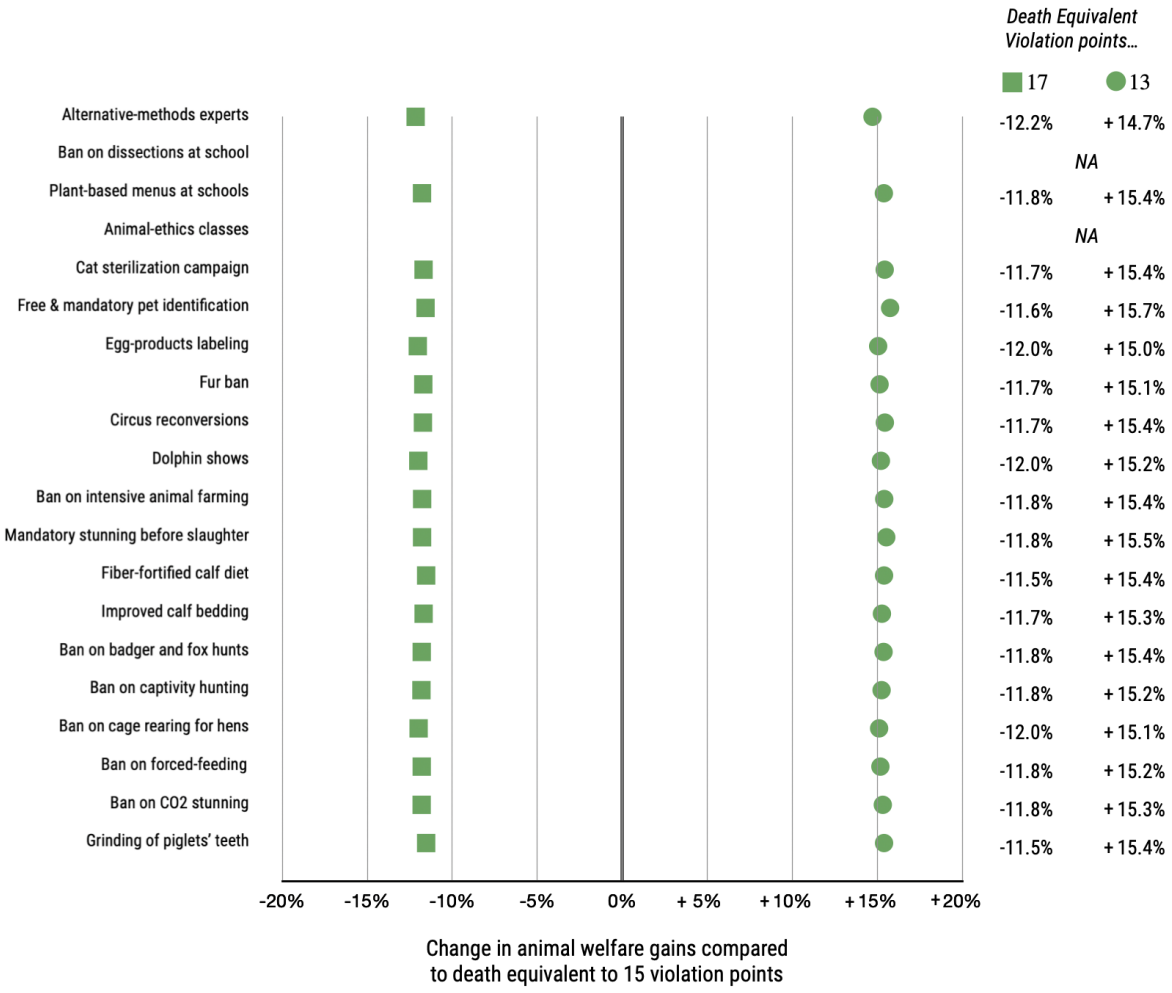


Figure B4: Changes in estimated animal welfare with two alternative calibrations of death equivalence in the 5FFI framework.



Supplementary Materials
Animals and Social Welfare

Romain Espinosa

April 2023

Supplementary Materials 1: Neurons and utility potentials

The numbers of cortical / pallial neurons comes from three sources. The principal source is Herculano-Houzel (2019) whose data constitute the largest collection of cortical / pallial neurons at the time of writing. For each large category of animals (e.g., foxes), I selected the species of animal that was the most representative of the animals discussed in the policies considered in the paper (e.g., Red fox - Vulpes vulpes). In some cases, there was no direct match in Herculano-Houzel (2019), and I then proceeded in two ways. First, when possible, I looked for the species that was the closest to species of interest. For instance, Herculano-Houzel (2019) contains no data for domestic pigs, but has data for wild boars, which I consider to be a sufficiently-good second-best approximation. If this was not possible, I considered Olkowicz et al. (2016) as an alternative source. The data for seven species were available in both datasets. For these animals, we observe that the number of cortical/pallial neurons is on average 41% larger in Herculano-Houzel (2019) (possibly due to the use of different techniques). When the data was not available in Herculano-Houzel (2019), I took data from Olkowicz et al. (2016) inflated by 41%. Last, data for some animals were unavailable. In this case, I either took the data for an animal which can be assumed to have a similar utility potential, or I dropped these animals which are then excluded from the application. Table SM1 lists the number of cortical / pallial neurons retained for the analysis. Last, I used the data from Jardim-Messeder et al. (2017) for dogs, as they are not included in Herculano-Houzel (2019) or Olkowicz et al. (2016).

Table SM1 summarizes the numbers of cortical/pallial neurons retained for each species. "Direct Herculano" indicates a direct match with the data from Herculano-Houzel (2019), "Closest Herculano" a close species in Herculano-Houzel (2019), "Inflated Olkowicz" data from Olkowicz et al. (2016) that I corrected for inflation, and "Substitute Herculano" or "Substitute Olkowicz" when, as last resort, I took another species in Herculano-Houzel (2019) or Olkowicz et al. (2016) that was expected to have similar utility potentials. Jardim-Messeder et al. (2017) is only used for dogs.

Table SM1: Estimates of the number of cortical / pallial neurons by species.

Animal	Species	Source	Neurons (10^6)
Human	Homo Sapiens	Direct Herculano (2019)	24526
Elephant	African elephant	Direct Herculano (2019)	5508
Killer whale	Orcinus	Direct Herculano (2019)	4729
Baboon	Papio hamadryas	Direct Herculano (2019)	2990
Dolphin	Bottlenosed dolphin	Direct Herculano (2019)	2366
Macaque	Long-tailed macaque	Direct Herculano (2019)	1441
Hippo	Hippopotamus amphibius	Direct Herculano (2019)	1318
Tiger	Panthera tigris	Direct Herculano (2019)	1182
Parrot	African grey parrot - Psittacus erithacus	Direct Herculano (2019)	1129
Lion	Panthera leo	Direct Herculano (2019)	1081
Bison	American bison	Direct Herculano (2019)	831
Bovine	Bos Taurus	Direct Herculano (2019)	790
Hyena	Crocuta crocuta	Direct Herculano (2019)	782
Panther	Panthera onca	Direct Herculano (2019)	686
Wolf	Gray wolf - Canis lupus	Direct Herculano (2019)	584
Fox	Red fox - Vulpes vulpes	Direct Herculano (2019)	528
Lemur	Lemur catta	Direct Herculano (2019)	517
Sheep	Ovis Aries	Direct Herculano (2019)	504
Wallaby	Macropus rufogriseus	Direct Herculano (2019)	287
Rabbit	Oryctolagus cuniculus	Direct Herculano (2019)	101
Pig	Wild Boar - Sus scrofa	Closest Herculano (2019)	554
Cat	Wild cat - Felis silvestris	Closest Herculano (2019)	198
Mink	European polecat	Closest Herculano (2019)	75
Giraffe	Giraffe	Inflated Olkowicz (2016)	2440
Emu	Emu	Inflated Olkowicz (2016)	619
Hen	Red Junglefowl - Gallus Gallus	Inflated Olkowicz (2016)	86
Rat	Rat	Inflated Olkowicz (2016)	44
Mouse	Mouse	Inflated Olkowicz (2016)	19
Dog	Canis familiaris	Jardim (2017)	528
Horse	Bos Taurus	Substitute Herculano (2019)	790
Zebra	Bos Taurus	Substitute Herculano (2019)	790
Badger	Wild cat - Felis silvestris	Substitute Herculano (2019)	198
Duck	Red Junglefowl - Gallus Gallus	Substitute Olkowicz (2016)	86
Goose	Red Junglefowl - Gallus Gallus	Substitute Olkowicz (2016)	86
Turkey	Red Junglefowl - Gallus Gallus	Substitute Olkowicz (2016)	86
Fox	Missing	Substitute Jardim (2017)	528
Ostrich	Missing	Missing	NA
Rhea	Missing	Missing	NA
Python	Missing	Missing	NA
Boas	Missing	Missing	NA
Raptor	Missing	Missing	NA
Alligator	Missing	Missing	NA
Fish	Missing	Missing	NA
Frog	Missing	Missing	NA

Supplementary Materials 2: Survey

Survey

S1. You are…
Mandatory answer

1. A man
2. A woman

S2. What is your year of birth?
Mandatory answer

S3b. What is the postal code of your city?
Mandatory answer

S3. What is the name of your municipality of residence?
Mandatory answer

S5. What professional activity do you currently have?
If you are looking for a job, please tick the professional activity sought.
Mandatory answer

1. Farmer operator
2. Craftsman
3. Shop owner and assimilated
4. Head of a company of 10 employees or more
5. Liberal profession
6. Public service executive
7. Professor or scientific job
8. Information, arts and entertainment profession
9. Administrative executive and business commercial
10. Engineer and et corporate technical executive
11. Teacher and assimilated
12. Health and social work supervision
13. Clergy, religious
14. Administrative supervision of the public service
15. Administrative and commercial supervision of private companies
16. Technician
17. Foreman, agent-control
18. Civilian employee and public service officer
19. Police officer and military.
20. Corporate administrative employee
21. Commercial employee
22. Personal services agent
23. Skilled worker
24. Driver
25. Unskilled specialized workers
26. Agricultural worker
27. Former farmer

28. Former self-employed
29. Former Senior Manager
30. Former Supervisor and Technician
31. Former employee
32. Former worker
33. Unemployed person who has never worked
34. Student
35. Person without professional activity, housewife / houseman

S8. Currently, you are...?
Mandatory answer

1. Company manager
2. Independent, trader, craftsman
3. Liberal profession
4. Private sector employee
5. Employee of a public enterprise
6. Civil servant and assimilated
7. Unemployed
8. Student
9. Retired
10. Housewife / houseman

S5B2. Within your household, you are…?
Mandatory answer

1. The household reference person, that is, the person with the highest income from the household
2. Another adult in the household
3. One of the children
4. Another person (grandparent, cousin, etc.) living in this household

[Question S5C asked only to respondents who declare they are not the household reference person (S5B2 = 2, 3, 4)
s5c : What professional activity does the reference person in the household currently occupy?
If this person is looking for a job, please tick the professional activity sought.
Mandatory answer

1. Farmer operator
2. Craftsman
3. Shop owner and assimilated
4. Head of a company of 10 employees or more
5. Liberal profession
6. Public service executive
7. Professor or scientific job
8. Information, arts and entertainment profession
9. Administrative executive and business commercial
10. Engineer and et corporate technical executive
11. Teacher and assimilated
12. Health and social work supervision
13. Clergy, religious
14. Administrative supervision of the public service
15. Administrative and commercial supervision of private companies

16. Technician
17. Foreman, agent-control
18. Civilian employee and public service officer
19. Police officer and military.
20. Corporate administrative employee
21. Commercial employee
22. Personal services agent
23. Skilled worker
24. Driver
25. Unskilled specialized workers
26. Agricultural worker
27. Former farmer
28. Former self-employed
29. Former Senior Manager
30. Former Supervisor and Technician
31. Former employee
32. Former worker
33. Unemployed person who has never worked
34. Student
35. Person without professional activity, housewife / houseman

II – Main part of the survey

Instructions:

You will see below a list of measures regarding animals that the State could implement in France. For each measure, we ask you to indicate how much you would be willing to pay at most to implement these measures.
In the event that the measure is implemented, payment will be made annually for a period of five years and will be levied by an increase in taxes.
We kindly ask you to respond as faithfully as possible to what you would be willing to pay. For example, please consider the impact this would have on your budget. Even if these are hypothetical situations, they help to inform the public debate on the subject, and it is therefore very important that you express yourself as if this were a real situation.

A) Willingness to pay questions

Random ordering of questions PROP1 to PROP20.
The sample is randomly split in half between NUMECH=1 and NUMECH=2.

PROP1. Today, two million animals are killed each year in France to carry out experiments in laboratories. Several alternative methods exist and could significantly reduce the number of animals thus killed. Some people want the ethics committees that issue authorizations for animal testing to include two specialists in alternative methods. How much would you be willing to pay at most per year to implement such a measure?

If NUMECH = 1	If NUMECH = 2
1) 0€ 2) Between 0.01€ and 0.99€ 3) Between 1€ and 1.99€ 4) Between 2€ and 2.99€ 5) Between 3€ and 3.99€ 6) Between 4€ and 4.99€ 7) Between 5€ and 5.99€ 8) Between 6€ and 6.99€ 9) Between 7€ and 7.99€ 10) Between 8€ and 8.99€ 11) Between 9€ and 9.99€ 12) 10€ or more	Numeric open field.

SUR1. How sure are you of your answer?
1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP1 = 0€
PQ1. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP2. Today, a million animals are killed every year in France for dissections in middle and high schools. Some people argue for the establishment of alternatives which do not involve the killing of animals. How much would you be willing to pay at most per year to ban the dissection of animals in middle and high school?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR2. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP2 = 0€

PQ2. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP3. An average French person eats 75.8 kilograms of meat a year, which kills 3 million animals a day. Some people claim that eating more plant-based proteins is one of the main ways to improve animal welfare. How much would you be willing to pay at most per year to introduce a daily menu without meat, fish, eggs or dairy products in school canteens?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR3. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP3 = 0€

PQ3. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP4. Today in France, some people are proposing to integrate the question of animals into moral and civic education courses at the secondary school and to present them as sentient beings. How much would you be willing to pay at most per year to set up an animal ethics course in middle and high school?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR4. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP4 = 0€

PQ4. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP5. It is estimated that a single pair of non-sterilized cats could conceive more than 20,000 offspring in just four years. To avoid the proliferation of abandoned cats, some people suggest carrying out sterilization campaigns in veterinarians in France for stray cats. How much would you be willing to pay at most per year to implement such a measure?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR5. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP5 = 0€

PQ5. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP6. Today in France, it is estimated that more than 40,000 domestic animals are lost per year without being able to find their owner because they are not identified. These animals often end up dying on the street. Some people offer to make the first visit to the veterinarian for pets free of charge in order to identify them. How much would you be willing to pay at most per year to implement such a measure?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR6. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP6 = 0€

PQ6. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP7. The majority of egg products made in France use eggs from caged hens. Some people are proposing to make labeling on rearing conditions compulsory for these processed products to inform consumers. How much would you be willing to pay at most per year to make labeling of egg-processed products mandatory?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR7. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP7 = 0€

PQ7. You have declared that you are not ready to pay for the implementation of this measure. Why?

Open field

PROP8. Today in France, more than 100,000 minks and rabbits are raised and killed each year for their furs. Some people propose to ban these farms that do not respect the biological needs of these animals and argue for non-animal alternatives for furs. How much would you be willing to pay at most per year to ban the production and sale of fur in France?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR8. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP8 = 0€

PQ8. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP9. Today in France, there are 1,200 animals used in circuses, including many wild animals such as lions and tigers. The mayor of Paris has set up financial support for circuses which decide to convert and stop using these animals. How much would you be willing to pay at most per year to help finance the transition of these circuses at the national level?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR9. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP9 = 0€

PQ9. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP10. Thirty dolphins and killer whales are being held in captivity in France today, which creates physical and mental health problems that can kill them. How much would you be willing to pay at most per year to ban the breeding and acquisition of dolphins and orcas in delphiniums?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR10. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP10 = 0€

PQ10. You have declared that you are not ready to pay for the implementation of this measure. Why?

Open field

PROP11. Some people today denounce in France the presence of "factory farms" which bring together very many animals, sometimes several tens of thousands on a single site. For example, half of the pork is produced by only 1% of farms in France. How much would you be willing to pay at most per year to introduce more stringent legislation on factory farms?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR11. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP11 = 0€
PQ11. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP12. In France, several slaughterhouses kill animals without stunning, which can create great suffering to animals. In these cases, the latter can be conscious up to ten minutes after having their throats slit. Some people ask to make it compulsory to stun all animals before slaughtering them. How much would you be willing to pay at most per year to prohibit slaughter without stunning?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR12. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP12 = 0€
PQ12. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP13. Today in France, nearly two million calves are raised for consumption. Most of them suffer from malnutrition because the food they are given aims to keep their meat white and does not meet all their biological needs. Some are calling for legislation to increase the minimum legal amount of fibrous feed to be given to calves to solve these deficiencies. How much would you be willing to pay at most per year to implement this measure?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR13. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP13 = 0€

PQ13. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP14. Today in France, two million calves are raised each year on the soil without litter, which makes rest periods very uncomfortable. To improve their well-being, some people offer to install a straw or edible litter box on farms. How much would you be willing to pay at most per year to implement this measure?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR14. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP14 = 0€

PQ14. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP15. Each year in France, more than 12,000 badgers and 600,000 foxes are killed during hunting. These animals are however not edible. Some people are asking for a ban on killing these animals. How much would you be willing to pay at most per year to ban the killing of badgers and foxes?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR15. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP15 = 0€

PQ15. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP16. Today in France, more than 50,000 animals are raised and kept in parks and paddocks for hunting. During hunting periods, hunters come to the pens to kill animals that cannot escape. Some people are asking for a ban on these captive hunting parks. How much would you be willing to pay at most per year to ban this practice?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR16. How sure are you of your answer?

1. Vous êtes certain(e) de votre choix
2. Vous n'êtes pas tout à fait certain(e) de votre choix
3. Vous n'êtes pas du tout certain(e) de votre choix

If PROP16 = 0€

PQ16. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP17. Today in France, out of the fifteen billion eggs produced each year, two thirds come from laying hens locked up all their lives in cages. Some people propose to ban this type of breeding that they consider the cruelest for hens. How much would you be willing to pay at most per year to ban the raising of laying hens in cages?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR17. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP17 = 0€

PQ17. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP18. In France, more than 66 million ducks are force-fed each year to produce *foie gras*. Force-feeding is prohibited in several countries of the European Union and consists of pushing a 20 to 30 cm pipe into the animal's throat to forcefully administer large amounts of food. Some people suggest prohibiting force-feeding in the production of foie gras. How much would you be willing to pay at most per year to ban forced-feeding?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR18. How sure are you of your answer?

1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP18 = 0€

PQ18. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP19. Today in France, a million pigs are stunned each year with carbon dioxide before being bled. This practice causes great pain to the pigs, which howl, try to flee and suffocate for several seconds before sinking into unconsciousness. How much would you be willing to pay at most per year to ban this practice for the benefit of other alternatives?

If NUMECH = 1	If NUMECH = 2
Same as for PROP1	Numeric open field.

SUR19. How sure are you of your answer?

1. You are sure of your choice

2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP19 = 0€
PQ19. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

PROP20. Today in France, nearly 22 million piglets get their teeth cut every year. This practice aims to avoid aggressive behavior between piglets, but is very painful for animals. Another technique, called grinding, is to round the tips of the piglets' teeth, which greatly reduces the suffering of the animals and achieves the same result. How much would you be willing to pay at most per year to prohibit the cutting of teeth in piglets for the benefit of grinding?

If NUMECH = 1	**If NUMECH = 2**
Same as for PROP1	Numeric open field.

SUR20. How sure are you of your answer?
1. You are sure of your choice
2. You are not entirely sure of your choice
3. You are not at all certain of your choice

If PROP20 = 0€
PQ20. You have declared that you are not ready to pay for the implementation of this measure. Why?
Open field

B) Questions on attitudes

ATT1. Do you strongly agree, agree, neither agree nor disagree, tend to disagree or strongly disagree with the following statements?

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

1) There are fundraising campaigns that I feel close to and for which I don't hesitate to contribute.
2) I tend to admire the individuals who voluntarily contribute to fundraising for national environmental programs and for animals.
3) I am happy when I give a financial contribution to a fundraising campaign.

(Random ordering of the items)

ATT2. How often do you eat meat?

1. At each meal
2. Every other meal
3. Once a week
4. Once a month or less

ATT3. Do you have cats or dogs?

1. Yes
2. No

ATT4. Did you go to a circus or a park with dolphins last year?

1. Yes
2. No

III – Closing questions

S4. What is the highest degree you have obtained?
Mandatory answer

1. No diploma
2. Certificate of primary studies or equivalent
3. Brevet des Collèges or equivalent
4. Vocational diploma or equivalent
5. General baccalaureate or equivalent
6. Two-year Higher Education diploma
7. Three-year Higher Education diploma
8. Four-year Higher Education diploma
9. Five-year or more Higher Education diploma
10. 10. School of engineering or business school

S27. Currently, you are...
Mandatory answer

1. Single
2. Married or remarried
3. Civil partnership
4. In cohabitation
5. Divorced
6. Widowed

SI1. Are you…?
Mandatory answer

1. A landlord
2. A tenant
3. Living with free accommodation

SI2. In which type of house do you live in?
Mandatory answer

1. A detached house
2. Collective housing

S9. Including yourself, how many people live in your household?
Mandatory answer

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6 and more

Question S10 asked only to those who say that they are not living alone in the previous question (S9 = 2-6)
S10. How many children under the age of 18 currently live in your household?
Mandatory answer

1. No child under 18
2. One
3. Two
4. Three
5. Four or more

S6. Which of the following political groups do you feel closest to or, say, the least distant?

1. Lutte Ouvrière
2. Le NPA - Nouveau Parti Anti-capitaliste
3. La France insoumise
4. Le Parti Communiste
5. Génération.s
6. Le Parti Socialiste
7. Europe écologie / Les Verts
8. Un autre mouvement écologiste
9. Le Parti Animaliste
10. Le Parti Radical de Gauche
11. Le MoDem
12. La République En marche !
13. L'UDI
14. Les Républicains (ex U.M.P.)
15. L'UPR
16. Debout la France
17. Les Patriotes
18. Le Rassemblement National (ex Front National)
19. None of these

S42. Do you pay income tax?

1. Yes
2. No

S26. Taking into account all the resources of your household, that is to say net wages, family allowances, unemployment benefits, pensions, and other net income, in which bracket are the NET monthly incomes of your household?

1. Less than 750 Euro per month
2. From 750 to 999 Euro per month
3. From 1 000 to 1 499 Euro per month
4. From 1 500 to 1 999 Euro per month
5. From 2 000 to 2 999 Euro per month
6. From 3 000 to 3 499 Euro per month
7. From 3 500 to 4 999 Euro per month
8. 5 000 Euro and month per month
9. I don't know

Question S25 asked only to those who answers « I don't know » or don't answer to the previous question.
S25. And if we are talking about annual income brackets, to make the answer easier for you. Taking into account all the resources of your household, that is to say, net wages, family allowances, unemployment benefits, pensions, pensions and other net incomes, in which bracket are the NET annual incomes of your household?

1. Less than 9 000 Euro per year
2. From 9 000 to 11 999 Euro per year
3. From 12 000 to 17 999 Euro per year
4. From 18 000 to 23 999 Euro per year
5. From 24 000 to 35 999 Euro per year
6. From 36 000 to 41 999 Euro per year
7. From 42 000 to 59 999 Euro per year
8. 60 000 Euro and more per year
9. I don't know

Supplementary Materials 3: Determinants of WTPs

I here explore the determinants of the average WTPs. The econometric model is that presented in Section 3.4, where the X vector contains a constant term and a series of (centered) binary variables reflecting demographics (female, paying income tax, age over 50, living in a large city, living in a large household, university degree, eating meat daily, visiting circuses, land ownership, and single). Given the non-linearity of the model, I estimate the marginal effect of each of these variables on the average WTPs, holding all other variables constant at their sample means (i.e. at zero, due to the normalization).

Figure SM1 displays the estimation results. The circle sizes are proportional to the marginal effects. There are statistically-significant correlations between a number of demographic variables and the WTPs. Women pay more for all animal-welfare policies, with this association being statistically significant for all of the 20 policies considered. This is consistent with previous work showing greater concern for animal welfare among women (e.g., Bennett et al. (2019)). Surprisingly, individuals who go to circuses also report larger WTPs for animal welfare, although this association is only significant at the 5% level for school interventions (plant-based menus, and ethics classes) and pets (sterilization and identification); they also reject animal experimentation and care about industrial farming (at the 10% level). Those who go to circuses may thus care about specific types of animal use, which do not include animal shows, hunting, or farmed animals.

On the contrary, older individuals are less likely to pay for animal welfare. We find a negative association between age and WTPs for all policies but one (mandatory stunning). This is also consistent with previous findings (Clark et al., 2017). Those who eat meat daily are also significantly less likely to pay for animal-welfare policies, including animal experimentation, interventions at schools, measures for pets, the regulation of trade, limitations on intensive farming, and improvements in hens' and pigs' living conditions; they are not significantly different from the rest of the population regarding animal shows and hunting. Last, there are noisier associations between WTPs and having a university degree: those with degrees pay significantly less to ban dissection at school, have a free and mandatory identification campaign of pets, and ban force-feeding. This may reflect a belief that dissection contributes to education, identification costs should born by pet owners, and banning force-feeding may affect their consumption of *foie-gras*, which is a luxury product that the richer may be more likely to consume.

Figure SM1: The estimated marginal effects of socio-demographics on the WTPs

Table SM2: Regression of WTPs on socio-economic variables.

	Alternatives	Dissection	Menus	Ethics	Sterilization	Identification	Label	Fur	Circuses	Dolphins
Female	12.93	8.35	8.89	10.93	13.72	8.16	9.17	18.51	12.34	13.73
	(4.91)	(3.18)	(3.29)	(3.31)	(4.57)	(4.89)	(2.98)	(6.62)	(4.86)	(4.55)
Income Tax	1.55	1.88	-0.4	5.69	4.42	4.54	0.73	2.22	-0.56	0.61
	(4.54)	(3.04)	(3.05)	(3.06)	(4.12)	(5.19)	(2.67)	(5.58)	(4.55)	(3.97)
Above 50	-10.94	-5.43	-11.06	-8.19	-13.22	-12.7	-8.76	-15.25	-13.13	-12.47
	(5.12)	(3.26)	(3.76)	(3.19)	(4.88)	(5.83)	(3.13)	(6.54)	(5.38)	(4.72)
Large City	1.02	-0.56	2.11	0.67	1.74	-5.34	1.75	4.75	0.25	1.9
	(4.12)	(2.75)	(2.81)	(2.56)	(3.63)	(4.85)	(2.42)	(5.12)	(4.13)	(3.67)
Large Household	-0.3	0.35	-2.54	-1.95	-5.15	-3.64	-2.46	-0.45	-4.41	-3.18
	(4.53)	(3.01)	(3.02)	(2.79)	(4.14)	(5.17)	(2.66)	(5.46)	(4.61)	(4.04)
University degree	-5.67	-6.15	-1.06	-4.84	-7.94	-11.9	-4.51	-5.52	-3.28	-6.58
	(4.27)	(3.01)	(2.8)	(2.74)	(3.99)	(5.37)	(2.58)	(5.15)	(4.17)	(3.87)
Meat daily	-10.19	-5.9	-6.8	-6.65	-8.24	-10.71	-5.5	-13.12	-6.03	-6.28
	(4.71)	(3.02)	(3.15)	(2.89)	(4.06)	(5.28)	(2.66)	(5.97)	(4.35)	(3.89)
Visit Circus	14.38	9.28	10.35	10.22	13.85	19.17	7.48	10.52	4.57	3.62
	(7.54)	(4.81)	(4.93)	(4.6)	(6.45)	(8.59)	(4.07)	(8.41)	(6.77)	(5.82)
Land Owner	-2.71	-7.36	-1.48	-5.59	0.23	-10.99	-1.18	-8.69	-3.26	-7.16
	(4.77)	(3.54)	(3.14)	(3.18)	(4.22)	(5.96)	(2.8)	(6.25)	(4.79)	(4.43)
Single	8.31	2.12	1.67	3.75	2.74	2.48	2.21	4.07	5.28	4.61
	(4.98)	(3.08)	(3.07)	(2.95)	(4.08)	(5.17)	(2.73)	(5.66)	(4.68)	(4.18)
LL	-2486.599	-2356.36	-2225.645	-2327.212	-2541.395	-2480.97	-2501.187	-2401.192	-2429.24	-2440.96

Notes: (1) Estimations are based on the entire sample, i.e. 1,473 observations. (2) The figures here are the estimated marginal effects, with standard errors in parentheses.

Table SM2.2: Regression of WTPs on socio-economic variables (cont'd).

	Intensive	Stunning	Fiber	Bedding	Foxes	Penned	Cage	Force-feeding	CO2	Grinding
Female	12.88	17.77	9.31	10.04	13.98	12.76	13.85	10.73	12.66	12.88
	(4.46)	(7.02)	(2.97)	(3.38)	(6.09)	(4.35)	(4.25)	(2.98)	(4.48)	(3.8)
Income Tax	3.03	5.79	3.7	1.6	5.69	3.62	4.26	4.68	5.18	2.19
	(4.04)	(6.48)	(2.84)	(3.14)	(5.65)	(3.92)	(3.7)	(2.57)	(4.25)	(3.22)
Above 50	-7.41	-9.29	-8.91	-5.8	-11.67	-9.94	-11.06	-9.95	-7.63	-11.07
	(4.28)	(6.69)	(3.15)	(3.32)	(6.15)	(4.34)	(4.22)	(3.03)	(4.39)	(3.87)
Large City	3.38	-0.76	2.38	1.11	4.22	-0.02	2.01	1.25	-2.35	1.1
	(3.68)	(5.75)	(2.52)	(2.85)	(5.03)	(3.49)	(3.32)	(2.17)	(3.79)	(2.93)
Large Household	0.39	-4.25	-2.5	0.62	-1.32	0.37	-2.98	-2.96	-2.35	-1.78
	(3.95)	(6.33)	(2.75)	(3.08)	(5.31)	(3.8)	(3.66)	(2.45)	(4.12)	(3.18)
University degree	-6.38	-6.04	-4.38	-4.84	-6.85	-7.29	-5.14	-5.91	-6.47	-5.89
	(3.9)	(5.91)	(2.63)	(2.98)	(5.26)	(3.82)	(3.45)	(2.46)	(4)	(3.15)
Meat daily	-8.8	-15.33	-6.46	-3.19	-7.13	-5.33	-6.32	-5.08	-11.68	-7.48
	(4.1)	(6.8)	(2.77)	(2.94)	(5.33)	(3.72)	(3.56)	(2.41)	(4.51)	(3.31)
Visit Circus	11.55	20.58	6.44	6.46	10.75	8	6.07	5.39	7.94	6.23
	(6.23)	(10.48)	(4.15)	(4.76)	(8.28)	(5.68)	(5.45)	(3.62)	(6.33)	(4.76)
Land Owner	-0.57	-3.6	-2.12	-1.47	-10.72	-5.62	-1.78	-4.74	-4.24	-3.61
	(4.18)	(6.62)	(2.88)	(3.27)	(6.33)	(4.19)	(3.78)	(2.64)	(4.38)	(3.43)
Single	6.77	10.96	1.56	4.01	9.22	8.12	2.73	3.8	5.69	1.14
	(4.29)	(6.98)	(2.76)	(3.24)	(6.02)	(4.29)	(3.7)	(2.5)	(4.3)	(3.22)
LL	-2504.584	-2465.376	-2521.177	-2533.255	-2203.782	-2363.228	-2544.852	-2262.793	-2494.67	-2495.618

Notes: (1) Estimations are based on the entire sample, i.e. 1,473 observations. (2) The figures here are the estimated marginal effects, with standard errors in parentheses.

Supplementary Materials 4: Uncertainty in WTPs

A major challenge in contingent valuation is that participants may not be confident in their answer, as they are not familiar with this elicitation method. In most situations, individuals make binary decisions of whether to buy a product or support a policy: they buy (support) it or not. Unfamiliarity with the decision space in the WTP survey may generate confusion and so noise in the data; this noise will bias the estimation of the mean if uncertain participants systematically overestimate or underestimate their WTP.

Another challenge, particular to this topic, is that people might not be used to thinking about animal-welfare policies in monetary terms, as most of the policies here have no market-based solutions. The lack of a benchmark might contribute to respondent confusion, again making the stated WTPs noisier.

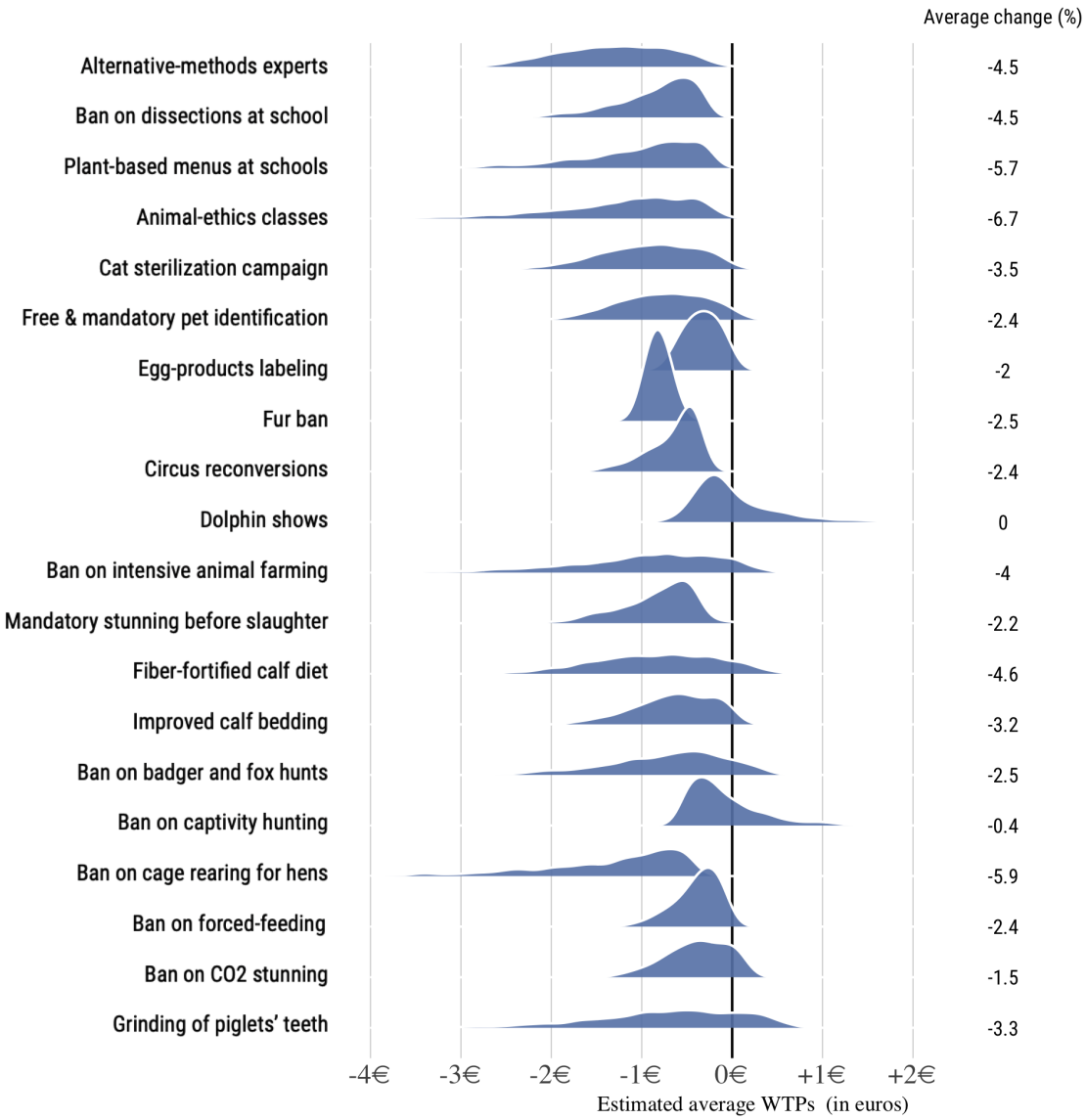
I tackle these concerns by considering the robustness of the results to respondents' confidence in their answers. The survey asked participants their confidence in their answer to each WTP question (certain, not entirely certain, and not certain at all): I label these high (H), moderate (M) and low (L). In what follows, I re-weight the observations by these confidence scores. The results in the body of the paper apply the sampling weights ω_j for individual j provided by the polling institute to reconstruct a representative sample, so that ($p_L = p_M = p_H$). The new weights are $\tilde{\omega}_{ij} = p_{i(j)}\omega_j$, where $p_{i(j)}$ is the confidence weight $i = \{L, M, H\}$ of individual j.

I test result robustness by simulating confidence weights and plotting the distribution of the estimated average WTPs, with $p_H = 1$ as the reference point. For each simulation, I draw a random weight p_L from a uniform distribution between 0 and 1 ($p_L \sim U[0, 1]$). At the two extremes, observations with low confidence are either given the same weight as observations with high confidence ($p_L = p_H = 1$) or are dropped ($p_L = 0$). Intermediate levels are assigned a lower, but still positive, weight in the analysis than highly-confident answers. The intermediate weight p_M is drawn from a uniform distribution between p_L and 1 ($p_M \sim U[p_L, 1]$). Moderately-confident answers therefore receive a weight that is equal to or larger than the weight of low-confidence answers ($p_M \geq p_L$), and up to the same weight as high-confidence answers ($p_M \leq p_H$). Last, as it was possible to continue the survey without answering the confidence question, I also define a weight for missing values $p_{NA} \sim U[0, 1]$. I simulate the set of weights 1,000 times following this procedure and estimate the average WTPs for each simulation. The estimation model is similar to the model of warm WTPs in the body of the paper, except for the sample weights. Figure SM2 shows the distribution of the differences between the estimated WTPs in the simulations from the original model (without weights).

There are two main findings. First, the average deviations are all negative (or zero for dolphin shows). Reducing the weight given to uncertain answers reduces the average WTPs. This suggests that uncertain participants report larger WTPs or, alternatively, that those with lower WTPs are more certain of their choice. Second, the gaps are relatively small, ranging from -3.60 Euros to +1.85 Euros (see Appendix Table A3 for the detailed results). Uncertainty-weighting reduces average WTPs by up to 6.7% (animal-ethics classes), but most gaps are below 5% in absolute value

(17 out of the 20 policies). Overall, the estimation results are robust to reported answer uncertainty.

Figure SM2: Robustness analysis: differences between the estimated average WTPs with uncertainty-weighting (1,000 simulations with random uncertainty weighting) and the original average WTPs without uncertainty-weighting.



Supplementary Materials 5: Average WTPs for multiple policies

The previous results represent the average WTPs of the French population for single policies. However, policy makers might be willing to bundle policies into a single reform project. In this case, the challenge is to estimate the average WTP for a bundle of policies rather than a single policy. Previous work in Economics has shown that the WTP for a bundle of policies is lower than the sum of the WTPs for the single policies comprising the bundle. This has been described as the *embedding phenomenon*. Decreasing marginal utility of altruistic preferences reduces the marginal utility of helping animals, so that the second policy increases utility by less than if it had been implemented first. Similarly, the presence of warm glow might significantly reduce the WTP for the bundle of policies. If individuals mostly care about *doing something* for animals, rather than the *impact* of their actions on animals, they might obtain high utility from the first action they undertake in favor of animals but a significantly lower utility boost from their subsequent actions, as the warm-glow component disappears

The challenge in estimating the WTP for a bundle of policies is to retrieve the so-called "cold" WTPs. Nunes and Schokkaert (2003) show that the cold WTP of a bundle of policies equals the sum of the cold WTPs of the single policies. I follow their work and retrieve cold utilities by removing the warm-glow component from the WTPs. I do so by controlling for the participants' propensity to be subject to the warm glow via the three questions in the survey relating to warm-glow preferences (see Table SM3). I recode the answers to these questions between -2 (strongly disagree) and +2 (strongly agree), and include them as continuous variables in the model. I then calculate the average WTPs for an individual with a zero score for the three questions, i.e. who is "indifferent" to warm-glow questions.

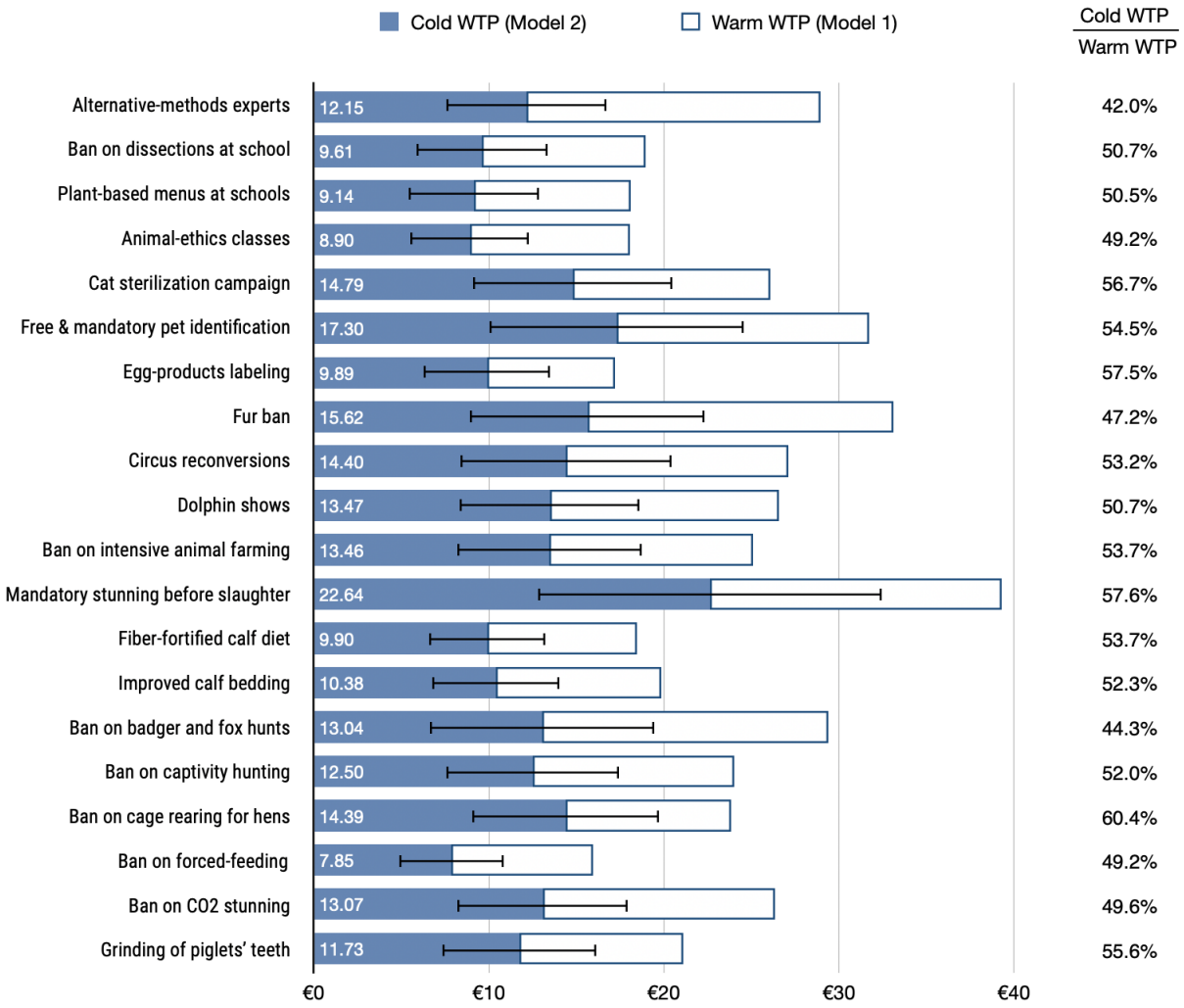
Table SM3: The weighted distribution of warm-glow questions (in %)

Question	Strongly disagree	Disagree	Indifferent	Agree	Strongly agree
There are fundraising campaigns that I feel close to and to which I don't hesitate to contribute.	12.9%	9.2%	28.3%	31.1%	18.5%
I tend to admire individuals who voluntarily contribute to fundraising for national environmental programs and for animals.	12.7%	6.8%	30.6%	29.5%	20.5%
I am happy when I give a financial contribution to a fundraising campaign.	14.3%	5.5%	37.3%	29.0%	14.0%

The new estimates appear in Figure SM3. The estimated cold WTPs are lower than the previously-estimated average WTPs, so that the warm-glow correction worked in the expected direction. The average cold WTPs are still significantly different from zero, and range from 7.85 Euros per year (banning force feeding) to 22.64 Euros (mandatory stunning). On average, the estimated cold WTPs are half as large as the warm WTPs previously estimated. The warm-glow effect is the largest for the introduction of alternative-methods experts in ethics committees, where the

cold WTP is only 42% of the warm WTP. At the other extreme, the ban on cage rearing is the least sensitive to warm-glow with the cold WTP being 60.4% of the warm WTP.

Figure SM3: Average WTPs for the twenty policies with warm-glow correction (cold WTPs)



Note: The spikes represent the 95% confidence intervals.

Supplementary Materials 6: Types of utilities

In the survey of the 20 measures for animals, participants could report only positive or zero WTPs. When they reported a zero WTP, they were asked to provide an open-ended justification for their choice. A research assistant, Ophélie Mélières, went through about one quarter of the answers and distinguished six categories of arguments:

1. I do not feel concerned
2. I am against the policy
3. I am in favor but in another way
4. I am in favor but I do not have enough money to pay
5. I am in favor but it is not for me to pay
6. No opinion

The research assistant screened all of the answers with zero WTPs, and categorized them using this classification. I use this categorization to calculate utility changes. Those who are against the measure are assumed to have a fall in utility; those who report being in favor but in another way, who do not have enough money to pay, or who think it is not for them to pay, are considered to have a hidden increase in utility. I use the term 'hidden', as these participants would enjoy the consequences of the reform but are not ready to pay for its implementation. Last, participants who reported not to be concerned, to have no opinion or who left the field empty are assumed to experience no utility change.

Supplementary Materials 7: Estimating avoided animal suffering

In this section, I estimate the number of animals that would be directly impacted by the policies, their species, and the violations of the Five Freedoms (5F) that would be avoided for each of them. I discuss policy by policy how I obtain these estimates. Note that, for the sake of simplicity, I here only consider the animals that are directly affected by the measures. As I assumed equal weight between violations in Section 2, I only need to calculate the number of violation points avoided for each animal to establish the change in 5FFI. Note that, by definition, the change in 5FFI for an avoided death is normalized at 1. I consider here the worst overall violation of the 5F. If death is avoided, I have $\Delta\zeta = 1$. If the animal lives under circumstances worse than death, I consider the larger violation score of $\Delta\zeta > 1$.

Policy No. 1: Include specialists in animal-free experimentation methods in all animal-experimentation ethics committees.

The French Ministry of Higher Education and Research publishes annual reports on the number of animals used in animal experiments in France.[1] These reports do not include (i) invertebrates (except for cephalopods), (ii) animals raised to produce animals for experiments, and (iii) animals killed for organ or tissue extraction. For each category of animal, the public data report the severity of the suffering that was generated by the experiment according to European legislation (mild, moderate, severe, death).

Table SM4 lists the number of animals used in animal experiments and their suffering. Note that almost all animals used in animal experiments are killed after the experiment, so that all animals here also suffer from death. Note also that I present here only the categories of animals that cover at least 0.10% of all animals used in experiments. The remaining group of animals represents 0.33% of the total number of animals used in experiments.

In Table SM4, 32.4% of the animals used in experiments suffer from mild harm, 14% from moderate harm, and 6.1% from severe harm. In addition, 47.5% of the animals undergo general anesthesia from which they do not recover.

The key challenge here is to estimate the potential gains from having specialists in animal-free experimentation methods in all ethics committees. There is currently no research on the share of animal experiments in France that could use alternative methods. I here consider that 10% of animals would be saved by this policy, but that not all types of animals are affected. While experiments on mice, fish, rats, and rabbits are relatively frequent (each representing over 5% of the animals used), the use of other species is relatively rare, and alternative methods may be less available for these "niche" experiments. I thus assume that the 10% reduction applies only to mice, fish, rats, and rabbits.

I define the avoided harm in the 5FFI as the largest avoided violations for the animals. For

[1] http://web.archive.org/web/20210721131729/https://cache.media.enseignementsup-recherche.gouv.fr/file/utilisation_des_animaux_fins_scientifiques/85/8/STAT_2019_1371858.pdf.

non-recovery, mild, and moderate harm, I consider therefore that the largest avoided harm is death, i.e., $\zeta = 1$. For animals that suffer from severe harm according to the European legislation, I assume that the avoided harm is equivalent to death plus two violation points (associated with freedom from pain and freedom from physical discomfort).

Summary of Policy No. 1			
Animal	Number	Avoided violation points	Confidence
Mouse	89,230	17	Low
Mouse	17,943	15	Low
Fish	13,011	17	Low
Fish	4,708	15	Low
Rat	14,392	17	Low
Rat	2,232	15	Low
Rabbit	13,294	17	Low
Rabbit	267	15	Low

Table SM4: Animals used in animal experimentation in France in 2019 by category of animals and category of harm (Source: French Ministry of Higher Education and Research)

Animal	Non-recovery	Mild	Moderate	Severe	Share (in %)
Mouse	73,641	294,075	584,577	179,430	60.67
Other fish	1,777	111,769	16,563	47,079	9.50
Rats	24,836	61,331	57,754	22,324	8.91
Rabbit	946	31,502	100,490	2,670	7.27
Hen	768	51,576	21,508	2,772	4.11
Zebra fish	795	13,124	35,122	2,067	2.74
Other birds	5,410	4,274	28,097	201	2.04
Guinea pig	762	8,043	27,221	1,397	2.01
Pig	3,103	4,870	4,195	449	0.68
Reptile	0	2,651	3,500	0	0.33
Hamster	24	2,419	2,140	1,329	0.32
Xenopus	218	5,207	252	0	0.30
Dog	135	2,885	1,686	192	0.26
Sheep	230	3,176	1,106	383	0.26
Macaque (Fascicularis)	35	2,134	657	97	0.16
Cattle	8	1,894	241	52	0.12
Others	860	3,535	1,752	87	0.33
Total	886,861	604,465	260,529	113,548	100
Share (in %)	47.5	32.4	14.0	6.1	100

Policy No. 2: Ban the dissection of animals in primary and secondary education.

Education programs in French schools have undergone a number of changes over recent years. Up to 2016, dissections were practiced at various stages in secondary schools. A 2016 Ministry of Education circular restricted the practice of dissections at schools by prohibiting dissections on invertebrates (other than cephalopods) and on "vertebrates or vertebrate products marketed for food".[2] Moreover, the circular prohibited the dissection of animals that were raised for this purpose.

Dissections are not obligatory and are left to the discretion of the teachers. During the third to fifth year of secondary school, students can still perform dissections. No official figures are provided regarding the number and types of animals killed each year for dissections. I contacted the Ministry, which did not wish to provide the figures. However, interviews with secondary school teachers indicate that they do continue to dissect frogs. Material to help teachers organize dissection classes is provided on the website of the Ministry of National Education (published in 2019).[3] The use of frogs is permitted for dissection as they are bought, usually frozen, from the food industry.

In 2020, there were 3.4 millions students in the first part of secondary school (*Collège*) in France, which lasts for four years.[4] Assuming one dissection per student during their *Collège* curriculum, we can estimate that about 850.000 students per year dissect frogs. Given that some teachers do not practice dissections, I assume that one out of two children effectively dissect a frog during the secondary school, for a total of 425.000 per year.

In the second part of secondary school (*lycée*), students can also carry out dissections. However, discussions with science teachers indicated that these students, when they do dissections, practice on larger-animals' organs, such as livers or eyes bought at butchers' shops. It is difficult to estimate the impact on animal welfare as buying these types of organs does not significantly alter the demand for meat (e.g., the eyes would not be used anyway). I here take a conservative approach and do not consider any impact on animal welfare from *lycées*.

Summary of Policy No. 2			
Animal	Number	Avoided violation points	Confidence
Frogs	425,000	15	Low

Policy No. 3: Introduce a daily plant-based menu in all school canteens.

There has been considerable debate in recent years in France about plant-based menus in schools. In 2018, a law (EGALIM) was passed to force school canteens to propose vegetarian meals to students at least once a week.[5] A recent investigation from Greenpeace France reported that 71% of French students had access to one vegetarian meal per week (and 3% twice a week or more, 20% from time to time, and 6% never). In March 2021, Greenpeace and the French Vegetarian Association (AVF) published a report on school canteen practices, indicating that about 16.6% of

[2] http://web.archive.org/web/20210615140258/https://www.education.gouv.fr/bo/16/Hebdo29/MENE1618745C.htm?cid_bo=104634.

[3] http://web.archive.org/web/20210621131103/https://edubase.eduscol.education.fr/fiche/15538.

[4] http://web.archive.org/web/https://www.education.gouv.fr/les-chiffres-cles-du-systeme-educatif-6515.

[5] http://web.archive.org/web/20210317155615/https://agriculture.gouv.fr/egalim-depuis-le-1er-novembre-un-menu-veg

children chose the vegetarian option when it was available. This proportion was twice as large in places that had implemented the vegetarian option for longer, and the report concluded that a longer exposure could increase the prevalence of vegetarian choices.

Considering these figures, we extrapolate the possible impact of an extension of the existing measure (one vegetarian option per week) to the proposed policy (every day). First, France had about 6.653 million students in elementary schools in 2020-2021 and 5.699 million in secondary schools, out of a population of 67 million.[6] Second, one out of two (resp. two out of three) students in elementary (resp. secondary) schools have lunch at the school canteen (source: the 2017 CNESCO report on school canteens). Third, students go to school five times a week for 36 weeks per year. Fourth, we consider that the children would now be offered 4 additional plant-based menus per week (as they already have these once a week) over the 14 lunch/dinner meals each week. Fifth, about 3% of the French population is vegetarian or vegan.

I calculate the overall change in demand for plant-based meals as:

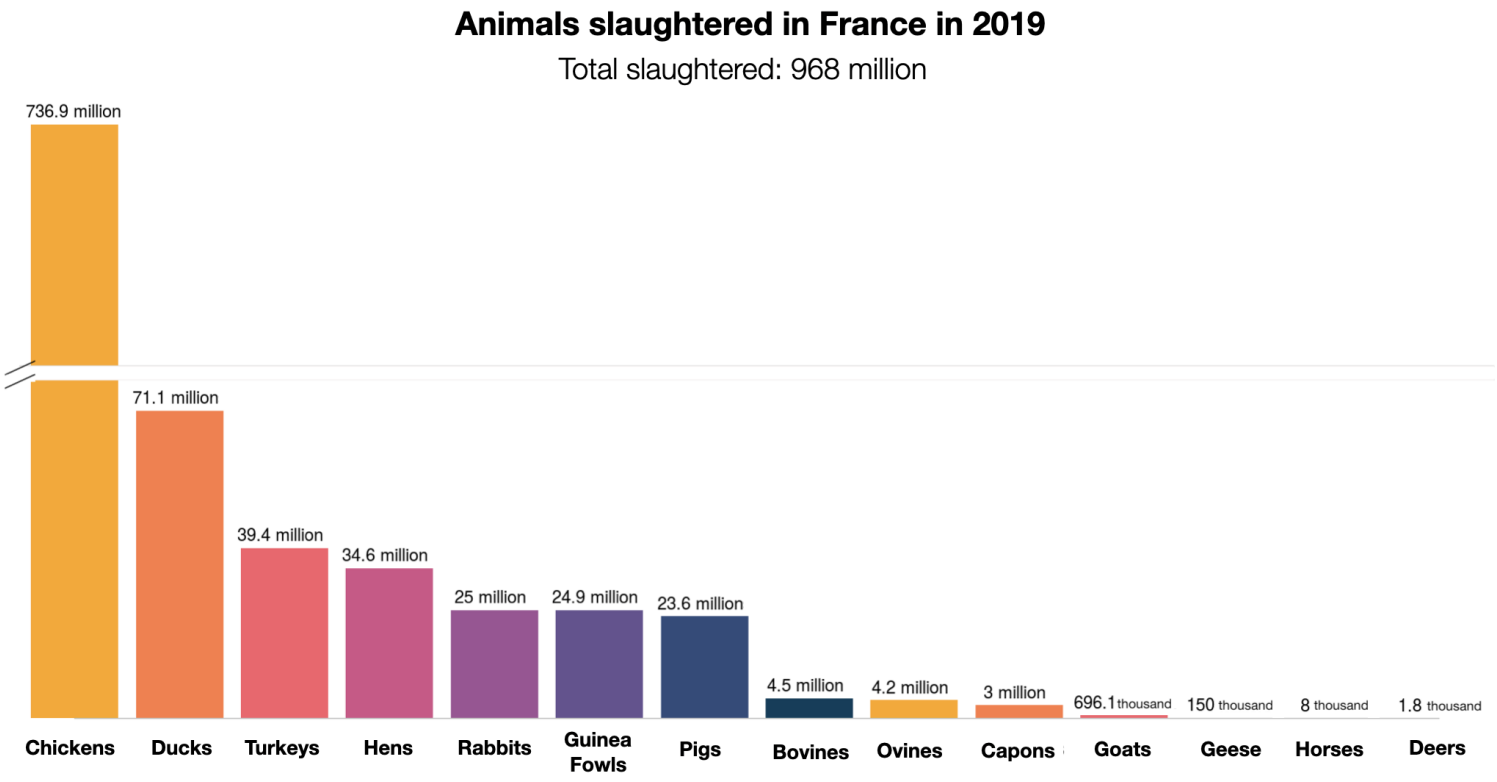
$$\frac{6.653 \times \frac{1}{2} + 5.699 \times \frac{2}{3}}{6.653 + 5.699} \times \frac{4}{14} \times 0.166 \times \frac{36}{52} \times \frac{6.655 + 5.699}{67} \times \frac{1}{0.97} = 0.36\% \tag{9}$$

Assuming that the demand for meat consumption would then fall by 0.36%, we need to calculate the number and types of animals that would be affected by this measure. Figure SM4 shows the number and types of animals killed each year in France for meat consumption. Note that we exclude here fish, which are sentient beings, but for which we lack data. I exclude capons, goats, geese, horses and deer, as these are unlikely to be served to children. I further drop ducks, which are mostly used for the production of foie gras (which is not served in schools).

Assuming that the 0.36% drop in meat consumption applies uniformly over the remaining animals, the numbers saved by the measure are: 2.65 million chickens, 142,000 turkeys, 125,000 hens, 90,000 rabbits, 89,600 guinea fowls, 85,000 pigs, 16,200 bovines, and 15,100 ovines. These figures correspond to the number of avoided deaths. Last, a majority of these animals would normally be raised by intensive farming. About 80% of the chickens in France are raised in intensive farming, and about 95% of the pigs. Most rabbits are also raised in cages. I thus consider that the avoided suffering is two violation points larger for animals in intensive farms, i.e. for 80% of the birds (chickens, turkeys, hens, guinea fowls), and 95% of pigs and rabbits.

[6] http://web.archive.org/web/https://www.education.gouv.fr/les-chiffres-cles-du-systeme-educatif-6515

Figure SM4: Number of animals slaughtered for meat consumption in France in 2019. (Source: French Ministry of Agriculture)



Summary of Policy No. 3			
Animal	Number	Avoided violation points	Confidence
Chicken	530,000	15	Medium
Turkey	28,400	15	Medium
Hen	25,000	15	Medium
Rabbit	4,500	15	Medium
Guinea Fowls	17,920	15	Medium
Pig	4,250	15	Medium
Bovine	16,200	15	Medium
Sheep	15,100	15	Medium
Chicken	2,120,000	17	Medium
Turkey	113,600	17	Medium
Hen	100,000	17	Medium
Rabbit	85,500	17	Medium
Guinea Fowl	71,680	17	Medium
Pig	80,750	17	Medium

Policy No. 4: Set up an animal-ethics course in school curricula.

No animal is directly affected by this measure in the short term.

Summary of Policy No. 4			
Animal	Number	Avoided violation points	Confidence
No direct impact			

Policy No. 5: Conduct sterilization campaigns for stray cats.

The issue of sterilizing stray cats is important, as their uncontrolled reproduction can lead to an exponential increase in the stray feline population. It is estimated that a single pair of cats can produce 20,746 offspring in just four years if nothing hinders their reproduction. The proliferation of stray cats poses public-health problems (the transmission of infectious diseases), but also affects animal welfare (fighting, under-nutrition, etc.) and the protection of wildlife. The Brigitte Bardot Foundation,[7] an animal-advocacy NGO, estimates that there are currently 11 million stray cats in France. Assuming that every year one tenth of this population is spayed, and assuming, very conservatively, that each spayed cat avoids one death per year, it can be assumed that 1.1 million deaths are avoided per year by this measure.

[7] https://web.archive.org/web/20200410095945/https:/www.fondationbrigittebardot.fr/la-fondation/nos-combats/sterilisation-chiens-chats/.

Summary of Policy No. 5			
Animal	Number	Avoided violation points	Confidence
Cat	1,100,000	15	High

Policy No. 6: Make the first visit to the veterinarian free and compulsory to identify pets.

Many pets remain unidentified in France, which prevents animal services from finding their owners when they get lost. In 2018, 80,000 dogs and cats were declared lost, and less than half of their owners were found. Unidentified lost animals are considered abandoned or wild, and risk either being euthanized or simply dying in the street. Making the first visit to the veterinarian free and compulsory to identify domestic mammals should encourage more owners to have their pet tattooed or chipped and register them in the national database (National Identification of Domestic Carnivores file).

Given the national figures, we can consider that about 40,000 cats and dogs would avoid being lost and then found every year if the policy was implemented. In addition, about 40,000 cats and dogs would avoid being lost for good. I consider that lost animals whose owner is not found suffer on average from severe violation for fear and distress from losing their owner. I assume moderate violation when the owner is found. I further assume moderate violations for hunger/thirst, physical discomfort, and pain/injury/disease for animals whose owners are not found, as a significant share of these go wild and die or are euthanized. When the owner is found, I assume mild violations due to the transition period. Last, I assume an equivalent distribution between cats and dogs.

Summary of Policy No. 6			
Animal	Number	Avoided violation points	Confidence
Cat	20,000	9	Medium
Cat	20,000	4	Medium
Dog	20,000	9	Medium
Dog	20,000	4	Medium

Policy No. 7: Establish mandatory labeling of egg products according to the system already in place for eggs.

Eggs sold in France are labeled with a number indicating the rearing conditions of the associated egg-laying hen: 0 - organic breeding, 1 - outdoor breeding, 2 - floor breeding, 3 - cage breeding. This nomenclature was thought to help consumers make informed choices. However, while this label is mandatory for unprocessed eggs, processed food is not required to report the type of eggs used in its preparation. Consumers only rarely know the rearing conditions of hens for processed foods (when firms voluntarily report the type of eggs used).

According to the National Committee for the Promotion of Eggs (CNPO), 71% of the eggs used in processed foods in 2018 came indeed from cage hens (code 3),[8] whereas on the contrary only 48% of unprocessed eggs were produced by cage hens. According to the European Commission, France had about 48 million laying hens in 2019, and 54% were raised in cages. Assuming that the mandatory labeling would equalize consumer behavior across types of eggs (processed and unprocessed), about 2.9 million laying hens would avoid cage-breeding every year were the policy to be implemented. Being conservative, we can assume that the demand will switch to floor breeding, which constitutes a modest improvement in hen welfare.

Compared to cage-breeding, floor-breeding animals benefit from lower density, which gives them more space (from 750 cm2 per hen to 1100 cm2 per hen) and better bedding. This is likely to produce a small improvement in the 5 freedoms, by reducing violations of the freedoms from physical discomfort, from pain, injury and disease, fear and distress, and the freedom to express normal patterns of behavior. I assume that the violations of these freedoms are one point lower in floor-breeding as compared to cage-breeding.

Summary of Policy No. 7			
Animal	Number	Avoided violation points	Confidence
Hen	2,900,000	4	High

Policy No. 8: Ban the production and sale of fur in France.

Fifteen fur farms were operating in France in 2019. As far as mink are concerned, four farms produce on average 10,000 mink per year per farm.[9] Orylag rabbits are raised in 11 farms that produce and kill in total 60,000 animals per year.[10] All of these animals are raised in cages. Repeated video footage from animal-advocacy NGOs show very severe violations of these animals' freedoms, both for mink[11] and Orylag rabbits.[12]

Prohibiting the sale of fur in France would prevent the demand from shifting to imports. I thus consider that the policy would avoid the death of 60,000 rabbits and 40,000 mink each year. Given the severe violations of the 5 freedoms documented by the NGOs, I consider two additional violation points compared to death, accounting for very severe violations in the freedom from physical discomfort, and freedom to express normal patterns of behaviors.

Summary of Policy No. 8			
Animal	Number	Avoided violation points	Confidence
Mink	40,000	17	High
Rabbit	60,000	17	High

[8] http://web.archive.org/web/20200205233614/https://oeuf-info.fr/infos-filiere/les-chiffres-cles/.

[9] http://web.archive.org/web/20210616065402/https://fourrure-info.fr/histoire/elevage-en-france/.

[10] http://web.archive.org/web/20210616065829/https://www.eleveurs-orylag.fr/fr/eleveurs/.

[11] https://www.youtube.com/watch?v=QraKK07Iu4E.

[12] https://www.youtube.com/watch?v=GqhwfafgRsc.

Policy No. 9: Subsidize circuses for conversion to shows without animals.

Subsidizing circuses to stop the use of animals in shows is relatively popular in France. In 2019, Paris launched a program to help circuses to transform t wild-animal-free shows, and provided financial support for this transformation (50.000 Euros per circus).[13] In 2021, some French Members of Parliament proposed a Law to ban the use of wild animals in circuses.

However, the overall number of animals used in circuses in France remains unknown, and no official figures are given by the State. I contacted the Member of Parliament in charge of the Bill (Laëtitia Romeiro Dias) who sent me the estimates of the number of wild animals used in circuses. These were prepared for the Bill's vote in Parliament (January 2021). While policy No. 9 targets all types of animals, I here evaluate the welfare impact on *wild* animals only, given that we do not have data on domestic animals (e.g., horses and camels). The welfare impact is therefore underestimated.

The document from Laëtitia Romeiro Dias distinguishes between three categories of animals according to the incompatibility between their biological needs and a life in captivity (high, medium and acceptable). There are three series of estimates of the number of wild animals using either (i) the national database registering wild animals (IFAP), (ii) a survey by the DDPP (Departmental Directorates for the Protection of Populations), and (iii) applications by circuses to obtain financial aid during the Covid crisis. Some data from these DDPP survey are labeled as 'overestimates'. To best approximate the number of animals, I take the largest number from these three sources, except when the data are said to be overestimated. In this case, I take a conservative approach and consider the largest number of the two remaining sources.

This produces the following figures:

- High incompatibility with a life in captivity: elephants (14), hippos (9), giraffes (1), macaques (39), baboons (63), lions (315), tigers (250), panthers and leopards (14), hyenas (1), wolves (6), alligators (2), ostriches (10), emus (2), rheas (2), zebras (26) and bison (1).[14]
- Medium incompatibility with a life in captivity: wallabies (9), lemurs (2), pythons (5), boas (4), raptors (564) and parrots (275).

Living in captivity in circuses implies considerable violations of the 5 freedoms for wild animals. Participation in shows requires breaking, close proximity to the public, overcrowding, and confinement in closed spaces, which go against the fundamental needs of wild animals. I thus consider that the life in captivity in circuses imposes severe (resp. very severe) violations on the freedoms from fear/distress, physical discomfort, pain/injury/diseases, and freedom to express normal patterns of behaviors for animals whose incompatibility is considered as medium (resp. high) by the national statistics.

[13] `http://web.archive.org/web/20210803160332/https://www.leparisien.fr/paris-75/paris-la-ville-acte-la-fin-des-animaux-sauvages-dans-les-cirques-15-11-2019-8194398.php`.

[14] Sea lions are not included here, as only the DDPP survey reports a positive number (20), which is said to be overestimated.

Summary of Policy No. 9			
Animal	Number	Avoided violation points	Confidence
Elephant	14	16	High
Hippo	9	16	High
Giraffe	1	16	High
Macaque	39	16	High
Baboon	63	16	High
Lion	315	16	High
Tiger	250	16	High
Panther	14	16	High
Hyena	1	16	High
Wolf	6	16	High
Alligator	2	16	High
Ostrich	10	16	High
Emu	2	16	High
Rhea	2	16	High
Zebra	26	16	High
Bison	1	16	High
Wallaby	9	12	High
Lemur	2	12	High
Python	5	12	High
Boa	4	12	High
Raptor	564	12	High
Parrot	275	12	High

Policy No. 10: Prohibit the reproduction and acquisition of dolphins and killer whales in dolphinariums.

In 2016, the French NGO *C'est Assez !* specialized in cetaceans reported that there were 27 dolphins and 4 killer whales in captivity in France.[15] Life in captivity is particularly unsuitable for these animals that usually travel great distances in the wild. There is evidence that these captive animals suffer from depression and even try to commit suicide by throwing themselves at full speed against the walls. Multiple cases in which animals attack and kill each other in the pools have also been reported.[16] The end of captivity and reintroduction into sanctuaries would therefore greatly improve their welfare. Similarly to circuses (Policy No. 9), I consider that dolphins and killer whales are very incompatible with life in captivity.

[15] https://web.archive.org/web/20200106162855/https://www.cestassez.fr/2016/05/les-delphinariums-en-france.html.

[16] http://web.archive.org/web/20210622070541/https://www.europe1.fr/societe/comment-lutter-contre-la-mortalite-des-dauphins-dans-les-parcs-dattraction-3221363.

Summary of Policy No. 10			
Animal	Number	Avoided violation points	Confidence
Dolphin	27	16	High
Killer whale	4	16	High

Policy No. 11: Prohibit industrial farming of the "factory-farm" type.

The Ministry of Agriculture has no statistical definition of the "factory-farms" brought up by NGOs. Small-Farmer Unions (in France: Confédération Paysanne) and NGOs (such as Greenpeace) consider factory-farms as those with a large number of animals in a single site. The number of animals per site is not harmful to animals *per se*, but is often associated with characteristics that are detrimental to animal welfare: high animal density, automatisation processes, and a lack of health monitoring. The risk of zoonotic events is also likely to increase the confinement of the animals, which leads to indoor farming.

In the absence of official estimates, I propose a statistical definition of factory farms. First, I exclude cows, hens, ducks, turkeys, rabbits, guinea fowls, sheep, and capons from the analysis due to insufficient data on the types of farms and their associated practises. I focus here on broilers, egg-laying hens, pigs, and rabbits, which represent about 85% of the animals killed for meat consumption in 2019. Second, I assume that farms can be considered as intensive if there are more than 20,000 hens or broilers or more than 1,000 pigs in a single farm. The data from the French Ministry of Agriculture[17] indicate that 78% of egg-laying hens, 70% of broilers, and 86.7% of pigs correspond to these criteria. The statistical department provides no information on the distribution of rabbit farms in France. It is however estimated that over 94% of rabbits in Europe are raised in cages, which I classify as intensive farming.[18] Looking at the number of animals killed in each in each category (see Figure SM4), I estimate the number of animals that would be affected by this policy.

The ban on intensive farms is likely to affect the overall demand for meat via three channels. Consumers will face higher prices, as intensive farms produce the cheapest products. Some consumers will reduce their meat consumption, some others will buy more expensive products (non-intensive farming), and others will buy other types of meat (non-intensive as well). I here take a conservative approach, and assume that demand falls by only 5%. I assume that the remaining demand is relocated to products with better farming practices (non-intensive). I assume that intensive farming has the same violations as discussed in Policy No. 8 (17 violation points) and that the impact on animals who are now raised in non-intensive farms would be the same as for Policy No. 7 (4 fewer violation points).

[17] Agreste, Graph Agri 2020.

[18] `http://web.archive.org/web/20210804115052/https://www.ciwf.fr/animaux-delevage/lapins/`.

Summary of Policy No. 11			
Animal	Number	Avoided violation points	Confidence
Hen	490038500	4	High
Hen	25638600	4	High
Pig	19438140	4	High
Rabbit	22325000	4	High
Hen	25791500	17	Medium
Hen	1349400	17	Medium
Pig	1023060	17	Medium
Rabbit	1175000	17	Medium

Policy No. 12: Mandatory stunning before slaughter.

The issue of compulsory stunning before slaughter is a very popular but also polarizing measure in France. On the one hand, the French legislation recognizes the sensitivity (including the nociception) of animals (Article 515-14 of the French Civil Code), and therefore prescribes the obligation of stunning animals before slaughter (Article R. 214-70 of the rural code). The European Union imposes the same obligation (Regulation n. 1099/2009). However, the obligation of stunning can be waived in three cases: ritual slaughter for religious reasons, the killing of farmed game (hunt), and emergency killing. It is estimated that 95% of the stunning exemptions are due to ritual slaughter. Ritual slaughter can only be carried out in an abattoir and so cannot be carried on farms.

Slaughter without stunning is already banned in a number European countries such as Finland, Greece, Switzerland, Denmark, Luxembourg, and the Netherlands. This practice is indeed a cause of significant suffering for the animal (ten minutes elapse between the live cut of a large bovine and its loss of consciousness) and presents considerable health risks (cut esophagus, and the risk of contamination of the meat). However, a Bill proposal in 2019 also noted that slaughter without stunning is carried out to reduce production costs.[19] In 2018, 40% of the bovines and 60% of the sheep killed in France for meat consumption were slaughtered without stunning. Note that 4.5 million bovines and 4.2 million sheep were slaughtered in France in 2019 (see Figure SM4 above).

In the context of ritual slaughter, exemption from stunning is only possible if the animal is immobilized by a mechanical process until it becomes unconscious. Each operator in contact with live animals is required to undergo training and have animal-protection skills certificate for slaughter without stunning. Last, ritual slaughter without stunning must correspond to an order from the halal or kosher industry, and veterinarians at the slaughterhouse have to check that slaughter without stunning does correspond to an order.

It is important to note that other solutions are possible, such as stunning the animals immediately after bleeding or reversible stunning by electronarcosis. This method, which has been used in

[19] `https://www.senat.fr/leg/ppl18-284.html`.

New Zealand for the past 30 years, has been recognized by local Muslim officials as meeting halal requirements.

A key question for our analysis is to determine the type of suffering that would be avoided by the policy. The ban of slaughtering without stunning is unlikely to diminish the demand for meat. Assuming that the government imposes restrictions on trade so as to ensure the same standards for imported goods, we can assume that the animals will be killed after electronarcosis as is accepted in New Zealand. The avoided suffering is the intense pain that occurs between throat-cutting and the loss of consciousness. Because of its intensity, but short duration, I consider a reduction of two violation points for the freedom from pain and one point for the freedom from fear/distress for 1.8 million bovines and 2.52 million sheep.

Summary of Policy No. 12			
Animal	Number	Avoided violation points	Confidence
Cattle	1,800,000	3	High
Ovines	2,520,000	3	High

Policy No. 13: Improving the share of fibers in calves' diet to fight against deficiencies.

Calves are generally fattened until they are 5 months old. Their diet aims in part to make their meat conform to consumer expectations, namely to produce white meat (considered better than its normal pink color). To produce white meat, calves are separated from their mother rapidly after birth and put in barns to prevent them from consuming fibrous foods containing iron, such as grass. This deficient diet helps ensure the white meat of veal.[20]

The lack of fibrous feed in calves' diets produces health issues on top of iron anemia. In pasture, the calf begins to consume solid food from the age of two weeks, which allows the development of the rumen (part of the stomach in ruminants). On the contrary, calves that do not have access to a solid diet nibble on certain objects in their stalls such as pieces of rubber. The non-food snacking activity of calves thus partially compensates for the solid food ingestion of grazing calves. In addition, veal calves regularly have clumps of hair in the rumen (due to licking the body), which is less the case when calves receive solid supplements.

Since 1991, a European directive has required the distribution of fibrous feeds of 50g to 250g per day depending on the age of the calf in order to maintain their hemoglobin level in the blood above 4.5 mmol / liter. However, animal-advocacy NGOs like Welfarm ask that the daily portion of fibrous feed be increased to 500g for calves over 15 days of age in order to have a hemoglobin level of at least 7.5 mmol / liter.[21]

Improving the share of fibers in calves' diet would affect the nearly 2 million calves that are slaughtered in France each year. It would improve their well-being during the 5 months of raising

[20] http://web.archive.org/web/20210707124947/https://agriculture.gouv.fr/le-bien-etre-et-la-protection-des-veaux.
[21] http://web.archive.org/web/20210707125011/https://welfarm.fr/veaux.

(from 15 days after birth to the slaughterhouse). I consider that this would avoid a moderate violation of the freedom from malnutrition.

Summary of Policy No. 13			
Animal	Number	Avoided violation points	Confidence
Cattle	2,000,000	2	High

Policy No. 14: Improve calf bedding by introducing edible elements.

The two million calves raised in France are generally used until the age of 5 months before being slaughtered. Currently, many of them are raised on the ground without litter. Some animal-rights NGOs propose improving their welfare by making it compulsory to have straw or edible litter on the ground[22]. Scientific evidence shows that the introduction of straw improves the welfare of calves by increasing floor-comfort.[23]

In France, the calf industry reported in 2018 that only 9% of the calves had straw as bedding, while 91% were raised on slatted floor[24]. I consider here that the implementation of the policy would avoid moderate violation of the freedom from physical discomfort for 91% of the two million calves raised each year in France.

Summary of Policy No. 14			
Animal	Number	Avoided violation points	Confidence
Cattle	1,820,000	2	High

Policy No. 15: Prohibit the digging up of badgers and foxes.

In France, animal-rights associations estimate that about 12,000 badgers[25] and between 600,000 to 1 million foxes[26] are hunted and killed every year. Hunting underground is a practice that is particularly criticized because it can cause great suffering to the animals hunted. The latter are pursued into their burrows where small dogs are introduced to attack them and draw them out. Hunting can thus produce several hours of intense stress and pain before the animals are finally killed with a gun or a bladed weapon. Animal-protection associations highlight the limited role of badgers in agricultural damage and claim that foxes even help limit agricultural degradation by preventing the proliferation of rodents.

[22] `http://web.archive.org/web/20210707125011/https://welfarm.fr/veaux`.

[23] Tuyttens, 2005, The importance of straw for pig and cattle welfare: A review, *Applied Animal Behaviour Science*, Vol. 92.

[24] IDELE, 2019, Repères techniques et économiques en élevage de veaux de boucherie, campagne 2017-2018.

[25] `http://web.archive.org/web/20210804123412/https://www.aspas-nature.org/actualites/deterrage-blaireaux-france-interdiction/`.

[26] `http://web.archive.org/web/20210804123530/https://www.aspas-nature.org/agir/petitions/protegeons-les-renards/`.

The overall impact of this policy on animal welfare is difficult to evaluate, as the increase in foxes can subsequently affect the welfare of rodents and other small animals. Accounting for the indirect effect of hunting regulations is a huge task that is beyond the scope of this paper, but is mentioned in the Discussion section. I here consider only the direct impact of the policies on animal welfare, and will thus take into account only the lives that are directly spared by the policies (12,000 badgers and 600,000 foxes).

Summary of Policy No. 15			
Animal	Number	Avoided violation points	Confidence
Badger	12,000	15	Medium
Foxes	600,000	15	Medium

Policy No. 16: Prohibit any form of hunting of animals kept in captivity.

According to animal-rights NGOs, there are about 1,300 parks and enclosures in France that practice enclosure hunting. These are visited by hunters who pay to come and hunt for a day. The animals are bred there in captivity or are imported from other farms. In total, 50,000 to 100,000 animals are killed each year in these parks, including wild boars, stags, roe deer and fallow deer.

Hunting in enclosures is authorized in France all year round. It induces significant suffering for the animals that are raised in intensive farms and are then hunted for several hours with no possibility of escape. Some associations claim that half of the animals hunted in this way are not killed by gunshot but rather by long metal daggers, generating more suffering. The prohibition of these hunting practices would thus avoid the death and severe suffering of these animals.

Detailed data about the number and species of the animals killed in captivity hunting are not available. To be conservative, I shall consider the NGO's lower-bound estimate of 50,000. In the absence of information, I will consider those animals to be wild boars. Last, because these animals suffer both from intensive farming and captive hunting, I consider that the avoided violation is death and four additional violations (fear/distress, physical discomfort, pain/injury, behavioral patterns).

Summary of Policy No. 16			
Animal	Number	Avoided violation points	Confidence
Wild boars	50,000	19	Medium

Policy No. 17: Ban on cage rearing for hens.

Four categories of eggs are currently sold in the European Union with specific markings. Category-3 eggs come from caged hens, category-2 eggs from hens kept indoors, category-1 eggs from free-range hens, and category-0 eggs are organic free-range eggs. The rearing conditions of caged hens (category 3) are generally considered as harmful to animal welfare. In cage farms, the hens do not go

outside and spend their entire lives with 13 hens per square meter. In June 2021, the European Commission announced its desire to end cage farming in the European Union.[27]

France has the third-most caged hens in the European Union (see Figure SM5). 2019 European data show that France has 48.3 million hens, of which 54.1% are raised in cages. Assuming that, following the implementation of the ban, the demand for cage eggs will transfer to indoor eggs (category 2), we can anticipate a moderate improvement of the living conditions of 23.1 million egg-laying hens. Similarly to Policy No. 7, I assume that the violations of the freedoms (except for freedom from hunger/thirst) are reduced by one point.

Summary of Policy No. 17			
Animal	Number	Avoided violation points	Confidence
Hen	23,100,000	4	High

Policy No. 18: Prohibit forced-feeding in the production of foie gras.

In 2019, about 30.8 million ducks and 283.000 geese were killed for the production of foie gras in France.[28] According to French legislation, the production of foie gras involves compulsory force-feeding (art. L. 654-27-1 of the French rural code). It is now banned in over 12 European countries.

During the force-feeding sessions, a 20 to 30 centimeter tube is pushed into the esophagus through which animals are forcefully administered large amounts of food. Fatty liver results from these forced-feeding sessions: the liver becomes hypertrophied and reaches up to ten times its normal size. Following force-feeding, the animals pant, suffocate, regurgitate and suffer from digestive and locomotion disorders. The mortality rate of force-fed animals can thus be 10 times higher than that of animals reared for their meat.

Ducks are forced to ingest up to 450g of food twice a day within 3 seconds, through the tube inserted into their esophagus. Ducks gain 2 kg in two weeks, reaching an average of 6.5 kg at the end of force-feeding. A Cambridge University report describes force-feeding as a situation of great distress for the animals (Rochlitz and Broom, 2017).

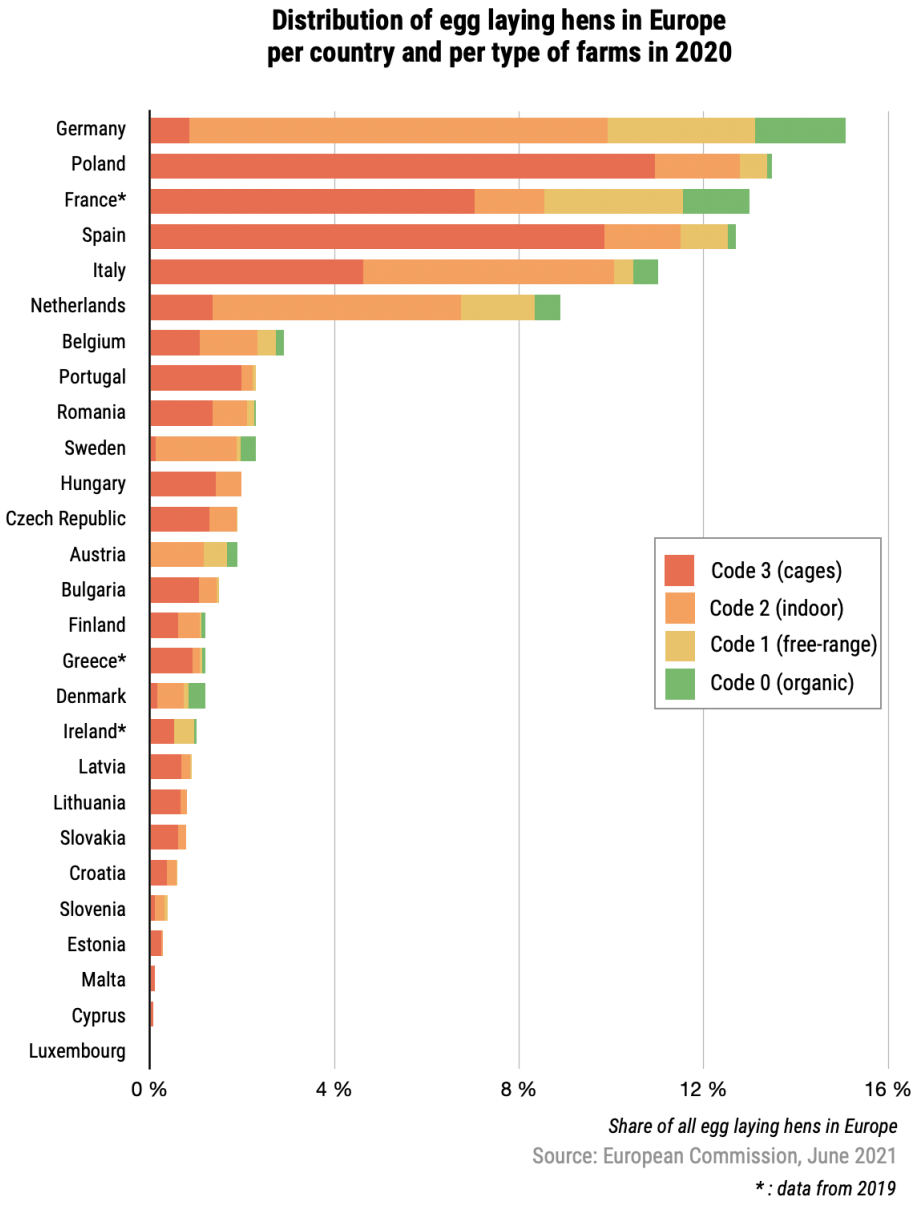
The main challenge to estimate the policy impact on animal welfare is to determine the counterfactual situation. If force-feeding is banned, what will happen to the market? We can imagine three non-exclusive scenarios. First, it is possible that the market will shrink as some producers will be forced to close. Second, some producers might still produce foie-gras but in more humane conditions, as in farms that produce foe gras without force feeding.[29] Third, cultured meat might replace the standard production of foie gras in the medium run. A French start-up, called Gourmey,

[27] http://web.archive.org/web/20210707145220/https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_3298.

[28] http://web.archive.org/web/20210211143516/https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/GraFra2020Chap12.10/Graf2050%20-%20Avi.,%20oeufs,%20foie%20gras,%20cuniculture.pdf.

[29] http://web.archive.org/web/20210414130115/https://www.lemonde.fr/planete/article/2013/12/28/en-espagne-une-exploitation-ethique-produit-du-foie-gras-sans-gavage-des-oies_4340991_3244.html.

Figure SM5: The distribution of egg-laying hens in Europe



specializes in the production of foie gras and plans to sell its product on the market in the coming years. However, while the technology of cultured foie gras exists, it currently lacks the capacity to produce at an industrial level and is not an immediate solution.

The shrinkage of the market and substitution towards cultured meat would avoid all suffering for ducks and geese. The production of foie-gras without force-feeding would reduce suffering but not remove it entirely (due to slaughtering). However, the shrinkage of the market could also induce a substitution effect towards other animal-based products, such as processed pork, which would also negatively affect animal welfare.

Given the uncertainty regarding the reform's consequence, I take a conservative approach and assume that the ban would only lead to a reduction of the violations of all freedom by two points for 30.8 million ducks and 283.000 geese.

Summary of Policy No. 18			
Animal	Number	Avoided violation points	Confidence
Ducks	30,800,000	10	Low
Geese	283,000	10	Low

Policy No. 19: Banning the use of carbon dioxide to stun and kill pigs in favor of other alternatives.

Many slaughterhouses use CO2 to stun pigs before slaughtering. Pigs are put in cradles that are lowered into CO2 pits, which aims to stun them. However, this technique causes suffering as the dizziness is not immediate. Pigs suffer from irritation of the mucous membranes, struggle and suffocate for periods of seconds to several minutes, according to experts. About 4 million pigs are stunned using this method every year in France according to farmed-animal NGOs (Welfarm).[30]

Gas alternatives to CO2 are currently unsatisfactory. The most-credible gas alternatives to CO2 for stunning are argon in high concentration (90%) and mixtures of neutral gases, Ar or N2 at 60% and CO2 at 30%. These mixtures are less aggressive for animals, but producing unconsciousness takes a longer time. There is also a significant risk of consciousness returning upon the return to a normal atmosphere.

While gas alternatives are more suitable to limit animal suffering in the basket, the longer required immersion time is unsuited to current rates of production. In addition, the significant risks of regaining consciousness when exiting the basket increases the risk of bleeding animals that are awake. Work remains to be done to improve gas stunning, either via alternatives to CO2 or using the current CO2 method.

The alternative that currently appears to be the least damaging is electronarcosis. This is increasingly used in the French farming industry: according to a Parliamentary report (Report No. 4038, September 2016), electric stunning is used for approximately 85% of pigs. In electronarcosis, two electrodes are placed on the pig's head through which an electric current passes to depolarize

[30] http://web.archive.org/web/20210624070925/https://welfarm.fr/news/501/86/%C3%89tourdissement-des-cochons-au-CO2-refusons-cette-pratique.

the animal's brain, causing it to lose consciousness. The advantage of this stunning method is that, when carried out correctly, it is less harmful to animal welfare than carbon sinks. An expert report conducted by the INRAE, the largest public scientific institution in France covering animal farming, argued that "it is very likely that the correct application of electronarcosis is not painful".[31]

Electronarcosis does however involve danger for 13% to 14% of pigs due to the improper positioning of the electrodes. However, this technique is thought to remain less harmful than CO2 sinks. Sébastien Arsac, the co-founder of the largest French NGO for farm-animal protection (L214), said: "In the case of gassing, it's worse: 100% of the animals suffer".

A total of 4 million pigs would be affected by the policy, and would be stunned by electronarcosis rather than carbon dioxide. In 14% of the cases, the electrodes may be improperly placed, which means that only 3.4 million pigs would actually see an improvement in stunning. CO2 stunning represents significant suffering that is however of limited duration. For this reason, I consider that the policy would avoid a two-point violation of the freedom from pain/injury and a one-point violation of the freedom from distress due to the shorter duration of the process.

Summary of Policy No. 19			
Animal	Number	Avoided violation points	Confidence
Pig	3,400,000	3	High

Policy No. 20: Prohibition of tooth cutting in piglets for the benefit of grinding.

Piglets are born with eight sharp teeth. In the animal farming industry, it is a common practice to severe these teeth just above the gum line (using wire cutters) or filed them down at the end (using a rotating grinding wheel). The objective of the industry is limit sow udder injury and facial injury from piglet fighting during lactation. This practice, also known as "wedge reduction" is not routinely authorized by European legislation (Commission Directive 2001/93 / EC) and partial sectioning of teeth (as opposed to grinding) is prohibited in some countries such as Germany, Denmark, Norway, or Switzerland.[32]

Wedge reduction can produce considerable suffering to piglets, both when the operation is carried out and afterwards. A scientific report for the NGO CIWF noted that tooth cutting is associated with numerous injuries: nerve infections (92%), hemorrhages (from 10.6% to 63%), and fractures (from 3.3% to 38%). While grinding can generate more stress among animals (it takes more time), it is usually recommended over tooth cutting as it reduces the risks of injury.

While wedge reduction can be seen as imposing great suffering on the animals, the switch from tooth cutting to grinding can be considered as only a minor improvement. I will thus consider that the policy only avoids a mild violation of the freedom from pain for the 23.3 million pigs that were farmed in 2020.

[31] http://web.archive.org/web/20201217123933/https://www6.paris.inrae.fr/depe/content/download/3390/33172/version/1/file/douleur-animale-rapport%5B1%5D.pdf.

[32] Source: CIWF, Réduction des coins des porcelets.

Summary of Policy No. 20			
Animal	Number	Avoided violation points	Confidence
Pigs	23,000,000	1	High

Supplementary Materials 8: The experiment with negative WTPs

In the above application of the animal-welfare valuation (AWV) model, I considered an experiment with only zero or positive WTPs, where participants explained their choice of a zero WTP via an open-ended question.

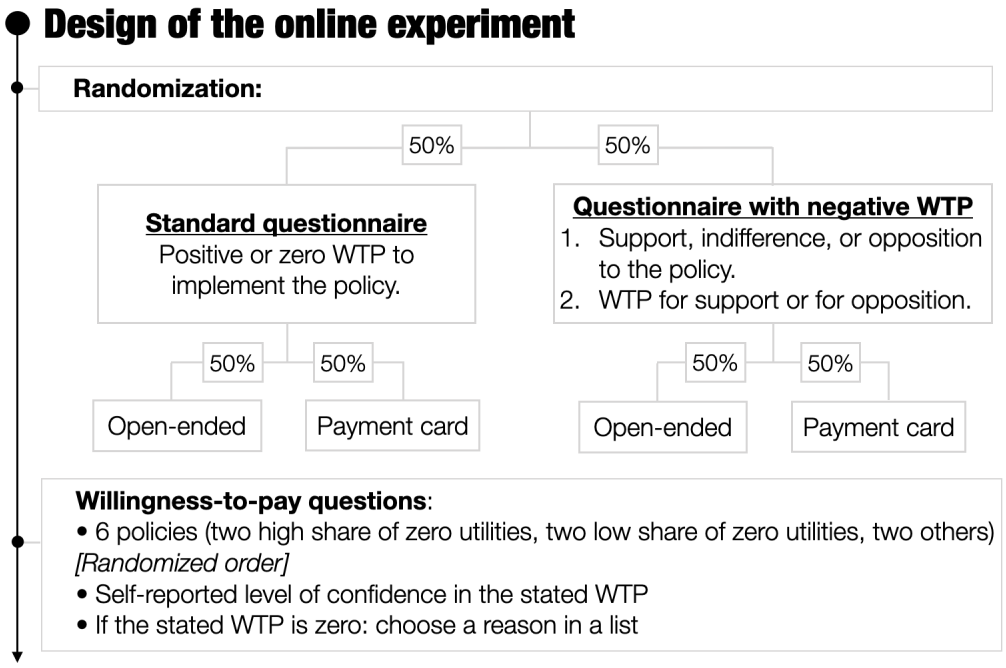
Asking for positive and zero WTPs only indirectly assumes that the (public) good at stake benefits everyone. As Clinch and Murphy (2001) underline, this assumption might not hold for all types of goods. For instance, when it comes to environmental goods, some may consider the actions to be beneficial for the environment while others take the opposite view. Researchers interested in evaluating the welfare impact of a policy should consider both the WTPs of the supporters of the reform and the willingness-to-accept (WTAs) of the opponents. Clinch and Murphy (2001) explain that, in this case, researchers should first elicit the support or opposition to the policy, and then the WTP either to support or oppose it.

To illustrate, I selected six of the 20 policies discussed in the body of the paper, and estimated both positive and negative WTPs in an experiment. Two policies were selected because they exhibited low human social-welfare gains: plant-based menus at school and the ban on force-feeding (see Figure **??**). Two other policies were chosen because of their high impact on human social-welfare (mandatory stunning before slaughtering and a fur ban). The last two policies are in between (a cat sterilization campaign and alternative-method experts in ethics committees). The experimental design is summarized in Figure SM6.

In the online experiment, participants are randomized across four conditions (a 2-by-2 design). Half are assigned to the standard version of the survey presented in the paper. In the baseline condition, participants can report positive or zero WTPs for the policies. Half of those participants (i.e. 25% of the overall sample) report their WTP using payments cards and half are assigned to the open-ended version of the survey. The remaining half of the participants are assigned to a modified version of the survey. Here they are first asked whether they support or oppose the policy, or whether they are indifferent. In the case of support (opposition), participants report their WTP to implement (prevent the implementation of) the policy. Here also, participants are randomly assigned to one of the two payment methods with equal probability. Similarly to the original survey, the order of policies was randomized, participants reported their confidence, and those with zero WTPs were asked to choose a reason from a list of arguments (with an 'Other' option).

The experiment was run online between the 5th and 6th October 2021 with a sample of French participants recruited via the online platform *Prolific*. The sample contained 631 participants and was not representative, except for gender balance. Average participant age was 28 (ranging from 18 to 66), half worked either full-time or part-time, and around 40% were students. In the final sample, 48.18% of participants took the standard survey (22.98% with the payment card and 25.2% with open-ended numeric fields), and 51.82% the condition with negative WTPs (24.25% with payment cards and 27.58% with open-ended numeric fields).

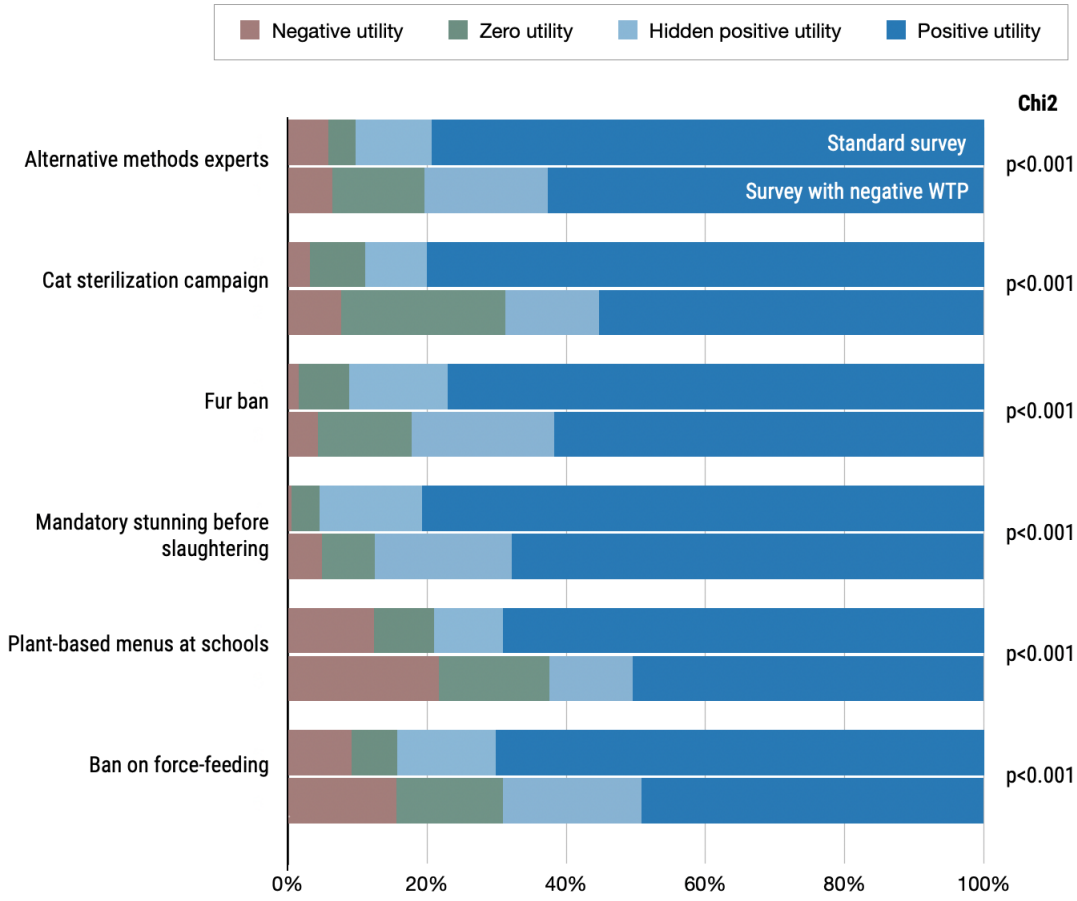
Figure SM6: Summary of the online experiment



I first reconstructed the types of utilities across the types of surveys (standard vs. negative WTP surveys) to see whether adding the possibility of opposing the reform significantly affects the propensity to support the reform. There are three key elements in Figure SM7. First, the sample in the standard version of the questionnaire is more supportive of the policies than the general population. For instance, about 2.9% of the participants who faced the standard survey would experience lower utility from the presence of alternative-methods experts in ethics committees, as against 10.2% in the general population. This selection bias holds for all policies: a sterilization campaign for stray cats (1.6% vs. 11.3%), a fur ban (0.8% vs. 5.7%), mandatory stunning before slaughter (0.3% vs. 3.9%), the introduction of plant-based menus at schools (6.0% vs. 22.6%), and a ban on the force-feeding of ducks (4.4% vs. 21.2%). Second, the policies with the largest shares of lower utility in the representative sample also produce the highest opposition rates in the Prolific sample with the standard version of the survey (a ban on force-feeding and plant-based menus at schools). The mandatory stunning of animals before slaughter and the ban on fur also exhibit the smallest shares of decreasing utility in both samples. Third, and more importantly, first asking participants about their support for the policy significantly impacts the share of participants who support or oppose the policy or who are indifferent. A Chi-squared test rejects the null hypotheses of equality of distributions across the versions of the survey for all of the six policies. In other words, asking participants first whether they support the policy before assessing their WTP significantly reduces support.

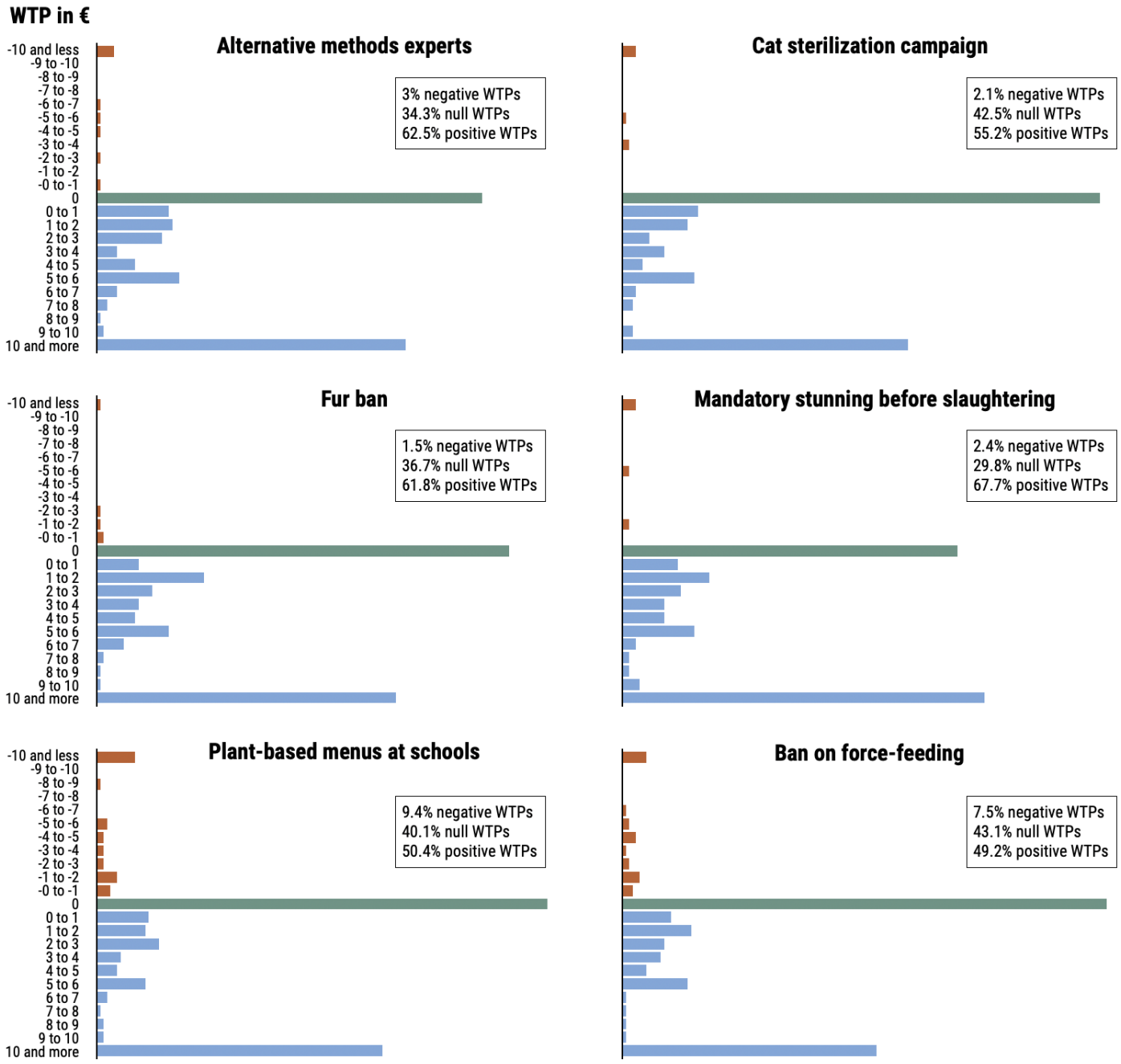
We next find small proportions of negative WTPs against the policies among the participants answering the modified version of the survey that allows for negative WTPs (see Figure SM8). The

Figure SM7: The distribution of utilities in the online experiment



mode of the distribution of WTPs for each policy is zero. Zero WTPs represent participants who are either indifferent to the reform or who support or oppose the reform but who do not want to pay for it (e.g., free-riding). The share of zero WTPs ranges from 29.8% to 43.1%. Positive WTPs cover the largest group of participants, ranging from 49.2% (a ban on force-feeding) to 67.7% (mandatory stunning). Negative WTPs are rare, at between 1.5% (a fur ban) and 9.4% (plant-based menus at schools).

Figure SM8: The distribution of WTPs in the online experiment



Supplementary Materials 9: R code for the valuation of animal welfare

```
animalWelfareBenefits=function(species_funct,avoidedViolationPoints_funct,q_funct
    =147000,psi_funct=0.9,deathEq_funct=15){

  #This function is based on the work "Animals and Social Welfare" of Romain
    Espinosa
  #It returns the benefits in euros (or costs) associated with the improvement (or
     the degradation)
  #of the welfare of ONE animal.

  #Psi: parameter of the utility potential function. Default: psi_funct=0.9
  #If Psi=1: constant returns to scale of cortical neurons.
  #If Psi>1: increasing returns to scale of cortical neurons.
  #If Psi<1: decreasing returns to scale of cortical neurons.

  #q: cost of one unit of QALY. Default: q_funct=147000 (France)

  #deathEq_funct: number of freedom violations equivalent to death. Default:
    deathEq_funct: 15
  #If the number of violation points is above the threshold: death is preferable
    for the animal.
  #If it is below 15, life is worth living.

  #avoidedViolationPoints_funct: number of freedom violation points that are
    avoided by the policy.
  #If positive: violation points are avoided
  #If negative: violation points are imposed on the animal

  #See below for the list of animals that can be used
  n_human_funct=24526423164
  if(species_funct=="Fox") n_funct=527910000
  if(species_funct=="Dolphin") n_funct=2366317756
  if(species_funct=="Lion") n_funct=1080510634
  if(species_funct=="Killer whale") n_funct=4728559487
  if(species_funct=="Elephant") n_funct=5507769831
  if(species_funct=="Rabbit") n_funct=101286495
  if(species_funct=="Hippo") n_funct=1318223360
  if(species_funct=="Macaque") n_funct=1441350071
  if(species_funct=="Baboon") n_funct=2989579505
  if(species_funct=="Tiger") n_funct=1181538010
  if(species_funct=="Panther") n_funct=685574023
  if(species_funct=="Hyena") n_funct=782166504
  if(species_funct=="Wolf") n_funct=584353906
  if(species_funct=="Bison") n_funct=831452389
  if(species_funct=="Wallaby") n_funct=286787179
  if(species_funct=="Lemur") n_funct=517493222
```

```
  if(species_funct=="Parrot") n_funct=1129301692
  if(species_funct=="Bovine") n_funct=790446591
  if(species_funct=="Sheep") n_funct=504059936
  if(species_funct=="Cat") n_funct=198241547
  if(species_funct=="Pig") n_funct=554054029
  if(species_funct=="Mink") n_funct=74975496
  if(species_funct=="Hen") n_funct=85614522
  if(species_funct=="Mouse") n_funct=19323212
  if(species_funct=="Rat") n_funct=43724056
  if(species_funct=="Giraffe") n_funct=2440084409
  if(species_funct=="Emu") n_funct=619189050
  if(species_funct=="Dog") n_funct=527910000
  if(species_funct=="Horse") n_funct=790446591
  if(species_funct=="Zebra") n_funct=790446591
  if(species_funct=="Duck") n_funct=85614522
  if(species_funct=="Goose") n_funct=85614522
  if(species_funct=="Turkey") n_funct=85614522
  if(species_funct=="Fox") n_funct=527910000
  if(species_funct=="Badger") n_funct=198241547

  return((n_funct/n_human_funct)^psi_funct*q_funct*(avoidedViolationPoints_funct/
    deathEq_funct))

}
```

Listing 1: Code for the economic valuation of animal welfare in R