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Karine Van Der Straeten and Takuro Yamashita

Toulouse School of Economics

On the veil-of-ignorance principle: Welfare-optimal information disclosure in voting

Karine Van der Straeten* Takuro Yamashita†

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Abstract

We consider a two-alternative (reform vs status quo) voting environment. A benevolent utilitarian social planner controls both the information pertaining to a payoff-relevant state of the world and the voting rule. We characterize the voting rule and the information disclosure policy that are jointly socially optimal. Although full transparency is sometimes (informally) argued as ideal, we show that full transparency is strictly suboptimal. The optimal policy discloses just the "anonymized" information about the value of the alternatives and the optimal voting rule is a qualified majority rule that becomes more lenient as the "anonymized" value of the reform (compared to the status quo) increases.

*Toulouse School of Economics, Institute for Advanced Study in Toulouse & CNRS. karine.van-der-straeten@tse-fr.eu

†Osaka School of International Public Policy, Osaka University. yamashita.takuro.osipp@osaka-u.ac.jp

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1 Introduction

Voters' information is crucially important in determining voting outcomes. In many decisions, access to the relevant information is distributed among multiple players (voters, experts, government), each with access to only a part of the information. For example, when voting for or against a reform, each voter may have some private information about how they will be affected in the short run, but acquiring all the relevant information about the long-term effects of the reform would be prohibitively costly for individual voters: they have to rely on other sources – government, media, experts – to inform their choices.

In order to provide some normative guidance on the optimal extent of transparency in this kind of setting, we consider in this paper a simple two-alternative environment ("reform" vs. "status quo"). A (utilitarian) benevolent social planner controls a part of the relevant information about the consequences of the alternatives, while each voter possesses their own private information too. The social planner chooses both an information disclosure policy and a voting mechanism.

Consider the example of a referendum on a ban on the sales of new petrol and diesel cars. When evaluating the welfare consequences of such a reform, the social planner and voters may face two types of uncertainty. The first one relates to the long-term expected benefits and costs of the reform: How likely is it that such a reform will help develop a strong domestic industry for battery-electric vehicles? Which regions are likely to benefit from this new industry or will be hurt by less traffic? What will be the impact on oil prices and how will it impact different economic sectors? These parameters are hard to evaluate for voters and require expertise knowledge. We will assume that this type of information is controlled by the social planner. The second type of incomplete information relates to voters preferences and their short term adjustment costs. The planner might be unsure about how difficult it would be for citizens to change their means of transportation (e.g. switch to public transportation), or about their willingness to sacrifice consumption to reduce CO2 emissions. This latter information is each voter's private information.

Given that we assume the social planner to be fully benevolent, a natural candidate for an optimal disclosure policy may be full disclosure. This is also often (somewhat informally) argued as ideal as a democratic principle. However, we show that it is strictly suboptimal. The optimal policy discloses just the "anonymized" information about the value of the alternatives, keeping voters behind a partial veil of ignorance.

More specifically, we consider the following problem. A group of voters choose by a referendum whether to implement a reform or keep the status quo. The value of the reform to each voter (relative to the status quo) is assumed to be the sum of two orthogonal real-valued components. The first component is each voter's private information: prior to the election, each voter receives a private signal about this first component. These signals are assumed to be uniformly i.i.d. across voters; we will refer to this component as the "idiosyncratic" value of the reform to each voter. This information is private in that neither the other voters nor the planner have access to it. By contrast, the second component, which is also voter-specific, is not under the voters' control in that they have no way to learn directly about it. Instead, they have to rely on the inquiries of the social planner. Voters are a priori symmetric with respect to this second component. We assume, as in Kamenica and Gentzkow [2011] or Alonso and Camara [2016], that the social planner can design a policy experiment that publicly reveals information about a payoff relevant state pertaining to the second component of all voters. For example, this second component could represent the long-term economic benefits and costs of the reform, which might be difficult for the voters to assess. In particular, it might be difficult to assess not only the total average effect of the reform for the economy (is it good or bad on average) but also its distributional consequences - who are the (relative) winners and losers. Once the result of the experiment is known, the social planner chooses the voting rule under which the referendum will be held. We assume that the objective of the social planner when designing the policy experiment and choosing the voting rule is to maximize the expected utilitarian welfare. In that sense, ex ante, the preferences of the government are perfectly aligned with those of the electorate as a whole. After observing the realization of their own private signal and the result of the policy experiment, voters apply Bayes' rule. They then vote according to the mechanism chosen by the planner, which decides whether the reform is implemented or not.

With only one voter, the problem is trivial: the social planner discloses all the information (which is the same thing as disclosing the "anonymized" information as there is only one voter) and delegates the decision to the voter. But as soon as there are at least two voters, full disclosure is shown to be strictly suboptimal. The reason is that voters exert externalities one on the other at the voting stage: when voting for the reform, a voter not only impacts his own welfare, but also that of other voters by making it more likely that the reform is implemented. This externality is positive if on average the expected welfare of other voters is higher under the reform than under the status quo, and negative otherwise. We show that not disclosing all the relevant information can in that case mitigate externalities and improve the voting outcome. A non-trivial aspect of the problem is that there are many ways of making the information "partially disclosed". Indeed, our problem is a complex information design problem in that the planner's information is represented by a multi-dimensional, continuous random vector, and that each voter has his own orthogonal private taste information. Not much is known about the general structures of the solution to this class of problems.[1]

We are able to characterize the optimal disclosure policy in this context: the optimal disclosure policy only provides *anonymized* information commonly to the voters. That is, if a reform will make some voters better off and others worse off (or some voters much better off and others only slightly better off), then the planner should only disclose the *average* gain of the reform across the electorate. A key property of the optimal information disclosure policy is thus to make all voters equally optimistic about the value of the reform for themselves (that is, regarding the part of the information

[1]See, for example, Malamud and Schrimpf [2021] and Dworczak and Kolotilin [2023], for Bayesian persuasion problems with multi-dimensional, continuous payoff states (but without private taste information); and Kolotilin et al. [2017] for persuasion mechanisms of a privately informed receiver in one-dimensional linear environments.

that is controlled by the social planner). To get the intuition, suppose that an information policy is such that, in some cases, after observing the result of the policy experiment and updating their beliefs, one voter, say voter 1, is more pessimistic about the value of the reform for himself than is another voter, say, voter 2. Assuming that the planner can "redistribute" good news across voters, the planner would then want to make voter 1 more optimistic and voter 2 less optimistic. As noted above, giving better news to voter 1 will make him more likely to vote in favor of the reform, which will exert an externality on the rest of the electorate whenever voter 1 is pivotal. The sign of this externality is a priori ambiguous, as it depends on the expected welfare of the rest of the electorate conditional on voter 1 being pivotal. Though the sign of the externality itself is ambiguous, comparison across voters is not. Informally, for any voter i, the expected welfare of the rest of the electorate (conditional on this voter being pivotal) is increasing with the beliefs of other voters regarding their own payoff. Which implies that the externality exerted by voter 1 when he gets better news is larger than the externality exerted by voter 2 if he gets better news. The best the planner can do is therefore to "redistribute" good news (or bad news) as equally as possible across voters and to keep voters' beliefs as aligned as possible. In a sense, voters should be kept under a partial "veil of ignorance".

Related literature

In our paper, the social planner chooses both the information disclosure policy and the voting mechanism. It therefore relates to the literature that studies each problem separately.

Regarding the latter: In our informational setting, the planner publicly reveals some information about a payoff-relevant state of the world and each voter's private information is irrelevant to the other voters' policy-related payoff (that is, his private information does not contain any information about whether the reform is good or bad for other voters). Therefore, closely related is the literature studying optimal voting rules in a private-value setting with cardinal preferences (See Barberà and Jackson [2006] or Azrieli and Kim [2014] in the case of two alternatives, and Gershkov et al. [2017] for any number of alternatives). In particular, we will borrow from this literature the result that given the realization of a policy experiment, the optimal voting rule is a weighted majority rule where the weight given to each voter depends on the planner's expectation about the utility of this voter for each alternative.

Regarding the former literature on information disclosure: Our work is related to a series of recent papers applying Bayesian persuasion to voting environments. Extending the framework with a single receiver of Kamenica and Gentzkow [2011], Alonso and Camara [2016] study a model where a group of uninformed voters must vote to choose whether to keep the status quo or implement a proposed reform. Prior to the vote a politician – who is assumed to be biased in favor of the reform – can influence voters' choices by strategically designing an experiment that reveals some information about voters' payoffs. Bardhi and Guo [2018] study an environment where a sender can design an experiment to inform voters about their (possibly) correlated payoff states. Assuming that the sender prefers the reform to be implemented whatever the state of the world, they characterize the sender-optimal policy when the voting rule is the unanimity rule. Compared to these two papers, a key difference of our model is that we assume that this politician/social planner is fully benevolent and maximizes the voters' aggregate welfare. Another key difference is that voters have some private information about how the reform is going to impact them individually. In our model, information disclosure therefore affects not only the probability that the reform is implemented, as in the previous papers, but also what is learned about the voters' idiosyncratic preferences (which is valuable to the benevolent planner). With multiple receivers, Bayesian persuasion is an appropriate approach to study optimal *public* disclosure policy, as assumed in this paper. Given any public disclosure policy and any (monotonic) voting mechanism, each voter plays his dominant action, and then our problem essentially becomes a Bayesian persuasion problem where a sender controls the informativeness of multi-dimensional continuous random variables. Rayo and Segal [2010], Malamud and Schrimpf [2021], and Dworczak and Kolotilin [2023] consider such problems with two or higher-dimensional random variables, and obtain general properties of the optimal disclosure policy. The specific structure of our problem enables us to fully characterize the optimal disclosure policy under certain conditions.[2]

Our results highlight a tension between information revelation and utilitarian social welfare maximization. Such a tension has already been noticed in the literature. Fernandez and Rodrik [1991] highlight the fact that in the presence of individual-specific uncertainty about the consequences of a reform, whether a majority supports the reform or not can critically depend on what is known about the identity of the winners and losers. In their setting, full information about the consequences of the reform is learned only if (and after) the reform is implemented. If the reform is implemented and a majority learns that it is actually hurt by it, the reform can be repelled.

[2]We share with all the aforementioned papers the assumption that information acquisition is costless: our focus is on disclosure only. Another strand of the literature instead considers settings where agents have to acquire information before making a collective decision, and that information acquisition is costly. For papers studying the optimal design of information acquisition, see for example Persico [2004], Caillaud and Tirole [2007], Gerardi and Yariv [2008], Gershkov and Szentes [2009].

By contrast, if a majority is against the reform ex ante, the reform is not implemented, even if ex post a majority might have turned out to be in favor. This implies a bias towards the status quo. Our information structure is different: we consider situations where the relevant information about the value of the reform can be learned ex ante; our focus is also different in that we look for the optimal information (and voting) design. Gersbach [1992] studies a setting where society has to decide whether to implement a project or not. Prior to voting on the project, society decides by a vote whether to acquire (full) information about the value of the project. He shows that a majority will always support public disclosure of information, although it might be sub-optimal from a social welfare perspective (See also Gersbach [1995] for similar insights in a setting where the decisions to acquire information are decentralized). Jackson and Tan [2012] study a two-alternative voting environment, where voters have their own, publicly-known biases for each of the two alternatives, but are imperfectly informed about their respective costs. Before the vote takes place, informed (and biased) experts can reveal some information about these costs. They provide an example where welfare would be higher if all information were suppressed (see also Schnakenberg [2015]). Contrary to this setting, we have no biased experts: the social planner is assumed to be fully benevolent and we characterize the welfare-optimal information policy. Sun et al. [2021] study the case where the (possibly biased) informed experts can reveal some information about the voters' *common* one-dimensional preference state. It is a common state in the sense that it affects each voter's preference in an homogeneous manner, and in this sense, their information structure is in our *anonymized* class by definition. Our paper considers a more general state space and shows that anonymized information is optimal. On the other hand, Sun et al. [2021] allow for more general objectives, and identify an appropriate *single-crossing* condition under which a censorship information policy is optimal.

A more distant literature has studied information aggregation in Condorcet Jury settings. In the jury metaphor, jurors agree that a guilty defendant should be convicted and an innocent acquitted (although they may differ in their thresholds of doubt), and each has some private information about the state of the world.[3] Our informational setting is fundamentally different from that studied in this literature in that, as noted above, we consider a situation where each voter's private information is irrelevant to the other voters' policy-related payoff.

2 Model

2.1 Environment

A society/committee with $N \geq 2$ individuals decides by a vote between two alternatives: $k = 1$ ("reform") and $k = 0$ ("status quo"). Voter i's payoff is

$$u_i = (\theta_i + \varepsilon_i)k$$

for $i = 1, ..., N$. That is, the payoff is normalized to 0 under the status quo, and is $\theta_i + \varepsilon_i$ under the reform. We assume that:

[3] This simple setting has been extended in many ways to explore a number of questions: information aggregation when decision is reached by strategic voters without (Austen-Smith and Banks [1996], Feddersen and Pesendorfer [1998]) or with a prior stage of deliberation (Austen-Smith and Feddersen [2006], Gerardi and Yariv [2007], when sequential voting is allowed (Dekel and Piccione [2000]), when information acquisition is costly (Persico [2004], Gershkov and Szentes [2009]), when voters can get additional advice from potentially biased experts (Jackson and Tan [2012], Schnakenberg [2015]), or when the decision is delegated to a (better informed) elected politician (Feddersen and Pesendorfer [1996], Feddersen and Pesendorfer [1997], Feddersen and Pesendorfer [1999]).

$\theta := (\theta_i)_{i=1}^N \in [-\overline{\theta}, \overline{\theta}]^N$, for some $\overline{\theta} > 0$, follows a joint distribution F, which is invariant with respect to permutations ("(N-)exchangeable"). The information about θ is controlled by the social planner (see below).

$\varepsilon := (\varepsilon_i)_{i=1}^N \in [-\overline{\varepsilon}, \overline{\varepsilon}]^N$, for some $\overline{\varepsilon} > 0$, is the vector of idiosyncratic payoff terms. We assume that the ε_i are i.i.d., with $\varepsilon_i \sim U[-\overline{\varepsilon}, \overline{\varepsilon}]$, whose realization is i's private information. We assume that $\overline{\varepsilon} \geq \overline{\theta}$, and each ε_i is distributed independently from θ.

The utilitarian social welfare is given by:

$$\sum_{i=1}^{N} (\theta_i + \varepsilon_i) k$$

if policy k is implemented.

2.2 Social Planner, Information Disclosure, and Voting Mechanism

The social planner is a benevolent (in the sense of maximizing utilitarian welfare) entity who designs the society's information about $\theta = (\theta_i)_{i=1}^N$ as well as the voting rule. Through this planner's solution, we can provide a normative benchmark regarding the socially desirable information structure and democratic process.

The planner designs a policy experiment that *publicly* reveals information about θ. It is denoted as follows:

$$\phi : [-\overline{\theta}, \overline{\theta}]^N \ (\equiv \Theta) \ \to \Delta(X),$$

for some (rich enough) space X, with the interpretation that, once $\theta \in \Theta$ is realized, a "signal" $x \in X$ is publicly disclosed to society, where x is drawn from distribution $\phi(\theta) \in \Delta(X)$. To the extent that the distribution

$\phi(\theta)$ varies with θ, the signal x provides some (possibly noisy / imperfect) information about the realized θ. Note that we assume a public revelation mechanism: voters and the social planner have the same information on θ following the observation of signal x.

Once a signal $x \in X$ has been publicly disclosed, the social planner chooses a voting mechanism (which can depend on x), and the vote takes place according to the voters' (weakly) undominated strategies.

By the standard argument in Bayesian persuasion, it is without loss of generality to assume $X = \Theta$, and for each $x = (x_i)_{i=1}^N$, $E[\theta_i|x] = x_i$. That is, the signal x directly tells what the expected value of θ_i should be, and voters and the social planner find (applying Bayesian updating) that, given signal x, the conditional expected value of θ_i is indeed x_i.

Definition 1. ϕ is the *full transparency* policy if for all $\theta \in \Theta$ and all i, $\mathbb{P}[x_i = \theta_i] = 1$.

Definition 2. ϕ is an *anonymous disclosure* policy if $\mathbb{P}[x_i = x_j,\ \forall i, j] = 1$.

Definition 3. ϕ *fully discloses the anonymized information* if for all $\theta \in \Theta$ and all i, $\mathbb{P}\Big[x_i = \frac{\sum_j \theta_j}{N}\Big] = 1$.

3 Results

3.1 Main result

Our main result is stated in Theorem 1:

Theorem 1. (i) The optimal disclosure policy is to fully disclose the anonymized information;

(ii) The optimal voting mechanism is an anonymous majority rule with threshold for approval $Min\Big\{Q \in \mathbb{N} : Q \geq \frac{N}{2}\Big(1 - \frac{\sum_j \theta_j}{N\bar{\varepsilon}}\Big)\Big\}$.

The rest of the section is devoted to giving a sketch of the proof and the intuition for this result. The full proof is in the appendix.

First, for any signal realization, we characterize the optimal voting rule. Second, we introduce some useful notation, in particular a notion of interim welfare. Third, we provide a simple example with two voters, which shows why full transparency is strictly suboptimal. Fourth, we show that for any non-anonymous disclosure policy, there is an anonymous policy that is welfare-improving. Last, we explain why fully disclosing anonymized θ is welfare-optimal.

3.2 Characterization of the signal-dependent optimal voting mechanism

For $x \in \Theta = [-\overline{\theta}, \overline{\theta}]^N$, let

$$Q^*(x) = Min\Big\{Q \in \mathbb{N} : Q \geq \frac{N}{2}\Big(1 - \frac{\sum_i x_i}{N\bar{\varepsilon}}\Big)\Big\} \tag{1}$$

Proposition 1. (**Optimal Voting Rule**) Assume that at the voting stage voters play (weakly) undominated strategies. Following a disclosure policy ϕ, when the realisation of the signal is $x \in \Theta = [-\overline{\theta}, \overline{\theta}]^N$,

(i) The anonymous qualified majority rule with threshold for approval $Q^*(x)$, that is, the reform is implemented iff at least $Q^*(x)$ voters vote in favor, is an optimal voting mechanism.

(ii) If x is such that $\frac{N}{2}\Big(1 - \frac{\sum_i x_i}{N\bar{\varepsilon}}\Big) \notin \mathbb{N}$, it is the unique optimal voting mechanism. Otherwise, exactly two voting rules are optimal: the qualified majority rule with threshold $Q^*(x)$ and the qualified majority rule with threshold $Q^*(x)+1$.

Proposition 1 states that for x such that $|\sum_i x_i|$ is small enough, the optimal voting rule is the simple majority rule. The optimal voting rule becomes more 'lenient' (approval requires a lower threshold) when $\sum_i x_i$ increases.

Proof. The proof directly follows from Barbera and Jackson [2006]. We know from their Proposition 1 that the optimal voting mechanism is as follows:

1. Assign two weights to each voter:

   (a) one (positive), $u^+(x_i)$, if he votes for the reform,

   (b) one (negative), $u^-(x_i)$, if he votes for the status quo,

   where

$$u^+(z) := \mathbb{E}[z+\varepsilon_i > 0], \tag{2}$$

$$u^-(z) := \mathbb{E}[z+\varepsilon_i < 0]. \tag{3}$$

2. Implement the reform if the profile of votes $m = (m_1, ..., m_N) \in \{0,1\}^N$ is such that

$$\sum_i \Big(m_i * u^+(x_i) + (1-m_i) * u^-(x_i)\Big) > 0 \tag{4}$$

where $m_i = 1$ means a vote in favor of the reform and $m_i = 0$ a vote against.[4]

[4]When $\sum_i \Big(m_i * u^+(x_i) + (1-m_i) * u^-(x_i)\Big) = 0$, welfare is the same whether the reform is implemented or not.

As this is a monotonic voting mechanism with two alternatives, voting sincerely is a weakly dominant strategy for each voter. Restricting attention to weakly dominant strategies, voter i votes for the reform if and only if $x_i + \varepsilon_i \geq 0$, and his voting weight is his expected utility conditional on his vote (and x_i). As $\varepsilon_i \sim U[-\overline{\varepsilon}, \overline{\varepsilon}]$,

$$u^+(z) = \frac{z + \overline{\varepsilon}}{2} \text{ and } u^-(z) = \frac{z - \overline{\varepsilon}}{2},$$

and Condition (4) is equivalent to

$$\sum_i u^-(x_i) + \overline{\varepsilon} \sum_i m_i = \frac{\sum_i x_i - N\overline{\varepsilon}}{2} + \overline{\varepsilon} \sum_i m_i > 0. \tag{5}$$

Thus the result. □

Notation For $Q = 1, ..., N$, denote

$$X(Q) := \Big\{ x \in \Theta : \Big(1 - \frac{2Q}{N}\Big)\overline{\varepsilon} < \frac{\sum_i x_i}{N} < \Big(1 - \frac{2(Q-1)}{N}\Big)\overline{\varepsilon} \Big\} \tag{6}$$

the set of signal realizations x for which $Q^*(x) = Q$, that is, the majority rule with threshold for approval Q is the unique optimal voting rule.

Note that for some Q, $X(Q)$ can be empty. More specifically, if $Q < \frac{N}{2}\Big(1 - \frac{\overline{\theta}}{\overline{\varepsilon}}\Big)$ or $Q > \frac{N}{2}\Big(1 + \frac{\overline{\theta}}{\overline{\varepsilon}}\Big) + 1$, Q is never optimal and $X(Q)$ is empty. In particular, if N is odd and $N\overline{\theta} < \overline{\varepsilon}$, the simple majority rule ($Q = \frac{N+1}{2}$) is optimal for all $x \in \Theta$.

3.3 Interim welfare

We introduce in this section a concept of interim welfare, whose properties will be key for our main result.

For each signal realization $x \in \Theta$, denote $W(x)$ the expected welfare conditional on x when the voting rule is the $Q^*(x)$-majority rule:

$$W(x) := \mathbb{P}\Big[\sum_i m_i \geq Q^*(x) \Big| x\Big] * \mathbb{E}\Big[\sum_i (x_i + \varepsilon_i) \Big| x, \sum_i m_i \geq Q^*(x)\Big], \tag{7}$$

where the m_i are independently distributed binary variables, with $m_i = 1$ with probability $p^+(x_i)$ and $m_i = 0$ with probability $p^-(x_i)$, where, for $z \in [-\overline{\theta}, \overline{\theta}]$,

$$p^+(z) := \mathbb{P}[z + \varepsilon_i > 0] = \frac{1}{2}\Big(1 + \frac{z}{\overline{\varepsilon}}\Big), \tag{8}$$

$$p^-(z) := \mathbb{P}[z + \varepsilon_i < 0] = \frac{1}{2}\Big(1 - \frac{z}{\overline{\varepsilon}}\Big). \tag{9}$$

W has the following properties:

1. W is continuous on $\Theta = [-\overline{\theta}, \overline{\theta}]^N$.

2. W has a continuous first derivative and a continuous second derivative on $X(Q)$, for $Q = 1, ..., N$ such that $X(Q)$ is not empty (See (6) for the definition of $X(Q)$).

3.4 A simple example: Suboptimality of a full disclosure policy

We illustrate with a very simple example why full transparency is strictly suboptimal.

Example 1. Assume there are two voters ($N = 2$) and regarding θ, there are two states of the world:

$$\Theta = \Big\{(m - \bar{\delta}, m + \bar{\delta}), (m + \bar{\delta}, m - \bar{\delta})\Big\},$$

both with equal probability, where m and $\bar{\delta}$ are some real numbers such that $m < 0$, $0 < \bar{\delta} < \overline{\varepsilon}$, and $|m| < \overline{\varepsilon} - \bar{\delta}$. In this example, there is no aggregate uncertainty about the average value of the reform in the electorate ($m < 0$), but voters and the social planner are uncertain about the ranking of the individuals (whether $\theta_1 < \theta_2$ or $\theta_2 < \theta_1$).

- *Full transparency.* Consider first the full transparency policy. Ex ante expected welfare is:

$$W^{Transp} = \frac{1}{2}W(m-\bar{\delta}, m+\bar{\delta}) + \frac{1}{2}W(m+\bar{\delta}, m-\bar{\delta}),$$

  where W is defined in (7).

- *Anonymized disclosure.* Consider now the policy that fully discloses the anonymized information, that is, a policy with $x_i = m$ for $i = 1, 2$. In this specific example, it is equivalent to no disclosure at all. Expected welfare in that case is:

$$W^{Anon} = W(m, m)$$

- Expected welfare is higher under anonymized disclosure. To prove this result, let us get the explicit expression for W in this example. Following any signal realization x such that $x_1 + x_2 < 0$, we know from Proposition 1 that the optimal voting rule is to implement the reform if and only if there is unanimity in favor ($Q^*(x) = 2$).[5] Therefore,

$$\begin{aligned} W(x_1, x_2) &= p^+(x_1)p^+(x_2)\Big(u^+(x_1) + u^+(x_2)\Big) \\ &= W_1(x) + W_2(x), \end{aligned}$$

  where $W_i(x) = p^+(x_1)p^+(x_2)u^+(x_i)$ for each i, and u^+ and p^+ are defined in (2) and (8), respectively. For $\delta \in [-\bar{\delta}, \bar{\delta}]$, let $H(\delta) = W(m-\delta, m+\delta)$, so that $W^{Transp} = \frac{1}{2}H(-\bar{\delta}) + \frac{1}{2}H(\bar{\delta})$ and $W^{Anon} = H(0)$.

  Straightforward computation show that H is concave on $[-\bar{\delta}, \bar{\delta}]$,[6] which implies that $W^{Anon} > W^{Transp}$: full transparency is strictly dominated.

[5]Indeed, from Proposition 1, $Q^*(x) = Min\Big\{Q \in \mathbb{N} : Q \geq 1 - \frac{x_1+x_2}{2\bar{\varepsilon}}\Big\} = 2$ when $x_1 + x_2 < 0$.

[6]Indeed, $H''(\delta) = -\frac{m+\bar{\varepsilon}}{2\bar{\varepsilon}^2} < 0$.

- *Economic intuition.* That H is concave on $[-\bar{\delta}, \bar{\delta}]$ implies that making the two voters "closer" in terms of information always improves the welfare. Equivalently, $\frac{\partial W(x)}{\partial x_1} > \frac{\partial W(x)}{\partial x_2}$ whenever $x_1 < x_2$. To get the economic intuition behind this key property, we decompose the effect of an increase in x_1 (and similarly, a decrease in x_2) into two components:

  - its effect on the welfare of voter 1 (i.e., $\frac{\partial W_1(x)}{\partial x_1}$), which we call the "*own effect*";
  - its effect on the welfare of voter 2 (i.e., $\frac{\partial W_2(x)}{\partial x_1}$), which we call the "*externality effect*".

  Regarding the own effect, by definition:

$$W_1(x) = p^+(x_1)p^+(x_2) * u^+(x_1) = p^+(x_2) * \int_{\varepsilon_1=-x_1}^{\varepsilon_1=1} (x_1 + \varepsilon_1)\frac{d\varepsilon_1}{2\bar{\varepsilon}},$$

  and therefore, the own effect is given by:

$$\frac{\partial W_1(x)}{\partial x_1} = p^+(x_1)p^+(x_2),$$

  which is simply the probability that the reform is implemented.[7]

  Analogously:

$$\frac{\partial W_2(x)}{\partial x_2} = p^+(x_1)p^+(x_2),$$

  that is, the own effect is the same for both voters.

[7]Because $W_1(x) = p^+(x_2) * \int_{\varepsilon_1=-x_1}^{\varepsilon_1=1} (x_1 + \varepsilon_1)\frac{d\varepsilon_1}{2\bar{\varepsilon}}$, increasing x_1 has two effects on this quantity. First, it increases the ex post utility of voter 1 whenever the reform is implemented. Second, it makes voter 1 more likely to vote in favor of the reform. But as this happens only when voter 1 is almost indifferent between the reform and the status quo, this latter effect does not impact voter 1's expected welfare.

Consider now the externality effect—the effect of a marginal increase in x_1 on voter 2's welfare:

$$\frac{\partial W_2(x)}{\partial x_1} = \frac{1}{2\bar{\varepsilon}} * p^+(x_2)u^+(x_2).$$

Intuitively, the expression is because a unit increase of x_1 increases the probability of 1's voting for the reform by $\frac{1}{2\bar{\varepsilon}}$; and voter 2 enjoys $u^+(x_2)$ in expectation conditional on his voting for the reform, which itself happens with probability $p^+(x_2)$. Analogously, we have:

$$\frac{\partial W_1(x)}{\partial x_2} = \frac{1}{2\bar{\varepsilon}} * p^+(x_1)u^+(x_1),$$

and therefore, these externality effects are ordered: $\frac{\partial W_1(x)}{\partial x_2} < \frac{\partial W_2(x)}{\partial x_1}$, whenever $x_1 < x_2$.

To summarize, the own effects are the same for both voters, while the externality effect is larger for the voter who initially gets the worse news. This explains why giving "better news" to the worse-off voter improves welfare. We will show in the next subsection that these properties hold generally.

- *Comparison to first-best.* We have just shown that anonymized disclosure dominates full transparency. Theorem 1 states that anonymous disclosure is actually the optimal information disclosure policy. Note nevertheless that disclosing the anonymized information does not achieve the first best outcome. The first best would require to implement the reform iff $2m + \varepsilon_1 + \varepsilon_2 > 0$.[8] By contrast, under anonymized information, the reform is implemented iff simultaneously $m + \varepsilon_1 > 0$

[8] To be exact, the first best would require to implement the reform if $2m+\varepsilon_1+\varepsilon_2 > 0$, to keep the status quo if $2m+\varepsilon_1+\varepsilon_2 < 0$, and to take either decision when $2m+\varepsilon_1+\varepsilon_2 = 0$.

and $m+\varepsilon_2 > 0$. The reason why the first best cannot be achieved in this simple example is very general: whatever the information disclosure policy, in some situations (realization of the idiosyncratic preferences) there will be a mismatch between what a (optimally-chosen qualified) majority of voters want, and what is socially optimal. For example, when $\varepsilon_1 = \overline{\varepsilon}$ and $\varepsilon_2 \in (-m-\bar{\delta}, -m)$, voter 2 votes against the reform since $m+\varepsilon_2 < 0$ - which implies that the status quo is maintained, although the ex post value of the reform is $2m+\overline{\varepsilon}+\varepsilon_2 > m+\overline{\varepsilon}-\bar{\delta} > 0$. This mismatch, also known as the "intense minority" problem, is well-known.[9] Our main result shows that keeping voters behind some "veil of ignorance" regarding their relative position in the society is useful in order to mitigate this mismatch.

$\square$

3.5 Optimality of Anonymous Policy

In this section, we show that for any non-anonymous disclosure policy, there is an anonymous policy that is welfare-improving.

Roughly, anonymizing information means that we send a less dispersed signal. For example, instead of sending a signal $x = (x_1, x_2, x_3, \ldots, x_N)$ with $x_1 < x_2$, imagine that we send $(x_1+\delta, x_2-\delta, x_3, \ldots, x_N)$, for a small positive

[9] The expression "intense minority" problem refers to a situation where a decision has to be made under a simple majority rule. In cases where a majority of voters mildly oppose a reform while a minority would strongly benefit from it, a majority will vote against the reform blocking its adoption, although it would be socially optimal (in the sense of welfare maximizing) to adopt the reform.

δ.[10] The expected welfare changes by:

$$\delta\Big(\frac{\partial W(x)}{\partial x_1} - \frac{\partial W(x)}{\partial x_2}\Big)$$

Thus, if this is positive, anonymizing information improves the expected welfare. Specifically, we prove the following:

Proposition 2. For all $x \in \bigcup_{Q=1}^{N} X(Q)$:

$$x_1 < x_2 \Rightarrow \frac{\partial W(x)}{\partial x_1} > \frac{\partial W(x)}{\partial x_2}.$$

Informally, Proposition 2 states that making any two voters marginally "closer" in terms of information improves welfare. To derive this result, as in the simple example above, we decompose the effect of an increase in x_i into two components:

- its effect of the welfare of voter i, which we call the *own effect*;
- its effect on the rest of the electorate, which we call the *externality effect*.

To define formally these two concepts, we introduce the following notation. For $i = 1, ...N$, let

$$W_i(x) \equiv \mathbb{P}\Big[k = 1\Big|x\Big] * \mathbb{E}\Big[x_i + \varepsilon_i\Big|k = 1, x\Big]$$

[10]The argument here is not rigorous, as we (intentionally, for simplicity) ignore the Bayesian constraint: $\mathbb{E}[\theta_i|x] = x_i$ for all i. The formal proof takes care of this Bayesian constraint by changing the policy for some other x' at the same time. Here, we omit this complication. Notice that, without this Bayesian constraint, the problem is analogous to the one where the planner promises some "transfer" from / to each agent, in a balanced-budget manner. This result will be formally stated in Lemma 5 in Appendix A.3.

denote the expected welfare of voter i conditional on x when the voting rule is the $Q^*(x)$-majority rule and let

$$W_{-i}(x) \equiv \sum_{j \neq i} W_j(x)$$

denote the expected social welfare excluding voter i.

With these notation, we have the following decomposition:

$$\frac{\partial W(x)}{\partial x_i} = \underbrace{\frac{\partial W_i(x)}{\partial x_i}}_{\text{Own Effect}} + \underbrace{\frac{\partial W_{-i(x)}}{\partial x_i}}_{\text{Externality Effect}}.$$

Lemmas 1 and 2 state some general properties of the own and externality effects, from which Proposition 2 directly follows.

Lemma 1. (Own effect: Comparison across voters). For $x \in \bigcup_{Q=1}^{N} X(Q)$, $i, j = 1, ..., N$:

$$\frac{\partial W_i}{\partial x_i}(x) = \frac{\partial W_j}{\partial x_j}(x) = \mathbb{P}\Big[k = 1 \Big| x\Big]$$

Marginally increasing x_i has an unambiguously positive effect on the welfare of voter i, which is equal to the probability that the reform is implemented. The proof of Lemma 1 is given in Appendix A.1. Intuitively, increasing x_i has a first, direct effect on the ex post utility of voter i, $x_i + \varepsilon_i$, whenever the reform is implemented. It also changes the critical value of ε_i that makes voter i indifferent between voting for and against the reform (as this critical value is $\epsilon_i = -x_i$), making it slightly more likely that the reform is implemented. But the latter effect is negligible, as it changes behavior for values of ϵ_i such that the voter is precisely indifferent between implementing the reform and not implementing it. The result follows.

This property implies that for any two voters i, j, the size of own effect is the same.

Lemma 2. (Externality effect: Comparison across voters). For $x \in \bigcup_{Q=1}^{N} X(Q)$:

$$x_1 < x_2 \implies \frac{\partial W_{-1}(x)}{\partial x_1} > \frac{\partial W_{-2}(x)}{\partial x_2}$$

The proof of Lemma 2 is given in the Appendix A.2. To get the intuition, notice that an increase in x_1 influences W_{-1} only through the probability that voter 1 votes in favor of the reform. It makes a difference whenever voter 1 is pivotal. The sign of the externality effect is a priori ambiguous, as it depends on the expected welfare of the rest of the electorate conditional on voter 1 being pivotal. Though the sign itself is ambiguous, comparison across voters is not. Informally, for any voter i, as the expected welfare of the rest of the electorate (conditional on voter i being pivotal) is likely to be increasing with the signals received by other voters, one expects that if for two voters 1 and 2, $x_1 < x_2$, then the externality effect of voter 1 is larger than the externality effect of voter 2.

Proposition 2 is a key step in proving Theorem 1. In particular, it will be used to show that in an hypothetical auxiliary environment where the social planner and all the voters *know* the realization of $\frac{\sum_{i=1}^{N} \theta_i}{N}$ (but not individual θ_i), disclosing no additional information is optimal. This result is stated formally and proved in Lemma 5 in Appendix A.3.

3.6 Full disclosure of anonymized information

The next main step in the proof of Theorem 1 is to show that once voters' beliefs are aligned, that is, they all have the same beliefs about their own θ_i, hiding further information does not help. This step relies on Proposition 3.

Proposition 3. For $z \in [-\overline{\theta}, \overline{\theta}]$, let $\widehat{W}(z) := W(z, \ldots, z)$. $\widehat{W}$ is convex on $[-\overline{\theta}, \overline{\theta}]$.

The proof of Proposition 3 is provided in the Appendix A.6. To get the intuition, we know from Kamenica and Gentzkow [2011] that the convexity of $\widehat{W}$ is closely related to the incentives to disclose. Informally, consider a very simple example where there is no uncertainty about the distributional consequences of the reform but only some aggregate uncertainty. Specifically, either the outcome is good for everybody ($\theta = (b, ..., b)$ for some $b > 0$) or bad for everybody ($\theta = -(b, ..., b)$), and both states are equally probable. Without any disclosure, $\mathbb{E}[\theta_i] = 0$ for all i, and ex ante welfare is $\widehat{W}(0)$. Under full (anonymized) disclosure, ex ante welfare is $\frac{1}{2}\widehat{W}(-b) + \frac{1}{2}\widehat{W}(b)$. Convexity of $\widehat{W}$ implies that the latter welfare is higher.

Now, let us explain why $\widehat{W}$ is convex. It relies on the monotonicity properties of the own effect and the externality effect introduced earlier. Indeed, when $\widehat{W}$ is differentiable,

$$\widehat{W}''(z) = \sum_{i,j} \frac{\partial^2 W_i}{\partial x_i x_j}(z, \ldots, z) + \sum_{i,j} \frac{\partial^2 W_{-i}}{\partial x_i x_j}(z, \ldots, z).$$

These monotonicity properties of the own effect and the externality effect are established in the following two lemmas.

Lemma 3. (Own effect: Monotonicity). For $x \in \bigcup_{Q=1}^{N} X(Q)$, $i, j = 1, ..., N$:

$$\frac{\partial^2 W_i}{\partial x_i x_j}(x) > 0$$

Lemma 4. (Externality effect: Monotonicity). For $x \in \bigcup_{Q=1}^{N} X(Q)$, for all $i, j = 1, ..., N$ such that $i \neq j$:

$$\frac{\partial^2 W_{-i}}{\partial x_i^2}(x) = 0 \text{ and } \frac{\partial^2 W_{-i}}{\partial x_i \partial x_j}\Big(\frac{\sum_l x_l}{N}, ..., \frac{\sum_l x_l}{N}\Big) > 0$$

The proofs of Lemmas 3 and 4 are in Appendices A.4 and A.5, respectively. The argument for the own effect is straightforward. Indeed, from Lemma 1, the own effect of x_1 on the welfare on voter 1 ($\frac{\partial W_1(x)}{\partial x_1}$) is equal to the probability that the reform is implemented. It is therefore increasing with all x_i, for $i = 1, ..., N$. The argument for the externality effect is more elaborate, and is relegated to Appendix A.5.

These properties of the own and externality effects show that $\widehat{W}$ is convex on all intervals where the optimal voting rule is uniquely defined (which guarantees that the first and second derivatives of W are well defined). We take care of the critical points where the voting rule switches in the formal proof in the Appendix.

The final step of the proof is to combine results in subsections $3.2 - 3.6$ to conclude the proof of Theorem 1 (See Appendix A.7)

4 Discussion

A key element of Theorem 1 is that the optimal information disclosure policy should keep voters as 'aligned' as possible in terms of beliefs. In this section, we discuss the role of two assumptions of the model of Section 2 in establishing this result: (i) the fact that the social planner can freely choose the voting rule, (ii) the assumption that voters are a priori symmetric.

Our objecrtive in this section is not to study in full generality alternative models with fixed voting rules or asymmetric voters. The aim is to examine an example in each of these two cases that will help us to understand the role played by the assumption concerned. These examples have been chosen to illustrate the point as simply as possible.[11]

[11] In particular, in each of these two examples we will consider situations where there is

4.1 The case of a fixed voting rule

Theorem 1 states that if the social planner can optimally choose both the information disclosure policy and the voting mechanism, then it is an optimal disclosure policy to fully disclose the anonymized information. In this section, we discuss whas happens if the voting rule is instead fixed, say, it is the simple majority rule. We keep the same model as in Section 2, with two important changes:

1. The voting rule is the simple majority rule and it is fixed. For simplicity, we assume that the number of voters N is odd, so that the reform is implemented if and only if at least $\frac{N+1}{2}$ voters vote in favor of the reform;

2. The planner only chooses a disclosure policy.

In that case, we have the following result.

Proposition 4. Assume N is odd and the voting rule is the simple majority rule. If $N\overline{\theta} < \overline{\varepsilon}$, then the optimal disclosure policy is to fully disclose the anonymized information.

Proof. From (6), the set of signal realisations for which the simple majority rule is optimal is $X(\frac{N+1}{2}) = \{x \in \Theta : |\sum_i x_i| < \overline{\varepsilon}\}$. Therefore, when $N\overline{\theta} < \overline{\varepsilon}$, the simple majority rule is the optimal voting rule whatever the information disclosure and the signal realization ($X(\frac{N+1}{2}) = \Theta$). The result in Proposition 4 is then a direct consequence of Theorem 1. □

no aggregate uncertainty about the value of the reform ($\sum_i \theta_i$ is constant) and where the only uncertainty relates to the distribution of the benefits of the reform between voters. We could easily construct examples with aggregate uncertainty that make a similar point, at the cost of heavier notation and somewhat more complex development.

Proposition 4 states that full disclosure of the anonymized information is optimal provided that $\overline{\theta}/\overline{\varepsilon}$ is not too large. Below, we provide a very simple example illustrating the importance of this upper bound on $\overline{\theta}/\overline{\varepsilon}$ for the result.

Example 2. Assume $N = 3$, $\overline{\theta} = \frac{9}{10}, \overline{\varepsilon} = 1$, and $\theta = \left(\frac{9}{10}, \frac{9}{10}, 0\right)$ or any of its permutations with equal probability $\frac{1}{3}$. Note that the condition $N\overline{\theta} < \overline{\varepsilon}$ does not hold. We show that in that case full disclosure dominates the anonymized disclosure policy.

Fron Definition (6), with $N = 3$ voters and $\varepsilon_i \sim [-1, 1]$,:

$$X(1) = \{x \in \Theta : 1 < \sum_i x_i < 3\}$$

$$X(2) = \{x \in \Theta : -1 < \sum_i x_i < 1\}$$

$$X(3) = \{x \in \Theta : -3 < \sum_i x_i < -1\}$$

where $X(Q)$ is the set of signal realization for which the majority rule with threshold for approval Q is the unique optimal voting rule.

Under both the anonymous discosure and the full disclose policies, $\sum_i x_i = 1.8 > 1$ and the optimal voting rule is to approve the reform iff at least one voter votes in favor. The majority rule is too restrictive.

It is straighfoward to compute that under full disclosure, the expected welfare is 1.78125, while under the anonymized disclosure policy, it is 1.7664, which is strictly lower.

The intuition is the following. As noted above, the simple majority rule is not optimal: it is too restrictive, as it does not select the reform when only one voter votes in favor. Compared to the anonymized policy disclosure, full disclosure decreases the probability that voters unanimously approve the reform (from 0.512 to 0.45125), which is bad for welfare as this corresponds to events in which the idiosyncratic shocks tend to be high. But it also increases the probability of a 2 to 1 votes in favor of the reform (from 0.384 to 0.49875), which is good for welfare. Under the assumptions made on the parameters, the latter effect dominates, and full disclosure outperforms anonymous disclosure. □

When the social planner cannot optimize on the voting rule and faces a voting rule that is, say, too restrictive, it is as if the information designer is somehow biased in favor of the reform: she tries to fix the inefficiency of the voting rule by choosing an information disclosure policy that increases the probability that the reform is implemented. This is reminiscent of the literature with a biased sender facing multiple receivers (See Alonso and Camara [2016] or Bardhi and Guo [2018]).

4.2 A priori heterogeneous voters

So far, we have considered an environment in which voters are a priori symmetric: F is N-exchangeable and all voters' idiosyncratic shocks are identically distributed. Studying in full generality the case of heterogeneous voters is beyond the scope of this paper. Still, we provide in this section an example showing that some of the results might remain valid.

A key feature of Theorem 1 is that when voters are a priori symmetric, the optimal disclosure policy keeps them as 'aligned' as possible. If a similar force is at play with a priori *asymmetric* voters, intuition suggests that the planner might want to "compensate" voters with a priori bad idiosyncratic shocks by giving them better news about their θ_i. If Bayesian plausibility prevents this, then anonymity might still be optimal.

We provide a simple example illustrating this point.

Example 3. Assume $N = 2$. Voter 1 is a priori in favor of the reform: the idiosyncratic shock ϵ_1 is uniformly distributed on $[b-\bar{\epsilon}, b+\bar{\epsilon}]$, with $0 \leq b \leq \bar{\varepsilon}$. Voter 2 is a priori against the reform: the idiosyncratic shock ϵ_2 is uniformly distributed on $[-b-\bar{\epsilon}, -b+\bar{\epsilon}]$.

As for θ, we assume as in Example 1, that there are two states of the world:

$$\Theta = \Big\{(m - \bar{\delta}, m + \bar{\delta}), (m + \bar{\delta}, m - \bar{\delta})\Big\},$$

both with equal probability, where m and $\bar{\delta}$ are some real numbers such that $m < 0$, $0 < b + \bar{\delta} < \bar{\varepsilon}$, and $|m| < \bar{\varepsilon} - \bar{\delta} - b$. [12]

We proceed in two steps: (1) We characterize the optimal voting rule for any disclosure policy and any signal realization. (ii) We show that when the voting rule is optimally chosen, then no disclosure (equivalent to the anonymous disclosure in the current environment) is optimal.

Step 1. Optimal voting rule. Since there is no aggregate uncertainity about the value of the reform, only signals such that $\sum_i x_i = 2m$ can happen. If following signal realisation x such that $\sum_i x_i = 2m$, voter i votes in favor of the reform iff $x_i + \varepsilon_i > 0$, one can check that the expected welfare conditional on both voters voting in favor of the reform is

$$\mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| x_1 + \varepsilon_1 > 0 \text{ and } x_2 + \varepsilon_2 > 0\Big] = \frac{1}{2}\sum_i x_i + \bar{\varepsilon} = m + \bar{\varepsilon}$$

while the expected welfare conditional on exactly one voter voting in favor

[12] These assumptions imply in particular that whatever his beliefs about θ_i, voter i might still vote for or against the reform depending on the realization of his idiosyncratic shock. When $b = 0$, these are exactly the assumptions made in Example 1.

of the reform is

$$\begin{aligned}
&\mathbb{E}\Big[\sum_i (x_i+\varepsilon_i)\Big| x_1+\varepsilon_1>0 \text{ and } x_2+\varepsilon_2<0\Big]\\
&\mathbb{E}\Big[\sum_i (x_i+\varepsilon_i)\Big| x_1+\varepsilon_1<0 \text{ and } x_2+\varepsilon_2>0\Big]\\
&=\frac{1}{2}\sum_i x_i-\bar{\varepsilon}=m-\bar{\varepsilon}
\end{aligned}$$

By assumption, $m+\bar{\varepsilon}>0$ and $m-\bar{\varepsilon}<0$. The optimal voting rule is therefore to implement the reform if and only if there is unanimous support and interim welfare when the voting rule is optimally chosen is

$$W(x)=\frac{x_1+b+\bar{\epsilon}}{2\bar{\epsilon}}\frac{x_2-b+\bar{\epsilon}}{2\bar{\epsilon}}(m+\bar{\epsilon})$$

Step 2. Optimal disclosure policy under unanimity voting rule. We show that, in that case, no disclosure is the optimal disclosure policy. We follow the proof in Kamenica and Gentzkow [2011]. If the belief that the state is $(m+\bar{\delta}, m-\bar{\delta})$ (good news for Voter 1) is μ, the expectation of θ_1 is

$$X_1(\mu):=\mu(m+\bar{\delta})+(1-\mu)(m-\bar{\delta})=m+\bar{\delta}(2\mu-1)$$

and the expectation of θ_2 is

$$X_2(\mu):=\mu(m-\bar{\delta})+(1-\mu)(m+\bar{\delta})=m+\bar{\delta}(1-2\mu)$$

Therefore, expected welfare is:

$$V(\mu)=W(X_1(\mu),X_2(\mu))$$

which is strictly concave in μ: no disclosure is uniquely optimal.

Notice that $V'(\mu)=0$ for $\mu=\frac{1}{2}(1-b/\bar{\delta})$. When $b=0$ (both voters are identical regarding the distribution of their idiosyncratic shock), $V(\mu)$

is maximized when $\mu = 1/2$ (no disclosure). If $b > 0$, maximizing $V(\mu)$ would require to give voter 2 better news (than $\mu = 1/2$). If possible, the planner would like to "compensate" voter 2 by systematically giving him a better news, in order to make the two voters' situations as close as possible. Bayesian plausibility prevents this. As a result, the planner cannot improve on no disclosure.

$\square$

5 Conclusion

In this paper, we study a simple two-alternative voting environment (reform vs. statu quo). A benevolent utilitarian social planner controls some of the relevant information about the consequences of the alternatives for each voter, while each voter also possesses her own private information. The social planner chooses both an information disclosure policy (i.e. a 'policy experiment' 'a la Kamenica and Gentzkow [2011]) and a voting mechanism (which may depend on the outcome of the experiment). We show that the optimal policy discloses only the "anonymized" information, effectively keeping voters behind a partial "veil of ignorance".

The literature has studied optimal information disclosure by biased experts in a voting environment, e.g. experts with a bias in favour of the reform. We identify another type of "misalignment" between voters and the information designer, which may prevent full disclosure: a voting mechanism only reveals some information about voters' ordinal preferences (each voter votes for or against the reform), while the social planner is concerned with *cardinal* preferences. This paper therefore highlights a tension between two democratic principles: democratic decision-making through voting on the one hand, and full transparency about the consequences of reforms on the other.

A APPENDIX: Proofs

A.1 Proof of Lemma 1.

Take $x \in \bigcup_{Q=1}^{N} X(Q)$. Let us decompose the interim welfare of voter 1, $W_1(x)$, depending on whether voter 1 is pivotal or not in getting the reform implemented:

$$\begin{aligned} W_1(x) =& \mathbb{P}\Big[\sum_{i\neq 1} m_l = Q^*(x) - 1 \Big| x_{-1}\Big] * \Big(p^+(x_1)u^+(x_1)\Big) \\ &+ \mathbb{P}\Big[\sum_{i\neq 1} m_l \geq Q^*(x) \Big| x_{-1}\Big] * x_1 \end{aligned}$$

where the m_i, for $i \geq 2$, are $N-1$ independently distributed binary variables, with $m_i = 1$ with probability $p^+(x_i)$ and $m_i = 0$ otherwise.

In this decomposition, the term on the first line of the RHS pertains to events such that voter 1 is pivotal in getting the reform implemented, in which case his expected utility is $p^+(x_1)u^+(x_1)$. The term on the second line pertains to events such the reform is implemented even if voter 1 votes against it. In this latter case, nothing is learnt about the idiosyncratic shock of voter 1 so his conditional expected utility is simply x_1.

Consider the term on the first line. The probability that 1 is pivotal does ot depend on x_1. Besides:

$$\frac{\partial}{\partial x_1}\Big(p^+(x_1)u^+(x_1)\Big) = \frac{\partial}{\partial x_1}\Big(\int_{x_1+\varepsilon_1\geq 0}(x_1+\varepsilon_1)\frac{d\varepsilon_1}{2\overline{\varepsilon}}\Big) = \int_{x_i+\varepsilon_i\geq 0}\frac{d\varepsilon_1}{2\overline{\varepsilon}} = p^+(x_1).$$

Therefore

$$\begin{aligned}\frac{\partial W_1(x)}{\partial x_1} =&\mathbb{P}\Big[\sum_{i\neq 1} m_i = Q^*(x)-1\Big|x_{-1}\Big] * p^+(x_1)\\ &+\mathbb{P}\Big[\sum_{i\neq 1} m_i \geq Q^*(x)\Big|x_{-1}\Big]\\ =&\mathbb{P}\Big[k=1\Big|x\Big]\end{aligned}$$

The effect of a marginal increase of x_1 on the welfare of voter 1 is simply the probability that the reform is implemented.

A.2 Proof of Lemma 2.

Take $x \in \bigcup_{Q=1}^{N} X(Q)$. By definition,

$$W_{-1}(x) \equiv \mathbb{P}\Big[k=1\Big|x\Big] * \mathbb{E}\Big[\sum_{i\neq 1}(x_i+\varepsilon_i)\Big|k=1,x\Big].$$

Decomposing $\mathbb{P}\Big[k=1\Big|x\Big]$ depending on whether voter 1 is pivotal or not in getting the reform implemented, one gets

$$\begin{aligned}&W_{-1}(x)\\ =&\mathbb{P}\Big[\sum_{i\neq 1} m_i = Q^*(x)-1\Big|x_{-1}\Big] * p^+(x_1) * \mathbb{E}\Big[\sum_{i\neq 1}(x_i+\varepsilon_i)\Big|\sum_{i\neq 1} m_i = Q^*(x)-1, x_{-1}\Big]\\ +&\mathbb{P}\Big[\sum_{i\neq 1} m_i \geq Q^*(x)\Big|x_{-1}\Big] * \mathbb{E}\Big[\sum_{i\neq 1}(x_i+\varepsilon_i)\Big|\sum_{i\neq 1} m_l \geq Q^*(x), x_{-1}\Big]\end{aligned}$$

where the m_i, for $i \geq 2$, are $N-1$ independently distributed binary variables, with $m_i = 1$ with probability $p^+(x_i)$ and $m_i = 0$ otherwise.

In this decomposition, the term on the first line of the right-hand-side pertains to events such that voter 1 is pivotal in getting the reform implemented. It depends on x_1 only through the probability that voter 1 votes in favor of the reform. The term on the second line pertains to events such the reform is implemented even if voter 1 votes against it. It does not depend on x_1. Therefore:

$$\begin{aligned}\frac{\partial W_{-1}}{\partial x_1}(x) = \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i = Q^*(x) - 1\Big| x_{-1}\Big] \\ * \mathbb{E}\Big[\sum_{i\neq 1}(x_i + \varepsilon_i)\Big| \sum_{i\neq 1} m_i = Q^*(x) - 1, x_{-1}\Big] \end{aligned} \tag{10}$$

The quantity $\frac{\partial W_{-1}}{\partial x_1}(x)$ is the externality that an increase in x_1 exerts on the rest of the electorate. Notice that it does not depend on x_1, and that its sign is ambiguous, as it depends on the expected welfare of the rest of the electorate conditional on voter 1 being pivotal.

Assume that x is such that $x_1 < x_2$. To compare $\frac{\partial W_{-1}}{\partial x_1}(x)$ and $\frac{\partial W_{-2}}{\partial x_2}(x)$, we decompose $\frac{\partial W_{-1}}{\partial x_1}(x)$ depending on whether voter 2 votes in favor of the reform or not:

$$\begin{aligned}\frac{\partial W_{-1}}{\partial x_1}(x) =& \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 2\Big| x_{-1,2}\Big] * p^+(x_2) \\ & * \Big(u^+(x_2) + \mathbb{E}\Big[\sum_{i\neq 1,2}(x_i + \varepsilon_i)\Big| \sum_{i\neq 1,2} m_i = Q^*(x) - 2, x_{-1,2}\Big]\Big) \\ & + \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 1\Big| x_{-1,2}\Big] * p^-(x_2) \\ & * \Big(u^-(x_2) + \mathbb{E}\Big[\sum_{i\neq 1,2}(x_i + \varepsilon_i)\Big| \sum_{i\neq 1,2} m_i = Q^*(x) - 1, x_{-1,2}\Big]\Big) \end{aligned} \tag{11}$$

Using the fact that

$$\begin{aligned} & u^+(x_2) + \mathbb{E}\Big[\sum_{i\neq 1,2}(x_i + \varepsilon_i)\Big| \sum_{i\neq 1,2} m_i = Q^*(x) - 2, x_{-1,2}\Big] \\ =& E\Big[\sum_{i}(x_i + \varepsilon_i)\Big| \sum_{i} m_i = Q^*(x), x\Big] - u^+(x_1) \end{aligned}$$

and similarly

$$u^-(x_2) + \mathbb{E}\Big[\sum_{i\neq 1,2}(x_i+\varepsilon_i)\Big|\sum_{i\neq 1,2} m_i = Q^*(x)-1, x_{-1,2}\Big]$$
$$= E\Big[\sum_i (x_i+\varepsilon_i)\Big|\sum_i m_i = Q^*(x)-1, x\Big] - u^-(x_1)$$

and rearranging terms, one gets:

$$\begin{aligned}
&\frac{\partial W_{-1}}{\partial x_1}(x) - \frac{\partial W_{-2}}{\partial x_2}(x)\\
=&\frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x)-2\Big|x_{-1,2}\Big]\\
&* \begin{pmatrix} \Big[p^+(x_2)-p^+(x_1)\Big]E\Big[\sum_i(x_i+\varepsilon_i)\Big|\sum_i m_i = Q^*(x), x\Big] \\ -p^+(x_2)u^+(x_1)+p^+(x_1)u^+(x_2)\end{pmatrix}\\
+&\frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x)-1\Big|x_{-1,2}\Big]\\
&* \begin{pmatrix} \Big[p^-(x_2)-p^-(x_1)\Big]E\Big[\sum_i(x_i+\varepsilon_i)\Big|\sum_i m_i = Q^*(x)-1, x\Big] \\ -p^-(x_2)u^-(x_1)+p^-(x_1)u^-(x_2)\end{pmatrix}
\end{aligned}$$

The result in Lemma 2 follows from the observation that $\overline{\varepsilon}p^+(x_i) = u^+(x_i)$ and $\overline{\varepsilon}p^-(x\_i) = -u^-(x_i)$, and that, by the optimality of the voting rule $Q^*(x)$:

$$E\Big[\sum_i(x_i+\varepsilon_i)\Big|\sum_i m_i = Q^*(x)-1, x\Big] < 0 < E\Big[\sum_i(x_i+\varepsilon_i)\Big|\sum_i m_i = Q^*(x), x\Big].$$

A.3 Statement and proof of Lemma 5

Consider an auxiliary environment where the social planner and all the voters know $\mu = \frac{\sum_{i=1}^N \theta_i}{N}$ (but not individual θ_i). Applying Proposition 2, we show that disclosing no additional information is optimal.

Lemma 5. Consider an auxiliary environment where the social planner and all the voters know $\mu = \frac{\sum_{i=1}^{N}\theta_i}{N}$ (but not individual θ_i). Then it is optimal to disclose no additional information.

Proof. Fix any $\mu \in [-\overline{\theta}, \overline{\theta}]$. Let $\Theta^{\mu} = \{\theta | \frac{\sum_{i=1}^{N}\theta_i}{N} = \mu\}$. Let $\xi^{\mu} \in \Delta(\Theta^m)$ be any disclosure policy (more formally, its equivalent, as discussed in Section 2). From Proposition 1, whatever the signal realization, the optimal voting rule is $Q^*(\mu, \ldots, \mu)$. Letting $W(x)$ denote the expected total welfare if the planner and the voters are informed of $x = (x_i)_{i=1}^{N}$, our problem is:

$$\max_{\xi^{\mu}} \int_x W(x) d\xi^{\mu}.$$

If no additional information is disclosed, the induced expected total welfare is:

$$W(\mu, \ldots, \mu).$$

Thus, it suffices to show:

$$W(\mu, \ldots, \mu) \geq \int_x W(x) d\xi^{\mu}.$$

Fix any policy ξ^{μ} with $\Pr(x_i \neq x_j,\ \exists i, j) > 0$. Fix $\lambda \in (0, 1)$, and define an alternative disclosure policy, $\tilde{\xi}^{\mu}$, by:

$$\tilde{\xi}^{m}(A) = \xi^{\mu}(\{x' | \exists x \in A; x' = (1-\lambda)x + \lambda(\mu, \ldots, \mu)\}),$$

for each (measurable) $A \subseteq \Theta$. $\tilde{\xi}^{\mu}$ is less convex than ξ^{μ} in the sense of the convex stochastic ordering, and hence, is feasible. Equivalently, $\tilde{\xi}^{\mu}$ can be described as a probability distribution such that, first, x is drawn according to ξ^{μ}, and then the actual value realized is given by $x' = (1-\lambda)x + \lambda(\mu, \ldots, \mu)$. This alternative description is useful in that the expected total welfare given $\tilde{\xi}^{\mu}$ is given by:

$$\int_x W((1-\lambda)x + \lambda(\mu, \ldots, \mu)) d\xi^{\mu},$$

and to show that $\tilde{\xi}^\mu$ is an improvement over ξ^μ, it suffices to show that

$$W((1-\lambda)x + \lambda(\mu, \dots, \mu)) > W(x)$$

whenever $x_i \neq x_j$ for some i, j.[13]

Hence, from here on, we fix an arbitrary x such that $x \neq (\mu, ..., \mu)$. For small λ, we have

$$W((1-\lambda)x + \lambda(\mu, \dots, \mu)) - W(x) \simeq \ \lambda \textstyle\sum_{i=1}^N (\mu - x_i) \frac{\partial W}{\partial x_i}(x).$$

Given that $\mu = \frac{1}{N} \sum_{j=1}^N x_j$,

$$\begin{aligned} \sum_{i=1}^N (\mu - x_i) W_i(x) &= \frac{1}{N} \sum_{i=1}^N \sum_{j=1}^N (x_j - x_i) \frac{\partial W}{\partial x_i}(x) \\ &= \frac{1}{2N} \sum_{i=1}^N \sum_{j=i}^N (x_j - x_i) \Big(\frac{\partial W}{\partial x_i}(x) - \frac{\partial W}{\partial x_j}(x) \Big) \end{aligned}$$

Thus, it suffices to show that $\frac{\partial W}{\partial x_i}(x) - \frac{\partial W}{\partial x_j}(x) > 0$ if $x_j > x_i$, for any given i, j and x. This is precisely the Condition obtained in Proposition 2. $\square$

A.4 Proof of Lemma 3

Take $x \in \bigcup_{Q=1}^N X(Q)$, $i = 1, ..., N$. From Lemma 1, the own effect for voter i is $\frac{\partial W_i}{\partial x_i}(x) = \mathbb{P}\Big[k = 1 \Big| x\Big]$, which is the probability that the reform is implemented. For $j = 1, ..., N$, this probability can be decomposed as:

$$\mathbb{P}[k = 1|x] = \mathbb{P}\Big[\sum_{l \neq j} m_l = Q^*(x) - 1 \Big| x_{-j}\Big] p^+(x_j) + \mathbb{P}\Big[\sum_{l \neq j} m_l \geq Q^*(x) \Big| x_{-j}\Big]$$

[13] More precisely, for each $n \in \mathbb{N}$, let

$$\mathcal{X}_n = \{x | W((1-\lambda)x + \lambda(\mu, \dots, \mu)) - W(x) > \frac{1}{n}\},$$

and let $\mathcal{X}_\infty = \bigcup_{n \in \mathbb{N}} \mathcal{X}_n$. Then $\xi^\mu(\mathcal{X}_\infty) > 0$ by assumption, which implies $\xi^\mu(\mathcal{X}_n) > 0$ for some n by continuity of a measure with respect to countable set operations.

where the m_l, for $m \neq j$, are $N-1$ independently distributed binary variables, with $m_l = 1$ with probability $p^+(x_l)$ and $m_l = 0$ otherwise. Therefore

$$\frac{\partial^2 W_i}{\partial x_i \partial x_j}(x) = \frac{1}{2\overline{\varepsilon}} \mathbb{P}\Big[\sum_{l \neq j} m_l = Q^*(x) - 1 \Big| x_{-j}\Big] > 0.$$

A.5 Proof of Lemma 4

Take $x \in \bigcup_{Q=1}^{N} X(Q)$.

From (10) in the proof of Lemma 2, $\frac{\partial W_{-1}}{\partial x_1}$ does not depend on x_1, which shows that $\frac{\partial^2 W_{-1}}{\partial x_1^2}(x) = 0$.

Let us now show that $\frac{\partial^2 W_{-1}}{\partial x_1 \partial x_2}\Big(\frac{\sum_l x_l}{N}, ..., \frac{\sum_l x_l}{N}\Big) > 0$. Taking the derivative with respect to x_2 of $\frac{\partial W_{-1}}{\partial x_1}(x)$ as given in (11) in Appendix A.2, and using the property that $\frac{\partial}{\partial x_2}\Big(p^+(x_2)u^+(x_2)\Big) = p^+(x_2)$, one gets:

$$\begin{aligned}
\frac{\partial^2 W_{-1}}{\partial x_1 \partial x_2}(x) =& \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i \neq 1,2} m_i = Q^*(x) - 2 \Big| x_{-1,2}\Big] * \\
& * \Big(p^+(x_2) + \frac{1}{2\overline{\varepsilon}} \mathbb{E}\Big[\sum_{i \neq 1,2} (x_i + \varepsilon_i) \Big| \sum_{i \neq 1,2} m_i = Q^*(x) - 2, x_{-1,2}\Big]\Big) \\
& + \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i \neq 1,2} m_i = Q^*(x)^*(x) - 1 \Big| x_{-1,2}\Big] * \\
& * \Big(p^-(x_2) - \frac{1}{2\overline{\varepsilon}} \mathbb{E}\Big[\sum_{i \neq 1,2} (x_i + \varepsilon_i) \Big| \sum_{i \neq 1,2} m_i = Q^*(x) - 1, x_{-1,2}\Big]\Big)
\end{aligned}$$

where the m_i, for $m = 1, ..., N$, are N independently distributed binary variables, with $m_i = 1$ with probability $p^+(x_i)$ and $m_i = 0$ otherwise. and therefore, using the fact that $\bar{\varepsilon} p^+(z) = u^+(z)$ and $\bar{\varepsilon} p^-(z) = -u^-(z)$, one has:

$$\begin{aligned}
\frac{\partial^2 W_{-1}}{\partial x_1 \partial x_2}(x) =& \frac{1}{(2\bar{\varepsilon})^2} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 2 \Big| x_{-1,2}\Big] \\
& * \Big(\mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x), x\Big] + u^+(x_2) - u^+(x_1)\Big) \\
& - \frac{1}{(2\bar{\varepsilon})^2} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 1 \Big| x_{-1,2}\Big] \\
& * \Big(\mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x) - 1, x\Big] + u^-(x_2) - u^-(x_1)\Big)
\end{aligned}$$

Therefore

$$\begin{aligned}
&\frac{\partial^2 W_{-1}}{\partial x_1 \partial x_2}\Big(\frac{\sum_l x_l}{N}, ..., \frac{\sum_l x_l}{N}\Big) \\
&= \frac{1}{(2\bar{\varepsilon})^2} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 2 \Big| x\Big] * \mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x), x\Big] \\
&- \frac{1}{(2\bar{\varepsilon})^2} * \mathbb{P}\Big[\sum_{i\neq 1,2} m_i = Q^*(x) - 1 \Big| x\Big] * \mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x) - 1, x\Big]
\end{aligned}$$

where the m_i, for $m = 1, ..., N$, are N independently distributed binary variables, with $m_i = 1$ with probability $p^+\Big(\frac{\sum_l x_l}{N}\Big)$ and $m_i = 0$ otherwise. By the optimality of the voting rule $Q^*(x) = Q^*\Big(\frac{\sum_l x_l}{N}, ..., \frac{\sum_l x_l}{N}\Big)$:

$$\mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x) - 1, x\Big] < 0 < \mathbb{E}\Big[\sum_i (x_i + \varepsilon_i)\Big| \sum_i m_i = Q^*(x), x\Big].$$

Therefore

$$\frac{\partial^2 W_{-i}}{\partial x_i \partial x_j}\Big(\frac{\sum_l x_l}{N}, ..., \frac{\sum_l x_l}{N}\Big) > 0$$

A.6 Proof of Proposition 3

We first introduce some additional notation.

Notation: For $Q = 0, 1, ..., N$, let

$$z_Q := \Big(1 - \frac{2Q}{N}\Big)\overline{\varepsilon} \in [-\overline{\varepsilon}, \overline{\varepsilon}] \tag{12}$$

$$Z(Q) := \Big\{ z \in [-\overline{\theta}, \overline{\theta}] : z_Q < z < z_{Q-1} \Big\} \tag{13}$$

Notice $z_0 = \overline{\varepsilon}$ and $z_N = \overline{\varepsilon}$. From (6), notice also that $x \in X(Q) \iff \frac{\sum_i x_i}{N} \in Z(Q)$, where $X(Q)$ is the set of signal realizations for which the majority rule with threshold for approval Q is the unique optimal voting rule. As noted when introducing $X(Q)$, $X(Q)$ (and therefore $Z(Q)$) can be an empty set for some integers Q.

The result in Proposition 3 is shown in two steps:

- Step 1: For any $Q = 1, ..., N$ such that $Z(Q) \neq \emptyset$, $\widehat{W}$ is convex on $Z(Q)$.
- Step 2: For any $Q = 1, ..., N-1$ such that $Z(Q) \neq \emptyset$ and $Z(Q+1) \neq \emptyset$:

$$\mathop{lim}_{z \nearrow z_Q} \widehat{W}'(z) \leq \mathop{lim}_{z \searrow z_Q} \widehat{W}'(z).$$

Proof of Step 1. Take any Q in $\{1, ..., N\}$ such that $Z(Q) \neq \emptyset$. $\widehat{W}$ is twice differentiable on $Z(Q)$. For $z \in Z(Q)$,

$$\widehat{W}'(z) = \sum_i \frac{\partial W}{\partial x_i}(z, \ldots, z)$$

and

$$\begin{aligned} \widehat{W}''(z) &= \sum_{i,j} \frac{\partial^2 W}{\partial x_i x_j}(z, \ldots, z) \\ &= \sum_{i,j} \frac{\partial^2 W_i}{\partial x_i x_j}(z, \ldots, z) + \sum_{i,j} \frac{\partial^2 W_{-i}}{\partial x_i x_j}(z, \ldots, z). \end{aligned} \tag{14}$$

From Lemmas 3 and 4, for $z \in Z(Q)$, both terms of the sum in (14) are strictly positive, due to the monotonicity of the 'own' and 'externality effects'.

This concludes the first part of the proof. $\square$

Proof of Step 2. It remains to study what happens at critical points where the optimal voting rule changes. To show that $\widehat{W}$ is convex on $[-\overline{\theta}, \overline{\theta}]$, it is sufficient to show that for any $Q = 1, ..., N-1$ such that $Z(Q) \neq \emptyset$ and $Z(Q+1) \neq \emptyset$:

$$\lim_{z \nearrow z_Q} \widehat{W}' \leq \lim_{z \searrow z_Q} \widehat{W}'.$$

We have, for $z \in \bigcup_{Q=1}^{N} Z(Q)$:

$$\begin{aligned}
\widehat{W}'(z) &= \sum_i \frac{\partial W}{\partial x_i}(z, \ldots, z) \\
&= N \frac{\partial W}{\partial x_1}(z, \ldots, z) \\
&= N \Big(\frac{\partial W_1}{\partial x_1}(z, \ldots, z) + \frac{\partial W_{-1}}{\partial x_1}(z, \ldots, z) \Big)
\end{aligned}$$

Notation For $z \in [-\overline{\theta}, \overline{\theta}]$, let $\{m_i^z\}_{i=1,\ldots,N}$ be N independently distributed binary variables, with $m_i = 1$ with probability $p^+(z)$ and $m_i = 0$ otherwise.

From Lemma 1, the own effect for voter 1 evaluated at $(z, ..., z) \in X(Q+1)$ is

$$\frac{\partial W_1}{\partial x_1}(z, ..., z) = \mathbb{P}\Big[\sum_i m_i^z \geq Q + 1 \Big]$$

and from (10) the externality effect is

$$\begin{aligned}
&\frac{\partial W_{-1}}{\partial x_1}(z, ..., z) \\
&= \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i = Q \Big| z\Big] * \mathbb{E}\Big[\sum_{i\neq 1}(z+\varepsilon_i)\Big| \sum_{i\neq 1} m_i^z = Q\Big] \\
&= \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i = Q \Big| z\Big] * \Big(\mathbb{E}\Big[\sum_{i}(z+\varepsilon_i)\Big| \sum_{i} m_i^z = Q\Big] - u^-(z)\Big)
\end{aligned}$$

Taking the limit of these two expressions when z goes to z_Q from below, and using the fact that by definition of z_Q, $\mathbb{E}\Big[\sum_i (x_i+\varepsilon_i)\Big| \sum_i m_i^{z_Q} = Q\Big] = 0$, one gets:

$$\begin{aligned}
&\lim_{z\nearrow z_Q} \frac{\partial W}{\partial x_1}(z, \ldots, z) \\
&= \mathbb{P}\Big[\sum_{i} m_i^{z_Q} \geq Q+1\Big] + \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i^{z_Q} = Q\Big] * \Big(-u^-(z)\Big) \\
&= \mathbb{P}\Big[\sum_{i} m_i^{z_Q} \geq Q+1\Big] + \frac{1}{2} * \mathbb{P}\Big[\sum_{i\neq 1} m_i^{z_Q} = Q\Big] * p^-(z_Q) \qquad (15)
\end{aligned}$$

where the second inequality comes from the observation that $-u^-(z) = \overline{\varepsilon}p^-(z)$.

Similarly, for $z \in Z(Q)$: the own effect is

$$\frac{\partial W_1}{\partial x_1}(z, ..., z) = \mathbb{P}\Big[\sum_i m_i^z \geq Q\Big]$$

and the externality effect is

$$\begin{aligned}
&\frac{\partial W_{-1}}{\partial x_1}(z, ..., z) \\
&= \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i = Q-1 \Big| z\Big] * \mathbb{E}\Big[\sum_{i\neq 1}(z+\varepsilon_i)\Big| \sum_{i\neq 1} m_i = Q-1, z\Big] \\
&= \frac{1}{2\overline{\varepsilon}} * \mathbb{P}\Big[\sum_{i\neq 1} m_i = Q-1 \Big| z\Big] * \Big(\mathbb{E}\Big[\sum_{i}(z+\varepsilon_i)\Big| \sum_{i} m_i = Q, z\Big] - u^+(z)\Big)
\end{aligned}$$

Taking the limit of these two expressions when z goes to z_Q from above, one gets:

$$\lim_{z \searrow z_Q} \frac{\partial W}{\partial x_1}(z,\ldots,z) = \mathbb{P}\Big[\sum_i m_i^{z_Q} \geq Q\Big] - \frac{1}{2} * \mathbb{P}\Big[\sum_{i\neq 1} m_i^{z_Q} = Q-1\Big] * p^+(z_Q) \tag{16}$$

Finally, combining (15) and (16), and noticing that

$$\mathbb{P}\Big[\sum_{i\neq 1} m_i^{z_Q} = Q-1\Big] * p^+(z_Q) + \mathbb{P}\Big[\sum_{i\neq 1} m_i^{z_Q} = Q\Big] * p^-(z_Q) = \mathbb{P}\Big[\sum_i m_i^{z_Q} = Q\Big]$$

one gets:

$$\lim_{z \searrow z_Q} \widehat{W}' - \lim_{z \nearrow z_Q} \widehat{W}' = \frac{N}{2}\mathbb{P}\Big[\sum_i m_i^{z_Q} = Q\Big]$$

which is positive. This concludes the second part of the proof, and shows that $\widehat{W}$ is convex on $[-\overline{\theta}, \overline{\theta}]$.

A.7 Proof of Theorem 1

We prove Theorem 1 in a number of steps.

First, we consider an auxiliary environment where all the voters *know* $\frac{\sum_{i=1}^N \theta_i}{N}$ (but not individual θ_i). Applying Lemma 5, for any x with $\frac{\sum_{i=1}^N x_i}{N} = \frac{\sum_{i=1}^N \theta_i}{N}$, we have:

$$\widehat{W}\left(\frac{\sum_{i=1}^N \theta_i}{N}\right) \geq W(x)$$

where $W(x)$ denotes the expected total welfare if the voters are informed of x (and the voting rule is $Q^*(x)$) and $\widehat{W}(z) = W(z, ..., z)$.

Applying Proposition 3, $\widehat{W}(z)$ is convex for $z \in [-\overline{\theta}, \overline{\theta}]$.

For $x \in [-\overline{\theta}, \overline{\theta}]$, let

$$W^*(x) := \widehat{W}\Big(\frac{\sum_{i=1}^N x_i}{N}\Big).$$

Then, $W^*(x) \geq W(x)$ for all $x \in \Theta = [-\overline{\theta}, \overline{\theta}]^N$, and moreover, it is convex. Indeed, for all $x, x' \in \Theta$, $\lambda \in [0,1]$:

$$\begin{aligned} W^*(\lambda x + (1-\lambda x')) &= \widehat{W}\Big(\frac{\sum_{i=1}^N (\lambda x_i + (1-\lambda) x_i'))}{N}\Big) \\ &= \widehat{W}\Big(\lambda \frac{\sum_{i=1}^N x_i}{N} + (1-\lambda)\frac{\sum_{i=1}^N x_i'}{N}\Big) \\ &\leq \lambda \widehat{W}\Big(\frac{\sum_{i=1}^N x_i}{N}\Big) + (1-\lambda)\widehat{W}\Big(\frac{\sum_{i=1}^N x_i'}{N}\Big) \\ &= \lambda W^*(x) + (1-\lambda x')W^*(x') \end{aligned}$$

where the inequality on the third line follows from the convexity of $\widehat{W}$.

The planner's problem is

$$\max_{\xi} \int_x W(x) d\xi,$$

which is not larger than

$$\max_{\xi} \int_x W^*(x) d\xi.$$

Note that:

$$\max_{\xi} \int_x W^*(x) d\xi = \int_\theta W^*(\theta) dF,$$

because W^* is convex. However, $W^*(\theta)$ is precisely the total welfare for each θ under the policy of fully disclosing the anonymized information. Therefore, it must be an optimal disclosure policy.

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