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# Economix



## Democracy, Epistocracy and Hybrid decision-making: Information specificity and costs of political governance

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# **Democracy, Epistocracy and Hybrid decision-making: Information specificity and costs of political governance**

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**Abstract** (105 words):

This paper contributes to the Democracy versus Epistocracy debate (Brennan and Landemore 2022) by providing a theoretical framework and a criterion to choose between democratic, hybrid, and epistocratic modes of political governance. From a normative perspective, we claim that the *specificity of information* should (at least partially) guide the choice between these modes of political governance because of its impact on *costs of political governance*. An issue has a degree of *information specificity* that determines costs of political governance combined in a *Social Costs Function*. Therefore, the model helps to assess the relative efficiency between democratic, hybrid, and epistocratic decision-making procedures to reach collective choices.

**Keywords:** Democracy – Epistocracy – Social Choice – Information – Social Costs Function

**Codes JEL :** D71 – D83 – P35

## Introduction

In recent years, many empirical results on citizens' behaviors, attitudes, and beliefs have been put forward to challenge the legitimacy of democracy as an efficient decision-making process (Caplan 2008, Somin 2016, Brennan 2016, Achen & Bartel 2016). It fosters the Democracy versus Epistocracy debate: rules of *the people* versus rules of *the wise*. Against the proponents of epistocratic mechanisms to counterbalance the effects of the ignorance of citizens, defenders of democracy have precisely stressed its epistemic value, both in decision-making (Estlund 2009, Landemore 2012) and knowledge-making (Lucky 2023). In *Debating Democracy* (2022), H el ene Landemore, one main advocate of epistemic democracy, and Jason Brennan, one main advocate of epistocracy, fueled a controversy but reached a consensus to consider that hybrid modes of political governance might be the best ones. Indeed, Landemore concludes that "strikingly, Brennan himself, like [her], counts on deliberation among randomly selected citizens as one key element of his preferred solution" (Brennan & Landemore 2022, 275).

To our knowledge, a systematic analysis of the key variables to choose between democratic, hybrid and epistocratic modes of political governance has not been produced yet. Therefore, this paper aims at providing a theoretical framework and an original model to do so. What criteria should guide this choice? From a normative perspective, we claim that the *specificity of information* should guide the choice between democracy, epistocracy, and hybrid modes of political governance to minimize *costs of political governance*.<sup>1</sup> Conceptually, information specificity is defined by three dimensions: uncertainty, the quantity of information, and the technicity of information. We then gather four main costs of political governance into a social costs function: 1) costs of disenfranchisement; 2) costs of a bad outcome; 3) costs of information search; and 4) costs of deliberation. The main logic of the model is analogous to Oliver Williamson's model of the governance costs of markets and hierarchies according to assets' specificity (1985; 1991).

The model belongs to the class of political economy models built from the ex-ante perspective of a "social planner" (Alesina and Tabellini 2007). More precisely, it is built from the perspective of a procedural designer. Hence, the aim of the model is to guide the social planner in her task of allocating issues between modes of governance so as to minimize social costs. We reason as if the procedural designer allocates issues on a one-by-one basis. The foundational normative claim that the decision-making procedures should minimize political costs considering information specificity is rather non-controversial. It could be endorsed by each side of the Democracy versus Epistocracy debate since both focus on epistemic issues coupled with a consequentialist argument. From a more positive perspective, the model and its theoretical foundations also help explain why some decisions are actually submitted directly to the people (direct democracy) or their representatives (indirect democracy),

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<sup>1</sup> Let's take the Covid-19 pandemic as an example. Who has to decide whether a country should be confined and along which rules? Who has to decide whether people should be vaccinated? The people, the parliament, the government, some committee informed by experts, experts themselves? We claim that the asset specificity of an issue at stake should determine the answer.

while others, conversely, are entrusted to non-elected independent expert bodies (epistocracy). We really consider this paper as the first theoretical milestone toward more theoretically complex and more empirically relevant systematic comparisons, since we limit here to a comparison of Democracy, Hybrid and Epistocracy considered in their ideal characterization (rather than actual implementations).

The main logic of the model is the following one: an issue  $X$  has a degree of *information specificity* ( $i_x$ ) that determines various costs of political governance combined in a *Social Costs Function* ( $SCF$ ) and, therefore, the relative efficiency between democratic ( $D$ ), hybrid ( $H$ ) and epistocratic ( $E$ ) modes of political governance. Section 1 provides the literature review. Section 2 characterizes Democracy and Epistocracy as alternative modes of political governance and then defines hybrid ones. Section 3 provides a definition of information specificity by presenting its various dimensions. Section 4 defines the concept of political governance costs and formalizes the social cost function associated to each mode of decision-making. Section 5 describes the result of the model. Section 6 provides an application. Section 7 concludes on the main limitations of this basic model and the avenues for theoretical progress and empirical research.

## **Section 1: Literature review**

This paper is made up of four tributaries. First, many 21<sup>st</sup> century works emphasize how Western liberal societies are currently facing a series of challenges that are undermining the prevailing institutional order, in particular liberal democracy (Mounk 2016; Rauch 2021; Rosanvallon 2020). This fragility expresses the polarization of preferences, beliefs, and opinions over the public policies to be pursued on a range of issues such as climate change, globalization, immigration, social protection, or identity politics. This fragility is also manifest in the declining trust in the founding institutions of representative democracy (Algan et al. 2017) and the success of populist parties (Guriev and Papaioannou 2022). Regardless of their political and ideological leanings, these parties claim to want to revitalize democracies, which have allegedly been captured by vested interests (Müller 2016; Berman and Kundnani 2021). Such current lack of a stable minimal democratic consensus in most societies raises concerns about the existing decision-making processes aimed at achieving collective choices (Chirat and Hédoïn 2024).

Second, the paper echoes the Democracy versus Epistocracy debate. Following the so-called “epistemic turn” in deliberative democracy (Landemore 2017), political theorists and philosophers have been increasingly emphasizing the fact that the justification and legitimacy of democracy depend on its epistemic properties and especially its ability to issue collective judgments tracking the “truth” (Estlund 2009; Landemore 2012). However, this approach to democracy is confronted by a growing literature emphasizing the epistemic defects of democracy that originate in the fact that voters tend to be biased and uninformed (Achen and Bartels 2016; Brennan 2016; Caplan 2008). The fact that democracy may not meet desirable epistemic requirements has encouraged some scholars to consider alternative political regimes more appropriate to make collective choices with an uninformed and incompetent electorate. Epistocracy seems to be the main alternative in this context.

Strikingly, public controversies share the stake of this debate, since the quarrels over the arguments specific to a social problem  $X$  are regularly coupled with quarrels on the best way to reach a collective decision on  $X$ . To take one example, the French-German TV public broadcast ARTE organized a debate on the French government's migration policy, following the crisis on the Italian island of Lampedusa, that explicitly moved from "what to do?" to "who should decide?": the people (by referendum), their representatives (Parliament), a citizens' convention (like the climate convention) or experts (at the level of the European Commission).<sup>2</sup> In such cases, the advocates of democratic procedures put forward some kind of "epistemic populism" (Bellolio 2020; Müller 2023), i.e., the idea that citizens have sufficient common sense to decide. They face the defenders of epistocracy, who insist on the technical and legal dimensions of the issue of migration that call for expert decision-making. Each side puts forward arguments that appear reasonably admissible. So, how could we cut the Gordian knot?<sup>3</sup>

Third, the paper echoes many political economy models that address the "How to decide who has to decide" question. The debate between "the Chicago School" and the "Virginia School" has focused on the relationship between political competition and democratic efficiency (Wittman 1989). The comparison between direct and representative democracy has emphasized the role of information asymmetries (Kessler 2005). Lastly, the literature on the delegation of collective choices to either politicians or bureaucrats has concentrated on the behavioral consequences of differential motivations, either intrinsic (Maskin and Tirole 2004) or extrinsic, i.e., related to accountability devices (Alesina et Tabellini 2007, 2008). While addressing the same general question, we put the emphasis on the epistemic rather than behavioral stakes of political governance.

Fourth, the model is tributary to Oliver Williamson's transaction cost economics, even if it does not consist of a replication of its framework. To answer the fundamental question "what is the best collective decision-making process?", we reason by analogy with Williamson's (1991) answer to the no less fundamental question "what is the best coordination process?". As a reminder, Williamson argues that the specificity of assets and the frequency of transactions determines the relative efficiency of the market, hierarchy, and hybrid modes of coordination. The originality and main contribution of the paper consist in disaggregating the ambiguous concepts of information and costs of political governance. The parsimony of the formal model we build enables to provide a simple benchmark for future research. At this stage, the main limitation is that we made strong assumptions, which might be considered unsatisfactory. But these latter are explicitly stated, so that they do not preclude dialogue or improvements of this innovative model.

## **Section 2: Democracy, Epistocracy, and Hybrid forms of political governance**

For sake of simplicity and following the core of the Democracy versus Epistocracy debate, we first consider three collective decision-making procedures: Democracy, Epistocracy and hybrid procedures. More precisely, Democracy ( $D$ ),

<sup>2</sup> The TV debate occurs on September 18, 2023 (<https://www.youtube.com/watch?v=ELLZMvpUYoc>).

<sup>3</sup> The answer is even less straightforward while having in mind the complex relationship between populism and technocracy and expertise (Bickerton et Accetti 2017; Caramani 2021).

Hybrid (*H*) and Epistocracy (*E*) are considered as decision-making procedures *so as to reach collective choices*. It means that they are distinct *modes of political governance*.<sup>4</sup> Democracy and Epistocracy are considered as opposite since democracy refers to “the rule by the people” while epistocracy refers to “the rule of the wise”. As a mode of political governance defined in opposition to democracy, epistocracy hinges on the disenfranchisement of a part of the electorate on epistemic grounds. The archetypal form of epistocracy as a collective decision-making procedure is any form of restricted electorate, where only those judged as sufficiently competent can express their voices through a ballot box.<sup>5</sup> Between Democracy and Epistocracy, considered as ideal types, there are various collective decision-making procedures that could be considered as “hybrid” modes of political governance. We use the terms hybrid for two reasons. First, these modes mixed democratic and epistocratic components.<sup>6</sup> Second, the model is based on the structural analogy with Williamson’s analysis, in which there are hybrid modes between coordination by the market and coordination by hierarchy.

In the model, Democracy is considered as a unique process of decision-making to reach collective choice. But one may like to distinguish subtypes, for instance between direct democracy and indirect democracy, that is to say, “representative government” (Manin 1997). The distinction between direct and indirect democracy will be introduced at a later stage. But the mere existence of an alternative between two procedures considered as democratic entails determining which of these democratic decision-making procedures is better than the other. The same question applies to discriminating between various hybrid or epistocratic institutional designs. We assume that these questions cannot appeal to an absolute answer, meaning independent of the issues at stake. However, defining an optimal or good procedure requires a unique criterion. In this paper, we assume that such criterion is political governance costs, combined in a Social Cost Function (*SCF*)<sup>7</sup>, which vary according to information specificity ( $i_X$ ). The model then enables us to determine whether Democracy (*D*), Hybrid (*H*) and Epistocracy (*E*) are more efficient through a comparison of their social costs function.

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<sup>4</sup> The paper focuses on the decision-making dimension only, not on the knowledge-making dimension of the Democracy versus Epistocracy debate.

<sup>5</sup> Jason Brennan (2016, 2022) propose an epistocratic design called the simulated oracle. He defines this procedure as follows: “When people vote, they put down A) their political preferences (whatever is being voted on) B) their demographic information, and C) take a quiz of basic political knowledge” (2022, 43). The enfranchisement lottery proposed by Lopez-Guerra (2011) is another example of epistocratic design. In the enfranchisement lottery, one draws from the general population and the citizens drawn must pass an epistocratic test after a certain number of weeks of training.

<sup>6</sup> The debates around the epistemic merits and shortcomings of democracy have indeed led some scholars to propose hybrid decision-making procedure, that have both democratic and epistocratic components. One of the most famous, since it was already advocated in the 19<sup>th</sup> century by John Stuart Mill (1865) in his essay *Considerations on Representative Government*, is plural voting. The democratic component lies in the fact that all citizens vote, while the epistocratic component lies in the break of the principle “one man, one vote” to give more weight to the vote of more informed citizens. Another hybrid form considered is citizens’ convention, that combined a democratic dimension, by randomly drawing a sub-set of the population that would vote, but only after having been trained and informed by experts, an epistocratic dimension.

<sup>7</sup> “Social” here refers to “social choice”.

Comparative study of political regimes can easily be biased. Raymond Aron ([1955] 2017) rightly pointed out in *The Opium of the Intellectuals* that it is risky to compare actual political institutions to hypothetical ideal regimes. For instance, it does not make sense to compare the functioning of current democratic regimes to an idealized Epistocracy. Since this article aims to establish a theoretical framework for comparative analysis to choose between different decision-making procedures to reach collective choices, we currently consider them all in their ideal form. What does this mean? For democracy, either direct or indirect, it implies that we reason as if it produces decision-making perfectly representing citizens' preferences. For epistocracy, it implies that disenfranchisement genuinely operates based on a criterion of epistemic competence. In other words, there is a greater command of information among members of the *decision-making body* in an epistocracy compared to a democracy. With the generic terms "decision-making body", we refer to enfranchised individuals. For democracy, it means that all members of the decision-making body - either all citizens with the right to vote (direct democracy) or all parliamentarians (representative democracy) - participate in the decision-making.

### Section 3: Information specificity

The information specificity ( $i_X$ ) of an issue  $X$  impacts the trade-off between the three modes of political governance since it impacts the social cost function of Democracy ( $SCF_D$ ), Hybrid ( $SCF_H$ ) and Epistocracy ( $SCF_E$ ). We define information specificity as the function of three variables. The first one is the degree of uncertainty ( $U_X$ ) of the issue  $X$  at stake. The second one is the quantity of information ( $Q_X$ ) related to the issue  $X$ . The third one is the technicity ( $T_X$ ) of information on the issue  $X$ . This is crucial to understand that we assume that these dimensions of information specificity are assumed *strictly independent*, commensurable and continuous over  $]0;1]$  or  $[0;1]$ . Formally, for each  $X$  :

$$i_X = f(U_X, Q_X, T_X) \quad \text{with} \quad i_X: ]0; 1] \times [0; 1] \times [0; 1] \rightarrow [0; 1]$$

The section presents and justifies the form taken by each of the variables determining the specificity of the information ( $i_X$ ) associated with an issue  $X$ .

#### 3.1 The degree of uncertainty

The first component of our variable labeled information specificity is "uncertainty". The concept of uncertainty is equivocal in economics. In line with the works of Herbert Simon (1955) and Anthony Downs (1957), we define uncertainty as incomplete information. In this sense, uncertainty is a measure of our ignorance, but an ignorance that cannot be reduced by either information or knowledge acquisition. Uncertainty enables to catch in the model the quantity of information the decision-making body can have *at best* on an issue  $X$ . In other words, the variable labeled uncertainty characterizes *the informational basis available* within the theoretically infinite space of information. Formally, we assume that uncertainty is a continuous variable on  $]0; 1]$ , i.e., there is varying degree of uncertainty. Theoretically, uncertainty runs from full uncertainty ( $U_X = 1$ ) to the limit world of complete information of



mainstream economics ( $U_X = 0$ ).<sup>8</sup> However, we deliberately exclude complete information ( $U_X = 0$ ). We do not want the choice between alternative modes of political governance to be plagued by the assumption that all information on all the past, present, and future states of the world are known.

We assume that the relationship between uncertainty  $U_X$  and information specificity  $i_X$  is inverse for the following reason: the more uncertainty, the lower information specificity, since, by definition, information is lacking.

Formally,  $U_X \in ]0, 1]$  and  $f_U' < 0$

In addition, we assume that when uncertainty is complete, i.e.,  $U_X = 1$ , then,  $i_X = 0$ .

### 3.2 The quantity of information

While uncertainty refers to the quantity of information the decision-making body can have *at best* on an issue  $X$ , the variable “quantity of information” ( $Q_X$ ) represents the quantity of available information that decision-making agents *should* have on an issue  $X$  to be considered as a sufficiently informed decision-maker, that is to say, to be considered as worth enfranchised. Hence the idea of a positive relationship between the quantity of information required and the specificity of information.

Formally,  $Q_X \in [0, 1]$  and  $f_Q' > 0$

Moreover,  $U_X$  and  $Q_X$  are assumed independent,  $Q_X$  being a percentage of the informational basis available. To illustrate this idea with an example related to government spending, consider two decisions (allocating the budget between ministries)  $y$  and (setting the level of the public budget)  $z$  with the same degree of uncertainty  $U_y = U_z$ . It could reasonably be argued that it requires more information (among the available informational basis) on the state of a national economy and public administrations to decide how to allocate the resources between ministries rather than to decide to raise or cut the overall public budget ( $Q_y > Q_z$ ).

### 3.3 The technicity of information.

The variable  $U_X$  and  $Q_X$  respectively captures the quantity of information a decision-making body *can* have on an issue  $X$  and the quantity of available information a decision-maker *should* have to be considered as sufficiently informed. In addition to these purely quantitative dimensions of information specificity, a qualitative (yet amenable to quantification at a formal level of reasoning) characterization of information specificity is required. That is why we include a variable related to the degree of technicity of information ( $T_X$ ). This variable allows to distinguish pure information from knowledge, followings Downs’s distinction (1957). *Lack of knowledge* refers to the fact that an agent may be partially or fully ignorant of the relevant mechanisms and relations between variables that account for well-identified phenomena. For instance, citizens will generally have partial knowledge and understanding of the mechanisms of money creation and more generally of the

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<sup>8</sup> Since there are always unknown future states of the world, probabilistic account, even subjective, of all future events are non sensical. But the model does not require this reductionist approach of uncertainty to reach a solution.

relevant issues related to monetary policy. In contrast, *lack of information* corresponds to a lack of data that makes one unable to assess the actual value of some variables related to monetary policy. For instance, a citizen may be ignorant of the current central bank's interest rates, or the details of monetary policies implemented in the past. Lack of knowledge requires education to be reduced, since it entails mastering the technical dimension of an issue  $X$ . That is why we assume that the more technical an issue  $X$  is, the more specific information is. Hence the positive relationship between  $T_X$  and  $i_X$ .

Formally,  $T_X \in [0, 1]$  and  $f_T' > 0$

Having presented each of the three components of information specificity, we can sum up its most general formal characterization:

- $i_X = f(U_X, T_X, Q_X)$
- $i_X: ]0; 1] \times [0; 1] \times [0; 1] \rightarrow [0; 1]$
- $f_U' < 0$
- $f_Q' > 0$
- $f_T' > 0$

#### Section 4: The Social Costs Function

The bundle of political governance costs, combined into a Social Costs Function, is the other main variable of the model. As a reminder, we consider three ideal modes of political governance to reach collective decision-making: ( $D$ ), ( $H$ ), and ( $E$ ). The relation between them regarding the scope of disenfranchisement is assumed to be always transitive. More citizens are enfranchised within democracy compared to Hybrid compared to Epistocracy.<sup>9</sup> Each of these decision-making procedures to reach collective choice generates the same kind of political governance costs that depend on information specificity ( $i_X$ ). But the level of each of these costs, for a given information specificity, varies according to each mode of decision making.

While reasoning through the structural analogy between asset specificity and information specificity on the one hand, and transaction costs and political costs of governance on the other, there are a major difference between our model and Williamson's. In this latter, transaction costs are univocally supported by firms. In our case, aiming to compare democratic, hybrid, and epistocratic decision-making processes to reach social choices, a crucial question is on whom the political costs identified are falling. Theoretically, there are two possibilities. Either (1) the cost is assumed to be supported by individuals, eventually unequally, or (2) the cost is assumed to be supported by the "society" as a whole. From an economic perspective, (2) is less attractive because it leaves unspecified who bears the cost. (1) has the advantage to identify who is supporting the cost and what can kind of cost. We retain this latter option to build our Social Costs Function ( $SCF$ ).

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<sup>9</sup> The aim of the paper being to build a framework for comparison, we do not distinguish in this paper between various procedures to disenfranchise. For instance, even if plural voting and citizen conventions are not identical, we consider both as belonging to the set of hybrid modes of political governance. Applied works to specific procedures would come later.

For each political mode of governance, the *SCF* relates political costs of governance to information specificity. Such *SCF* enables: 1) to identify who are the individual supporting costs; 2) what kinds of costs they are supporting; 3) how these costs are aggregated. If the political costs of governance can be measured monetarily, finding the *SCF* is relatively straightforward. However, the costs included in the model are heterogeneous in their nature and unequally distributed among citizens, according to both their individual preferences and material conditions of living. However, we assumed, that the four distinct costs identified as contributing to political governance costs are commensurable, so that we can define an aggregate *SCF* for  $(D)$ ,  $(H)$  and  $(E)$ .

The Social Costs Function should not be confused with a Social Welfare Function (*SWF*). The model aims at determining which modes of political governance is the most efficient to minimize political governance costs – combined in the *SCF* - according to information specificity. It is not to propose a theory of justice, i.e., “an ordering of alternative social states” that is “formally analogous to the individual's ordering of alternative social states” (Arrow 1973, 14). Therefore, the model we propose is compatible with several *SWF* since it does not provide an arbitrage between various *SWF*, but only between decision-making procedures. The implicit assumption is that the *SCF* of  $(D)$ ,  $(H)$ , and  $(E)$  does not depend on the *SWF* that the theoretically benevolent social planner would take as a guide. Our *SCF* measures the welfare loss caused by political governance compared to a hypothetical situation where no costs of political governance are taken into account.

Formally, the *SCF* of decision-making process  $(P)$ , labelled  $SCF_P(i_X)$  is composed of three terms : a fixed cost  $C_P$  ; the sum of variable costs  $k_P(i_X)$ ; an “error-term”  $\varepsilon$  defining an area of viability rather than an optimal frontier in order to be consistent with the uncertainty assumption. The bundle of variable costs  $k_P(i_X)$  include the cost of a bad outcome  $k_b(i_X)$ ; the cost of searching information  $k_s(i_X)$ ; and the cost of deliberation  $k_d(i_X)$ . We assume that variable costs exist only when uncertainty is not maximal, i.e., for  $U_X \neq 1$  and, therefore,  $i_X \neq 0$

Hence,

- $\forall i \in ]0,1] , SCF_P(i_X) = C_P + k_P(i_X) + \varepsilon$
- $\forall i \in ]0,1] k_P(i_X) = k_{b_P}(i_X) + k_{s_P}(i_X) + k_{d_P}(i_X)$ .
- for  $i = 0, SCF_P(i_X) = C_P$

In addition, we assume that:

- $k_P'(i_X) > 0$  and  $k_P''(i_X) > 0$
- $k_D'(i_X) > k_H'(i_X) > k_E'(i_X) > 0$
- $C_D < C_H < C_E$

These assumptions are justified in the following presentation of each cost included within the Social Costs Function.

#### 4.1 The (fixed) cost of disenfranchisement

First, the *SCF* include the cost of disenfranchising part of the electorate. By definition, this cost bears on disenfranchised citizens. In the model, this is the only cost unrelated to information specificity, i.e., a fixed cost. Disenfranchising citizens – either through a lottery, an epistemic test, or any other devices - means that some of them cannot, as persons, express their preferences. Since disenfranchising a part of the electorate breaks formal equality (no matter the size of such part), a moral egalitarian account of democracy legitimate to consider a cost of disenfranchisement. Moral egalitarianism has yet been challenged by the “lottery objection”<sup>10</sup> and “no impact objection”.<sup>11</sup> However advocates of democracy argue against these claims that democracy at least enables citizens to equally exert “basic autonomy” (Jacob 2015). Therefore, the cost of disenfranchisement assumed in the model is derived from the assumption that humans have a *preference for autonomy*, i.e., taking part to collective decision-making. Such preference might obviously be empirically distributed with various intensities throughout the electorate and according to issues at stake.<sup>12</sup>

We take for granted that such a cost of disenfranchisement is important. Depending on what the precise underlying political philosophy calls for, this cost could be considered either (1) a subjective psychological cost induced by the lack of respect that person who are disenfranchised support or (2) an objective well-being cost related to the fact that their ideas and interests are disregarded. In the model, we assume that this cost affects the well-being of any disenfranchised individual. Assuming that the intensity of citizens’ preference for expressing their voice is not related to the criteria by which disenfranchisement occurs, the more disenfranchised citizens, the higher the cost of disenfranchisement. Yet, since the more epistocratic a procedure is, the more numerous disenfranchised citizens are, then  $C_D < C_H < C_E$ . In addition, even in Democracy, some citizens are disenfranchised. Hence,  $C_D > 0$  and, by transitivity,  $C_H > 0$  and  $C_E > 0$ .

This transitive relationship between the cost of disenfranchisement of (*D*), (*H*), and (*E*) has direct implications on the result of the model (see section 5). That is why the gap between  $C_D$ ,  $C_H$ , and  $C_E$  matters. If the cost of disenfranchisement is assumed to be independent of the information specificity  $i_X$  of the issue *X* at stake, it is not independent of the issue *X* itself. We assume that the more morally uncertain the issue at stake is, the greater the gap between  $C_D$  and  $C_H, C_E$ . The notion of *moral uncertainty* captures the fact that for some issues, there is uncertainty about the validity or relevance of different moral theories and principles (MacAskill et al. 2020). In this case, asserting based on which principles and theory the decision should be made might be difficult. Moral uncertainty is more likely (though not exclusively) to be significant in issues fostering genuine values conflicts. In such cases, we may lack clear

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<sup>10</sup> The lottery objection refers to the fact that “if democracy were merely about the equal consideration of interests among members of a political community, then a lottery in which each had an equal chance to assert his or her choice would serve this purpose just as well” (Jacob 2015, 62).

<sup>11</sup> Originally developed by Downs (1957), it has been put forward recently by Brennan (2016) to justify why citizens have no moral duty to vote, and sometimes explain why citizens might not intrinsically value democratic decision-making.

<sup>12</sup> Empirically, Towfigh et al. (2016) show for instance that citizens are less willing to accept the outcome of institutions and expert committees, relative to direct-democracy mechanisms, when the issue at stake is important to them.

criteria to assess the judgments that are crucial to account for an individual's political positioning.

Moral uncertainty as we define it also encompasses subjective attitudes (i.e., preferences) toward risk and time. With respect to many issues, individuals may radically differ regarding the degree of risk they are willing to support or the value they give to future benefits and harms compared to immediate ones. In many cases, there is just no fact of the matter that determines what the justified risk and time preferences are. It follows that a large range of preferences cannot be easily discarded from the collective choice. We discuss one of these cases below, concerning the social choice to give up or not nuclear energy. In those cases where moral uncertainty is high, including because it is impossible to reject outright conflicting attitudes toward risk and time, it is plausible to argue that disenfranchisement is individually more costly as it prevents the judgments of some individuals from weighing in collective choices without clear justification. Therefore, there is for such morally uncertain issues, *ceteris paribus*, a stronger presumption in favor of democracy (see section 6).

#### 4.2 The cost of a bad outcome

Second, the *SCF* includes a cost of reaching a collective decision that led to a "bad outcome", labelled  $k_b(i)$ . At first sight, one can believe that considering an outcome as bad requires a *SWF* to assess the worthiness between potential outcomes. However, in this model, a bad outcome means that the decision taken by the decision-making body does not produce the desired outcome in terms of well-being effects because of "informational failures." *In other words, another decision would have been better without such informational failures for given preferences of individuals and (no matter) how they are aggregated.* We assume that the likelihood of a bad outcome because of informational failures is negatively related to uncertainty, since, by definition, high uncertainty means a low available informational basis. On the contrary, the cost of a bad outcome is positively related to the two other components of information specificity. Indeed, if an issue  $X$  requires high quantity of information ( $Q$ ) which is technical ( $T$ ), then a bad outcome is more likely to happen. Therefore, formally :

- $k'_b(U) < 0$
- $k'_b(Q) > 0$
- $k'_b(T) > 0$

Hence:

- $k'_b(i_X) \geq 0$  (Proof in Appendix 1)

In addition, we assume that the marginal cost of a bad outcome is increasing with information specificity. Formally

- $k_b''(i_X) \geq 0$ .

The likelihood of bad outcomes is related to information failures. Therefore, when those mastering information specificity, namely "quasi-experts" or "experts" of an issue  $X$ , are numerous among members of the decision-making body, one can

assume that the likelihood of a bad outcome is inferior compared to the case in which everybody has an equal voice. Hence, the more disenfranchisement occurs through true competence requirements (i.e., an ideal epistocracy), the more expert the decision-making body is. Therefore, the marginal cost of a bad outcome is higher for Democracy compared to Hybrid compared to Epistocracy. Formally  $\forall i \in [0,1], k_{b_D}'(i_X) > k_{b_H}'(i_X) > k_{b_E}'(i_X)$ .

This proposition needs to be evaluated against well-known formal results put forward by epistemic democrats that, to the contrary, indicate that a democratic procedure is likely to *lessen* the cost of a bad outcome compared to an alternative regime. The first is the well-known ‘Jury Theorem’ first proposed by the French philosopher and mathematician Nicolas de Condorcet. The original theorem applies in the restrictive case where a binary collective judgment (‘true’ or ‘false’) must be formed on a proposition through a majoritarian aggregation rule. It shows that if (1) everyone’s judgment is more likely than not to be correct and (2) each individual’s judgment is statistically independent of others’ judgments, then the probability that the collective judgment is correct increases nonlinearly with the size of the population. A large population of individuals with a probability just above one-half of being correct is thus almost sure of issuing a correct collective judgment through the majority rule. The second formal result is sometimes called the ‘Miracle of Aggregation.’ The basic idea is the following. Consider some variable  $x$  defined over some interval and whose true value is  $x^*$ . Each individual  $j$  in a population forms a judgment  $x_j$  over  $x$ ’s true value and a collective judgment is formed by looking at which individual judgment is majoritarian. Suppose that a subset of individuals knows the true value of  $x$  while others form their judgment randomly according to a uniform distribution across the interval. Then, as the population grows larger, the probability that errors ‘cancel each other out’ increases, allowing the subset of knowledgeable individuals (even if very small) to decisively shift the balance in favor of the correct answer. A third formal result is due to Hong and Page (2004) and is generally known as the ‘Diversity Trumps Ability Theorem’ (Page 2007). The general idea is that a team of low-performing but diverse agents becomes better at solving problems when the team grows larger than a team exclusively composed of the most performing but minimally diverse agents.

These formal results all point toward the same lesson: number is more relevant than competence to track the truth. Because a democratic system favors the number over the competence and epistocracy the reverse, the three surveyed formal results should downplay our confidence that the cost of bad outcomes decreases with the degree of expertise of the electorate. Whether this must be the case depends on two kinds of considerations: on the one hand, which is the domain of validity of the formal results? On the other hand, is the proposed interpretation of the results acceptable? The significance of the Jury Theorem and the Miracle of Aggregation in this respect is largely impeded by the former kind of considerations. As it is largely acknowledged in the literature, we can rarely expect the two conditions of the Jury Theorem (let’s call them the ‘minimal competence’ condition and the ‘independence’ condition) to be met in practice. Not only do people largely form their beliefs on the basis of others’ attitudes

and behavior,<sup>13</sup> thus making it highly unlikely that their judgments are statistically independent, but the minimal competence condition is also very demanding, in particular, once we want to extend the theorem to non-binary choices (Estlund 2009: 228-30). In a similar way, it is not clear that Miracle of Aggregation applies to modern democracies, especially because there is no reason to think that the distribution of judgments is such that the required canceling of errors occurs. The problem is again that the mechanisms through which people empirically form judgments make very hard to obtain the kind of distribution the theorem assumes. Finally, though the empirical relevance of the Diversity Trumps Ability Theorem might be affected by its narrow domain of validity (Brennan 2016: 180-8), the interpretation of the theorem has also been attacked (Thompson 2014). Part of the problem lies in the correspondence between the mathematical objects featured in the theorem and what they are thought to represent under a socioeconomic interpretation (e.g., what is a ‘problem-solver’ and her ‘attributes’). Moreover, according to this critic, what the interpretation of the theorem attributes to diversity should rather be seen as the benefits of randomness. Though the debate over this complicated issue is not fully settled,<sup>14</sup> the point is that these formal results do not decisively show that the marginal cost of bad outcomes is lower for democracy than for epistocracy or a hybrid regime at any level of information specificity.

### 4.3 The cost of searching for information

Third, because of assuming uncertainty ( $U$ ) throughout the model, i.e., incomplete information, it is costly to search for information. The cost of information search  $k_s(i)$  corresponds to the value of resources (including time) required to gather the relevant information and knowledge to make a good decision. Such a cost is amenable to monetary measure and, consequently, can be expressed in terms of well-being. The assumption is that the higher information specificity ( $i_X$ ), the greater the cost of search, since more information is available ( $U$  is low), more is required ( $Q$  is high), which is in addition more technical ( $T$  is high). Formally:

- $k_s'(U) < 0$
- $k_s'(Q) > 0$
- $k_s'(T) > 0$

Hence, since  $f_U' < 0$  and  $f_Q', f_T' > 0$ :

- $k_s'(i_X) > 0$

We assume in addition that the return of search is decreasing.<sup>15</sup>

- $k_s''(i_X) > 0$ .

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<sup>13</sup> The most prominent case corresponds to situations of ‘informational cascades’ (Bikhchandani, Hirshleifer, and Welch 1992).

<sup>14</sup> See for instance Kuehn (2017) for a defense of the Hong-Page theorem and its ‘democratic’ interpretation.

<sup>15</sup> One might be tempted to assumed increasing return to information search. But we assume that the increase in information specificity offset potential learning by searching effect.

By definition, the Hybrid mode of political governance selects fewer and better-informed agents than Democracy; and Epistocracy selects fewer and better-informed agents than Hybrid and, by transitivity, Democracy. Hence, for a given level of information specificity, the cost of searching an additional piece of information is superior in D compared to H and, by transitivity, E. Formally,  $\forall i_X \in [0,1], k'_{s_D}(i_X) > k'_{s_H}(i_X) > k'_{s_E}(i_X)$ .

To be consistent with the definition of uncertainty *à la* Herbert Simon (1955, 1956), we also endorse his view on information search rather than George Stigler's (1961).<sup>16</sup> The consequence is straightforward: we add an “error term”  $\varepsilon$  to the *SCF*. Endorsing the logic behind Simon (1955) behavioral model of rational choice indeed implies that facing uncertainty, the *decision-making body* would search for a satisficing quantity of information, rather than an optimal one, to reach a “satisfying”, rather than “optimal”, decision. Without such error term, the *SCF* enables to determine the optimality frontier between *D, H, E*. With such an error term, we refer to an area of viability around the optimality frontier.

#### 4.4 The cost of deliberation

The third variable cost considered in the model is related to deliberation. The cost of deliberation is similar in nature to the cost of searching for information, i.e., it is amenable to monetary measure and can be expressed in terms of well-being. It is supported by both the persons deliberating as well as every individual expecting that a decision is made. We assume the more information specificity; the more deliberation is costly. Since more information is available (*U* is low), more is required (*Q* is high), which is more technical (*T* is high), the available informational basis and knowledge involved in deliberation are indeed greater. Put formally:

- $k'_a(Q) > 0$
- $k'_a(T) > 0$
- $k'_a(U) < 0$

Hence:

- $k'_a(i_X) > 0$

In addition, we assume that the marginal cost of deliberation is increasing, since the longer the process, the higher the costs supported by both individuals belonging to the decision-making body and citizens waiting for a decision.

- $k''_a(i_X) > 0$ .

One could with good reasons argue that deliberation does not occur in the same manner in democratic settings compared to hybrid or epistocratic ones. Even within the bundle of democratic decision-making procedures, deliberation might differ for instance between direct democracy and indirect democracy. But since we theoretically investigate the role of information specificity on political costs of governance between democracy and epistocracy considered as ideal modes of governance rather than actual

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<sup>16</sup> On their theoretical differences, see Mongin (1986).



settings, we assume an identical deliberation process at this stage. This means that the composition and size of the decision-making body do not affect the way its members deliberate: public debate, rational arguments, emotional arguments, information provision by experts, information provision by lobbies, etc. Since deliberation costs are assumed to be independent of the type of decision-making process, it only depends on the number of persons involved in the electoral body. Hence, by transitivity between D, H and E:  $\forall i_X \in [0,1], k'_{d_D}(i_X) > k'_{d_H}(i_X) > k'_{d_E}(i_X)$ .

## Section 5: Result

As a reminder:

- (1)  $i_X = f(U_X, Q_X, T_X)$
- (2)  $SCF_P(i_X) = C_P + k_P(i_X) + \varepsilon$
- (3)  $0 < C_D < C_H < C_E$
- (4)  $k_P'(i_X) > 0$  and  $k_P''(i_X) > 0$
- (5)  $k_D'(i_X) > k_H'(i_X) > k_E'(i_X) > 0$

Political governance costs play in the model the same role as transaction costs in Williamson's. Consequently, the question we face can be reformulated as follows: for a given issue  $X$ , where  $i_X$  represents the information specificity of the issue at stake, which collective decision-making process minimizes political costs of governance? The modeling strategy we propose enables to compare  $SCF_D$  with  $SCF_H$  and  $SCF_E$  (2) according to information specificity (1). Whatever the issue at stake, the (fixed) cost of disenfranchisement included in the  $SCF$  is inferior for democratic compared to hybrid and epistocratic decision-making (3). In addition, variable costs increase with the specificity of information at an increasing rate (i.e., the  $SCF$  is convex) and (4) the marginal cost of Democracy is superior to that of Hybrid which is superior to that of Epistocracy (5). Therefore, there exists for any issue  $X$ , a pivotal value of information specificity  $i_D^*$  below which Democracy ( $D$ ) is better than Hybrid (and by transitivity Epistocracy) to minimize political governance costs. Also, it exists for any issue  $X$ , a pivotal value  $i_E^*$  from which Epistocracy is better than Hybrid (and by transitivity Democracy) to minimize political governance costs.<sup>17</sup> Hence:

*Proposition:* The higher information specificity, the more efficient epistocracy (i.e., disenfranchisement occurring on competence) compared to democracy and hybrid modes of governance. The reverse hold.

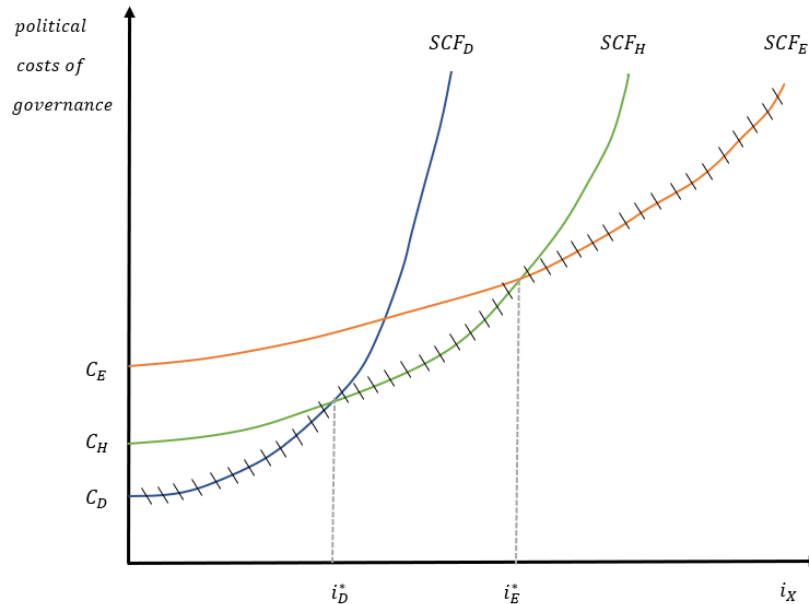
*Corollary:* The larger the informational basis (i.e., low uncertainty), the more information ( $Q$ ) and the more knowledge ( $T$ ) are required, the more efficient epistocracy is compared to democracy and hybrid modes.

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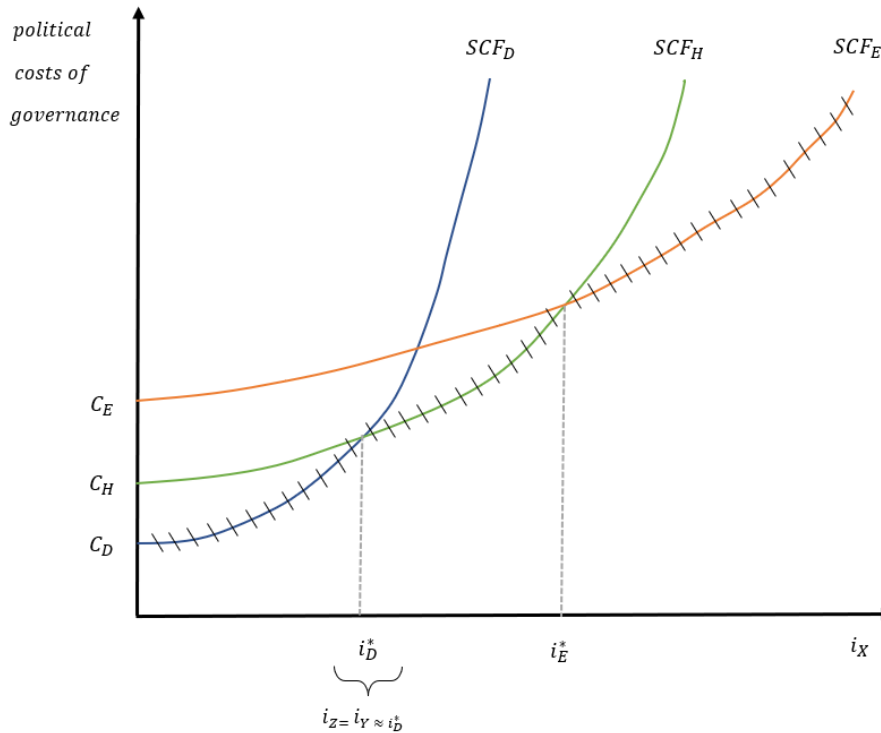
<sup>17</sup> Theoretically, of course, the  $SCF_D$  can be below  $SCF_H$  and  $SCF_E$  for any value of  $i_X$ . This limit case occurs when the moral uncertainty surrounding the issue at stake issue is so high that Democracy is more efficient, even if uncertainty is low and the quantity and technicity of information high.

We provide a simple diagrammatic illustration of one possible formalization of the choice between these three modes of political governance. It represents the *SCF* of each mode. The optimality frontier is clearly visible, and the area of viability is shaded to take into account the error term of the *SCF*.

*Figure 1: Social Costs Function of Democracy, Hybrid and Epistocracy*



In case the information specificity of an issue is equivalent to one of the two equilibrium points, a further criterion is required. We argue that the frequency of decisions, analogous to the frequency of transactions in Williamson's, can play that role. Assume two issue Y and Z with the same level of information specificity, i.e.,  $i_Y = i_Z \approx i_D^*$ . Y and Z are situated at the pivotal point from which Hybrid becomes more efficient than Democracy. If Y requires very regular decisions compared to Z, then, Hybrid will be preferred for Y and Democracy for Z. The main argument lies in the fact that hybrid is less costly in terms of deliberation costs for member of the decision-making body.



## Section 6: Applications

### 6.1 Case #1: The Use of Nuclear Energy

As a first application, we consider the case of energetic transition and more specifically the following issue: the degree of reliance of society on nuclear energy that can be collectively chosen. An option, already chosen by many countries, is to not build new nuclear power plants and progressively reduce the share of nuclear energy in the energy mix of the country until this share falls to zero. An alternative option is to maintain the share of nuclear energy or even to increase it by building new nuclear power plants. The relevant considerations for this collective choice are in particular that over the short run, nuclear energy allows to maintain consumption energy while decreasing carbon emissions. On the other hand, the use of nuclear energy is associated with potentially high risks and presents society with the issue of dealing with nuclear waste.

We consider first the degree of information specificity along the three variables  $U$ ,  $Q$ , and  $T$ . Uncertainty ( $U$ ) here mostly refers to the informational basis available related to the evaluation of risks and knowledge of future consequences entailed by the use (or not) of nuclear energy. For instance, what are the probabilities of the different possible kinds of accidents and what is their degree of seriousness? What are the long-term environmental impact and economic consequences of the collective choice of the energy mix? Uncertainty can therefore reasonably be assessed here from moderate to high. Given that the available informational basis is either moderate or low (high uncertainty), the quantity of information ( $Q$ ) needed to make an informed choice can be assessed as moderate or high and its technicity ( $T$ ) be evaluated as relatively high. Knowledge related to nuclear energy is indeed highly complex. For instance, the

assessment of consequences generated by the choice of an energetic mix depends on detailed technical knowledge about the production process.

While the high level of technicity  $T$  and the quite high level of  $Q$  militates for the adoption of an epistocratic regime, the fact that the uncertainty  $U$  is high or moderate implies that the information specificity involved in the decision-making is moderate or low (+). But what about the cost of disenfranchisement? As explained, the issue of nuclear energy is to some extent morally uncertain, since it depends on individual preferences toward risk and time. Hence, a quite significant gap between  $C_D, C_H$  and  $C_E$ . Overall, the specificity of information is moderate or high (+) and the cost of disenfranchisement significant, so that the model recommends taking a decision on nuclear energy through a hybrid mode of governance to minimize political governance costs. Once the decision-body would be enfranchised, it should be noted that the final choice to use nuclear energy will be fundamentally affected by the preferences of its members with respect to risk and time. But the legitimacy of the decision would be greater compared to an epistocratic one.

## 6.2 Case #2: The Death Penalty

We now consider as a second application the case of the death penalty. As of December 2022, the death penalty was maintained legally and as a practice in 55 countries in the world while 109 countries have completely abolished it.<sup>18</sup> In most countries, the abolition of the death penalty has resulted from a vote of the parliament. The decision to abolish or not the death penalty is indeed a clear case where the political cost of governance seems to be minimized by a democratic procedure. Though scientific evidence, in particular about the hypothetical dissuasive nature of capital punishment might be relevant, the quantity  $Q$  and technicity  $T$  of the information at stake is fairly low. On the other hand, the issue may be viewed as displaying a moderate or high degree of (informational) uncertainty  $U$ , at least at the time the decision is made in a given country. Importantly, the case of the death penalty also involves significant *moral uncertainty*.<sup>19</sup> Hence, the fixed costs of disenfranchisement will typically be high (see section 4.1). Disenfranchising citizens means barring them from having their judgments weighed in the collective choice while there are only weak and controversial reasons to consider that these judgments are non-ambiguously mistaken. The attitudes with respect to the death penalty are essentially subjective and it might be difficult to assess them in terms of their truth-value.

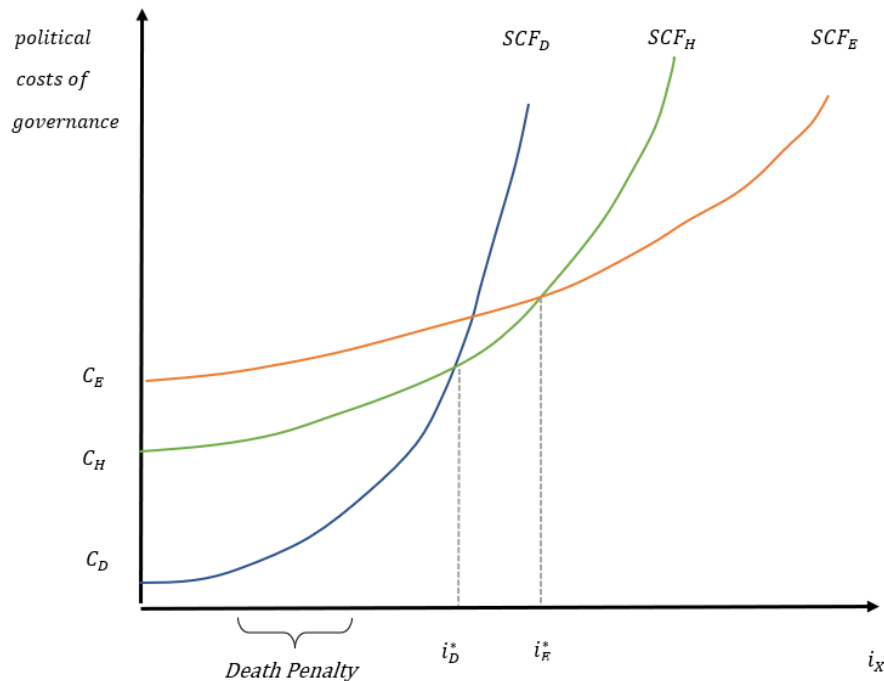
To summarize, low  $Q$  and  $T$  and a moderate or high  $U$  entail that information specificity is low. Moreover, the significant fixed costs of disenfranchisement contribute to an increase in the gap between the  $SCF$  of hybrid and epistocratic modes of governance compared to a democratic one. Therefore, the political costs of

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<sup>18</sup> See Amnesty International's report "Abolitionist and retentionist countries as of December 2022" (<https://www.amnesty.org/en/documents/act50/6591/2023/en/>).

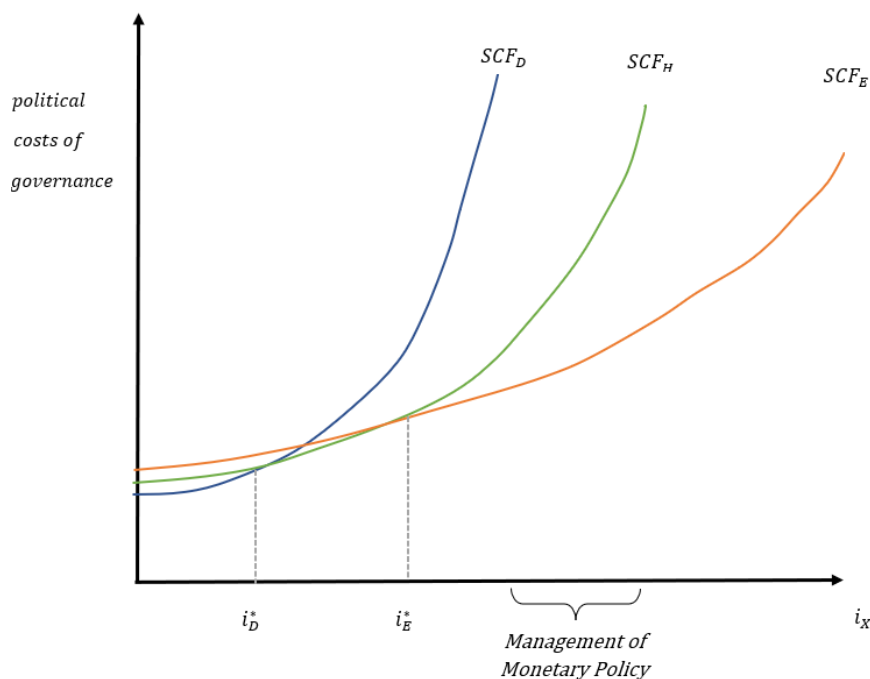
<sup>19</sup> It might indeed be argued that given the prevailing social morality in most countries in the world, the moral uncertainty surrounding the death penalty is fairly low. There is indeed a large agreement that it cannot be justified from any normative stance. However, such an agreement does generally not prevail at the time the death penalty is abolished – this was for instance not the case in France in 1981 for instance.

governance in the case of decision-making about the death penalty are very likely to be minimized with democracy.



### 6.3 Case #3: Monetary Policy

As our third application, we consider the case of monetary policy. This is a standard example discussed in the economics literature to illustrate the legitimacy of technocratic decision-making within a democratic regime. The case of monetary policy indeed has a bunch of interesting features. First, monetary mechanisms have long been studied by macroeconomists and a large range of theories and models are now available to account for their functioning. Second, specialized knowledge with respect to monetary history is also abundant and provides precious insights into the effectiveness of different monetary policies in different circumstances. Finally, macroeconomists generally agree that the effectiveness of monetary policy depends on expectations and its “credibility,” i.e., whether it can be rationally expected that the policy announced will be maintained in the future. The first two elements indicate that, *in so far as monetary policy is given widely agreed objectives*, the level of information specificity is fairly high. Both the quantity  $Q$  and the technicity  $T$  of the information involved in monetary policy decision-making are relatively high and on the other hand uncertainty is rather low. Indeed, the set of all expected consequences, i.e., the available informational basis, of a monetary policy decision, is generally well-known.



If we grant these judgments on the value of the components of information specificity, the political cost of governance is minimized with epistocracy, i.e., a regime of collective decision-making where all power is granted to experts. This conclusion must nonetheless be moderated once we consider that the scope of monetary policy includes not only the management of monetary policy but also the choice of its objectives. While treaties for instance impose the European Central Bank to have price stability as the primary objective of its monetary policy, full employment and growth are also objectives that are actively pursued by the U.S. Federal Reserve. In both cases, the choice of the objectives is not democratic.<sup>20</sup> It might be argued that information specificity is lower with respect to the choice of objectives, because of more (informational) uncertainty. In addition, there is a higher moral uncertainty regarding the objectives of monetary policy compared to its implementation, so the costs of disenfranchisement are higher. Factoring these considerations in the overall assessment of the political costs of governance of the different regimes leads to a less straightforward conclusion. However, in absolute terms, information specificity remains fairly high for both the objectives and management of monetary policy.

Regarding the costs of disenfranchisement, one can be tempted to argue that democratic control over the objectives of monetary policy may foster some instability undermining the policy's credibility and, consequently, increasing the risk of a bad outcome. This militates to consider that the costs of disenfranchisement remain relatively low for the issue of the objective of monetary policy. Note however that this conclusion fundamentally depends on the acceptance of the claim (made by mainstream economists working in the framework of rational expectations theory) that the independence of central banks is the most efficient way to prevent bad outcomes resulting from the use of monetary policy. An alternative theoretical account – with

<sup>20</sup> Of course, ultimately the legal standing of both the Federal Reserve and the European Central Bank is based on treaties or a parliamentary act thought to reflect democratic decisions.

essentially (post-)Keynesian roots – suggests that the effectiveness of monetary policy may not be so much tied to credibility as defined in the rational expectations framework. Moreover, not all economists agree with the claim that democratic control of the monetary policy and its objectives entails the kind of instability that worries mainstream macroeconomists. Clearly, in such cases surrounded by theoretical and scientific controversy, the costs of disenfranchisement should be regarded as being far higher than in the scenario of the implementation of monetary policy, thus leaving the possibility that the epistocratic mode of governance might not be the cost-minimizing one. Obviously, our model cannot settle this kind of theoretical dispute. However, it again helps to highlight the relevant considerations that should determine the choice of a decision-making procedure.

## **Section 7: Conclusion**

This paper aimed to provide a theoretical framework by clarifying the concept of information to build a formal model capable of determining the mode of political governance that minimizes political costs of governance. We arrive at a strong conclusion. Even when considering an ideal epistocracy compared to an ideal democracy, and even when accounting for the governance costs generated by epistemic failures, epistocracy is not always the best mode of governance. As with any formal model, this result is driven by the assumptions of the model. In particular, the hypothesis that the cost of disenfranchisement increases with rising moral uncertainty explains why a democratic regime can minimize governance costs, even when a high level of information and knowledge is required for members of the decision-making body. This result is significant in two respects. First, unlike an epistemic defense of democracy, it considers the problem of legitimacy, and thus the acceptability, of political decisions, which is one aspect that is at the roots of the current crisis of 21<sup>st</sup> liberal democracy. Second, assuming radical uncertainty, it rejects the idea, shared by both the epistocracy and epistemic democracy camps, that political decision-making can be reduced to the pursuit of “truth”.

This initial milestone model calls for numerous theoretical and empirical refinements. Firstly, the model can be augmented by behavioral components, in particular to address the trade-off between indirect democracy and direct democracy, which lies at the heart of principal-agent-based political economy models. Secondly, further theoretical investigation should be carried out on the functional form that could be given to the social costs function. Thirdly, the theoretical framework can be applied to examine real decision-making mechanisms rather than ideal ones only. For instance, we plan to use it to analyze the advantages and disadvantages of various epistocratic lotteries proposed in the Democracy versus Epistocracy literature. Fourthly, the theoretical framework can be enhanced by incorporating institutional variations into the analysis of Social Cost Functions. For example, between two countries, the cost of disenfranchisement is not necessarily the same for a given issue at stake, depending on their democratic capital and their political and cultural history. Finally, the model currently relies on (arguably too) simplifying assumptions, such as for instance that political deliberation operates identically regardless of the decision-

making process. Introducing complexity into these processes should lead to a renewed perspective on the analysis of the different costs considered in the model.

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## Appendix 1

We assume that

- $k_b'(U) < 0$
- $k_b'(Q) > 0$
- $k_b'(T) > 0$

And, we know that

- $k_b'(U) = i'(U) \times k_b'(i(U))$
- $i'(U) < 0$
- $k_b'(Q) = i'(Q) \times k_b'(i(Q))$
- $i'(Q) > 0$
- $k_b'(T) = i'(T) \times k_b'(i(T))$
- $k_b'(T) > 0$

Hence:

- $k_b'(i) \geq 0$

The demonstration is the same for  $k_s'(i) \geq 0$  and  $k_d'(i) \geq 0$