Implementation with a Sympathizer*

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Abstract

We study Nash implementation under complete information with the distinctive feature that the planner knows neither individuals' state-contingent preferences (payoff states) nor how they correspond to the states of the economy on which the social goal depends. Our main question is whether or not the planner can extract only the essential information about individuals' underlying preferences and simultaneously implement the given social goal. Our setup is especially relevant when the planner cannot use mechanisms asking for the full revelation of the payoffs states due to privacy and political correctness concerns or non-disclosure and confidentiality agreements. In economic environments with at least three individuals, we show that the planner may Nash implement a social goal while extracting only the essential information about the payoff states from the society whenever this goal has standard monotonicity properties and one of the individuals whose identity is not necessarily known to the planner and the other individuals, is a sympathizer. Vaguely put, such an agent is inclined toward the truthful revelation of the essential information about how states of the economy are associated with individuals' preferences, while he is not inclined to reveal the realized 'true' state of the economy. Then, in every Nash equilibrium of the mechanism we design, all individuals truthfully disclose the same essential information about the payoff states.

Keywords: Nash Implementation; Privacy; Maskin Monotonicity; Partial Honesty; Behavioral Implementation.

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Table of Contents

List of Tables

1 Introduction

In the implementation problem, a planner (she) is responsible for the decentralization of a social goal that depends on information that she seeks to elicit from the society via a mechanism. Her foresight of individuals' behavior is crucial for the design of such mechanisms. The standard approach assumes that the planner knows how the *states of the economy*, on which the social goal depends, correspond to the individuals' payoff characteristics (*payoff states*). In this context, the seminal works of Maskin (1999, circulated since 1977), Moore and Repullo (1990), and Dutta and Sen (1991) provide characterizations of social goals that admit mechanisms the equilibria of which coincide with a given goal under complete information.[1]

The critical difference of our setup is that the planner does not have any information about the connection between individuals' state-contingent preferences and the states of the economy. Still, she is tasked with implementing a given social goal.[2]

In a nutshell, we analyze full implementation under rationality and complete information with the distinctive feature that the planner observes neither the realized state of the economy (determining the social goal) nor individuals' associated state-contingent preferences (payoff states) and does not know how the states of the economy and the payoff states are related. We investigate the scope of the essential information about individuals' payoffs the planner needs to elicit to implement the given social goal. This is especially relevant when planners have to refrain from using mechanisms inquiring directly about individuals' rankings of alternatives (payoff states) due to privacy and political correctness concerns or non-disclosure and confidentiality agreements.[3]

As a concrete example, the planner could be an *international agency* (such as the IMF, the World Bank, or the UNICEF) authorized to implement a development policy in a country by choosing the 'appropriate' policy alternative depending on the state of that country's economy. The stakeholders in the country's welfare know the state of the economy (e.g., the level of corruption) and have a ranking of the feasible policy options (depending on the level of corruption). To foster synergies and promote joint decisions, the international organization aims to decentralize its policy decisions,

[1]Complete information involves situations when payoff characteristics are commonly known within the society but not to the planner. For more, see Maskin and Sjöström (2002), Palfrey (2002), and Serrano (2004). On the other hand, Korpela (2012) and de Clippel (2014) extend this analysis to cases in which individuals' behavior does not necessarily satisfy the weak axiom of revealed preferences (WARP), which is generally regarded as rationality.

[2]As the planner does not know the association between states of the economy and payoff states, she is not necessarily responsible for formulating what is socially desirable.

[3]Privacy and mechanism design is naturally related as discussed in Nissim et al. (2012), Pai and Roth (2013), and Chen et al. (2016). Indeed, preservation of privacy is even enforced by law in many instances, e.g., the California Consumer Privacy Act, the General Data Protection Regulation of the European Union, and the Turkish Personal Data Protection Law.

taking a mechanism design approach. However, the agency knows that elicitation of the minimal essential information from the country's stakeholders is critical; asking the native stakeholders' rankings of all policy alternatives may not be feasible because many of them may not wish to reveal seemingly 'problematic' information about their country's state to a 'foreign power' since they may get punished publicly by being branded as a 'comprador.'[4]

Alternatively, the planner could be an *implementation consulting agency* (e.g., McKinsey Implementation (McKinsey, 2018)) responsible for implementing a given policy contingent on the information about the financial and operational state of a firm that its client has acquired through either a merger or an acquisition. The policy calls for a choice from a set of feasible alternatives based on the state of the newly acquired firm on which its employees' rankings of these alternatives depend. The implementation consulting agency uses a mechanism design approach to decentralize the policy decision. In such cases, the inquiries about the payoff states of the acquired firm's employees may need to be restricted. Because these employees may not be at liberty to reveal all their knowledge due to non-disclosure or confidentiality agreements as their rankings of policy alternatives may disclose information detrimental to the previous owner.

First, we establish that if the planner knows that a social choice correspondence (SCC) is implementable by a mechanism in Nash equilibrium, then she infers that there is a profile of sets *rational-consistent* with this SCC without necessarily knowing the full specification of sets that appear in this profile. Therefore, the knowledge of the existence of a rational-consistent profile constitutes the minimal information pertinent to the association between individuals' preferences and the states of the economy in conjunction with the Nash implementability of the given SCC. Moreover, the existence of a profile rational-consistent with the SCC is equivalent to the well-known Maskin monotonicity of this SCC.[5] Consequently, our necessity result also highlights that if the revelation of a rational-consistent profile is not admissible on the grounds of privacy, political correctness, and non-disclosure or confidentiality agreements, then implementation is not *feasible*.

[4]According to the Oxford University Press, a comprador is a "person who acts as an agent for foreign organizations engaged in investment, trade, or economic or political exploitation."

[5]The equivalence between Maskin monotonicity and rational-consistency pointed out by de Clippel (2014) is presented explicitly in Barlo and Dalkıran (2022, Lemma 3). The behavioral version of rational-consistency, namely, consistency, is at the heart of de Clippel's characterization of Nash implementability in behavioral domains. Given individuals' choices, a profile of sets indexed for an individual, a state, and a socially optimal alternative at that state, is said to be *consistent* with a social goal if (*i*) for all individuals, all states, and all socially optimal alternatives in that state, this alternative is chosen at that state by that individual from the corresponding set, and (*ii*) an alternative being socially optimal in the first state, but not in the second, implies that there exists an individual who does not choose that alternative at the second state from the set indexed for that individual and that alternative and the first state. Then, the *necessity* result establishes that the *opportunity sets* sustained by the mechanism that implements a given social goal, sets of alternatives that an individual can obtain by changing his messages while others' remain the same, form a profile of sets consistent with this social goal. Moreover, the existence of a consistent profile of sets can be used to modify the canonical mechanism—by utilizing this profile as opportunity sets—to deliver a *sufficiency* result. (de Clippel, 2014)

Our *second* and the main result is that with at least three individuals, if the planner knows that the *environment* is *economic*, the implementation is feasible as discussed in the previous paragraph, and one of the individuals (whose identity is not necessarily known to the planner and the other individuals) is a *sympathizer*, then she infers the following: The given SCC is Nash implementable by a mechanism that elicits the essential information concerning rational-consistency from the society unanimously. That is, if the planner knows that the SCC possesses a rational-consistent profile of sets and inquiring about it is admissible, then she no longer needs to know the association between the payoff states and the states of the economy to identify a rational-consistent profile of sets and to implement the SCC. She can simply ask the individuals for the minimal essential information, knowing that all announce the same profile of rational-consistent sets, and design the mechanism using this profile.

The *economic environment* assumption requires that agents' choices are not perfectly aligned: for any alternative and any payoff state, there exist two individuals who do not choose that alternative in that state from the set of all alternatives. Therefore, it demands that there is some weak form of disagreement in the society at every payoff state.[6]

We attain the notion of *sympathy* by modifying *partial honesty* of Dutta and Sen (2012) so that it involves only announcements of profiles of sets. In that regard, we restrict attention to mechanisms that involve each agent announcing a profile of sets. A *sympathizer* of the SCC, then, is an individual who strictly prefers an action that consists of the announcement of a profile rational-consistent with this SCC coupled with some messages to another action that involves announcing an inconsistent profile and the same messages, whenever both actions deliver this individual's most preferred alternatives among those he can sustain via unilateral deviations. Thus, a sympathizer is not a snitch or an informer because he does not feel obligated or inclined to truthfully reveal the realized state of the economy or the associated payoff state. In essence, sympathy relates only to the truthful revelation of the association between the states of the economy and the payoff states. Further, a sympathizer of a given SCC does not have to be inclined to truthfully reveal a rational-consistent profile of sets associated with another SCC. So, a sympathizer serves the planner as a guide and can be thought of as a proponent of the policy the planner aims to implement.[7]

In our initial example with the international agency, a sympathizer is a native stakeholder who 'believes' in the policy the agency is tasked to implement. This individual is inclined to reveal a

[6]This assumption is also used in Jackson (1991), Bergemann and Morris (2008), Kartik and Tercieux (2012), and Barlo and Dalkıran (2021, 2022).

[7]According to Cambridge Dictionary, a sympathizer is "a person who supports a political organization or believes in a set of ideas." In fact, implementation is not possible in our setup if there are no individuals who are inclined to reveal some information about the association between the states of the economy and the payoff states or the realized state of the economy and its associated payoff state.

profile of choice sets such that in every state of the economy, individuals' choices from the corresponding sets are aligned with the agency's policy. Such a profile discloses only the essential information needed for implementation while revealing some partial admissible information about associated payoff states. So, in the context of our example with the consulting agency, the agency can decentralize its policy as long as the revelation of the sympathizing employee of the acquired firm (who is enthusiastic about climbing up the ladder in the new organization) does not violate his non-disclosure or confidentiality agreements with the previous owner.

The mechanism that we employ in our main (sufficiency) result differs from the canonical mechanism in a particular manner: It asks every individual a profile of sets, the realized state of the economy, an alternative, and an integer. The distinctive feature is that the *opportunity sets*—alternatives that an individual attains by unilateral deviations—associated with the situation in which all agents announce the same state of the economy and an alternative socially optimal at that state are determined according to the announced profiles of sets as long as profile announcements of all but one agree. Thus, the planner needs to know neither the payoff states nor individuals' state-contingent lower contour sets. The presence of a sympathizer ensures that in equilibrium, all agents announce the same rational-consistent profile of sets. As a result, the identity of the sympathizer is not disclosed in any Nash equilibrium of our mechanism.

The existence of a rational-consistent profile is at the core of the Nash implementability of the given SCC. Yet, the planner, who does not know how states of the economy and payoff states are related, cannot identify/verify this central condition on her own. To extend our sufficiency result to a setting where the planner draws the inference of existence of rational-consistency by herself, we provide the following result: The planner deduces the existence of a profile rational-consistent with the given SCC whenever she knows that this SCC possesses a Maskin monotonic extension to the set of all payoff states even if she does not know the full specification of this extension.

We extend our analysis and results to the behavioral domain (by allowing but not insisting on violations of WARP) in the Appendix.[8] We also consider extensions of our sufficiency result to noneconomic environments using the behavioral version of the no-veto property and continuing to work with three or more individuals. In the resulting behavioral setting, we attain another version of our sufficiency result by replacing the economic environment assumption with *societal non-satiation* and having at least two *strong sympathizers* the identities of whom are privately known to themselves, but not to the planner.[9]

[8]An incomplete list of papers on behavioral implementation contains Hurwicz (1986), Eliaz (2002), Barlo and Dalkiran (2009), Saran (2011), Korpela (2012), de Clippel (2014), Saran (2016), Hayashi et al. (2020), and Barlo and Dalkıran (2022).

[9]*Societal non-satiation* demands that for every alternative and every payoff state, there exists an individual who does not choose that alternative at that state from the set of all alternatives. This restriction is weaker than the economic

Our paper is closely related to the literature on implementation with partial honesty, pioneered by Dutta and Sen (2012).[10] Their construction assumes that at least one of the individuals has a preference for honesty. To formulate this, individuals' preferences on alternatives are extended to messages when dealing with mechanisms that involve the announcement of a payoff state. A partially honest individual is assumed to strictly prefer a message involving the announcement of the 'true' payoff state when none of his deviations make him strictly better off. Then, that study shows that all SCCs satisfying the no-veto property can be implemented in Nash equilibrium whenever the society contains at least three individuals, one of whom, whose identity is privately known only by himself, is partially honest. This sufficiency result does not need Maskin monotonicity. On the other hand, sympathy for an SCC involves an inclination toward the truthful revelation of profiles of sets with this SCC but not truthful announcements of the realized states of the economy and the associated payoff states. That is why sympathy for an SCC differs from partial honesty. Indeed, unlike many papers on implementation with partial honesty, we need a Maskin monotonicity type of requirement to extract information about the states of the economy. In Section 5, we analyze the relation between sympathy and partial honesty in detail.

Another related paper is Barlo and Dalkıran (2021) which studies "suitable notions of implementation [under incomplete information] for environments in which planners do not observe all the data on individuals' choices and are partially informed about the association of individuals' preferences with states of the economy." That article differs from the current paper in three folds. In that paper, (*i*) the planner has missing data on individuals' choices and hence is not completely ignorant; (*ii*) there are no sympathizers and/or partially honest individuals in the society to help the planner; (*iii*) the equilibrium notion, while related to Nash equilibrium, is different.

The rest of the paper is organized as follows. We present the preliminaries in Section 2 and a motivating example in Section 3. Our main result is in Section 4. Section 5 displays the relation between sympathy and partial honesty. Section 6 contains a result on the inference of the existence

environment assumption and allows for more Nash equilibria in the mechanism we employ. But, with more Nash equilibria to handle comes the need for more power: instead of a single sympathizer, now we need at least two strong sympathizers. A *strong sympathizer* of the SCC is an individual who strictly prefers an action that consists of the announcement of a profile rational-consistent with this SCC coupled with some messages to another action that involves announcing an inconsistent profile and some other messages, whenever both actions deliver this individual's most preferred alternatives among those he can sustain via unilateral deviations. So, a strong sympathizer is a sympathizer.

[10] An incomplete list in this literature consists of Matsushima (2008a), Matsushima (2008b), Kartik and Tercieux (2012), Kartik et al. (2014), Korpela (2014), Saporiti (2014), Ortner (2015), Doğan (2017), Kimya (2017), Lombardi and Yoshihara (2017), Mukherjee et al. (2017), Lombardi and Yoshihara (2018), Savva (2018), Hagiwara (2019), and Lombardi and Yoshihara (2020). See also Dutta (2019) for a survey of recent results in this literature. Another strand of related papers analyzes the characterization of jurors' preferences on rankings of contestants when jurors are not necessarily impartial and have incentives to misreport the true ranking of contestants. See Amorós (2009) and Amorós (2013). Yadav (2016) considers the effects of partial honesty in the model of Amorós (2013).

of a rational-consistent profile, while Section 7 concludes. In the Appendix, Section A presents a behavioral formulation, Section B contains our analysis of noneconomic environments, and Section C includes the proofs.

2 Preliminaries

Let X be a set of *alternatives*, 2^X the set of all subsets of X, and $\mathcal{X} := 2^X \setminus \{\emptyset\}$. For all $x \in X$, let $\mathcal{X}_x$ be the set of all non-empty subsets of X containing x. $N = \{1, ..., n\}$ denotes a *society* with a finite set of individuals where $n \geq 2$.

Below, we introduce our setting under the *rational domain*. On the other hand, our construction and results extend to the behavioral domain as well, and these are presented in the Appendix.

Ω denotes the set of all *feasible payoff states* and is in one-to-one correspondence with all the admissible payoff characteristics of the environment. The *preferences* of individual $i \in N$ at payoff state $\omega \in \Omega$ is captured by a complete and transitive binary relation, a ranking, $R_i^\omega \subseteq X \times X$.[11] The *ranking profile of the society* is given by $\mathbf{R} = (R_i^\omega)_{i \in N,\ \omega \in \Omega}$ and it is in one-to-one correspondence with Ω. Given $i \in N$, $\omega \in \Omega$, and $x \in X$, $L_i^\omega(x) := \{y \in X \mid x R_i^\omega y\} \in \mathcal{X}_x$ denotes the *lower contour set of individual i at payoff state ω of alternative* x, and we let $\mathbb{L}_i^\omega(x) := \{S \in \mathcal{X}_x \mid S \subset L_i^\omega(x)\}$ identify the collection of sets that contain x and are subsets of $L_i^\omega(x)$.

We let Θ be the set of *states of the economy*. A *social choice correspondence* (SCC) defined on the states of the economy is $f : \Theta \to \mathcal{X}$, a non-empty valued correspondence mapping Θ into X. Given $\theta \in \Theta$, $f(\theta)$ denotes the set of alternatives that the planner desires to sustain at θ and is referred to as f*-optimal* alternatives at θ.

The *identification function* $\pi^* : \Theta \to \Omega$ captures the association of states of the economy with the payoff states, where π^* is an injection, i.e., for all $\theta \in \Theta$, there exists a distinct $\omega \in \Omega$ such that $\pi^*(\theta) = \omega$. To model a situation in which the planner does not know how to associate the states of the economy with the payoff states, we assume that the planner does not know $\pi^* : \Theta \to \Omega$.

We restrict attention to *complete information*. The information and knowledge requirements of our model are as follows:

(*i*) the planner knows N, X, Ω, Θ, and $f : \Theta \to \mathcal{X}$; and

(*ii*) N, X, Ω, Θ, $\pi^* : \Theta \to \Omega$, $f : \Theta \to \mathcal{X}$, and the realized state of the economy $\theta \in \Theta$ are common knowledge among the individuals; and

(*iii*) items (*i*) and (*ii*) are common knowledge among the individuals and the planner.

[11] A binary relation $R \subseteq X \times X$ is *complete* if for all $x, y \in X$ either xRy or yRx or both; *transitive* if for all $x, y, z \in X$ with xRy and yRz implies xRz.

The essence of the asymmetry of information between the planner and the individuals involves the identification function π^* and the realized state of the economy θ.

A mechanism $\mu = (A, g)$ assigns each individual $i \in N$ a non-empty *message space* A_i and specifies an *outcome function* $g : A \to X$ where $A := \times_{j \in N} A_j$. $\mathcal{M}$ denotes the set of all mechanisms. Given a mechanism $\mu \in \mathcal{M}$ and $a_{-i} \in A_{-i} := \times_{j \neq i} A_j$, the *opportunity set* of individual i pertaining to others' message profile a_{-i} in mechanism μ is $O_i^\mu(a_{-i}) := g(A_i, a_{-i})$ where $g(A_i, a_{-i}) = \{g(a_i, a_{-i}) : a_i \in A_i\}$. Consequently, $a^* \in A$ is a ***Nash equilibrium*** of μ at $\omega \in \Omega$ if for all $i \in N$, $g(a^*)\, R_i^\omega\, g(a_i, a_{-i}^*)$ for all $a_i \in A_i$ (equivalently, $g(a^*)\, R_i^\omega\, x$ for all $x \in O_i^\mu(a_{-i}^*)$). Given mechanism μ, the correspondence $NE^\mu : \Theta \twoheadrightarrow 2^X$ identifies Nash equilibrium outomes of μ at $\theta \in \Theta$ and is defined by $NE^\mu(\theta) := \{x \in X \mid \exists a^* \in A \text{ s.t. } a^* \text{ is a Nash equilibrium of } \mu \text{ at } \pi^*(\theta) \text{ and } g(a^*) = x\}$. Then, the notion of Nash implementation, which can be verified by an all-seeing party, is: An SCC $f : \Theta \to \mathcal{X}$ is ***implementable by a mechanism*** $\mu \in \mathcal{M}$ ***in Nash equilibrium***, if for all $\theta \in \Theta$, $f(\theta) = NE^\mu(\theta)$.

Below, we show that a variant of monotonicity of Maskin (1999), the rational version of consistency of de Clippel (2014), is related to Nash implementation:[12]

Definition 1. *A profile of sets* $\mathbf{S} := (S_i(x, \theta))_{i \in N,\ \theta \in \Theta,\ x \in f(\theta)}$ *is* **rational-consistent** *with the given SCC* $f : \Theta \to \mathcal{X}$ *if*

(*i*) *for all* $i \in N$*, all* $\theta \in \Theta$*, and all* $x \in f(\theta)$*,* $S_i(x, \theta) \in \mathbb{L}_i^{\pi^*(\theta)}(x)$*; and*

(*ii*) $x \in f(\theta)$ *and* $x \notin f(\tilde{\theta})$ *with* $\theta, \tilde{\theta} \in \Theta$ *implies there is* $j \in N$ *with* $S_j(x, \theta) \notin \mathbb{L}_j^{\pi^*(\tilde{\theta})}(x)$.

Let $\mathcal{S}(f)$ *denote the set of all profiles of sets that are rational-consistent with* f.

In words, a profile of sets $\mathbf{S}$ is rational-consistent with a given SCC f, if (i) for every individual i and state of the economy θ and alternative x in $f(\theta)$, x is one of the best alternatives according to $R_i^{\pi^*(\theta)}$ in the set $S_i(x, \theta)$; and (ii) if x is f-optimal at θ but not at $\tilde{\theta}$, then there exists $j \in N$ such that x is not among the best alternatives according to $R_j^{\pi^*(\tilde{\theta})}$ in $S_j(x, \theta)$.

When the planner knows that a mechanism $\mu^* = (A^*, g^*)$ implements SCC $f : \Theta \to \mathcal{X}$ in Nash equilibrium, then she infers the following: for all $\theta \in \Theta$ and all $x \in f(\theta)$, there is some $a^x \in A^*$ such that $g^*(a^x) = x$ and for all $i \in N$, $g^*(a^x) R_i^{\pi^*(\theta)} x'$ for all $x' \in O_i^{\mu^*}(a_{-i}^x)$, even though the planner does not know exactly what $\pi^*(\theta)$ is and precisely which message profile a^x corresponds to—unless there is a unique $a^x \in A$ delivering x. Therefore, for all $i \in N$, all $\theta \in \Theta$, and all $x \in f(\theta)$, the planner infers that there is a set $S_i(x, \theta) := O_i^{\mu^*}(a_{-i}^x)$ (the full specification of which she may not know) from which one of the top ranked alternatives of i at the true payoff ranking, $R_i^{\pi^*(\theta)}$, includes x. In other words,

[12] There are many variants of Maskin monotonicity in the literature. See for example, Eliaz (2002), Barlo and Dalkiran (2009), Sanver (2017), Koray and Yildiz (2018), and Lombardi and Yoshihara (2018).

the planner infers that (*i*) of rational-consistency holds. For (*ii*) of rational-consistency, suppose that the planner knows that $x \in f(\theta)$ and $x \notin f(\tilde{\theta})$ for some $\theta, \tilde{\theta} \in \Theta$. Then, the planner (knowing that μ^* implements f in Nash equilibrium) infers that a^x cannot be a Nash equilibrium at the payoff state $\pi^*(\tilde{\theta})$ even though she does not know what the profile a^x and $\pi^*(\tilde{\theta})$ are. This is because otherwise she figures out that a^x being a Nash equilibrium at $\pi^*(\tilde{\theta})$ implies, by (*ii*) of Nash implementation, $g^*(a^x) = x$ is in $f(\tilde{\theta})$. So, there is an individual $j \in N$ who does not rank x as the first alternative in $S_j(x,\theta) = O_j^{\mu^*}(a_{-j}^x)$ using ranking $R_j^{\pi^*(\tilde{\theta})}$. In other words, in this situation, the planner infers that there is an individual j such that the underlying payoff state, $\pi^*(\tilde{\theta})$ that she does not know, is so that $S_j(x,\theta) \notin \mathbb{L}_j^{\pi^*(\tilde{\theta})}(x)$; enabling us to conclude that the planner deduces that (*ii*) of rational-consistency holds. These deliver the following necessity theorem proved above:

Theorem 1. *If the planner knows that the SCC $f : \Theta \to \mathcal{X}$ is Nash implementable, then the planner infers that $\mathcal{S}(f) \neq \emptyset$ without necessarily knowing the full specification of sets that appear in $\mathcal{S}(f)$.*

In our setup, the planner is not fully informed about how to associate the states of the economy with the payoff states. But, she needs this information to design mechanisms. Indeed, it is natural to consider mechanisms in which the planner *asks* individuals' help. Nevertheless, this endeavor is fruitful only when there is some hope for Nash implementation, i.e., when the planner infers that $\mathcal{S}(f) \neq \emptyset$; or else, by Theorem 1, she deduces that f is not Nash implementable. In Section 4, we establish that if the planner knows the existence (but not the full specification) of a rational-consistent profile with a given SCC, then she can extract the rest of the information about this profile from the society while implementing this SCC, whenever there exists a sympathizer among the individuals.

3 A Motivating Example

Now, we provide a motivating example illustrating our setup as well as displaying that the minimal essential information that the planner needs to implement a given SCC involves asking for a rational-consistent profile of sets.

Let the set of individuals $N = \{\text{Ann}, \text{Bob}, \text{Charlie}\}$ (abbreviated by A, B, and C, respectively) constitute a graduate class intending to take a topics course from a visiting professor. The topics the professor can cover is one of the following alternatives $X = \{x, y, z, t\}$. The professor (she) wishes to cover topic x if the state of the class is 'enthusiastic', $\theta^{(1)}$, and topic t if the class's state is 'not enthusiastic', $\theta^{(2)}$. Therefore, the goal of the professor (the planner) can be summarized by the SCC f that demands x at $\theta^{(1)}$ and t at $\theta^{(2)}$ where the states of the class is given by $\Theta = \{\theta^{(1)}, \theta^{(2)}\}$ (that is, $f(\theta^{(1)}) = \{x\}$ and $f(\theta^{(2)}) = \{t\}$). For simplicity, we assume that it is common knowledge that the students' state-contingent preferences consist of strict rankings of the topics.

The visiting professor does not have any additional information about students' state-contingent preferences. In particular, she does not know which of the preference profiles (alternatively, payoff states) are associated with the enthusiastic state of the class $\theta^{(1)}$ and the non-enthusiastic state of the class $\theta^{(2)}$. In this example, the set of payoff states, Ω, equals all strict rankings of $\{x, y, z, t\}$. As there are 24 possible strict rankings of $\{x, y, z, t\}$ at each one of the two states of the class, the total number of all possible associations of the states of the class with the payoff states (alternatively, the total number of all possible identification functions $\pi^* : \Theta \to \Omega$) equals $(\#\Omega)^2 = (24^3)^2 = 191102976$.

The professor wishes to take an implementation approach and decentralize the decision concerning the topic to be covered in the class. However, she has no clue how the students make their choices from their opportunity sets at a state of the class without knowing the identification function π^*. For example, at $\theta^{(1)}$, she knows that the outcome to be implemented is topic x, while she does not have any information about students' strict rankings associated with $\theta^{(1)}$. Therefore, she cannot design mechanisms implementing the given SCC. On the other hand, the students having taken many classes together commonly know each others' strict rankings and whether or not the state of the class is enthusiastic. Hence, if it were commonly known that there is a sympathizing student in the class, then the professor could ask the students for guidance to design the opportunity sets of the mechanism.

In this study, we aim to extract only the necessary information from the society and refrain from relying on the revelation of payoff states as it may not be admissible in many environments due to privacy concerns or non-disclosure and confidentiality agreements (as discussed in the introduction). In the context of this example, the professor may not be able to employ mechanisms that ask students to reveal their own and others' strict rankings of topics due to privacy concerns, university policies, and consequences in terms of getting recommendation letters from the visiting professor.

Thanks to the necessity theorem, Theorem 1, we know that the minimal information the planner needs to implement the SCC f involves the knowledge of the existence of a profile of sets of alternatives $\mathbf{S} = (S_i(x, \theta^{(1)}), S_i(t, \theta^{(2)}))_{i=A,B,C}$ where (*i*) every i chooses x from $S_i(x, \theta^{(1)})$ at $\theta^{(1)}$ and t from $S_i(t, \theta^{(2)})$ at $\theta^{(2)}$ with the following additional requirement: (*ii*) for any $a \neq x$, there is $j \in \{A, B, C\}$ who does not choose a from $S_j(x, \theta^{(1)})$ at $\theta^{(1)}$, and for any $b \neq t$, there is $j \in \{A, B, C\}$ who does not choose b from $S_j(t, \theta^{(2)})$ at $\theta^{(2)}$. It is easy to see that (*i*) and (*ii*) above are equivalent to rational-consistency in this example. If in addition the planner knows the specifications of sets in the profile $\mathbf{S}$, then she can use this information to design a mechanism with opportunity sets corresponding to $\mathbf{S}$ so that due to (*i*), x is a Nash equilibrium outcome of this mechanism at $\theta^{(1)}$ and t a Nash equilibrium outcome at $\theta^{(2)}$, and due to (*ii*), there is no Nash equilibrium outcome at $\theta^{(1)}$ or $\theta^{(2)}$ that leads to a 'bad' (non f-optimal) outcome chosen from these opportunity sets.

By (i), $S_i(x, \theta^{(1)})$ must be a subset of $L_i^{\pi^*(\theta^{(1)})}(x)$, the lower contour set of i at payoff state $\pi^*(\theta^{(1)})$ of x, containing x; and $S_i(t, \theta^{(2)})$ has to be a subset of $L_i^{\pi^*(\theta^{(2)})}(t)$ containing t. Thus, $S_i(x, \theta^{(1)})$ is one of the following eight sets of alternatives: $\{x, y, z, t\}$, $\{x, y, z\}$, $\{x, y, t\}$, $\{x, z, t\}$, $\{x, y\}$, $\{x, z\}$, $\{x, t\}$, $\{x\}$. Similarly, $S_i(t, \theta^{(2)})$ is one of eight sets that constitute the subsets of alternatives $\{x, y, z, t\}$ containing t. Since there are three students and two states of the class, we have less than $(8^3)^2 = 262144$ possible candidates for rational-consistent profiles.[13] Consequently, in this example, the professor asking for students' guidance via the revelation of rational-consistent profiles of sets involves less information (no more than 262144 possible candidates) than asking students about the class's ranking profile and the state of the class (191102976 possible candidates) even when the latter is admissible.

Therefore, in this example, the minimal information the planner needs does not necessarily contain the full specifications of the lower contour sets of individuals at the corresponding states of the economy for the given socially optimal alternatives, as illustrated below.

Suppose the professor learns that the mechanism $\mu = (M, g)$ specified in Table 1 implements the SCC f in Nash equilibrium. Then, as $g(a^x) = x$ with $a^x = (U, L, W)$ and $f(\theta^{(1)}) = \{x\}$, the

Charlie

W (Bob)

Ann	*L*	*R*
U	x	y
D	y	z

E (Bob)

Ann	*L*	*R*
U	z	y
D	y	t

Table 1: A $2 \times 2 \times 2$ mechanism that implements $f : \Theta \to \mathcal{X}$ in Nash equilibrium.

professor infers that a^x is the unique Nash equilibrium at $\pi^*(\theta^{(1)})$, and similarly, $a^t = (D, R, E)$ the unique Nash equilibrium at $\pi^*(\theta^{(2)})$. Thus, $O_i^\mu(a_{-i}^x) = S_i(x, \theta^{(1)})$ and $O_i^\mu(a_{-i}^t) = S_i(t, \theta^{(2)})$ for all $i = A, B, C$ where $S_A(x, \theta^{(1)}) = S_B(x, \theta^{(1)}) = \{x, y\}$, $S_C(x, \theta^{(1)}) = \{x, z\}$, $S_A(t, \theta^{(2)}) = S_B(t, \theta^{(2)}) = \{y, t\}$, and $S_C(t, \theta^{(2)}) = \{z, t\}$. Then, $\mathbf{S} = (S_i(x, \theta^{(1)}), S_i(t, \theta^{(2)}))_{i=A,B,C}$ is a profile of sets rational-consistent with the SCC f. The rational-consistent profile $\mathbf{S}$ reveals to the professor only that at the enthusiastic state of the class, $\theta^{(1)}$, Ann and Bob strictly prefer x over y and Charlie strictly prefers x over z while at the class's non-enthusiastic state, $\theta^{(2)}$, Ann and Bob strictly prefer t over y and Charlie strictly prefers t over z. However, there are many possible ranking profiles inducing this rational-consistent profile of sets.[14] To illustrate that the professor does not need to know the full

[13] At the very least, we know that $S_i(x, \theta^{(1)}) = \{x\}$ for all $i = A, B, C$ cannot be a part of a rational-consistent profile because otherwise x emerges as a bad Nash equilibrium outcome at state of the class $\theta^{(2)}$.

[14] Indeed, there are $(12^3 - 8^3)^2 = 1478656$ many strict ranking profiles that sustain this profile in rational-consistency. To see this, notice that at each state of the class $\theta \in \{\theta^{(1)}, \theta^{(2)}\}$, there are 12^3 many ranking profiles that satisfy (i) of rational-consistency, while 8^3 many of them fail (ii) of rational-consistency.

specification of students' lower contour sets, we note that the above mechanism Nash implements the SCC f for both of the following distinct pairs of strict ranking profiles: $\omega^{(1)} = (xyzt, zxty, tyxz)$ and $\omega^{(2)} = (txzy, xtyz, ytzx)$) with $\pi^*(\theta^{(1)}) = \omega^{(1)}$ and $\pi^*(\theta^{(2)}) = \omega^{(2)}$; and $\tilde{\omega}^{(1)} = (txyz, xzty, yxzt)$ and $\tilde{\omega}^{(2)} = (xtzy, ztyx, txyz)$) with $\pi^*(\theta^{(1)}) = \tilde{\omega}^{(1)}$ and $\pi^*(\theta^{(2)}) = \tilde{\omega}^{(2)}$.

Notwithstanding, the professor needs to extract the information about rational-consistent profiles of sets (or realized payoff states and states of the class, if admissible) from the class. In fact, when the professor is not informed of a rational-consistent profile of sets (or cannot deduce such a profile from the payoff state the students report), then she cannot succeed in the implementation of the SCC at hand. But, in general, the students do not have any incentives to report truthfully when revealing rational-consistent profiles of sets (or the payoff state along with the state of the class).

That is precisely why we introduce a sympathizer, a student who likes the research of the visiting professor and supports her teaching plan. As a result, this student strictly prefers to reveal a rational-consistent profile of sets when he is indifferent between the resulting outcomes.

We wish to emphasize that a sympathizer is inclined to truthfully reveal a rational-consistent profile of sets (which relates to the revelation of the identification function π^*) if indifferent between the consequences. But, a partially honest individual strictly prefers to truthfully reveal payoff state and identification function combinations if all else equal. Thus, sympathy is essentially different from partial honesty. We refer the reader to Section 5 for a detailed discussion of these aspects.

Our main result, Theorem 2, demands that it is commonly known that the environment is economic (meaning that there is a mild form of disagreement in the society in the sense that $N - 1$ or more individuals cannot top rank an alternative at any one of the payoff states), there is a rational-consistent profile of sets of alternatives, and the society contains a sympathizer (whose identity is not necessarily known by anyone apart from himself). Then, the planner can extract the information about the specification of a rational-consistent profile from the society unanimously and design the opportunity sets of the mechanism using this profile and implement the given SCC in Nash equilibrium.

In this particular example, at each state of the class there are 5184 ranking profiles (payoff states) satisfying the economic environment specification.[15] Indeed, $\omega^{(1)}$, $\omega^{(2)}$, $\tilde{\omega}^{(1)}$ and $\tilde{\omega}^{(2)}$ specified above are among payoff states in which the economic environment assumption holds. On the other hand, there are no more than 512^2 profiles of sets rational-consistent with the SCC f. Ergo, in this example, the information content needed for the revelation of rational-consistency in our construction is no more than 512^2 while the information content would equal 5184^2 if we were to employ revelation of payoff states and states of the class by using partial honesty as opposed to sympathy. In this

[15] We note that at each state of the class, there are $24^3 = 13824$ possible ranking profiles while 8640 of them fail the economic environment assumption.

respect, our construction requires less information than asking individuals to reveal payoff states and states of the class even when doing so is admissible.

4 The Planner Asking for Guidance

The planner aims to elicit the information about the specification of a rational-consistent profile of sets from the society. To that end, the planner uses a *sympathizer* of the social goal, a guide who is inclined toward the truthful revelation of a rational-consistent profile but neither the realized state of the economy nor its associated payoff state.

To formalize these, for any SCC $f : \Theta \to \mathcal{X}$, we restrict attention to mechanisms in which one of the components of each individual's messages involves the announcement of a profile of sets indexed for $i \in N$, $\theta \in \Theta$, and $x \in f(\theta)$. We refer to such game forms as *guidance mechanisms* and denote them by $\mathcal{M}^S \subset \mathcal{M}$. In that regard, we let $\mathcal{S}$ denote the set of all profile of sets of alternatives $\mathbf{S} = (S_i(x,\theta))_{i\in N,\ \theta\in\Theta,\ x\in f(\theta)}$ with the property that $x \in S_i(x,\theta)$ for all $i \in N$, $\theta \in \Theta$, and $x \in f(\theta)$. The guidance mechanism $\mu \in \mathcal{M}^S$ is such that $A_i := \mathcal{S} \times M_i$ for each $i \in N$ for some non-empty M_i and $M := \times_{i\in N} M_i$ and a generic message (action) $a_i \in A_i$ is $a_i = (\mathbf{S}^{(i)}, m_i)$. We note that for any SCC f, the set of rational-consistent profiles, $\mathcal{S}(f)$, is contained in $\mathcal{S}$.

In what follows, we provide an extension of individuals' preferences over alternatives to choices on messages in guidance mechanisms.

For any $f : \Theta \to \mathcal{X}$, any $\mu \in \mathcal{M}^S$, and any $\omega \in \Omega$, the correspondence $BR_i^{\omega} : A_{-i} \twoheadrightarrow A_i$ identifies individual i's ***best responses*** at ω to others' messages. In particular, if individual i is a standard economic agent, and *not a sympathizer* of f at $\theta \in \Theta$, then for all $a_{-i} \in A_{-i}$,

$$a_i \in BR_i^{\pi^*(\theta)}(a_{-i}) \text{ if and only if } g(a_i, a_{-i})\, R_i^{\pi^*(\theta)}\, g(a_i', a_{-i}) \text{ for all } a_i' \in A_i.$$

For sympathizers, the following holds:

Definition 2. *Given an SCC $f : \Theta \to \mathcal{X}$ and a guidance mechanism $\mu \in \mathcal{M}^S$, we say that individual $i \in N$ is a* **sympathizer** of f at the realized state of the economy $\theta \in \Theta$ *if for all $a_{-i} \in A_{-i}$,*

(*i*) $\mathbf{S} \in \mathcal{S}(f)$*,* $\tilde{\mathbf{S}} \notin \mathcal{S}(f)$*, and* $m_i \in M_i$ *implies* $(\mathbf{S}, m_i) \in BR_i^{\pi^*(\theta)}(a_{-i})$ *and* $(\tilde{\mathbf{S}}, m_i) \notin BR_i^{\pi^*(\theta)}(a_{-i})$ *if*

$$g((\mathbf{S}, m_i), a_{-i})\, R_i^{\pi^*(\theta)}\, g(a_i', a_{-i}) \text{ for all } a_i' \in A_i, \text{ and}$$
$$g((\tilde{\mathbf{S}}, m_i), a_{-i})\, R_i^{\pi^*(\theta)}\, g(a_i'', a_{-i}) \text{ for all } a_i'' \in A_i; \text{ and}$$

(*ii*) *in all other cases,* $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ *if and only if* $g(a_i, a_{-i})\, R_i^{\pi^*(\theta)}\, g(a_i', a_{-i})$ *for all* $a_i' \in A_i$*.*

We say that the environment satisfies the **sympathizer property** *with respect to SCC f if, for every state of the economy $\theta \in \Theta$, there exists at least one sympathizer of f at θ, while the identity of each sympathizer of f at θ is privately known only by himself.*

In words, a sympathizer i of f at θ strictly prefers a rational-consistent profile $\mathbf{S}$ coupled with a message profile m_i to a non-rational-consistent profile $\tilde{\mathbf{S}}$ coupled with the same message profile m_i whenever both action profiles, $(\mathbf{S}, m_i)$ and $(\tilde{\mathbf{S}}, m_i)$, lead to alternatives among the best according to $R_i^{\pi^*(\theta)}$. Therefore, individuals' best responses in a guidance mechanism μ at $\pi^*(\theta)$ are obtained using the usual preference maximization along with an additional lexicographic tie-breaking rule favoring the announcement of rational-consistent profiles of sets. In fact, i's best responses are *standard* if $\mu \notin \mathcal{M}^S$ and/or the announcement of a rational-consistent profile coupled with some messages does not deliver the top-ranked alternative in i's opportunity set and/or i is not a sympathizer of f at θ.

On the other hand, if the guidance mechanism μ associated with f is such that i is a sympathizer of f at θ and can obtain her top-ranked alternative in her opportunity set via the announcement of a rational-consistent profile, then her best responses are not in one-to-one correspondence with her preferences $R_i^{\pi^*(\theta)}$. To reflect the novel nature of Nash equilibrium obtained from such best responses, we introduce the concept of Nash* equilibrium: Given a mechanism $\mu \in \mathcal{M}$, $a^* \in A$ is a ***Nash** equilibrium*** of μ at $\omega \in \Omega$ if, for all $i \in N$, $a_i^* \in BR_i^{\omega}(a_{-i}^*)$. Nash and Nash* equilibrium coincide when $\mu \notin \mathcal{M}^S$ and/or there are no sympathizers of f at θ and/or i is a sympathizer of f at θ but there is no $(\mathbf{S}, m_i)$ with $\mathbf{S} \in \mathcal{S}(f)$ and $g((\mathbf{S}, m_i), a_{-i}^*) \; R_i^{\pi^*(\theta)} \; g(a_i', a_{-i}^*)$ for all $a_i' \in A_i$ while a^* is a Nash equilibrium at $\pi^*(\theta)$. In general, the set of Nash* equilibrium at ω is a subset of the set of Nash equilibrium at ω of the same mechanism. The notion of Nash* implementation is the following:

Definition 3. *We say that an SCC $f : \Theta \to \mathcal{X}$ is* **implementable by a mechanism** $\mu \in \mathcal{M}$ **in Nash* equilibrium**, *if*

(*i*) *for any $\theta \in \Theta$ and $x \in f(\theta)$, there exists $a^x \in A$ such that $g(a^x) = x$ and $a_i^x \in BR_i^{\pi^*(\theta)}(a_{-i}^x)$ for all $i \in N$; and*

(*ii*) *for any $\theta \in \Theta$, $a^* \in A$ with $a_i^* \in BR_i^{\pi^*(\theta)}(a_{-i}^*)$ for all $i \in N$ implies $g(a^*) \in f(\theta)$.*

When the mechanism in this definition is not in $\mathcal{M}^S$, Nash* implementation coincides with Nash implementation. Furthermore, the necessary condition we attain employing Nash* implementation is not independent of the mechanism. Hence, it is not helpful in constructing mechanisms that can be employed in the sufficiency direction.

Our main result uses the following assumption:

Definition 4. *We say that the* **economic environment** *assumption holds whenever for any payoff state $\omega \in \Omega$ and any alternative $x \in X$, there are two individuals $i, j \in N$ with $i \neq j$ and there are two alternatives $y^i, y^j \in X$ such that $y^i P_i^{\omega} x$ and $y^j P_j^{\omega} x$.*

The economic environment assumption demands that for every payoff state and alternative, there are two individuals not choosing that alternative from the set of all alternatives at that given payoff state. This assumption, therefore, needs a weak form of disagreement in the society.

The following is our main result:

Theorem 2. *Suppose $n \geq 3$, and that the planner knows that*

(i) *the environment is economic, and it satisfies the sympathizer property, and*

(ii) *the SCC $f : \Theta \to \mathcal{X}$ has a rational-consistent profile of sets, i.e., $\mathcal{S}(f) \neq \emptyset$, while she does not necessarily know the full specification of the sets that appear in $\mathcal{S}(f)$.*

Then, the planner infers that f is Nash implementable by a guidance mechanism $\mu \in \mathcal{M}^S$, and for any state of the economy $\theta \in \Theta$ and any Nash* equilibrium $\bar{a} = (\bar{\mathbf{S}}^{(i)}, \bar{m}_i)_{i \in N}$ of mechanism μ at payoff state $\pi^*(\theta)$, $\bar{\mathbf{S}}^{(i)} = \mathbf{S} \in \mathcal{S}(f)$ for all $i \in N$.*

Theorem 2 establishes sufficiency for three or more individuals by utilizing a guidance mechanism that extracts the information about rational-consistency from the society unanimously and implements the desired goal if the following hold: The planner knows that the environment is economic and satisfies the sympathizer property while there is a rational-consistent profile of sets.

The construction featured in the proof utilizes the following guidance mechanism $\mu \in \mathcal{M}^S$ with $\mu = (A, g)$ defined as follows: $A_i := \mathcal{S} \times \Theta \times X \times \mathbb{N}$ where a generic member $a_i = (\mathbf{S}^{(i)}, \theta^{(i)}, x^{(i)}, k^{(i)}) \in A_i$ with $\mathbf{S}^{(i)} \in \mathcal{S}$, $\theta^{(i)} \in \Theta$, $x^{(i)} \in X$, and $k^{(i)} \in \mathbb{N}$ with the convention that $m_i = (\theta^{(i)}, x^{(i)}, k^{(i)})$ and $M_i := \Theta \times X \times \mathbb{N}$ so that $A_i = \mathcal{S} \times M_i$. The outcome function $g : A \to X$ is defined via the rules specified in Table 2.

Rule 1 :	$g(a) = x$	if $\mathbf{S}^{(i)} = \mathbf{S}$ for all $i \in N \setminus \{i'\}$ for some $i' \in N$, and $m_j = (\theta, x, \cdot)$ for all $j \in N$ with $x \in f(\theta)$,
Rule 2 :	$g(a) = \begin{cases} x' & \text{if } x' \in S_j(x,\theta) \text{ where } S_j(x,\theta) = \mathbf{S}\|_{j,\theta,x \in f(\theta)}, \\ x & \text{otherwise.} \end{cases}$	if $\mathbf{S}^{(i)} = \mathbf{S}$ for all $i \in N \setminus \{i'\}$ for some $i' \in N$, and $m_i = (\theta, x, \cdot)$ for all $i \in N \setminus \{j\}$ with $x \in f(\theta)$, and $m_j = (\theta', x', \cdot) \neq (\theta, x, \cdot)$,
Rule 3 :	$g(a) = x^{(i^*)}$ where $i^* = \min\{j \in N \mid k^{(j)} = \max_{i' \in N} k^{(i')}\}$	otherwise.

Table 2: The outcome function of the mechanism with three or more individuals.

We note that planner's knowledge enables her to construct this mechanism without knowing $\pi^* : \Theta \to \Omega$.

In words, *Rule 1* holds when all individuals but one announce the same profile of sets $\mathbf{S} \in \mathcal{S}$, while all individuals announce the same state of the economy, θ, and the same alternative, x, that is f-optimal at the announced state of the economy θ. Then, the outcome is the unanimously announced alternative x. *Rule 2*, on the other hand, is in effect when all individuals but an odd-man-out, i', announce the same profile of sets $\mathbf{S} \in \mathcal{S}$, while all individuals apart from an individual j (who may or may not be i') announce the same state of the economy, θ, and the same alternative x that is in $f(\theta)$. Then, the outcome equals the alternative announced by j, x', whenever this alternative is in $\mathbf{S}|_{j,\theta,x\in f(\theta)}$, the set of alternatives corresponding to that in the profile of sets $\mathbf{S}$ for individual j, the state of the economy θ, and alternative x. Finally, *Rule 3* involves all the other cases, in which the outcome equals to the announced alternative of the individual winning the integer game.

We wish to point out that the construction involving the odd-man-out concerning the announcement of a profile of sets is reminiscent of the mechanism in Dutta and Sen (2012, Theorem 1) while the construction of the odd-man-out concerning the announcement of a state of the economy and an associated f-optimal alternative is reminiscent of the mechanism in Maskin (1999, Theorem 3).

5 Sympathy versus Partial Honesty

In this section, we analyze the relation between sympathy and partial honesty in our framework. First of all, we wish to reemphasize that we consider environments in which the planners are limited in terms of inquiring about payoff states due to privacy and political correctness concerns or non-disclosure and confidentiality agreements. We also wish to stress that a sympathizing individual is identified for the SCC to be implemented. Therefore, a sympathizer of an SCC f, does not have to be inclined to truthfully reveal a profile of sets rational-consistent with another SCC f'.

In what follows, we show that even if detailed inquiries about payoff states are admissible, the extent of information the planner seeks to elicit via the help of a sympathizer is 'less' than the extent of information she obtains thanks to a partially honest individual in her endeavor to implement a given SCC. We also display that if the planner aims to extract the information about the relation between Θ and Ω with the help of a *weakly partially honest* individual—who at the realized state (θ, ω, π^*) with $\pi^*(\theta) = \omega$, is inclined toward the truthful announcement of π^* but not (θ, ω)—, then rational-consistency (Maskin monotonicity) type of requirements concerning (θ, ω) emerge.[16]

We adopt the convention that a state under complete information is to encompass all the information that is common knowledge among the individuals. Consequently, we define a *grand state* as the combination of a state of the economy, a payoff state, and a mapping $\pi : \Theta \to \Omega$. Let

[16]See Lombardi and Yoshihara (2018) that obtains a necessary condition for partially honestly Nash implementability, namely, partial-honesty monotonicity.

$\Sigma := \{(\theta, \omega, \pi) \in \Theta \times \Omega \times \Pi \mid \pi(\theta) = \omega\}$ be the set of grand states where a generic member $\sigma \in \Sigma$ is $\sigma = (\theta, \omega, \pi)$ with $\pi(\theta) = \omega$ and $\Pi := \{\pi' \mid \pi' : \Theta \to \Omega$ such that π' is an injection$\}$. The SCC $f : \Theta \to \mathcal{X}$ is defined on Θ; thus, we consider its natural extension onto Σ: $f(\sigma) = f(\theta)$ for all $\sigma = (\theta, \omega, \pi) \in \Sigma$.

To formalize partial honesty, we consider mechanisms that involve the announcement of a grand state, $\mathcal{M}^{\Sigma}$, which consists of mechanisms of the form $\mu^{\Sigma} = (A^{\Sigma}, g^{\Sigma})$ with $(\sigma^{(i)}, m_i) \in A_i^{\Sigma} := \Sigma \times M_i$ for some message space M_i for all $i \in N$. Given a mechanism $\mu \in \mathcal{M}^{\Sigma}$, we say that individual $i \in N$ is ***partially honest at the realized grand state*** $\sigma^T = (\theta^T, \omega^T, \pi^T) \in \Sigma$ if for all $a_{-i} \in A_{-i}$,

(i) if $\tilde{\sigma} \in \Sigma \setminus \{\sigma^T\}$, then for all $m_i, \tilde{m}_i \in M_i$, we have $(\sigma^T, m_i) \in BR_i^{\omega^T}(a_{-i})$ and $(\tilde{\sigma}, \tilde{m}_i) \notin BR_i^{\omega^T}(a_{-i})$ whenever $g^{\Sigma}((\sigma^T, m_i), a_{-i}) R_i^{\omega^T} g^{\Sigma}(a_i', a_{-i})$ for all $a_i' \in A_i^{\Sigma}$, and $g^{\Sigma}((\tilde{\sigma}, \tilde{m}_i), a_{-i}) R_i^{\omega^T} g^{\Sigma}(a_i'', a_{-i})$ for all $a_i'' \in A_i^{\Sigma}$; and

(ii) in all other cases, $a_i \in BR_i^{\omega^T}(a_{-i})$ if and only if $g^{\Sigma}(a_i, a_{-i}) R_i^{\omega^T} g^{\Sigma}(a_i', a_{-i})$ for all $a_i' \in A_i^{\Sigma}$.

On the other hand, if i is ***not partially honest at the realized grand state*** $\sigma^T \in \Sigma$, then $a_i \in BR_i^{\omega^T}(a_{-i})$ if and only if $g^{\Sigma}(a_i, a_{-i}) R_i^{\omega^T} g^{\Sigma}(a_i', a_{-i})$ for all $a_i' \in A_i^{\Sigma}$.

In words, if individual i is partially honest at the realized grand state σ^T, then he strictly prefers to announce σ^T along with a message profile m_i over announcing a grand state $\tilde{\sigma} \neq \sigma^T$ coupled with another message $\tilde{m}_i$ whenever both actions (σ^T, m_i) and $(\tilde{\sigma}, \tilde{m}_i)$ deliver alternatives that are $R_i^{\omega^T}$ optimal among those attainable via unilateral deviations. In all other cases, the preferences of i (regardless of whether or not i is partially honest) are given according to his realized ranking $R_i^{\omega^T}$.

By a slight modification of Dutta and Sen (2012, Theorem 1), one can obtain the following result: If the planner knows that the economic environment assumption holds, and for every grand state $\sigma \in \Sigma$, there is a partially honest individual at σ (even if she does not know the identity of this agent), then she infers that any SCC $f : \Theta \to \mathcal{X}$ is Nash* implementable, and in every such equilibrium all individuals announce the realized grand state.[17] We wish to emphasize that this sufficiency result does not need a Maskin monotonicity type of condition as in Dutta and Sen (2012) and Kartik and Tercieux (2012).

To relate partial honesty to sympathy, we introduce a weaker notion of partial honesty in $\mathcal{M}^{\Sigma}$ where at a realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^T)$, the individual at hand is 'honest' with respect to the announcement of π but not (θ, ω): Given a mechanism $\mu^{\Sigma} \in \mathcal{M}^{\Sigma}$, we say that individual $i \in N$ is ***weakly partially honest at the realized grand state*** $\sigma^T = (\theta^T, \omega^T, \pi^T) \in \Sigma$ if for all $a_{-i} \in A_{-i}^{\Sigma}$,

(i) if $\tilde{\sigma} = (\tilde{\theta}, \tilde{\omega}, \pi^T) \in \Sigma$ and $\hat{\sigma} = (\hat{\theta}, \hat{\omega}, \hat{\pi}) \in \Sigma$ with $\hat{\pi} \neq \pi^T$, then for all $\tilde{m}_i, \hat{m}_i \in M_i$, we have

[17] We note that when the environment is economic, then every SCC $f : \Theta \to \mathcal{X}$ satisfies the no-veto property.

$(\tilde{\sigma}, \tilde{m}_i) \in BR_i^{\omega^T}(a_{-i})$ but $(\hat{\sigma}, \hat{m}_i) \notin BR_i^{\omega^T}(a_{-i})$ whenever $g^{\Sigma}((\tilde{\sigma}, \tilde{m}_i), a_{-i}) R_i^{\omega^T} g^{\Sigma}(a'_i, a_{-i})$ for all $a'_i \in A_i^{\Sigma}$, and $g^{\Sigma}((\hat{\sigma}, \hat{m}_i), a_{-i}) R_i^{\omega^T} g^{\Sigma}(a''_i, a_{-i})$ for all $a''_i \in A_i^{\Sigma}$; and

(*ii*) otherwise, $a_i \in BR_i^{\omega^T}(a_{-i})$ if and only if $g^{\Sigma}(a_i, a_{-i}) R_i^{\omega^T} g^{\Sigma}(a'_i, a_{-i})$ for all $a'_i \in A_i^{\Sigma}$.

But, if i is ***not weakly partially honest at the realized grand state*** $\sigma^T \in \Sigma$, then $a_i \in BR_i^{\omega^T}(a_{-i})$ if and only if $g^{\Sigma}(a_i, a_{-i}) R_i^{\omega^T} g^{\Sigma}(a'_i, a_{-i})$ for all $a'_i \in A_i^{\Sigma}$.

When individual i is weakly partially honest at the realized grand state σ^T, then he strictly prefers to announce a grand state $\tilde{\sigma}$ involving the true identification function π^T along with a message profile $\tilde{m}_i$ over announcing a grand state $\hat{\sigma}$ involving a false identification function $\hat{\pi} \neq \pi^T$ coupled with another message $\hat{m}_i$ whenever both actions $(\tilde{\sigma}, \tilde{m}_i)$ and $(\hat{\sigma}, \hat{m}_i)$ deliver alternatives that are $R_i^{\omega^T}$ optimal among those attainable via unilateral deviations. As before, in all other cases, i's preferences (regardless of whether or not i is weakly partially honest) are given according to his true ranking $R_i^{\omega^T}$.

When we investigate mechanisms involving the announcement of identification functions, denoted by $\mathcal{M}^{\pi}$, we consider mechanisms of the form $\mu^{\pi} = (A^{\pi}, g^{\pi})$ with $(\pi^{(i)}, m_i^{\pi}) \in A_i^{\pi} := \Pi \times M_i^{\pi}$ for some message set M_i^{π}.

Thus, i being weakly partially honest at the realized grand state $\sigma^T = (\theta, \omega, \pi^*) \in \Sigma$ in mechanism $\mu^{\Sigma} \in \mathcal{M}^{\Sigma}$ implies if $g^{\Sigma}((\tilde{\sigma}, \tilde{m}_i), a_{-i}) R_i^{\omega} g^{\Sigma}(a'_i, a_{-i})$ for all $a'_i \in A_i^{\Sigma}$, and $g^{\Sigma}((\hat{\sigma}, \hat{m}_i), a_{-i}) R_i^{\omega} g^{\Sigma}(a''_i, a_{-i})$ for all $a''_i \in A_i^{\Sigma}$, then $((\tilde{\theta}, \tilde{\omega}, \pi^*), \tilde{m}_i) = (\pi^*, \tilde{\mathbf{m}}_i^{\pi}) \in BR_i^{\omega}(a_{-i})$ and $((\hat{\theta}, \hat{\omega}, \hat{\pi}), \hat{m}_i) = (\hat{\pi}, \hat{\mathbf{m}}_i^{\pi}) \notin BR_i^{\omega}(a_{-i})$ where $\tilde{\mathbf{m}}_i^{\pi} = (\tilde{\theta}, \tilde{\omega}, \tilde{m}_i)$ and $\hat{\mathbf{m}}_i^{\pi} = (\hat{\theta}, \hat{\omega}, \hat{m}_i)$; i.e., i is partially honest at the realized grand state $\sigma^T = (\theta, \omega, \pi^*) \in \Sigma$ in the particular implied mechanism $\mu^{\pi} = (A^{\pi}, g^{\pi}) \in \mathcal{M}^{\pi}$ with $\tilde{\mathbf{m}}_i^{\pi}, \hat{\mathbf{m}}_i^{\pi} \in \mathbf{M}_i^{\pi} = \Theta \times \Omega \times M_i$.

On the other hand, a sympathizer is defined for guidance mechanisms $\mathcal{M}^S$ consisting of $\mu^S = (A^S, g^S)$ where the individuals are to announce profiles of sets $\mathbf{S} \in \mathcal{S}$ and choose some messages, i.e., $A_i^S := \mathcal{S} \times M_i^S$ for some M_i^S. Below, we show that the definition of a weakly partially honest individual in mechanisms $\mu^{\Sigma} \in \mathcal{M}^{\Sigma}$ resembles our notion of a strong sympathizer in mechanisms $\mu^S \in \mathcal{M}^S$ which is defined as follows: Given an SCC $f : \Theta \to \mathcal{X}$ and $\mu^S \in \mathcal{M}^S$, $i \in N$ is a ***strong sympathizer*** of f at the realized state of the economy $\theta \in \Theta$ if for all $a_{-i} \in A_{-i}^S$,

(*i*) if $\mathbf{S} \in \mathcal{S}(f)$ and $\hat{\mathbf{S}} \notin \mathcal{S}(f)$, then for all $m_i, \hat{m}_i \in M_i^S$, we have $(\mathbf{S}, m_i) \in BR_i^{\omega}(a_{-i})$ and $(\hat{\mathbf{S}}, \hat{m}_i) \notin BR_i^{\pi^*(\theta)}(a_{-i})$ whenever we have $g^S((\mathbf{S}, m_i), a_{-i}) R_i^{\pi^*(\theta)} g^S(a'_i, a_{-i})$ for all $a'_i \in A_i^S$, and $g^S((\hat{\mathbf{S}}, \hat{m}_i), a_{-i}) R_i^{\pi^*(\theta)} g^S(a''_i, a_{-i})$ for all $a''_i \in A_i^S$; and

(*ii*) in all other cases, $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ if and only if $g^S(a_i, a_{-i}) R_i^{\pi^*(\theta)} g^S(a'_i, a_{-i})$ for all $a'_i \in A_i^S$.

However, if $i \in N$ is ***not a strong sympathizer*** of f at $\theta \in \Theta$, then $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ if and only if $g^S(a_i, a_{-i}) R_i^{\pi^*(\theta)} g^S(a'_i, a_{-i})$ for all $a'_i \in A_i^S$.

In words, if individual i is a strong sympathizer of the SCC f at the state of the economy θ, then he strictly prefers to announce a rational-consistent profile of sets $\mathbf{S} \in \mathcal{S}(f)$ and a message m_i as opposed to a profile of sets $\tilde{\mathbf{S}} \notin \mathcal{S}(f)$ that is not rational-consistent and another message $\hat{m}_i$ whenever both actions $(\mathbf{S}, m_i)$ and $(\tilde{\mathbf{S}}, \hat{m}_i)$ result in alternatives that are $R_i^{\pi^*(\theta)}$ optimal among those that he can attain via unilateral deviations. In essence, strong sympathy implies an inclination towards truthful revelation of a rational-consistent profile by placing no restriction on the rest of the messages in the guidance mechanism while sympathy insists also on the truthful revelation of a rational-consistent profile but demands the remaining messages to equal one another. That is why every strong sympathizer is a sympathizer yet a sympathizer does not have to be a strong sympathizer.

To associate sympathy and partial honesty, we fix the SCC $f : \Theta \to \mathcal{X}$ such that $\mathcal{S}(f) \neq \emptyset$, and consider a weakly partially honest individual i at the realized grand state $\sigma^T = (\theta, \omega, \pi^*)$ in a mechanism (involving announcements of grand states) $\mu^\Sigma \in \mathcal{M}^\Sigma$. As formalized above, i is inclined to announce only π^* truthfully. Thus, if we replace the announcement of an identification function $\pi \in \Pi$ by the announcement of a profile of sets $\mathbf{S} \in \mathcal{S}$, then a weakly partially honest individual i in $\mu^\Sigma \in \mathcal{M}^\Sigma$ at the realized grand state σ^T is akin to a strong sympathizer of f at the realized state of the economy θ in the associated $\mu^S \in \mathcal{M}^S$. Moreover, if the planner is informed of π^*, then she can construct the set of rational-consistent profiles $\mathcal{S}(f)$. But, she cannot identify π^* if she is informed of only an element $\mathbf{S}$ in $\mathcal{S}(f)$. That is why to implement a given SCC, the extent of information the planner seeks to elicit with the help of a sympathizer via a mechanism $\mu^S \in \mathcal{M}^S$ is 'less' than the extent of information the planner obtains thanks to a weakly partially honest individual in a mechanism $\mu^\Sigma \in \mathcal{M}^\Sigma$.

When detailed inquiries about payoff states are admissible, and the planner intends to implement a given SCC $f : \Theta \to \mathcal{X}$ by extracting the information about the relation between Θ and Ω with the help of a weakly partially honest individual via a mechanism involving the announcements of grand states, $\mu^\Sigma \in \mathcal{M}^\Sigma$, then the following necessary condition, a variation on Maskin monotonicity, emerges: We say that an SCC $f : \Theta \to \mathcal{X}$ is ***Maskin monotonic on*** Θ if $x \in f(\theta) \setminus f(\tilde{\theta})$ implies there is $j \in N$ such that $L_j^{\pi^*(\tilde{\theta})}(x) \nsubseteq L_j^{\pi^*(\theta)}(x)$, i.e., there is $y \in X$ such that $xR_j^{\pi^*(\theta)}y$ and $yP_i^{\pi^*(\tilde{\theta})}y$. Then, one can obtain the following sufficiency result using weak partial honesty: Suppose $n \geq 3$, and the planner knows that

(*i*) the environment is economic, and at every realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^*)$, there is a weakly partially honest individual at σ^T, and

(*ii*) the SCC $f : \Theta \to \mathcal{X}$ is Maskin monotonic on Θ.

Then, the planner infers that f is Nash* implementable by mechanism $\mu^\Sigma \in \mathcal{M}^\Sigma$, and for any realized grand state $\sigma^T = (\theta^T, \omega^T \pi^*)$, in any Nash* equilibrium $\bar{a} = ((\bar{\theta}^{(i)}, \bar{\omega}^{(i)}, \bar{\pi}^{(i)}), \bar{m}_i)_{i \in N}$ of mechanism μ^Σ at σ^T, we have $\bar{\pi}^{(i)} = \pi^*$ for all $i \in N$. As $\pi(\theta) = \omega$ for every $\sigma = (\theta, \omega, \pi) \in \Sigma$, the corresponding canonical mechanism $\mu^\Sigma \in \mathcal{M}^\Sigma$ establishing this result simplifies to the following: $A_i^\Sigma = \Theta \times \Pi \times X \times \mathbb{N}$ with $a_i = (\theta^{(i)}, \pi^{(i)}, x^{(i)}, k^{(i)})$ with $\theta^{(i)} \in \Theta$, $\pi^{(i)} \in \Pi$, $x^{(i)} \in X$, and $k^{(i)} \in \mathbb{N}$, where $g^\Sigma : A^\Sigma \to X$ is specified via the following rules:

Rule 1. If $a_i = (\theta, \pi, x, k)$ and $x \in f(\theta)$ for all $i \in N$, then $g^\Sigma(a) = x$; and

Rule 2. If $a_i = (\theta, \pi, x, k)$ with $x \in f(\theta)$ for all $i \in N \setminus \{j\}$ for some $j \in N$ and $a_j = (\theta', \pi', x', k')$, then $g^\Sigma(a)$ equals x' if $x' \in L_j^{\pi(\theta)}(x)$ and x otherwise.

Rule 3. For any action profile $a \in A^\Sigma$ that does not satisfy either of Rules 1 and 2, $g^\Sigma(a) = y^{(i^*)}$ where i^* is the winner of the integer game.

It is clear that for all realized grand states $\sigma^T = (\theta^T, \omega^T, \pi^*)$, and all $x \in f(\theta^T)$, $a^* \in A^\Sigma$ given by $a_i^* = (\theta^T, \pi^*, x, 1)$ for all $i \in N$ is a Nash* equilibrium of this mechanism at σ^T. To see $g^\Sigma(a^*) \in f(\theta^T)$, consider the following: First, if a^* is a Nash* equilibrium at the realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^*)$, then a^* cannot be under either of Rules 2 or 3 thanks to the economic environment assumption. Second, by letting a^* be a Nash* equilibrium at σ^T under Rule 1 and denoting it by $a_i^* = (\theta', \pi', x', k')$ for all $i \in N$ with $x' \in f(\theta')$, we see that $g^\Sigma(a^*) = x'$. Thus, if $\pi' \neq \pi^*$, then letting the weakly partially honest individual at the realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^*)$ be the first agent without a loss of generality, we note that $g^\Sigma(\tilde{a}_1, a_{-1}^*) = x'$ where $\tilde{a}_1 = (\theta', \pi^*, x', k')$ and hence $a_1^* \notin BR_1^{\pi^*(\theta^T)}(a_{-1}^*)$; implying a contradiction to a^* being a Nash* equilibrium at σ^T. Ergo, $\pi' = \pi^*$. The rest of the argument follows from Maskin monotonicity on Θ: If $g^\Sigma(a^*) = x' \notin f(\theta^T)$, then there is $j \in N$ and $y \in L_j^{\pi^*(\theta')}(x')$ such that $y P_j^{\pi^*(\theta^T)} x'$; a contradiction with a^* being Nash* at σ^T as $L_j^{\pi^*(\theta')}(x') = O_j^{\mu^\Sigma}(a_{-j}^*)$ by Rules 1 and 2.

Given the above result, the following natural question arises: Can a mechanism asking individuals only the realized state of the economy and its associated payoff state besides an alternative and an integer deliver the desired implementation result? Below, we show that the answer is negative with a weakly partially honest or sympathizing individual. To that regard, suppose that $n \geq 3$, and the planner knows that the environment is economic, and at every realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^*)$, there is a weakly partially honest individual (or a sympathizer of f) at σ^T, and the SCC $f : \Theta \to \mathcal{X}$ is Maskin monotonic on Θ (and hence $\mathcal{S}(f) \neq \emptyset$). Consider a mechanism μ as described above where $\mu = (A, g)$ with $A = \Theta \times \Omega \times X \times \mathbb{N}$ and $g : A \to \mathcal{X}$ is specified as follows:

Rule 1. If $a_i = (\theta, \omega, x, k)$ and $x \in f(\theta)$ for all $i \in N$, then $g(a) = x$; and

Rule 2. If $a_i = (\theta, \omega, x, k)$ with $x \in f(\theta)$ for all $i \in N \setminus \{j\}$ for some $j \in N$ and $a_j = (\theta', \omega', x', k')$, then $g(a)$ equals x' if $x' \in L_j^{\omega}(x)$ and x otherwise.

Rule 3. In all other cases, $g(a) = y^{(i^*)}$ where i^* is the winner of the integer game.

When analyzing bad Nash* equilibria at a realized grand state $\sigma^T = (\theta^T, \omega^T, \pi^*)$ of this mechanism, a certain case involves an action profile a^* under Rule 1 with $a_i^* = (\theta', \omega', x', k')$ for all $i \in N$ and $x' \in f(\theta')$. If $\pi^*(\theta') = \omega'$, then Maskin monotonicity on Θ implies that a^* cannot be a Nash* equilibrium at σ^T unless $g(a^*) = x' \in f(\theta^T)$. However, if $\pi^*(\theta') \neq \omega'$, $x' \notin f(\theta^T)$, and for all $i \in N$, $x' R_i^{\pi^*(\theta^T)} y$ for all $y \in L_i^{\omega'}(x')$ (as $L_i^{\omega'}(x') = O_i^{\mu}(a_{-i}^*)$ for all $i \in N$ due to Rules 1 and 2), then x' arises as a bad Nash* equilibrium outcome at σ^T. This is because, the weakly partially honest (or sympathizing) individual is not inclined to truthfully reveal the realized payoff state $\pi^*(\theta^T)$. For the elimination of this case, we need a partially honest individual at the realized grand state σ^T. However then, as discussed above on page 16, we know that a slight modification of Dutta and Sen (2012, Theorem 1) delivers a related conclusion without the need of Maskin monotonicity on Θ.

6 Inference of Rational-Consistency

Below, we present a way of ensuring the planner's inference of the existence of a rational-consistent profile of sets. It involves Maskin monotonicity: We say that a correspondence mapping Ω, payoff states, into 2^X, (possibly empty) subsets of alternatives, is an *extension of an SCC* $f : \Theta \to \mathcal{X}$ *to* Ω, denoted by $f_\Omega : \Omega \to 2^X$, if $f(\theta) = f_\Omega(\pi^*(\theta))$ for all $\theta \in \Theta$. Thus, f_Ω is non-empty-valued for all $\omega \in \pi^*(\Theta)$. Moreover, if the SCC $f : \Theta \to \mathcal{X}$ possesses an extension to Ω, then $f(\theta) \neq f(\theta')$ implies $\pi^*(\theta) \neq \pi^*(\theta')$, where $\theta, \theta' \in \Theta$. That is why there is no loss of generality to restrict attention to injective identification functions π^*.

The notion of Maskin monotonicity formulated for correspondences defined on Ω is as follows: A correspondence $\phi : \Omega \to 2^X$ is ***Maskin monotonic on*** Ω if $x \in \phi(\omega)$ and $L_i^{\omega}(x) \subseteq L_i^{\tilde{\omega}}(x)$ for all $i \in N$ implies $x \in \phi(\tilde{\omega})$, where $\omega, \tilde{\omega} \in \Omega$.[18]

The following result provides a sufficient condition for the planner's inference of the existence of a profile rational-consistent with a given SCC:

[18] For SCC defined on Ω, $\phi : \Omega \to \mathcal{X}$, the existence of a rational-consistent profile of sets with ϕ on Ω is equivalent to Maskin monotonicity of ϕ on Ω: For *sufficiency*, suppose that there is a profile of sets $\mathbf{S} = (S_i(x, \omega))_{i \in N,\ \omega \in \Omega,\ x \in \phi(\omega)}$ that is rational-consistent with ϕ and $x \in \phi(\omega)$ but $x \notin \phi(\tilde{\omega})$. Then, by (*ii*) of rational-consistency, there is $j \in N$ such that $S_j(x, \omega) \notin \mathbb{L}_j^{\tilde{\omega}}(x)$, i.e., $S_j(x, \omega) \in \mathcal{X}_x$ is not a subset of $L_j^{\tilde{\omega}}(x)$. But, by (*i*) of rational-consistency we observe that $S_j(x, \omega) \in \mathbb{L}_j^{\omega}(x)$ and hence $S_j(x, \omega)$ is a subset of $L_j^{\omega}(x)$ that contains x. Thus, we conclude that $j \in N$ is such that $L_j^{\omega} \nsubseteq L_j^{\tilde{\omega}}$, which establishes that f is Maskin monotonic on Ω. For *necessity*, suppose that ϕ is Maskin monotonic on Ω and let $\mathbf{S}$ be given by $S_i(x, \omega) = L_i^{\omega}(x)$ for all $i \in N$, all $\omega \in \Omega$, and all $x \in \phi(\omega)$. Then, (*i*) of rational-consistency is trivially satisfied. For (*ii*) of rational-consistency, suppose that $x \in \phi(\omega)$ and $x \notin \phi(\tilde{\omega})$ for some $\omega, \tilde{\omega} \in \Omega$. By Maskin monotonicity, there is $j \in N$ such that $L_j^{\omega}(x) \nsubseteq L_j^{\tilde{\omega}}(x)$. So, $L_j^{\omega}(x) = S_j(x, \omega)$ implies $S_j(x, \omega)$ is not in $\mathbb{L}_j^{\tilde{\omega}}(x)$.

Proposition 1. *If the planner knows that SCC $f : \Theta \to \mathcal{X}$ has a Maskin monotonic extension to Ω even if she does not know the full specification of this extension, she infers that $\mathcal{S}(f)$ is non-empty without necessarily knowing the specification of sets that appear in $\mathcal{S}(f)$.*

Proposition 1 establishes the following: Suppose that the planner knows that $f : \Theta \to \mathcal{X}$ has a Maskin monotonic extension to Ω, $f_\Omega : \Omega \to 2^X$, while she does not know its full specification. She knows only $f_\Omega(\pi^*(\theta))$ which equals $f(\theta)$ while she does not know $\pi^*(\theta)$. Thus, she is completely ignorant of the shape of f_Ω on $\Omega \setminus \pi^*(\Theta)$. Still, the planner figures out that $\mathbf{L}^{\pi^*(\Theta)} := (L_i^\omega(x))_{i\in N,\ \omega\in\pi^*(\Theta),\ x\in f_\Omega(\omega)}$ is a rational-consistent profile with $f_\Omega|_{\pi^*(\Theta)} = f$, without knowing the full specifications of (i) the identification function $\pi^* : \Theta \to \Omega$, (ii) the lower contour sets that appear in $\mathbf{L}^{\pi^*(\Theta)}$, and (iii) the Maskin monotonic extension f_Ω.[19]

As a result, the information the planner infers from knowing that SCC $f : \Theta \to \mathcal{X}$ has a Maskin monotonic extension to Ω, the specification of which she does not know, does not suffice to construct the standard canonical mechanisms employed in Maskin (1999), Moore and Repullo (1990), Dutta and Sen (1991), and de Clippel (2014). That is because the planner does not necessarily know individuals' lower contour sets, which, in these mechanisms, are equal to their opportunity sets for cases when all individuals announce the same state and alternative.[20]

7 Concluding Remarks

We consider full implementation under complete information with the additional feature that the planner does not know individuals' underlying state-contingent choices. Our main result is that if there are at least three individuals and the planner knows that the environment is economic, satisfies the sympathizer property, and there is a rational-consistent profile of sets with the given SCC, then she infers the following: This SCC is implementable by a guidance mechanism under Nash* equilibrium by eliciting the information concerning rational-consistency from the society. Moreover, in every Nash* equilibrium, all individuals announce the same profile that is rational-consistent with the given SCC.

[19] Proposition 2 offers an extension of this result to the behavioral domain using consistency of de Clippel (2014).

[20] If the planner were to know that the environment is economic, the full specification of a correspondence $f_\Omega : \Omega \to 2^X$, f_Ω is a Maskin monotonic extension of $f : \Theta \to \mathcal{X}$ to Ω, and that inquiring about the payoff states is admissible, then she can construct a variant of the canonical mechanism using her knowledge about $(L_i^\omega(x))_{i\in N,\ \omega\in\Omega,\ x\in f_\Omega(\omega)}$. Then, she infers that this mechanism, $\mu^* = (A^*, g^*)$, Nash implements f_Ω and hence $f = f_\Omega\mid_{\pi^*(\Theta)}$ (since she knows $\pi^*(\Theta) \subset \Omega$ even though she does not know the exact form of π^*): $A_i^* := X \times X \times \Theta \times \Omega \times \mathbb{N}$ where each $a_i = (x^{(i)}, y^{(i)}, \theta^{(i)}, \omega^{(i)}, k^{(i)}) \in A_i^*$ obeys the requirement that $x^{(i)} \in f(\theta^{(i)}) \cap f_\Omega(\omega^{(i)})$, $y^{(i)} \in X$, $\theta^{(i)} \in \Theta$, $\omega^{(i)} \in \Omega$, and $k^{(i)} \in \mathbb{N}$. The outcome function $g^* : A^* \to X$ is as follows: Rule 1: $g^*(a) = x$ if $a_i = (x, y, \theta, \omega, \cdot)$ for all $i \in N$; Rule 2: $g^*(a)$ equals y' if $y' \in L_j^\omega(x)$ and x otherwise, whenever $a_i = (x, y, \theta, \omega, \cdot)$ for all $i \in N \setminus \{j\}$ and $a_j = (x', y', \theta', \omega', \cdot) \neq (x, y, \theta, \omega, \cdot)$; Rule 3: $g^*(a) = x^{(i^*)}$ where $i^* = \min\{j \in N : k^{(j)} \geq \max_{i'\in N} k^{(i')}\}$.

Appendix

A A Behavioral Formulation

To facilitate extended exposition, we present a behavioral formulation of our setting that allows (but does not insist on) violations of WARP. We restate and prove our results with this formulation that encompasses the rational domain.

The *(individual) choice* of agent $i \in N$ at a feasible payoff state $\omega \in \Omega$ is captured by the choice correspondence $C_i^\omega : \mathcal{X} \to \mathcal{X}$ with the requirement that for any $S \in \mathcal{X}$, $C_i^\omega(S) \subset S$. Given alternative $x \in X$, individual $i \in N$, and payoff state $\omega \in \Omega$, we refer to a set $S \in \mathcal{X}$ with $x \in C_i^\omega(S)$ as a *choice set* of individual i at payoff state ω for alternative x. The societal choice topography on Ω is given by the profile of individual choice correspondences $C(\Omega) := (C_i^\omega(S))_{i\in N,\ \omega\in\Omega,\ S\in\mathcal{X}}$.[21]

Given a mechanism $\mu \in \mathcal{M}$, $a^* \in A$ constitutes a ***behavioral Nash equilibrium*** of μ at a payoff state $\omega \in \Omega$ if $g(a^*) \in \cap_{i\in N} C_i^\omega(O_i^\mu(a_{-i}^*))$. Then, ***behavioral Nash implementability*** is: an SCC $f : \Theta \to \mathcal{X}$ is implementable by a mechanism $\mu \in \mathcal{M}$ in behavioral Nash equilibrium if (i) for any $\theta \in \Theta$ and $x \in f(\theta)$, there is $a^x \in A$ such that $g(a^x) = x$ and $x \in \cap_{i\in N} C_i^{\pi^*(\theta)}(O_i^\mu(a_{-i}^x))$; and (ii) for any $\theta \in \Theta$, $a^* \in A$ with $g(a^*) \in \cap_{i\in N} C_i^{\pi^*(\theta)}(O_i^\mu(a_{-i}^*))$ implies $g(a^*) \in f(\theta)$.

If an SCC $f : \Theta \to \mathcal{X}$ is implementable by a mechanism $\mu \in \mathcal{M}$ in behavioral Nash equilibrium, we define the profile of sets sustained by μ as follows: $\mathbf{S}^\mu := (S_i^\mu(x,\theta))_{i\in N,\ \theta\in\Theta,\ x\in f(\theta)}$ with $S_i^\mu(x,\theta) := O_i^\mu(a_{-i}^x)$ for any $i \in N$, $\theta \in \Theta$, and $x \in f(\theta)$ while $a^x \in A$ is such that $g(a^x) = x$ and $g(a^x) \in C_i^{\pi^*(\theta)}(O_i^\mu(a_{-i}^x))$ for all $i \in N$. Then, the necessity result of de Clippel (2014) tells us that if f is behavioral Nash implementable by a mechanism $\mu \in \mathcal{M}$, then $\mathbf{S}^\mu$ is a profile consistent with f:

Definition 5. *Given SCC $f : \Theta \to \mathcal{X}$, a profile $\mathbf{S} := (S_i(x,\theta))_{i\in N,\ \theta\in\Theta,\ x\in f(\theta)}$ is* **consistent** *with $f : \Theta \to \mathcal{X}$ if*

(i) *for all $\theta \in \Theta$ and all $x \in f(\theta)$, $x \in \cap_{i\in N} C_i^{\pi^*(\theta)}(S_i(x,\theta))$; and*

(ii) *$x \in f(\theta)$ and $x \notin f(\theta')$ for some $\theta, \theta' \in \Theta$ implies $x \notin \cap_{i\in N} C_i^{\pi^*(\theta')}(S_i(x,\theta))$.*

$\mathcal{S}(f)$ denotes the set of all profiles of sets that are consistent with f.

Under WARP, rational-consistency and consistency are equivalent.[22] Moreover, using de Clippel's necessity result and following similar arguments leading to Theorem 1, enable us to conclude

[21] This setting encompasses the rational domain: Under rationality, every individual's choice correspondence satisfies WARP at every feasible payoff state. So, for any given $i \in N$ and $\omega \in \Omega$, there exists a complete and transitive binary preference relation $R_i^\omega \subseteq X \times X$ such that for any $x, y \in X$, $xR_i^\omega y$ if and only if $x \in C_i^\omega(\{x,y\})$. Therefore, for any given $i \in N$ and $\omega \in \Omega$ and $S \in \mathcal{X}$, $C_i^\omega(S) = \{x^* \in S \mid x^* R_i^\omega y,\ \text{for all } y \in S\}$.

[22] In words, a profile of sets $\mathbf{S}$ is consistent with a given SCC $f : \Theta \to \mathcal{X}$, if (i) the set $S_i(x,\theta)$ is a choice set of alternative x by individual i at payoff state $\pi^*(\theta)$ for all $i \in N$, all $\theta \in \Theta$, and all $x \in f(\theta)$; and (ii) if x is f-optimal at θ but not at θ' for some $\theta, \theta' \in \Theta$, then there exists $j \in N$ such that x is not chosen from $S_j(x,\theta)$ by j at $\pi^*(\theta')$.

the following: If the planner knows that f is behavioral Nash implementable, then she infers that $\mathcal{S}(f) \neq \emptyset$ without necessarily knowing the full specification of sets that appear in $\mathcal{S}(f)$.

Now, we extend the notion of sympathy to the behavioral domain: For any $f : \Theta \to \mathcal{X}$, any $\mu \in \mathcal{M}^S$, and any $\omega \in \Omega$, the correspondence $BR_i^{\omega} : A_{-i} \twoheadrightarrow A_i$ constitutes i's behavioral best responses at ω given others' messages. If i is a standard economic agent, *not a sympathizer* of f at $\theta \in \Theta$, then for all $a_{-i} \in A_{-i}$, $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ if and only if $g(a_i, a_{-i}) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}))$. For sympathizers, the following holds:

Definition 6. *Given an SCC $f : \Theta \to \mathcal{X}$ and a guidance mechanism $\mu \in \mathcal{M}^S$, individual $i \in N$ is a*

1. **behavioral sympathizer** *of f at $\theta \in \Theta$ if for all $a_{-i} \in A_{-i}$,*
   - (i) *$g((\mathbf{S}^{(i)}, m_i), a_{-i}), g((\tilde{\mathbf{S}}^{(i)}, m_i), a_{-i}) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}))$ with $\mathbf{S}^{(i)} \in \mathcal{S}(f)$, $\tilde{\mathbf{S}}^{(i)} \in \mathcal{S} \setminus \mathcal{S}(f)$, and $m_i \in M_i$ implies $(\mathbf{S}^{(i)}, m_i) \in BR_i^{\pi^*(\theta)}(a_{-i})$ and $(\tilde{\mathbf{S}}^{(i)}, m_i) \notin BR_i^{\pi^*(\theta)}(a_{-i})$; and*
   - (ii) *in all other cases, $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ if and only if $g(a_i, a_{-i}) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}))$.*
2. **strong behavioral sympathizer** *of f at $\theta \in \Theta$ if for all $a_{-i} \in A_{-i}$,*
   - (i) *$g((\mathbf{S}^{(i)}, m_i), a_{-i}), g((\tilde{\mathbf{S}}^{(i)}, \tilde{m}_i), a_{-i}) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}))$ with $\mathbf{S}^{(i)} \in \mathcal{S}(f)$, $\tilde{\mathbf{S}}^{(i)} \in \mathcal{S} \setminus \mathcal{S}(f)$, and $m_i, \tilde{m}_i \in M_i$ implies $(\mathbf{S}^{(i)}, m_i) \in BR_i^{\pi^*(\theta)}(a_{-i})$ and $(\tilde{\mathbf{S}}^{(i)}, \tilde{m}_i) \notin BR_i^{\pi^*(\theta)}(a_{-i})$; and*
   - (ii) *in all other cases, $a_i \in BR_i^{\pi^*(\theta)}(a_{-i})$ if and only if $g(a_i, a_{-i}) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}))$.*

The environment satisfies the behavioral sympathizer property *(*strong behavioral sympathizer property*) with respect to SCC f if for all $\theta \in \Theta$, there is at least* one *behavioral sympathizer (at least* two *strong behavioral sympathizers, resp.) of f at θ, while the identity of each behavioral sympathizer (strong behavioral sympathizer, resp.) of f at θ is privately known only by himself.*

An immediate consequence of this definition is that given an SCC f, every strong behavioral sympathizer of f at θ is a behavioral sympathizer of f at θ.[23]

The notion of behavioral Nash* implementation is obtained by modifying Definition 3 using the behavioral best response correspondences specified in Definition 6.

Some of our results adopt the following assumptions:

[23]The first part of Definition 6 says the following: Given an SCC f, guidance mechanism μ, any one of others' actions a_{-i}, and any state of the economy $\theta \in \Theta$, a behavioral sympathizer i of f at θ chooses to announce a consistent profile of sets $\mathbf{S}^{(i)}$ as well as a message profile m_i; he does not choose to announce an inconsistent profile $\tilde{\mathbf{S}}^{(i)}$ and to select the same message profile m_i whenever both action profiles, $(\mathbf{S}^{(i)}, m_i)$ and $(\tilde{\mathbf{S}}^{(i)}, m_i)$, lead to alternatives which are among those chosen by individual i at $\pi^*(\theta)$ from his opportunity set corresponding to others' behavior a_{-i} (namely, $O_i^{\mu}(a_{-i})$). On the other hand, the second part of Definition 6 demands the following: A strong behavioral sympathizer i of f at θ chooses to announce a consistent profile of sets $\mathbf{S}^{(i)}$ while selecting a message profile m_i; he does not choose to announce an inconsistent profile $\tilde{\mathbf{S}}^{(i)}$ coupled with selecting some other message profile $\tilde{m}_i$ whenever both action profiles, $(\mathbf{S}^{(i)}, m_i)$ and $(\tilde{\mathbf{S}}^{(i)}, \tilde{m}_i)$, result in alternatives that are among the chosen by i at $\pi^*(\theta)$ from $O_i^{\mu}(a_{-i})$.

Definition 7. *We say that*

(i) *the environment features* **societal non-satiation** *if for any payoff state* $\omega \in \Omega$ *and any alternative* $x \in X$*, there is an individual* $i \in N$ *such that* $x \notin C_i^{\omega}(X)$*.*

(ii) *the* **behavioral economic environment** *assumption holds if for any payoff state* $\omega \in \Omega$ *and any alternative* $x \in X$*, there are two agents* $i, j \in N$ *with* $i \neq j$ *such that* $x \notin C_i^{\omega}(X) \cup C_j^{\omega}(X)$*.*

(iii) *an SCC* $f : \Theta \to \mathcal{X}$ *satisfies the* **behavioral no-veto property** *if for any state of the economy* $\theta \in \Theta$*,* $x \in \cap_{i \in N \setminus \{j\}} C_i^{\pi^*(\theta)}(X)$ *for some* $j \in N$ *implies* $x \in f(\theta)$*.*

We note that the behavioral economic environment assumption implies societal non-satiation. Moreover, the behavioral no-veto property vacuously holds in behavioral economic environments.[24]

The following is the behavioral counterpart of our main result which is equivalent to Theorem 2 under WARP:

Theorem 3. *Suppose* $n \geq 3$*, and that the planner knows that*

(i) *the environment is behavioral economic, it satisfies the behavioral sympathizer property, and*

(ii) *the SCC* $f : \Theta \to \mathcal{X}$ *is such that* $\mathcal{S}(f) \neq \emptyset$*, while she does not necessarily know the full specification of the sets that appear in* $\mathcal{S}(f)$*.*

Then, the planner infers that f *is behavioral Nash** *implementable by a guidance mechanism* $\mu \in \mathcal{M}^S$*, and for any state of the economy* $\theta \in \Theta$ *and any behavioral Nash** *equilibrium* $\bar{a} = (\bar{\mathbf{S}}^{(i)}, \bar{m}_i)_{i \in N}$ *of mechanism* μ *at payoff state* $\pi^*(\theta)$*,* $\bar{\mathbf{S}}^{(i)} = \mathbf{S} \in \mathcal{S}(f)$ *for all* $i \in N$*.*

We wish to emphasize that under WARP, behavioral Nash equilibrium is equivalent to Nash equilibrium, behavioral Nash* equilibrium to Nash* equilibrium, and the corresponding implementation notions are equivalent. Also, consistency is equivalent to rational-consistency, a behavioral sympathizer to a sympathizer (while we refer to a strong behavioral sympathizer as a strong sympathizer), the behavioral no-veto property, and behavioral economic environment assumption to their rational versions, respectively. When the meaning is clear, we refer to these behavioral notions without spelling out the 'behavioral' label.

[24] Societal non-satiation requires that for any given payoff state, all individuals do not choose the same alternative from the set of all alternatives at that payoff state. The behavioral economic environment assumption demands that for every payoff state and alternative, there are two agents not choosing that alternative from the set of all alternatives at that payoff state. The behavioral no-veto property demands that if an alternative is chosen from the set of all alternatives at a payoff state by every individual but one, then that alternative has to be f-optimal at the corresponding state of the economy. This notion ignores the welfare of the agent who does not agree with the rest of the society. Benoit and Ok (2006) and Barlo and Dalkiran (2009) obtain implementation results with *limited-veto-power*, a weaker condition than the no-veto property.

B Noneconomic Environments

We extend our analysis to noneconomic environments by using the same mechanism specified on Table 2. We note that the economic environment assumption dispenses with the Nash* equilibria that may arise under Rules 2 and 3 as well as some that may emerge under Rule 1. Equilibria that arise under Rule 3 are not desirable because, in such equilibria, all individuals apart from the sympathizers do not need to announce a consistent profile of sets. As a result, the relevant information about the societal choice topography cannot be extracted in equilibrium from these individuals. Fortunately, societal non-satiation is sufficiently strong to rule out such equilibria.

If we adopt societal non-satiation along with the no-veto property, then we allow for some additional equilibria under Rules 1 and 2. Then, for any payoff state, we need *at least two strong sympathizers*. This is because our mechanism is such that when we deal with an equilibrium at a payoff state under Rules 1 or 2 in which all but one individual announce the same profile of sets while the odd-man-out is announcing a different profile, by changing his announcement concerning the profile, each agent different from the odd-man-out can trigger Rule 3, and hence, obtain any alternative he desires by also changing his integer choice. Because we need the equilibrium announcement of the profile of sets by all but the odd-man-out to be consistent with the social goal, we have to make sure that there is a strong sympathizer among those announcing the same profile; sympathy does not suffice as this agent also needs to change his integer choice.[25]

Another interesting consequence of the additional equilibria that emerge under Rules 1 and 2 is that, now, all but one agent announce the same consistent profile.

Our second sufficiency result also provides a robustness check for Theorems 2 and 3:

Theorem 4. *Let $n \geq 3$ and the SCC $f : \Theta \to \mathcal{X}$ be given. Suppose that*

(i) *the planner knows that the environment features societal non-satiation and satisfies the strong sympathizer property, and*

(ii) *without necessarily knowing the full specification of sets that appear in $\mathcal{S}(f)$, the planner knows that $\mathcal{S}(f) \neq \emptyset$ and that f satisfies the no-veto property.*

[25]The need to have an additional partially honest agent does not appear in Dutta and Sen (2012). They work in the rational domain with an informed planner (knowing the identification function $\pi^* : \Theta \to \Omega$) and assume that a *partially honest* agent strictly prefers to reveal the payoff state truthfully when he is indifferent. To see why they do not need an additional partially honest individual, consider the canonical mechanism without the announcement of a profile of choice sets and a Nash equilibrium in which the rule that implies the opportunity sets of all but one individual, i^*, equals X. Then, they do not need to guarantee that one of those individuals $i \neq i^*$ (different from the odd-man-out i^*) is partially honest as the no-veto property delivers the desired conclusion. However, no-veto does not help in our case, and we need to ensure that one of those individuals $i \neq i^*$ is a sympathizer and hence announces a consistent profile.

Then, the planner infers that f is Nash* implementable by a guidance mechanism $\mu \in \mathcal{M}^S$, and for any state of the economy $\theta \in \Theta$ and any Nash* equilibrium $\bar{a} = (\bar{\mathbf{S}}^{(i)}, \bar{m}_i)_{i \in N}$ of mechanism μ at payoff state $\pi^*(\theta)$, $\bar{\mathbf{S}}^{(i)} = \mathbf{S} \in \mathcal{S}(f)$ for all $i \in N \setminus \{j\}$ for some $j \in N$.

Theorem 4 justifies that noneconomic environments impose more knowledge requirements on the planner seeking to elicit information about consistency from the society. Indeed, the knowledge of the existence (but not necessarily the full specification) of a consistent profile no longer suffices even with the help of two strong sympathizers. The hypothesis of Theorem 4 includes the assumption that the planner knows that the SCC satisfies the no-veto property, a piece of information that the planner cannot verify herself since she does not know $\pi^* : \Theta \to \Omega$ and hence individuals' state-contingent choices.

Using arguments leading to Proposition 1, the following result, presented without proof, establishes that the planner infers (*ii*) of Theorem 4 if she knows the following: f has an extension to Ω, f_Ω, the full specification of which the planner does not know, that satisfies the no-veto property and possesses a consistent profile.

Proposition 2. *Suppose that the planner knows that SCC $f : \Theta \to \mathcal{X}$ has an extension $f_\Omega : \Omega \to 2^X$ that possesses a consistent profile of sets and satisfies the no-veto property, while she does not know the full specification of f_Ω. Then, she infers that f satisfies the no-veto property and $\mathcal{S}(f)$ is nonempty without necessarily knowing the specification of sets that appear in $\mathcal{S}(f)$.*

C Proofs

C.1 Proof of Theorem 2 and 3

We prove Theorem 3 for extended applicability as Theorems 2 and 3 are equivalent under WARP. The proof is constructive and employs the mechanism specified on Table 2 and is presented via two claims. The first establishes that the planner infers (*i*) of Nash* implementation holds, while the second delivers her inference of (*ii*) of Nash* implementation.

Claim 1. *Even if the planner does not know $\mathcal{S}(f)$ and the realized payoff state $\pi^*(\theta)$, she makes the following deduction for all $\theta \in \Theta$ and for all $x \in f(\theta)$: If $a^x \in A$ were $a_i^x = (\mathbf{S}, \theta, x, 1)$ for some $\mathbf{S} \in \mathcal{S}(f)$, for all $i \in N$, then a^x would be a Nash* equilibrium of μ at $\pi^*(\theta)$ (i.e., $a_i^x \in BR_i^{\pi^*(\theta)}(a_{-i}^x)$ for all $i \in N$) and $g(a^x) = x$.*

Proof. The planner does not know $\mathcal{S}(f)$, the realized state of the economy θ, and the association $\pi^* : \Theta \to \Omega$. But still, she deduces that if the individuals were to use this action profile, then Rule 1 would apply and $g(a^x) = x$. As she contemplates on agents choosing such that $\mathbf{S}^{(i)} = \mathbf{S} \in \mathcal{S}(f)$ for all $i \in N$, she infers that individual deviations can only result in Rules 1 and 2. Hence, she deduces that $O_i^{\mu}(a_{-i}^x) = S_i(x, \theta)$ where $S_i(x, \theta) = \mathbf{S}|_{i,\theta,x \in f(\theta)}$ due to the definition of the mechanism as she is informed of $\mathbf{S}$ by the society on account of observing a^x. Thus, she infers that if i were not a sympathizer of f at θ, then, by (i) of consistency, $x \in C_i^{\pi^*(\theta)}(S_i(x, \theta))$, which is equivalent to $a_i^x \in BR_i^{\pi^*(\theta)}(a_{-i}^x)$. This is a deduction she makes without knowing $\pi^*(\theta)$. She also deduces that if i were a sympathizer of f at θ, then $\mathbf{S} \in \mathcal{S}(f)$ and $x \in C_i^{\pi^*(\theta)}(S_i(x, \theta))$ (which she infers due to (i) of consistency without knowing $\pi^*(\theta)$) would imply $a_i^x \in BR_i^{\pi^*(\theta)}(a_{-i}^x)$. ■

Claim 2. *Even if the planner does not know $\mathcal{S}(f)$ and the realized payoff state $\pi^*(\theta)$, she makes the following deduction for all $\theta \in \Theta$: If $a^* \in A$ were a Nash* equilibrium of $\mu \in \mathcal{M}^S$ at $\pi^*(\theta)$ for some $\theta \in \Theta$, then $g(a^*)$ would be in $f(\theta)$.*

Proof. The planner knows that contemplating a Nash* equilibrium a^* at $\pi^*(\theta)$ for some θ under Rule 1 such that $a_i^* = (\mathbf{S}', \theta', x', k')$ with $x' \in f(\theta')$, and $a_i^* \in BR_i^{\pi^*(\theta)}(a_{-i}^*)$ for all $i \in N$ implies that, as Rule 1 holds, $g(a^*) = x'$ and $O_i^{\mu}(a_{-i}^*) = S_i(x', \theta') = \mathbf{S}'|_{i,\theta',x' \in f(\theta')}$ for all $i \in N$ due to Rules 1 and 2.

Then, the planner deduces that $\mathbf{S}' \in \mathcal{S}(f)$, or else individual i, the sympathizer of f at θ who she knows exists, has a profitable deviation: i could deviate to $a_i' = (\mathbf{S}'', m_i^*, a_{-i}^*)$ with $\mathbf{S}'' \in \mathcal{S}(f)$ and $m_i^* = (\theta', x', k')$ implies $g(\mathbf{S}'', m_i^*, a_{-i}^*) = g(a^*) = x' \in C_i^{\pi^*(\theta)}(S_i(x', \theta'))$ (due to $a_i^* \in BR_i^{\pi^*(\theta)}(a_{-i}^*)$ implying $x' = g(a^*) \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}^*))$ and $O_i^{\mu}(a_{-i}^*) = S_i(x', \theta')$—inferences the planner makes without knowing $\pi^*(\theta)$ but by contemplating such a Nash* equilibrium at $\pi^*(\theta)$). So, she deduces that $(\mathbf{S}'', m_i^*) \in BR_i^{\pi^*(\theta)}(a_{-i}^*)$ and $(\mathbf{S}', m_i^*) \notin BR_i^{\pi^*(\theta)}(a_{-i}^*)$, which constitutes a contradiction to a^* being a Nash* equilibrium at $\pi^*(\theta)$.

Next, the planner infers that $x' \notin f(\theta)$ leads to an impasse: She deduces that if $x' \in f(\theta')$, $x' \notin f(\theta)$, and $\mathbf{S}' \in \mathcal{S}(f)$, then there is $j \in N$ (whose identity the planner does not know) such that $x' \notin C_j^{\pi^*(\theta)}(S_j(x', \theta'))$. Recall that she knows $O_j^{\mu}(a_{-j}^*) = S_j(x', \theta')$. So, she infers $x' \notin C_j^{\pi^*(\theta)}(S_j(x', \theta'))$ implies $a_j^* \notin BR_j^{\pi^*(\theta)}(a_{-j}^*)$ and hence a^* cannot be a Nash* at $\pi^*(\theta)$, which delivers a contradiction.

Another type of Nash* equilibrium a^* at $\pi^*(\theta)$ under Rule 1 the planner needs to consider is one where there exists an individual i' such that $a_{i'}^* = (\mathbf{S}'', \theta', x', k')$ whereas $a_i^* = (\mathbf{S}', \theta', x', k')$ for all $i \in N \setminus \{i'\}$ with $\mathbf{S}' \neq \mathbf{S}''$. Then she figures out that, by Rules 1 and 3, $O_i^{\mu}(a_{-i}^*) = X$ for all $i \in N \setminus \{i'\}$ as any one of $i \neq i'$ could deviate to $a_i = (\mathbf{S}, \theta', y, k)$ with $\mathbf{S} \neq \mathbf{S}'$, $y \in X$ and $k > k'$. Since a^* is a Nash* equilibrium at $\pi^*(\theta)$, she deduces that $g(a^*) \in C_i^{\pi^*(\theta)}(X)$ for all $i \neq i'$ which she knows is a contradiction to the environment being economic.

The planner also makes the deduction that there cannot be a Nash* equilibrium under Rules 2 or 3: If there were such a Nash* equilibrium $\bar{a} \in A$, then, thanks to the definition of the mechanism, she infers that $O_i^{\mu}(\bar{a}_{-i}) = X$ for all $i \in N \setminus \{j\}$ for some $j \in N$. By her hypothesis that $\bar{a}$ is Nash* under either Rules 2 or 3, she figures out that $\bar{a}_\ell \in BR_\ell^{\pi^*(\theta)}(\bar{a}_{-\ell})$ for all $\ell \in N$ implies $g(\bar{a}) \in \cap_{i \in N \setminus \{j\}} C_i^{\pi^*(\theta)}(X)$. She knows that this is not possible due to the economic environment assumption. ■

C.2 Proof of Proposition 1

Suppose that the planner knows that an SCC $f : \Theta \to X$ possesses a Maskin monotonic extension $f_\Omega : \Omega \to 2^X$, but she does not know its full specification. Still, she infers that $\mathbf{S}$ given by $S_i(x,\theta) = L_i^{\pi^*(\theta)}(x)$ for all $i \in N$, all $\theta \in \Theta$, and all $x \in f(\theta)$ must be so that (*i*) of rational-consistency holds trivially (even though she knows neither $\pi^*(\theta)$ nor $L_i^{\pi^*(\theta)}(x)$ while she infers that $f_\Omega(\pi^*(\theta))$ equals $f(\theta)$). For her inference of (*ii*) of rational-consistency, suppose that she knows $x \in f(\theta)$ and $x \notin f(\tilde{\theta})$ for some $\theta, \tilde{\theta} \in \Theta$. As she knows that $f(\theta) = f_\Omega(\pi^*(\theta))$ and $f(\tilde{\theta}) = f_\Omega(\pi^*(\tilde{\theta}))$ and f_Ω is Maskin monotonic, she infers that (even though she does not know $\pi^*(\theta)$ and $\pi^*(\tilde{\theta})$) it must be that there exists $j \in N$ such that $L_j^{\pi^*(\theta)}(x) \nsubseteq L_j^{\pi^*(\tilde{\theta})}(x)$, and hence $L_j^{\pi^*(\theta)}(x) = S_j(x,\theta)$ delivers the desired conclusion of her inference of $S_j(x,\theta) \notin \mathbb{L}_j^{\pi^*(\tilde{\theta})}(x)$.

C.3 Proof of Theorem 4

Instead of using the no-veto property, we prove our second sufficiency theorem with a weaker condition, (*ii*′) stated below. Combining it with societal non-satiation and consistency delivers a condition akin to condition μ of Moore and Repullo (1990), condition λ of Korpela (2012)), and strong consistency of de Clippel (2014).

(*ii*′) without necessarily knowing the full specification of sets that appear in $\mathcal{S}(f)$, the planner knows that $\mathcal{S}(f) \neq \emptyset$ and the following hold:

For any $\theta \in \Theta$, for any $\mathbf{S} \in \mathcal{S}(f)$, $x \in C_j^{\pi^*(\theta)}(S_j(x',\theta'))$ where $j \in N$, $\theta' \in \Theta$, $x' \in f(\theta')$, $S_j(x',\theta') = \mathbf{S}|_{j,\theta',x' \in f(\theta')}$, and $x \in C_i^{\pi^*(\theta)}(X)$ for all $i \in N \setminus \{j\}$ implies $x \in f(\theta)$.

We note that (*ii*) of Theorem 4 implies (*ii*′) above.

The proof employs mechanism μ used in the proof of Theorem 2 (involving rules specified in Table 2). Moreover, every strong sympathizer of f at θ is a sympathizer of f at θ. Thus, the proof of Claim 1 can be used without any modifications to establish that for all $\theta \in \Theta$ and for all $x \in f(\theta)$, the planner infers the following: if every individual were to play $(\mathbf{S}, \theta, x, 1)$ for some $\mathbf{S} \in \mathcal{S}(f)$ (even if the planner does not know $\mathcal{S}(f)$ and the function π^*), then this action profile would be Nash* at $\pi^*(\theta)$ and $g(a^x) = x$. Therefore, what remains to be shown is:

Claim 3. *Even if the planner does not know $\mathcal{S}(f)$ and the realized payoff state $\pi^*(\theta)$, she makes the following deduction for all $\theta \in \Theta$: If $a^* \in A$ were a Nash* equilibrium of $\mu \in \mathcal{M}^S$ at $\pi^*(\theta)$ for some $\theta \in \Theta$, then $g(a^*)$ would be in $f(\theta)$.*

Proof. The proof of the claim involves the analysis of three cases.

Case 1. *The planner contemplates the situation where $a^* \in A$ be a Nash* equilibrium at $\pi^*(\theta)$ for some $\theta \in \Theta$ such that Rule 1 holds: $a_i^* = (\mathbf{S}^{(i)}, \theta', x', k')$ for all $i \in N$ with $\mathbf{S}^{(i')} = \mathbf{S}$ for all $i' \neq j$ for some $j \in N$ and $x' \in f(\theta')$. Then, she infers that $g(a^*) = x'$.*

Proof of Claim 3 under Case 1. First, we prove that the planner deduces that $\mathbf{S} \in \mathcal{S}(f)$. Therefore, in all Nash* equilibria under Case 1, she infers that all but one player announce the same profile of sets that must be among the consistent profiles of sets with the SCC f.

If the planner considers $\mathbf{S}^{(j)} = \mathbf{S}$, then letting the first player be one of the strong sympathizers of f at θ without a loss of generality, the planner infers the following: If $\mathbf{S} \notin \mathcal{S}(f)$, then deviating to $\bar{a}_1 = (\bar{\mathbf{S}}, \theta', x', k')$ with $\bar{\mathbf{S}} \in \mathcal{S}(f)$ results in $g(\bar{\mathbf{S}}, m_1^*, a_{-1}^*) = g(\mathbf{S}, m_1^*, a_{-1}^*) = x'$ (due to Rule 1) and $x' \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}^*))$ for all $i \in N$ (since a^* is a Nash* equilibrium at $\pi^*(\theta)$) where $m_1^* = (\theta', x', k')$; thus, $a_1^* \notin BR_1^{\pi^*(\theta)}(a_{-1}^*)$, a contradiction to a^* being Nash* at $\pi^*(\theta)$.

If the planner contemplates on $\mathbf{S}^{(j)} \neq \mathbf{S}$, $\mathbf{S} \notin \mathcal{S}(f)$, j not being a strong sympathizer of f at θ while one of the strong sympathizers of f at θ being the first player, then she infers the following: Agent 1 deviating to $\bar{a}_1 = (\bar{\mathbf{S}}, \theta', x', \bar{k})$ with $\bar{\mathbf{S}} \in \mathcal{S}(f)$ and $\bar{k} > k'$ results in $g(\bar{\mathbf{S}}, \bar{m}_1, a_{-1}^*) = g(\mathbf{S}, m_1^*, a_{-1}^*) = x'$ (due to Rules 1 and 3) and $x' \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}^*))$ for all $i \in N$ (since a^* is a Nash* equilibrium at $\pi^*(\theta)$) where $m_1^* = (\theta', x', k')$ and $\bar{m}_1 = (\theta', x', \bar{k})$; ergo, $a_1^* \notin BR_1^{\pi^*(\theta)}(a_{-1}^*)$, a contradiction to a^* being a Nash* equilibrium at $\pi^*(\theta)$.[26]

The same reasoning detailed in the previous paragraph delivers the planner's inference of a contradiction if $\mathbf{S}^{(j)} \neq \mathbf{S}$, $\mathbf{S} \notin \mathcal{S}(f)$, and j is a strong sympathizer of f at θ. Because then she makes the deduction that there would be another strong sympathizer of f at θ and he would have a profitable deviation opportunity.[27]

Suppose that the planner considers the situation where $g(a^*) = x' \notin f(\theta)$ because otherwise she would be done with Case 1. Then, she knowing that $x' \in f(\theta')$ and $x \notin f(\theta)$ and $\mathbf{S} \in \mathcal{S}(f)$ with $\theta, \theta' \in \Theta$ implies (due to (*ii*) of consistency) there exists $i^* \in N$ such that $x' \notin C_{i^*}^{\pi^*(\theta)}(S_{i^*}(x', \theta'))$ where $S_{i^*}(x', \theta') = \mathbf{S}|_{i^*, \theta', x' \in f(\theta')}$. There appears two subcases she needs to check. The first is one where a^* is such that $\mathbf{S}^{(i)} = \mathbf{S}$ for all $i \in N$. Then, $O_i^{\mu}(a_{-i}^*) = S_i(x', \theta')$ (by Rules 1 and 2) and, as a^* is Nash* at $\pi^*(\theta)$, it must be that $x' \in C_i^{\pi^*(\theta)}(O_i^{\mu}(a_{-i}^*))$ for all $i \in N$. So, she obtains a contradiction as $x' \in C_{i^*}^{\pi^*(\theta)}(S_{i^*}(x', \theta'))$. The second subcase that the planner needs to consider is one where a^* is such that $\mathbf{S}^{(i)} = \mathbf{S}$ for all $i \in N \setminus \{j\}$ for some $j \in N$ and $\mathbf{S}^{(j)} \neq \mathbf{S}$. Then, by Rules 1 and 2 and 3,

[26] This is why we have to strengthen sympathy to strong sympathy, as the deviating individual has to change his integer choice as well.

[27] The need for an additional strong sympathizer arises due to this case. To see this, suppose that there is only one strong sympathizer of f at θ and consider the situation when $\mathbf{S}^{(j)} \neq \mathbf{S}$ and j is the only strong sympathizer of f at θ. Then, $\mathbf{S} \notin \mathcal{S}(f)$ does not necessarily result in a contradiction as there is no other strong sympathizer of f at θ among those who are announcing an inconsistent profile of sets $\mathbf{S}$. Hence, one of the agents whose opportunity set equals X must be a strong sympathizer of f at θ.

$O_i^\mu(a_{-i}^*) = X$ for all $i \neq j$ and $O_j^\mu(a_{-j}^*) = S_j(x', \theta')$ where $S_j(x', \theta') = \mathbf{S}|_{j,\theta',x' \in f(\theta')}$ and $\mathbf{S} \in \mathcal{S}(f)$ as was shown above. Because that a^* is a Nash* equilibrium at $\pi^*(\theta)$, the planner infers that $x' \in C_i^{\pi^*(\theta)}(X)$ for all $i \neq j$ while $x' \in C_j^{\pi^*(\theta)}(S_j(x', \theta'))$ and $x' \in f(\theta')$. As the planner knows (ii') holds, she concludes $x \in f(\theta)$, which is in contradiction to $x \notin f(\theta)$. ■

Case 2. *Suppose that the planner considers a Nash* equilibrium* a^* *at* $\pi^*(\theta)$ *in which Rule 2 applies:* $a_i^* = (\mathbf{S}^{(i)}, m_i^*)$ *with* $\mathbf{S}^{(i)} = \mathbf{S}$ *for all* $i \in N \setminus \{i'\}$ *for some* $i' \in N$ *and* $m_j^* = (\theta', x', k')$ *for all* $j \in N \setminus \{\ell\}$ *for some* $\ell \in N$ *with* $\theta' \in \Theta$ *and* $x' \in f(\theta')$ *while* $m_\ell^* = (\theta'', x'', k'') \neq (\theta', x', k')$.

Proof of Claim 3 under Case 2. The first step is to prove the planner's inference of $\mathbf{S} \in \mathcal{S}(f)$. We point out that this establishes the observation that the planner deduces that in all Nash* equilibria in which Rule 2 applies, all but one individual announce the same profile of sets, which has to be one of the profiles consistent with the SCC f.

Suppose that the planner contemplates on $\mathbf{S} \notin \mathcal{S}(f)$. Then, she knows that there is a strong sympathizer of f at θ, individual $i^* \neq i'$, with $\mathbf{S}^{(i^*)} = \mathbf{S}$ as she knows that there are at least two strong sympathizers of f at θ. She imagines (without a loss of generality) $i^* = 1$. If $\mathbf{S}^{(i')} \neq \mathbf{S}$, player 1 deviating to $\bar{a}_1 = (\bar{\mathbf{S}}, \bar{m}_1)$ where $\bar{\mathbf{S}} \in \mathcal{S}(f)$ and $\bar{m}_1 = (\tilde{\theta}, g(a^*), \bar{k})$ with $\tilde{\theta} \in \Theta$ and $\bar{k} > k', k''$ implies that Rule 3 applies and as a result $g(\bar{\mathbf{S}}, \bar{m}_1, a_{-1}^*) = g(\mathbf{S}, m_1^*, a_{-1}^*) = g(a^*)$ which is in $C_1^{\pi^*(\theta)}(O_1^\mu(a_{-1}^*))$ due to a^* being a Nash* equilibrium at $\pi^*(\theta)$. But then, the planner infers that as player 1 is a strong sympathizer of f at θ, $a_1^* \notin BR_1^{\pi^*(\theta)}(a_{-1}^*)$, a contradiction to a^* being Nash* at $\pi^*(\theta)$. If $\mathbf{S}^{(i')} = \mathbf{S}$, then the planner deduces that all players are announcing $\mathbf{S}$; and hence, player 1 deviating to $\bar{a}_1 = (\bar{\mathbf{S}}, m_1^*)$ where $\bar{\mathbf{S}} \in \mathcal{S}(f)$ implies no deviations apart from individual 1's announcing $\bar{\mathbf{S}}$ instead of $\mathbf{S}$ and as a result $g(\bar{\mathbf{S}}, m_1^*, a_{-1}^*) = g(\mathbf{S}, m_1^*, a_{-1}^*) = g(a^*) \in C_1^{\pi^*(\theta)}(O_1^\mu(a_{-1}^*))$ as a^* is Nash* at $\pi^*(\theta)$. However, player 1 being a strong sympathizer of f at θ implies $a_1^* \notin BR_1^{\pi^*(\theta)}(a_{-1}^*)$, contradicting to a^* being a Nash* equilibrium at $\pi^*(\theta)$.

Having established the planner's inference of $\mathbf{S} \in \mathcal{S}(f)$, we note the following: If she considers $\mathbf{S}^{(i')} \neq \mathbf{S}$, then she knows that $O_i^\mu(a_{-i}^*) = X$ for all $i \neq i'$ (by any one of such $i \neq i'$ deviating to $\mathbf{S}^{(i)} \neq \mathbf{S}$ and choosing the highest integer and any alternative) while $O_{i'}^\mu(a_{-i'}^*) = S_{i'}(x', \theta')$ if $i' = \ell$ and $O_{i'}^\mu(a_{-i'}^*) = X$ if $i \neq \ell$ (by i' deviating to $m'_{i'} \neq (\theta', x', k')$ and making Rule 3 apply). Thus, if $i' = \ell$, $\mathbf{S} \in \mathcal{S}(f)$ and a^* being Nash* at $\pi^*(\theta)$ implying $g(a^*) \in C_i^{\pi^*(\theta)}(X)$ for all $i \neq i'$ and $g(a^*) \in C_{i'}^{\pi^*(\theta)}(S_{i'}(x', \theta'))$ with $x' \in f(\theta')$ enables the planner to employ condition (ii') and conclude that $g(a^*) \in f(\theta)$. But if she contemplates on $i' \neq \ell$, then she figures out that $\mathbf{S} \in \mathcal{S}(f)$ and a^* being Nash* at $\pi^*(\theta)$ imply $g(a^*) \in C_i^{\pi^*(\theta)}(X)$ for all $i \in N$, which is in contradiction to societal non-satiation. So, she deduces that in all Nash* equilibria in which Rule 2 applies, all but one individual announce the same profile of sets which has to be one of the profiles consistent with f.

If the planner considers $\mathbf{S}^{(i')} = \mathbf{S}$, then she infers that $O^{\mu}_{j}(a^*_{-j}) = X$ for all $j \neq \ell$ (by any one of such $j \neq \ell$ deviating to $m'_j \neq m^*_j$) while $O^{\mu}_{\ell}(a^*_{-\ell}) = S_{\ell}(x', \theta')$ (by Rule 2). Hence, she deduces that $\mathbf{S} \in \mathcal{S}(f)$, a^* being Nash* at $\pi^*(\theta)$ implying $g(a^*) \in C_j^{\pi^*(\theta)}(X)$ for all $j \neq \ell$ and $g(a^*) \in C_{\ell}^{\pi^*(\theta)}(S_{\ell}(x', \theta'))$ with $x' \in f(\theta')$, and condition (ii') conduce to $g(a^*) \in f(\theta)$. ■

Case 3. *The planner infers that under Rule 3, there cannot be a Nash* equilibrium at* $\pi^*(\theta)$ *for any* $\theta \in \Theta$.

Proof of Claim 3 under Case 3. If the planner contemplates on such a Nash* equilibrium, a^*, she infers that $O^{\mu}_{i}(a^*_{-i}) = X$ for all $i \in N$ and $g(a^*) \in C_i^{\pi^*(\theta)}(X)$ for all $i \in N$ (on account of a^* being Nash* at $\pi^*(\theta)$). This, she concludes, results in a contradiction with societal non-satiation. ■

These conclude the proof of Claim 3, and hence, the proof of Theorem 4. ■

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