

The Incompatibility of *SD*-Efficiency and *SD*-Strategy-Proofness

Manuel Eberl

October 11, 2017

Abstract

This formalisation contains the proof that there is no anonymous and neutral Social Decision Scheme for at least four voters and alternatives that fulfils both *SD*-Efficiency and *SD*-Strategy-Proofness. The proof is a fully structured and quasi-human-readable one. It was derived from the (unstructured) SMT proof of the case for exactly four voters and alternatives by Brandl *et al.* [1].

Their proof relies on an unverified translation of the original problem to SMT, and the proof that lifts the argument for exactly four voters and alternatives to the general case is also not machine-checked.

In this Isabelle proof, on the other hand, all of these steps are also fully proven and machine-checked. This is particularly important seeing as a previously published informal proof of a weaker statement contained a mistake in precisely this lifting step. [2]

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1 Incompatibility of SD-Efficiency and SD-Strategy-Proofness

theory *SDS-Impossibility*

imports

Randomised-Social-Choice.SDS-Automation

Randomised-Social-Choice.Randomised-Social-Choice

begin

1.1 Preliminary Definitions

locale *sds-impossibility* =

anonymous-sds agents alts sds +

neutral-sds agents alts sds +

sd-efficient-sds agents alts sds +

strategyproof-sds agents alts sds

for *agents* :: 'agent set **and** *alts* :: 'alt set **and** *sds* +

assumes *agents-ge-4*: *card agents* ≥ 4

and *alts-ge-4*: *card alts* ≥ 4

locale *sds-impossibility-4-4* = *sds-impossibility agents alts sds*

for *agents* :: 'agent set **and** *alts* :: 'alt set **and** *sds* +

fixes *A1 A2 A3 A4* :: 'agent **and** *a b c d* :: 'alt

assumes *distinct-agents*: *distinct* [*A1, A2, A3, A4*]

and *distinct-alts*: *distinct* [*a, b, c, d*]

and *agents*: *agents* = {*A1, A2, A3, A4*}

and *alts*: *alts* = {*a, b, c, d*}

begin

lemma *an-sds*: *an-sds agents alts sds* <proof>

lemma *ex-post-efficient-sds*: *ex-post-efficient-sds agents alts sds* <proof>

lemma *sd-efficient-sds*: *sd-efficient-sds agents alts sds* <proof>

lemma *strategyproof-an-sds*: *strategyproof-an-sds agents alts sds* <proof>

lemma *distinct-agents'* [*simp*]:

A1 \neq *A2* *A1* \neq *A3* *A1* \neq *A4* *A2* \neq *A1* *A2* \neq *A3* *A2* \neq *A4*

A3 \neq *A1* *A3* \neq *A2* *A3* \neq *A4* *A4* \neq *A1* *A4* \neq *A2* *A4* \neq *A3*

<proof>

lemma *distinct-alts'* [*simp*]:

a \neq *b* *a* \neq *c* *a* \neq *d* *b* \neq *a* *b* \neq *c* *b* \neq *d*

c \neq *a* *c* \neq *b* *c* \neq *d* *d* \neq *a* *d* \neq *b* *d* \neq *c*

<proof>

lemma *card-agents* [*simp*]: *card agents* = 4 **and** *card-alts* [*simp*]: *card alts* = 4

<proof>

lemma *in-agents* [*simp*]: *A1* \in *agents* *A2* \in *agents* *A3* \in *agents* *A4* \in *agents*

<proof>

lemma *in-alt*s [simp]: $a \in \text{alts } b \in \text{alts } c \in \text{alts } d \in \text{alts}$

<proof>

lemma *agent-iff*: $x \in \text{agents} \iff x \in \{A1, A2, A3, A4\}$

$(\forall x \in \text{agents}. P x) \iff P A1 \wedge P A2 \wedge P A3 \wedge P A4$

$(\exists x \in \text{agents}. P x) \iff P A1 \vee P A2 \vee P A3 \vee P A4$

<proof>

lemma *alt-iff*: $x \in \text{alts} \iff x \in \{a, b, c, d\}$

$(\forall x \in \text{alts}. P x) \iff P a \wedge P b \wedge P c \wedge P d$

$(\exists x \in \text{alts}. P x) \iff P a \vee P b \vee P c \vee P d$

<proof>

1.2 Definition of Preference Profiles and Fact Gathering

preference-profile

agents: *agents*

alts: *alts*

where $R1 = A1: [c, d], [a, b] \quad A2: [b, d], a, c \quad A3: a, b, [c, d] \quad A4: [a, c], [b, d]$

and $R2 = A1: [a, c], [b, d] \quad A2: [c, d], a, b \quad A3: [b, d], a, c \quad A4: a, b, [c, d]$

and $R3 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: d, [a, b], c \quad A4: c, a, [b, d]$

and $R4 = A1: [a, b], [c, d] \quad A2: [a, d], [b, c] \quad A3: c, [a, b], d \quad A4: d, c, [a, b]$

and $R5 = A1: [c, d], [a, b] \quad A2: [a, b], [c, d] \quad A3: [a, c], d, b \quad A4: d, [a, b], c$

and $R6 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: [a, c], [b, d] \quad A4: d, b, a, c$

and $R7 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: a, c, d, b \quad A4: d, [a, b], c$

and $R8 = A1: [a, b], [c, d] \quad A2: [a, c], [b, d] \quad A3: d, [a, b], c \quad A4: d, c, [a, b]$

and $R9 = A1: [a, b], [c, d] \quad A2: [a, d], c, b \quad A3: d, c, [a, b] \quad A4: [a, b, c], d$

and $R10 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: [a, c], d, b \quad A4: [b, d], a, c$

and $R11 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: d, [a, b], c \quad A4: c, a, b, d$

and $R12 = A1: [c, d], [a, b] \quad A2: [a, b], [c, d] \quad A3: [a, c], d, b \quad A4: [a, b, d], c$

and $R13 = A1: [a, c], [b, d] \quad A2: [c, d], a, b \quad A3: [b, d], a, c \quad A4: a, b, d, c$

and $R14 = A1: [a, b], [c, d] \quad A2: d, c, [a, b] \quad A3: [a, b, c], d \quad A4: a, d, c, b$

and $R15 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: [b, d], a, c \quad A4: a, c, d, b$

and $R16 = A1: [a, b], [c, d]$ $A2: [c, d], [a, b]$ $A3: a, c, d, b$ $A4: [a, b, d], c$
and $R17 = A1: [a, b], [c, d]$ $A2: [c, d], [a, b]$ $A3: [a, c], [b, d]$ $A4: d, [a, b], c$
and $R18 = A1: [a, b], [c, d]$ $A2: [a, d], [b, c]$ $A3: [a, b, c], d$ $A4: d, c, [a, b]$
and $R19 = A1: [a, b], [c, d]$ $A2: [c, d], [a, b]$ $A3: [b, d], a, c$ $A4: [a, c], [b, d]$
and $R20 = A1: [b, d], a, c$ $A2: b, a, [c, d]$ $A3: a, c, [b, d]$ $A4: d, c, [a, b]$
and $R21 = A1: [a, d], c, b$ $A2: d, c, [a, b]$ $A3: c, [a, b], d$ $A4: a, b, [c, d]$
and $R22 = A1: [a, c], d, b$ $A2: d, c, [a, b]$ $A3: d, [a, b], c$ $A4: a, b, [c, d]$
and $R23 = A1: [a, b], [c, d]$ $A2: [c, d], [a, b]$ $A3: [a, c], [b, d]$ $A4: [a, b, d], c$
and $R24 = A1: [c, d], [a, b]$ $A2: d, b, a, c$ $A3: c, a, [b, d]$ $A4: b, a, [c, d]$
and $R25 = A1: [c, d], [a, b]$ $A2: [b, d], a, c$ $A3: a, b, [c, d]$ $A4: a, c, [b, d]$
and $R26 = A1: [b, d], [a, c]$ $A2: [c, d], [a, b]$ $A3: a, b, [c, d]$ $A4: a, c, [b, d]$
and $R27 = A1: [a, b], [c, d]$ $A2: [b, d], a, c$ $A3: [a, c], [b, d]$ $A4: [c, d], a, b$
and $R28 = A1: [c, d], a, b$ $A2: [b, d], a, c$ $A3: a, b, [c, d]$ $A4: a, c, [b, d]$
and $R29 = A1: [a, c], d, b$ $A2: [b, d], a, c$ $A3: a, b, [c, d]$ $A4: d, c, [a, b]$
and $R30 = A1: [a, d], c, b$ $A2: d, c, [a, b]$ $A3: c, [a, b], d$ $A4: [a, b], d, c$
and $R31 = A1: [b, d], a, c$ $A2: [a, c], d, b$ $A3: c, d, [a, b]$ $A4: [a, b], c, d$
and $R32 = A1: [a, c], d, b$ $A2: d, c, [a, b]$ $A3: d, [a, b], c$ $A4: [a, b], d, c$
and $R33 = A1: [c, d], [a, b]$ $A2: [a, c], d, b$ $A3: a, b, [c, d]$ $A4: d, [a, b], c$
and $R34 = A1: [a, b], [c, d]$ $A2: a, c, d, b$ $A3: b, [a, d], c$ $A4: c, d, [a, b]$
and $R35 = A1: [a, d], c, b$ $A2: a, b, [c, d]$ $A3: [a, b, c], d$ $A4: d, c, [a, b]$
and $R36 = A1: [c, d], [a, b]$ $A2: [a, c], d, b$ $A3: [b, d], a, c$ $A4: a, b, [c, d]$
and $R37 = A1: [a, c], [b, d]$ $A2: [b, d], [a, c]$ $A3: a, b, [c, d]$ $A4: c, d, [a, b]$
and $R38 = A1: [c, d], a, b$ $A2: [b, d], a, c$ $A3: a, b, [c, d]$ $A4: [a, c], b, d$
and $R39 = A1: [a, c], d, b$ $A2: [b, d], a, c$ $A3: a, b, [c, d]$ $A4: [c, d], a, b$
and $R40 = A1: [a, d], c, b$ $A2: [a, b], c, d$ $A3: [a, b, c], d$ $A4: d, [a, b], c$

$c, [a, b]$
and $R41 = A1: [a, d], c, b \quad A2: [a, b], d, c \quad A3: [a, b, c], d \quad A4: d,$
 $c, [a, b]$
and $R42 = A1: [c, d], [a, b] \quad A2: [a, b], [c, d] \quad A3: d, b, a, c \quad A4: c,$
 $a, [b, d]$
and $R43 = A1: [a, b], [c, d] \quad A2: [c, d], [a, b] \quad A3: d, [a, b], c \quad A4: a,$
 $[c, d], b$
and $R44 = A1: [c, d], [a, b] \quad A2: [a, c], d, b \quad A3: [a, b], d, c \quad A4: [a,$
 $b, d], c$
and $R45 = A1: [a, c], d, b \quad A2: [b, d], a, c \quad A3: [a, b], c, d \quad A4: [c,$
 $d], b, a$
and $R46 = A1: [b, d], a, c \quad A2: d, c, [a, b] \quad A3: [a, c], [b, d] \quad A4: b,$
 $a, [c, d]$
and $R47 = A1: [a, b], [c, d] \quad A2: [a, d], c, b \quad A3: d, c, [a, b] \quad A4: c,$
 $[a, b], d$
(proof)

derive-orbit-equations (*an-sds*)

$R10 \ R26 \ R27 \ R28 \ R29 \ R43 \ R45$
(proof)

prove-inefficient-supports (*ex-post-efficient-sds sd-efficient-sds*)

$R3 [b]$ **and** $R4 [b]$ **and** $R5 [b]$ **and** $R7 [b]$ **and** $R8 [b]$ **and**
 $R9 [b]$ **and** $R11 [b]$ **and** $R12 [b]$ **and** $R14 [b]$ **and** $R16 [b]$ **and**
 $R17 [b]$ **and** $R18 [b]$ **and** $R21 [b]$ **and** $R22 [b]$ **and** $R23 [b]$ **and**
 $R30 [b]$ **and** $R32 [b]$ **and** $R33 [b]$ **and** $R35 [b]$ **and** $R40 [b]$ **and**
 $R41 [b]$ **and** $R43 [b]$ **and** $R44 [b]$ **and** $R47 [b]$ **and**
 $R10 [c, b]$ *witness:* $[a: 1 / 2, b: 0, c: 0, d: 1 / 2]$ **and**
 $R15 [c, b]$ *witness:* $[a: 1 / 2, b: 0, c: 0, d: 1 / 2]$ **and**
 $R19 [c, b]$ *witness:* $[a: 1 / 2, b: 0, c: 0, d: 1 / 2]$ **and**
 $R25 [b, c]$ *witness:* $[c: 0, d: 1 / 2, a: 1 / 2, b: 0]$ **and**
 $R26 [c, b]$ *witness:* $[b: 0, d: 1 / 2, a: 1 / 2, c: 0]$ **and**
 $R27 [c, b]$ *witness:* $[a: 1 / 2, b: 0, c: 0, d: 1 / 2]$ **and**
 $R28 [b, c]$ *witness:* $[c: 0, d: 1 / 2, a: 1 / 2, b: 0]$ **and**
 $R29 [b, c]$ *witness:* $[a: 1 / 2, c: 0, d: 1 / 2, b: 0]$ **and**
 $R39 [b, c]$ *witness:* $[a: 1 / 2, c: 0, d: 1 / 2, b: 0]$
(proof)

derive-strategyproofness-conditions (*strategyproof-an-sds*)

distance: 2
 $R1 \ R2 \ R3 \ R4 \ R5 \ R6 \ R7 \ R8 \ R9 \ R10 \ R11 \ R12 \ R13 \ R14 \ R15 \ R16 \ R17 \ R18 \ R19$
 $R20$
 $R21 \ R22 \ R23 \ R24 \ R25 \ R26 \ R27 \ R28 \ R29 \ R30 \ R31 \ R32 \ R33 \ R34 \ R35 \ R36 \ R37$
 $R38 \ R39 \ R40$
 $R41 \ R42 \ R43 \ R44 \ R45 \ R46 \ R47$
(proof)

lemma *lottery-conditions:*

assumes *is-pref-profile* R

shows $\text{pmf}(\text{sds } R) a \geq 0 \text{ pmf}(\text{sds } R) b \geq 0 \text{ pmf}(\text{sds } R) c \geq 0 \text{ pmf}(\text{sds } R) d \geq 0$
 $\text{pmf}(\text{sds } R) a + \text{pmf}(\text{sds } R) b + \text{pmf}(\text{sds } R) c + \text{pmf}(\text{sds } R) d = 1$
 ⟨proof⟩

1.3 Main Proof

lemma *R45 [simp]*: $\text{pmf}(\text{sds } R45) a = 1/4 \text{ pmf}(\text{sds } R45) b = 1/4$
 $\text{pmf}(\text{sds } R45) c = 1/4 \text{ pmf}(\text{sds } R45) d = 1/4$
 ⟨proof⟩

lemma *R10-bc [simp]*: $\text{pmf}(\text{sds } R10) b = 0 \text{ pmf}(\text{sds } R10) c = 0$
 ⟨proof⟩

lemma *R10-ad [simp]*: $\text{pmf}(\text{sds } R10) a = 1/2 \text{ pmf}(\text{sds } R10) d = 1/2$
 ⟨proof⟩

lemma *R26-bc [simp]*: $\text{pmf}(\text{sds } R26) b = 0 \text{ pmf}(\text{sds } R26) c = 0$
 ⟨proof⟩

lemma *R26-d [simp]*: $\text{pmf}(\text{sds } R26) d = 1 - \text{pmf}(\text{sds } R26) a$
 ⟨proof⟩

lemma *R27-bc [simp]*: $\text{pmf}(\text{sds } R27) b = 0 \text{ pmf}(\text{sds } R27) c = 0$
 ⟨proof⟩

lemma *R27-d [simp]*: $\text{pmf}(\text{sds } R27) d = 1 - \text{pmf}(\text{sds } R27) a$
 ⟨proof⟩

lemma *R28-bc [simp]*: $\text{pmf}(\text{sds } R28) b = 0 \text{ pmf}(\text{sds } R28) c = 0$
 ⟨proof⟩

lemma *R28-d [simp]*: $\text{pmf}(\text{sds } R28) d = 1 - \text{pmf}(\text{sds } R28) a$
 ⟨proof⟩

lemma *R29-bc [simp]*: $\text{pmf}(\text{sds } R29) b = 0 \text{ pmf}(\text{sds } R29) c = 0$
 ⟨proof⟩

lemma *R29-ac [simp]*: $\text{pmf}(\text{sds } R29) a = 1/2 \text{ pmf}(\text{sds } R29) d = 1/2$
 ⟨proof⟩

lemmas *R43-bc [simp]* = *R43.support*

lemma *R43-ad [simp]*: $\text{pmf}(\text{sds } R43) a = 1/2 \text{ pmf}(\text{sds } R43) d = 1/2$

$\langle proof \rangle$

lemma *R39-b* [*simp*]: $pmf (sds R39) b = 0$
 $\langle proof \rangle$

lemma *R36-a* [*simp*]: $pmf (sds R36) a = 1/2$ **and** *R36-b* [*simp*]: $pmf (sds R36) b = 0$
 $\langle proof \rangle$

lemma *R36-d* [*simp*]: $pmf (sds R36) d = 1/2 - pmf (sds R36) c$
 $\langle proof \rangle$

lemma *R39-a* [*simp*]: $pmf (sds R39) a = 1/2$
 $\langle proof \rangle$

lemma *R39-d* [*simp*]: $pmf (sds R39) d = 1/2 - pmf (sds R39) c$
 $\langle proof \rangle$

lemmas *R12-b* [*simp*] = *R12.support*

lemma *R12-c* [*simp*]: $pmf (sds R12) c = 0$
 $\langle proof \rangle$

lemma *R12-d* [*simp*]: $pmf (sds R12) d = 1 - pmf (sds R12) a$
 $\langle proof \rangle$

lemma *R12-a-ge-one-half*: $pmf (sds R12) a \geq 1/2$
 $\langle proof \rangle$

lemma *R44* [*simp*]:
 $pmf (sds R44) a = pmf (sds R12) a$ $pmf (sds R44) d = 1 - pmf (sds R12) a$
 $pmf (sds R44) b = 0$ $pmf (sds R44) c = 0$
 $\langle proof \rangle$

lemma *R9-a* [*simp*]: $pmf (sds R9) a = pmf (sds R35) a$
 $\langle proof \rangle$

lemma *R18-c* [*simp*]: $pmf (sds R18) c = pmf (sds R9) c$
 $\langle proof \rangle$

lemma *R5-d-ge-one-half*: $pmf (sds R5) d \geq 1/2$
 $\langle proof \rangle$

lemma *R7* [*simp*]: $pmf (sds R7) a = 1/2$ $pmf (sds R7) b = 0$ $pmf (sds R7) c$

$= 0$ pmf (sds R7) $d = 1/2$
(proof)

lemma R5 [simp]: pmf (sds R5) $a = 1/2$ pmf (sds R5) $b = 0$ pmf (sds R5) $c = 0$ pmf (sds R5) $d = 1/2$
(proof)

lemma R15 [simp]: pmf (sds R15) $a = 1/2$ pmf (sds R15) $b = 0$ pmf (sds R15) $c = 0$ pmf (sds R15) $d = 1/2$
(proof)

lemma R13-aux: pmf (sds R13) $b = 0$ pmf (sds R13) $c = 0$ pmf (sds R13) $d = 1 - \text{pmf (sds R13) } a$
and R27-R13 [simp]: pmf (sds R27) $a = \text{pmf (sds R13) } a$
(proof)

lemma R13 [simp]: pmf (sds R13) $a = 1/2$ pmf (sds R13) $b = 0$ pmf (sds R13) $c = 0$ pmf (sds R13) $d = 1/2$
(proof)

lemma R27 [simp]: pmf (sds R27) $a = 1/2$ pmf (sds R27) $b = 0$ pmf (sds R27) $c = 0$ pmf (sds R27) $d = 1/2$
(proof)

lemma R19 [simp]: pmf (sds R19) $a = 1/2$ pmf (sds R19) $b = 0$ pmf (sds R19) $c = 0$ pmf (sds R19) $d = 1/2$
(proof)

lemma R1 [simp]: pmf (sds R1) $a = 1/2$ pmf (sds R1) $b = 0$
(proof)

lemma R22 [simp]: pmf (sds R22) $a = 1/2$ pmf (sds R22) $b = 0$ pmf (sds R22) $c = 0$ pmf (sds R22) $d = 1/2$
(proof)

lemma R28 [simp]: pmf (sds R28) $a = 1/2$ pmf (sds R28) $b = 0$ pmf (sds R28) $c = 0$ pmf (sds R28) $d = 1/2$
(proof)

lemma R39 [simp]: pmf (sds R39) $a = 1/2$ pmf (sds R39) $b = 0$ pmf (sds R39) $c = 0$ pmf (sds R39) $d = 1/2$
(proof)

lemma R2 [simp]: pmf (sds R2) $a = 1/2$ pmf (sds R2) $b = 0$ pmf (sds R2) $c = 0$ pmf (sds R2) $d = 1/2$
(proof)

lemma R42 [simp]: pmf (sds R42) $a = 0$ pmf (sds R42) $b = 0$ pmf (sds R42) $c = 1/2$ pmf (sds R42) $d = 1/2$

$\langle proof \rangle$

lemma R37 [simp]: $pmf (sds R37) a = 1/2 pmf (sds R37) b = 0 pmf (sds R37) c = 1/2 pmf (sds R37) d = 0$
 $\langle proof \rangle$

lemma R24 [simp]: $pmf (sds R24) a = 0 pmf (sds R24) b = 0 pmf (sds R24) d = 1 - pmf (sds R24) c$
 $\langle proof \rangle$

lemma R34 [simp]:
 $pmf (sds R34) a = 1 - pmf (sds R24) c pmf (sds R34) b = pmf (sds R24) c$
 $pmf (sds R34) c = 0 pmf (sds R34) d = 0$
 $\langle proof \rangle$

lemma R14 [simp]: $pmf (sds R14) b = 0 pmf (sds R14) d = 0 pmf (sds R14) c = 1 - pmf (sds R14) a$
 $\langle proof \rangle$

lemma R46 [simp]: $pmf (sds R46) a = 0 pmf (sds R46) c = 0 pmf (sds R46) d = 1 - pmf (sds R46) b$
 $\langle proof \rangle$

lemma R20 [simp]: $pmf (sds R20) a = 0 pmf (sds R20) c = 0 pmf (sds R20) d = 1 - pmf (sds R20) b$
 $\langle proof \rangle$

lemma R21 [simp]: $pmf (sds R21) d = 1 - pmf (sds R21) a pmf (sds R21) b = 0 pmf (sds R21) c = 0$
 $\langle proof \rangle$

lemma R16-R12: $pmf (sds R16) c + pmf (sds R16) a \leq pmf (sds R12) a$
 $\langle proof \rangle$

lemma R16 [simp]: $pmf (sds R16) b = 0 pmf (sds R16) c = 0 pmf (sds R16) d = 1 - pmf (sds R16) a$
 $\langle proof \rangle$

lemma R12-R14: $pmf (sds R14) a \leq pmf (sds R12) a$
 $\langle proof \rangle$

lemma R12-a [simp]: $pmf (sds R12) a = pmf (sds R9) a$
 $\langle proof \rangle$

lemma R9 [simp]: $pmf (sds R9) b = 0 pmf (sds R9) d = 0 pmf (sds R14) a = pmf (sds R35) a pmf (sds R9) c = 1 - pmf (sds R35) a$
 $\langle proof \rangle$

lemma *R23* [*simp*]: $\text{pmf } (sds \ R23) \ b = 0 \ \text{pmf } (sds \ R23) \ c = 0 \ \text{pmf } (sds \ R23) \ d = 1 - \text{pmf } (sds \ R23) \ a$
 ⟨*proof*⟩

lemma *R35* [*simp*]: $\text{pmf } (sds \ R35) \ a = \text{pmf } (sds \ R21) \ a \ \text{pmf } (sds \ R35) \ b = 0$
 $\text{pmf } (sds \ R35) \ c = 0 \ \text{pmf } (sds \ R35) \ d = 1 - \text{pmf } (sds \ R21) \ a$
 ⟨*proof*⟩

lemma *R18* [*simp*]: $\text{pmf } (sds \ R18) \ a = \text{pmf } (sds \ R14) \ a \ \text{pmf } (sds \ R18) \ b = 0$
 $\text{pmf } (sds \ R18) \ d = 0 \ \text{pmf } (sds \ R18) \ c = 1 - \text{pmf } (sds \ R14) \ a$
 ⟨*proof*⟩

lemma *R4* [*simp*]: $\text{pmf } (sds \ R4) \ a = \text{pmf } (sds \ R21) \ a \ \text{pmf } (sds \ R4) \ b = 0$
 $\text{pmf } (sds \ R4) \ c = 1 - \text{pmf } (sds \ R4) \ a \ \text{pmf } (sds \ R4) \ d = 0$
 ⟨*proof*⟩

lemma *R8-d* [*simp*]: $\text{pmf } (sds \ R8) \ d = 1 - \text{pmf } (sds \ R8) \ a$
and *R8-c* [*simp*]: $\text{pmf } (sds \ R8) \ c = 0$
and *R26-a* [*simp*]: $\text{pmf } (sds \ R26) \ a = 1 - \text{pmf } (sds \ R8) \ a$
 ⟨*proof*⟩

lemma *R21-R47*: $\text{pmf } (sds \ R21) \ d \leq \text{pmf } (sds \ R47) \ c$
 ⟨*proof*⟩

lemma *R30* [*simp*]: $\text{pmf } (sds \ R30) \ a = \text{pmf } (sds \ R47) \ a \ \text{pmf } (sds \ R30) \ b = 0$
 $\text{pmf } (sds \ R30) \ c = 0 \ \text{pmf } (sds \ R30) \ d = 1 - \text{pmf } (sds \ R47) \ a$
 ⟨*proof*⟩

lemma *R31-c-ge-one-half*: $\text{pmf } (sds \ R31) \ c \geq 1/2$
 ⟨*proof*⟩

lemma *R31*: $\text{pmf } (sds \ R31) \ a = 0 \ \text{pmf } (sds \ R31) \ c = 1/2 \ \text{pmf } (sds \ R31) \ b +$
 $\text{pmf } (sds \ R31) \ d = 1/2$
 ⟨*proof*⟩

lemma *absurd*: *False*
 ⟨*proof*⟩

end

1.4 Lifting to more than 4 agents and alternatives

lemma *finite-list'*:
 assumes *finite A*

obtains xs **where** $A = \text{set } xs \text{ distinct } xs \text{ length } xs = \text{card } A$
<proof>

lemma *finite-list-subset*:

assumes *finite* A $\text{card } A \geq n$

obtains xs **where** $\text{set } xs \subseteq A$ *distinct* xs $\text{length } xs = n$
<proof>

lemma *card-ge-4E*:

assumes *finite* A $\text{card } A \geq 4$

obtains $a \ b \ c \ d$ **where** *distinct* $[a, b, c, d]$ $\{a, b, c, d\} \subseteq A$
<proof>

context *sds-impossibility*

begin

lemma *absurd*: *False*

<proof>

end

end

References

- [1] F. Brandl, F. Brandt, and C. Geist. Proving the incompatibility of Efficiency and Strategyproofness via SMT solving. *Proceedings of the 25th International Joint Conference on Artificial Intelligence (IJCAI)*, 2016. Forthcoming.
- [2] F. Brandl, F. Brandt, and W. Suksompong. The impossibility of extending Random Dictatorship to weak preferences. *Economics Letters*, 141:pp. 44 – 47, 2016.