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# **Voter Participation Models**

## ***Voting Environment***

two homogeneous groups  $k = S, L$  of size  $N_S \leq N_L$

groups always vote for their own group

if group  $k$  wins members get a per capita prize of  $v_k$  otherwise zero

the group casting the most votes wins

in a tie, the flip a coin for the prize

## ***Costs of Voting***

same for both groups

each group member privately draws a type  $y$  from uniform distribution on  $[0, 1]$

type determines cost of voting  $c(y)$  possibly negative but strictly increasing

$$c(\underline{y}) = 0$$

voters with  $y \leq \underline{y}$  are committed voters, they vote no matter what civic duty, camaraderie of the polling place, and so forth

## ***Palfrey Rosenthal Pivotal Voter Model***

finitely many voters in each group

voters act independently and maximize their own utility

look for a threshold equilibrium of the form: vote if  $y \leq \hat{y}$  do not vote if  $y > \hat{y}$

so that the equilibrium is characterized by two cutpoints  $\hat{y}_S, \hat{y}_L$

a voter is pivotal conditional on his not voting his group loses by one vote or ties: in this case the voter can swing the election bringing an expected gain of  $v_k/2$

given the cutoffs we can compute  $P_k(\hat{y}_k, \hat{y}_{-k})$  of a voter being pivotal in group  $k$

then the equilibrium condition is  $c(\hat{y}_k) = P_k(\hat{y}_k, \hat{y}_{-k})v_k/2$

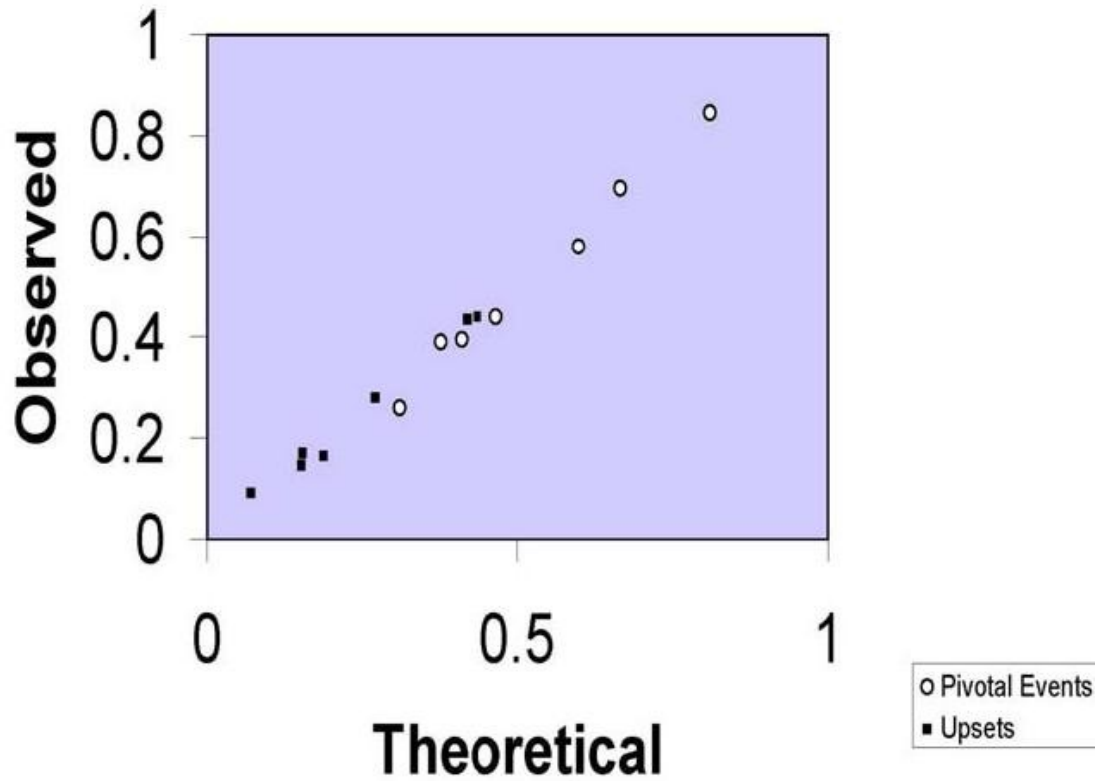
these can be shown to exist, but there is no general proof of uniqueness

## ***Comparative Statics***

- *size effect*: increase in size of the electorate leads to lower turnout rates
- *competition effect*: turnout higher in elections that are expected to be closer if everyone voted
- *underdog effect*: turnout among supporters of more popular candidate or party less than turnout among supporters of the less popular candidate

## Laboratory Data

with up to 51 voters (from Palfrey and Levine)



## *Field Data*

from Stephen Coate, Michael Conlin, and Andrea Moro

Eligible voters $n$	N. of obs.	Data	Pivotal-voter model
$n < 247$	48	0.62	0.65
$247 < n < 434$	48	0.55	0.51
$434 < n < 900$	48	0.43	0.40
All within-sample ( $n < 900$ )	144	0.54	0.52

Table 4: Average turnout as a percentage of eligible voters: model vs. data



## *Closeness of Elections*

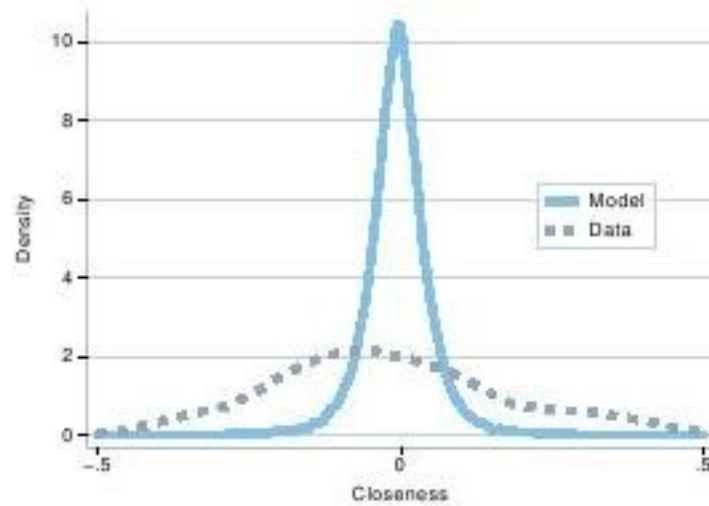


Figure 3: Distributions over closeness, model vs. data (within-sample)

## ***The Issue***

the calculation of the closeness of the election from data on participation has nothing to do with the *motivation* of voters to vote

that is: given the assumption that voters from each group are drawn i.i.d. with a common probability of participation that alone determines the distribution of election closeness

so we can conclude that voters are not drawn i.i.d. with a common participation probability

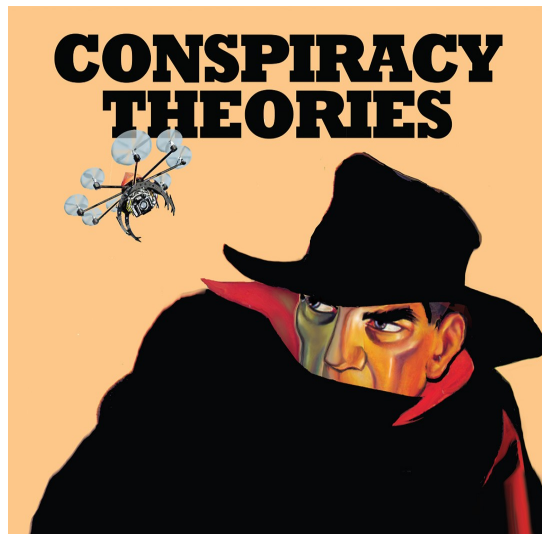
## ***Ethical Voter Models***

voters act as if the entire group did what they did (Coates and Conlin)  
or even take into account the costs of the other group (Federson and Sandroni)

since voters are colluding it isn't obvious how groups can randomize so both of these papers introduce complicated aggregate shocks so that for certain choices of parameters the outcome is random enough that there is a pure strategy equilibrium

## ***Voter Participation with Collusive Parties***

David K. Levine and Andrea Mattozzi



## Overview

Woman who ran over husband for not voting pleads guilty USA Today April 21, 2015

- classical political conflict model: Palfrey-Rosenthal rational voter participation
- Palfrey-Rosenthal focus on individual behavior: pivotality
- many empirical problems with size of electorate (“paradox of voting”)
- ignores the roles of parties and social norms
- large literature in sociology and behavioral economics about social motivations for voting: conformity, shame, peer pressure
- we use a simple model of peer enforcement of social norms within parties
- key new feature: the social norms are endogenous

## ***Basic Setup***

- primary social model currently used: “ethical voters” (*the* model for non-voting conflict) – we nest this model
- we also assume two collusive parties
- parties can enforce social norms through peer punishment
- results in unique mixed strategy equilibrium of all-pay auction
- enforcement costless and equal prize: large party advantaged
- costly enforcement and equal prize of intermediate size: small party advantaged
- surplus obtained by parties same as second price auction
- look subsequently at “noise:” conditions for pure strategy equilibria and the role of pivotality

## *Mixing*

- ethical voter models of Federson/Sandroni and Coate/Conlin use “sufficiently large” aggregate shocks to avoid mixed equilibria
- can look at mixed equilibrium with ethical voters – unnatural?
- mixing certainly natural with collusive parties; results apply as well to ethical voter models
- we initially stick to the original Palfrey/Rosenthal model without noise
- we observe that GOTV (get out the vote) effort by parties is a carefully guided secret which makes sense only if the party is engaging in a mixed strategy



## Cost of Voting

identical party members privately draw a type  $y$  from a uniform distribution on  $[0, 1]$

determines a cost of voting  $c(y)$ , possibly negative and increasing continuously differentiable, has  $c'(y) > 0$  and  $c(\underline{y}) = 0$  (committed voters)

linear in Coate/Conlin





## ***Peer Monitoring Model***

simplified version of Levine/Modica, based on Kandori

social norm a threshold  $\varphi$  and rule to vote is  $y \leq \varphi$

- each member of the party audited by another party member
- auditor observes whether or not auditee voted
- auditee did not vote and norm not violated probability  $\pi$  that auditor will learn this.

$\pi = 0$  then the auditor learns nothing

$\pi = 1$  the auditor perfectly observes whether  $y$  is above or below the threshold  $\varphi$

(auditing costless so unlike Levine/Modica only one round needed)

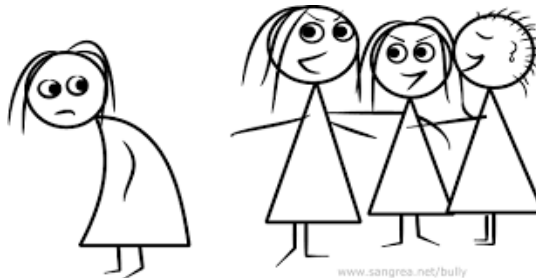
## Peer Punishment

party can impose punishments  $0 \leq P \leq \bar{P}$  on members.

- auditee voted or is discovered not to have violated the policy: not punished
- auditee did not vote and the auditor cannot determine whether or not the auditee violated the policy, the auditee is punished with a loss of utility  $P$

social norm is *incentive compatible*

if and only if  $P = c(\varphi)$



## Cost of Monitoring

$\varphi$  participation rate of the party (probability of voting)

total cost of inducing participation  $D(\varphi) = C(\varphi) + M(\varphi)$

participation cost:  $C(\varphi) = \int_{\underline{y}}^{\varphi} c(y) dy$  is the total cost

$C'(\varphi) = c(\varphi)$  so  $C(\varphi)$  is increasing and convex

monitoring cost:  $M(\varphi) = \int_{\varphi}^1 (1 - \pi) P dy$

incentive compatibility requires  $P = c(\varphi) = C'(\varphi)$

so write  $M(\varphi) = (1 - \pi)(1 - \varphi)C'(\varphi)$ .

$c(\bar{y}) = \bar{P}$  most possible turnout

## Convexity and Concavity

$C(\varphi)$  is necessarily convex

$M(\varphi)$  is not

and so  $D(\varphi)$  may or may not be

**Theorem:** *We have  $C(\underline{y}) = M(\underline{y}) = 0$  so  $D(\underline{y}) = 0$ . The participation cost  $C(\varphi)$  is twice continuously differentiable strictly increasing and strictly convex. The monitoring cost  $M(\varphi)$  is continuously differentiable. If  $\bar{y} = 1$  (that is  $c(1) \leq \bar{P}$  so that full participation is possible) the monitoring cost  $M(\varphi)$  cannot be concave, must be decreasing over part of its range and  $M(1) = 0$  so  $D(1) = C(1)$ .*

at  $\underline{y}$  no punishment cost since punishment is not needed to turn out the committed voters

at  $\bar{y} = 1$  everybody votes so nobody is actually punished.

## All Pay Auction

population of  $N$  voters

two parties  $k = S, L$  of size  $\eta_k N$  where  $\eta_S + \eta_L = 1$ .

side that produces the greatest **expected** number of votes wins prize worth  $v_L > 0$  and  $v_S > 0$  per capita

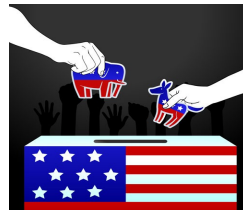
thresholds  $\underline{y}_k < \bar{y}_k$  with cost function  $D_k(\varphi_k)$

generic assumption  $\eta_S \underline{y}_S \neq \eta_L \underline{y}_L$  and  $\eta_S \bar{y}_S \neq \eta_L \bar{y}_L$

large party  $L$  can turn out the most voters  $\eta_L \bar{y}_L > \eta_S \bar{y}_S$

assume  $D'_k(\varphi) > 0$

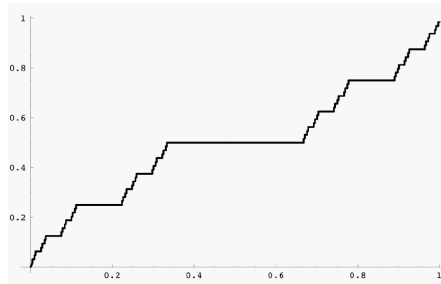
for  $\varphi_k < \underline{y}_k$  cost is  $D_k(\varphi_k) = 0$



## Strategies

probability measure represented by cumulative distribution function

$F_k$  on  $[\eta_k \underline{y}_k, \eta_k \bar{y}_k]$



$\eta_k \varphi_k$  is the *bid*

tie-breaking rule a measurable function  $B_S$  from  $[\max \eta_k \underline{y}_k, \eta_S \bar{y}_S]^2 \rightarrow [0, 1]$  with  $B_S(\eta_S \varphi_S, \eta_L \varphi_L) = 0$  for  $\eta_S \varphi_S < \eta_L \varphi_L$  and  $B_S(\eta_S \varphi_S, \eta_L \varphi_L) = 1$  for  $\eta_S \varphi_S > \eta_L \varphi_L$  with  $B_L = 1 - B_S$

## Equilibrium

$F_S, F_L$  are an *equilibrium* if there is a tie-breaking rule  $B_S$  such that

$$\int v_k B_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) F_k(d\eta_k \varphi_k) F_{-k}(d\eta_{-k} \varphi_{-k}) - \int D_k(\varphi_k) F_k(d\eta_k \varphi_k) \geq \\ \int v_k B_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) \tilde{F}_k(d\eta_k \varphi_k) F_{-k}(d\eta_{-k} \varphi_{-k}) - \int D_k(\varphi_k) \tilde{F}_k(d\eta_k \varphi_k)$$

for all cdfs  $\tilde{F}_k$  on  $[\eta_k \underline{y}_k, \eta_k \bar{y}_k]$

by the Lebesgue decomposition theorem the cdf  $F_k$  may be decomposed into a density for a continuous random variable  $f_k$  and a discrete density  $\phi_k$  along with a singular measure (such as a Cantor measure) that can be ruled out in equilibrium

## ***Advantaged and Disadvantaged Parties***

$\hat{\varphi}_k$  defined by  $D(\hat{\varphi}_k) = v_k$  or  $\hat{\varphi}_k = \bar{y}_k$  if there is no solution  
most the part is willing and able to turnout (willingness to pay)  
generic assumption  $\eta_L \hat{\varphi}_L \neq \eta_S \hat{\varphi}_S$

$d$  (the “disadvantaged” party) for which  $\eta_d \hat{\varphi}_d < \eta_{-d} \hat{\varphi}_{-d}$   
 $-d$  the “advantaged” party





## ***Conceding and Taking Elections***

a party *concedes* the election if it makes a bid that has zero probability of winning in equilibrium

a party *takes* the election if it makes a bid that has probability one of winning in equilibrium.

the election is *contested* if neither party either concedes or takes the election

analysis of equilibrium a variant on that of Hillman and Riley



## Main Theorem

There is a unique mixed equilibrium. The disadvantaged party earns zero and the advantaged party earns  $v_{-d} - D_{-d}((\eta_d/\eta_{-d})\hat{\varphi}_d) > 0$ . If  $\hat{\varphi}_k \leq (\eta_{-k}/\eta_k)\underline{y}_{-k}$  then party  $k$  is disadvantaged, always concedes the election by bidding  $\eta_k \underline{y}_k$  and party  $-k$  always takes the election by bidding  $\eta_{-k} \underline{y}_{-k}$ .

If  $\hat{\varphi}_k > (\eta_{-k}/\eta_k)\underline{y}_{-k}$  for  $k \in \{S, L\}$  then in  $(\max_k \eta_k \underline{y}_k, \eta_d \hat{\varphi}_d)$  the mixed strategies of the players have no atoms, and are given by continuous densities

$$f_k(\eta_k \varphi_k) = D_{-d}'((\eta_k/\eta_{-k})\varphi_k)/(\eta_{-k} v_{-k}).$$

(continued on next slide)

Only a disadvantaged party concedes the election by bidding  $\eta_d \underline{y}_d$  with probability

$$\phi_d(\eta_d \underline{y}_d) = 1 - D_{-d}((\eta_d / \eta_{-d}) \hat{\varphi}_d) / v_{-d} + D_{-d}((\eta_L / \eta_{-d}) \underline{y}_L) / v_{-d}$$

and it has no other atom.

The only time an advantaged party turns out only its committed voters with positive probability is if it has the most committed voters in which case the probability is equal to

$$\phi(\eta_{-d} \bar{y}_{-d}) = D_d((\eta_{-d} / \eta_d) \underline{y}_{-d}) / v_d.$$

When the small party is advantaged it has no other atom. If the large party is advantaged and  $\hat{\varphi}_S = \bar{y}_S$ , the party takes the election with probability

$$\phi(\eta_S \bar{y}_S) = 1 - D_{-d}((\eta_S / \eta_L) \bar{y}_S) / v_S$$

by bidding  $\eta_S \bar{y}_S$

## ***Comparative Statics***

1. only the relative sizes of parties matters
2. if value of the prize to the party with the least committed voters is small enough then it is disadvantaged and concedes the election with very high probability. If value of the prize to large party very large with very high probability small party turns out only its committed voters and large party acts preemptively turning out as many voters as the small party is capable of turning out
3. the disadvantaged party can have a better than 50% chance of winning the election
4. in a contested election probability of winning by advantaged party increases with own valuation. surplus of advantaged party (and hence welfare) strictly increasing with its own valuation and reduction in the valuation of the disadvantaged party

## Common Prize

$$N_S v_S = N_L v_L = V$$

$D(\varphi)$  strictly increasing and twice differentiable in  $[\underline{y}, \bar{y}]$  and  $D''(\varphi)$  univalent meaning  $D(\varphi)$  either convex or concave on  $[\underline{y}, \bar{y}]$ , but not both.

**Theorem:** If  $D(\varphi)$  is convex than the small party is disadvantaged. If  $D(\varphi)$  is concave and for some  $\underline{y} < \hat{y} < \bar{y}$  we have  $D(\hat{y}) < V/\eta_L < D(\bar{y})$  and

$$\frac{2\underline{y}D'(\underline{y})}{\hat{y}^2 - \underline{y}^2} < -\max_{\underline{y} \leq y \leq \hat{y}} D''(y)$$

then for  $(\eta_S/\eta_L)\bar{y} > \hat{\varphi}_L$  and in particular for  $\eta_S$  close enough to  $\eta_L$  the small party is advantaged.

## ***Small Party Advantaged***

$V$  is neither too large nor too small

- too large loses because of large turnout
- too small issue decided by committed voters

need small  $\underline{y}$  and large  $\bar{y}$  so that issue is decided by strategy not constraints

$D$  must be sufficiently concave for the small party to overcome the size advantage of the large party

- high costs of monitoring (generates high concavity)
- homogeneous costs of participation (generates low convexity)

## Efficiency

measured by surplus  $v_{-d} - D((\eta_d/\eta_{-d})\hat{\varphi}_d) > 0$

(not by whether the party with the largest  $v_j$  won)

worst case: when parties are very similar and  $\bar{y}$  constraint does not bind

note: something very fishy about efficiency here

not clear we have a good theoretical grasp of why voting might be a good idea

(why not select a random subset of voters to vote?)



## ***Interpretation of $\hat{\varphi}_k$***

$\hat{\varphi}_k$  in general (not just for voting) measures willingness to pay when there is a 0-1 decision

- demonstrate, do not demonstrate
- strike, do not strike
- lobbying effort

Remark: the disadvantaged party gets a surplus of zero, the advantaged party gets the surplus of winning minus of submitting a bid equal to the willingness to pay of the disadvantaged part

exactly the same surpluses as a second price auction in weakly undominated strategies; same true for first price auction if equilibrium exists

- in the case of lobbying  $\varphi$  is not “lost” but may be in part income to politicians



## Interpretation of $\underline{y}$

$\underline{y}$  are “committed voters”

may in fact be due to a different social norm: “civic duty to vote” also enforced by monitoring but independent of party

- seems less likely to be a factor in non-voting situations such as lobbying, demonstrations, or striking
- not that there wouldn't be people committed to demonstrating, etc. but just that there are probably few of them compared to committed voters

in the case of lobbying we expect  $\underline{y} < 0$ , that is the lowest individual cost is positive

$$D(0) = 0 \text{ but } \lim_{y \rightarrow 0^+} M(0) > 0$$

fixed cost of getting anybody to contribute – studied by Levine/Modica  
much more favorable to small group

## ***Voter Suppression (Martinelli)***

each party can increase monitoring cost  $\theta$  of opposing party to an amount  $\bar{\theta} > \theta$  by incurring cost  $G > 0$ .

**Theorem:** If  $\bar{\theta}$  is sufficiently close to  $\theta$  then only the advantaged party will suppress votes. If  $G$  is sufficiently small it will choose to do so and this will be a strict Pareto improvement.



## ***Political Contests***

conflict resolution function: probability of winning the election a continuous function of the expected number of voters each party turns out

- outcome of the election decided by the actual number of votes rather than the expected number (binomial)
- correlation in the draws of  $y$  by voters
- random errors in the counting of votes
- ballots validation
- court intervention

pivotality in the incentive constraint

going to assume  $\bar{y} = 1$ , large enough (even if terribly costly) punishments

## ***The Contest Model***

probability of the small group winning the prize is given by a conflict resolution function  $p_S(\eta_S\varphi_S, \eta_L\varphi_L) \in [0, 1]$  with

$$p_L(\eta_L\varphi_L, \eta_S\varphi_S) = 1 - p_S(\eta_S\varphi_S, \eta_L\varphi_L).$$

strategy a cumulative distribution function  $F_k$  on  $[0, 1]$

per capita costs of turning out voters  $D_k(\varphi_k, F_{-k})$  depends on  $F_{-k}$  because of pivotality

$p_S, D_k$  continuous (weak convergence for probability measures)

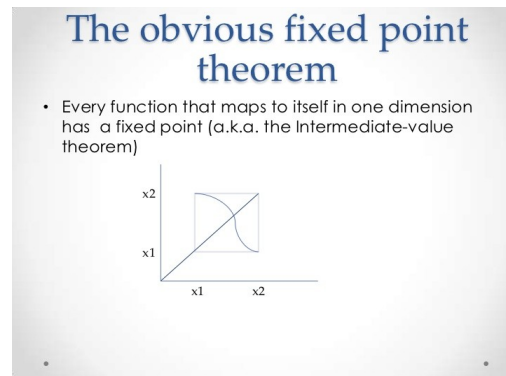
no assumption of monotonicity for  $D_k$  (makes little sense with pivotal

## Equilibrium

We say that  $F_S, F_L$  are an *equilibrium* of the conflict resolution model if

$$\int v_k p_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) F_k(d\eta_k \varphi_k) F_{-k}(d\eta_{-k} \varphi_{-k}) - \int D_k(\varphi_k, F_{-k}) F_k(d\eta_k \varphi_k) \geq \int v_k p_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) \tilde{F}_k(d\eta_k \varphi_k) F_{-k}(d\eta_{-k} \varphi_{-k}) - \int D_k(\varphi_k, F_{-k}) \tilde{F}_k(d\eta_k \varphi_k) .$$

**Theorem:** An equilibrium of the conflict resolution model exists.



## Upper Hemi-Continuity

a sequence of conflict resolution models

$$p_S^N(\eta_S \varphi_S, \eta_L \varphi_L), D_S^N(\varphi_S, F_L), D_L^N(\varphi_L, F_S)$$

all-pay auction with costs  $D_k(\varphi_k)$  differentiable

on  $(\underline{y}_k, 1]$  with  $(1/\gamma) > D_k'(\varphi) > \gamma$  for some  $\gamma > 0$  and  $\eta_S \hat{\varphi}_S \neq \eta_L \hat{\varphi}_L$ .

conflict resolution models converge to the all-pay auction if for all  $\epsilon > 0$  and  $\eta_S \varphi_S > \eta_L \varphi_L + \epsilon$  we have  $p_S^N(\eta_S \varphi_S, \eta_L \varphi_L) \rightarrow 1$  uniformly, and  $\eta_S \varphi_S < \eta_L \varphi_L - \epsilon$  implies  $p_S^N(\eta_S \varphi_S, \eta_L \varphi_L) \rightarrow 0$  uniformly, and  $D_k^N(\varphi_k, F_{-k}) \rightarrow D_k(\varphi_k)$  uniformly.

**Theorem:** If  $F_k^N$  are equilibria of the conflict resolution models and  $F_k$  is the unique equilibrium of the all-pay auction then  $F_k^N \rightarrow F_k$ .

## Population Size

$N$  represents population size and conflict resolution function binomial arising from independent draws of type by the different voters.

Chebychev's inequality gives the needed uniform convergence of

$$p_S^N(\eta_S \varphi_S, \eta_L \varphi_L)$$



## High Value Elections

**Theorem:** Suppose  $v_L \rightarrow \infty$ . Then  $F_L(1 - \epsilon) \rightarrow 0$ .

- as prize grows large the large group almost certainly turns out all of its voters
- in all-pay auction case it turns out only enough voters to beat the small party

first fix  $N$  and make the size of the prize large enough that the large party will turn out most of its voters

now fix the size of the prize and increase the number of voters so that equilibrium converges to all-pay auction equilibrium

so that the turnout of the large party must decline until it matches the number of voters in the small party

declining turnout with population size, but not due to pivotality



## Pure Strategy Equilibrium

objective functions

$p_k(\eta_k\varphi_k, \eta_{-k}\varphi_{-k})v_k - D_k(\varphi_k, F_{-k})$  single-peaked in  $\eta_k\varphi_k$

for example:  $p_k$  is concave and  $D_k$  convex, at least one strictly

all equilibria are pure strategy equilibria (as in Coate-Conlin)

suppose symmetry  $p_L(\eta_L\varphi_L, \eta_S, \varphi_S) = p_S(\eta_L\varphi_L, \eta_S\varphi_S)$ , when is

$p_k(\eta_k\varphi_k, \eta_{-k}\varphi_{-k}) = p(\eta_k\varphi_k/\eta_{-k}\varphi_{-k})$  concave?

when one party turns out twice as many voters as the other it must none-the-less have at least a 25% chance of losing

concavity means “a lot” of variance in the outcome

single-peakedness is a lot weaker (Herrera, Morelli and Nunnari)

## Tullock Contests

types  $y_k$  have a particular common and idiosyncratic component where the common component may be correlated between the two groups can get the probability of winning to be the Tullock contest success function

$$\frac{1}{1 + (\eta_{-k}\varphi_{-k}/(\eta_k\varphi_k))^\alpha} = \frac{(\eta_k\varphi_k)^\alpha}{(\eta_k\varphi_k)^\alpha + (\eta_{-k}\varphi_{-k})^\alpha}.$$

sufficient condition to be concave is that  $\alpha \leq 1$

as  $\alpha \rightarrow \infty$  approach the case of the all-pay auction



## Pivotality

social norm  $\varphi_k$

two partial conflict resolution functions

$P_k^0(\eta_k \varphi_k, \eta_{-k} \varphi_{-k})$  all voters but one follow the social norm, remaining does not vote

$P_k^1(\eta_k \varphi_k, \eta_{-k} \varphi_{-k})$  all voters but one follow the social norm, remaining does vote

differentiable and non-decreasing in  $\varphi_k$

conflict resolution function is given by the average

$$p_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) = \varphi_k P_k^1(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) + (1 - \varphi_k) P_k^0(\eta_k \varphi_k, \eta_{-k} \varphi_{-k})$$

probability of being pivotal is given by the difference

$$Q_k(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) = P_k^1(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}) - P_k^0(\eta_k \varphi_k, \eta_{-k} \varphi_{-k}).$$

## Incentive Constraints

pivotal cutoff  $\gamma_k(\varphi_k, F_{-k})$  solution to  $c(\gamma_k) = Q_k(\eta_k \varphi_k, \eta_{-k} F_{-k}) v_k$ .

unique and continuous.

For  $y \geq \gamma_k(\varphi_k, F_{-k})$  incentive constraint for voting accounting for  
pivotality  $c(y) - Q_k(\eta_k \varphi_k, \eta_{-k} F_{-k}) v_k \leq P_k$

noting the probability of being pivotal depends on the mixed strategy of the other group

monitoring cost for  $\varphi_k \geq \gamma_k(\varphi_k, F_{-k})$  is

$$M(\varphi_k, F_{-k}) = \psi(1 - \pi)(1 - \varphi_k)(c(\varphi_k) - Q_k(\eta_k \varphi_k, \eta_{-k} F_{-k}) v_k).$$

assumption about cost of getting someone not to vote does not matter

introduce a multiplier  $\psi$  on the monitoring cost

**Theorem:** If  $\hat{\varphi}_k < 1$  then as  $\psi \rightarrow \infty$  we have

$$F_k^\psi (|\varphi_k - \gamma_k(\varphi_k, F_{-k}^\psi)| \leq \epsilon) \rightarrow 1.$$

but this need be not Palfrey/Rosenthal because the possibility of correlation; type of equilibrium discussed in Pogorelskiy