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Abstract

Pareto dominated agreements are shown to prevail with positive probability in an open set of status quo in a Markov perfect equilibrium of a one-dimensional dynamic bargaining game with endogenous status-quo. This equilibrium is continuous, symmetric, with dynamic preferences that satisfy the single-plateau property. It is also shown that there does not exist a symmetric equilibrium with single-peaked preferences.

1 Introduction

Dynamic legislative bargaining with endogenous status quo in one-dimensional policy spaces was introduced in an influential paper by Baron (1996). He characterized Markov Perfect equilibria in pure strategies with the property that bargaining dynamics resemble myopic dynamics with legislators that have single-peaked preferences. In particular, legislators' dynamic preferences exhibit a sinlge-peakedness property so that at each status quo they either successfully propose an agreement that is closest to their dynamic ideal (which may differ from their static ideal agreement) among those acceptable by a majority, or they are able to successfully propose their ideal agreement. Eventually, when the median legislator becomes the proposer, the median's ideal prevails in that and all subsequent periods so that a dynamic median voter theorem applies in this setting.

The main purpose of this note is to show in a model with three legislators and quadratic payoffs that there exists a Markov Perfect equilibrium such that agreements outside the Pareto set prevail with positive probability in an open set of status quo (Proposition 3). Thus, Pareto dominated agreements are possible in a setting we might least expect them, since the underlying majority rule preferences feature a core point at the median legislator's ideal. Ruling out Pareto dominated agreements seems a natural starting point in an attempt to bound equilibrium payoffs in the general majority rule spatial model as a way to mitigate for the absence of stable or core agreements. The present result establishes that we cannot, in general, rely on the Pareto set to bound possible agreements, even when a Condorcet winner exists.

The equilibrium involves mixing on the part of the proposers, whose dynamic payoffs exhibit a single-plateau property. These plateaus extend outside the Pareto set, yielding the paradoxical equilibrium outcomes. In particular, it is exactly this mixing involving Pareto dominated agreements at the two extremes of the policy spectrum that balances out legislators' expected payoff so that strictly Pareto dominated agreements are nevertheless part of the set of their dynamic

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ideal agreements. Despite its paradoxical nature, the equilibrium features a number of redeeming properties. First, mixed strategies are continuous in the status quo, satisfying a restriction that has refining power in continuous state stochastic games. Second, the equilibrium is symmetric around the median maintaining the symmetry of legislators' myopic preferences. In fact, it is shown (Proposition 1) that there does not exist a symmetric equilibrium with single-peaked dynamic payoffs, that is, a symmetric equilibrium of the type characterized by Baron (1996). Finally, inefficiency is of transient nature as the median legislator's ideal eventually prevails in all periods, that is, the equilibrium is consistent with Baron's dynamic median voter theorem.

Besides the work of Baron (1996), a number of other papers study bargaining with endogenous status quo in the one-dimensional spatial model.[1] Zapal (2014) develops a general algorithm characterizing pure strategy equilibria (when they exist) with single-peaked preferences in a more general version of the present model. He also shows that strategic moderation complements non-moderation by players on the other side of the median. The model of electoral competition of Forand (2014) can also be interpreted as a dynamic bargaining model with non-stationary recognition probabilities that preclude proposals from the median. Cho (2014) studies a setting similar to the present model but allowing for the division of a fixed budget to be part of the agreement (but not of the status quo). He also establishes a symmetric equilibrium in mixed strategies but without equilibrium Pareto dominated agreements.

In a distributive agreement space, the question of Pareto efficiency in the dynamic majority rule model is taken up systematically by Anesi and Seidmann (2013). As in Richter (2014), they allow for waste (i.e., agreements that do not exhaust the budget) and obtain equilibria with Pareto dominated agreements, a form of inefficiency they term *static*. The main differences of their study with the present model are, first, that Pareto inefficiency in the present model arises in the presence of a Condorcet winner and, second, that they allow for discontinuous Markov perfect equilibria, that is, equilibria inducing discontinuous dynamic preferences over agreements.

2 Setup

The model is a special case of Baron's (1996) one-dimensional dynamic bargaining model. There are three players indexed by $i = 1, 2, 3$ who must reach a decision x from policy space $X = \mathbb{R}$ in each of a countable infinity of periods. Each period t starts with a status quo $s \in X$. Player i is recognized with probability $p_i = \frac{1}{3}$ to offer a proposal $z \in X$. Then players vote and if at least two approve the proposal, then $x = z$, otherwise $x = s$. The game then moves to the next period with new status quo $s' = x$. Player i receives stage payoff $u_i(x)$ if decision x is reached in period t, where $u_i : X \to \mathbb{R}$ is quadratic taking the form[2]

$$u_i(x) = -(x - (i - 2))^2, i = 1, 2, 3.$$

[1] Other studies of bargaining with endogenous status quo include Epple and Riordan (1987), Kalandrakis (2004), Battaglini and Coate (2007), Duggan, Kalandrakis and Manjunath (2008), Anesi (2010), Riboni and Ruge-Murcia (2010), Kalandrakis (2010), Duggan and Kalandrakis (2011), Diermeier and Fong (2011), Battaglini and Palfrey (2012), Battaglini, Nunnari and Palfrey (2012), Diermeier and Fong (2012), Bowen and Zahran (2012), Duggan and Kalandrakis (2012), Diermeier, Egorov and Sonin (2013), Dziuda and Loeper (2013), Baron and Bowen (2014), Bowen, Chen and Eraslan (2014), Barseghyan and Coate (2014), Nunnari (2014).

[2] Note that players 1, 2, and 3 have (stage payoff) ideal points at -1, 0, and 1, respectively.

Players discount the future with a common factor $\delta \in [0,1)$ and overall payoffs are discounted sums of per period utilities.

Baron (1996) analyzed pure strategy equilibria in stationary Markov strategies. I consider such equilibria as a special case of equilibria that also allow for mixing on the part of the proposer. Specifically, a stationary Markov strategy for i can be decomposed into a measurable proposal function $\pi_i : X \to \mathcal{P}(X)$ where $\mathcal{P}(X)$ is the set of Borel probability measures in X, and a measurable voting function $\alpha_i : X \times X \to \{0,1\}$. Accordingly, $\pi_i(s)$ is the lottery over proposals that i offers when the status quo is s, and $\alpha_i(s,z) = 1$ if i votes to approve proposal z when the status quo is s while $\alpha_i(s,z) = 0$ if the corresponding vote is against the proposal. Denote a profile of such strategies by $\sigma = (\pi_i, \alpha_i)_{i=1,2,3}$. The collective decision on proposal z when the status quo is s is given by

$$\alpha(s,z;\sigma) = \begin{cases} 1 & if \quad \sum_{j=1,2,3} \alpha_j(s,z) \geq 2 \\ 0 & if \quad \sum_{j=1,2,3} \alpha_j(s,z) < 2. \end{cases}$$

Then i's expected payoff from agreement x in the current period, given play governed by strategy profile σ in the future, can be written recursively as

$$U_i(x;\sigma) = (1-\delta)u_i(x) + \delta \sum_{j=1}^{3} p_j \int \left(\alpha(x,z;\sigma)U_i(z;\sigma) + (1-\alpha(x,z;\sigma))U_i(x;\sigma)\right) \pi_i(x)(dz). \tag{1}$$

An equilibrium is now defined as follows:

Definition 1. *A strategy profile σ is an equilibrium if for all i and all s,*

$$\alpha_i(s,z) = \begin{cases} 1 & if \quad U_i(z;\sigma) > U_i(s;\sigma) \\ 0 & if \quad U_i(z;\sigma) < U_i(s;\sigma) \end{cases} \quad \text{for all } z, \text{ and} \tag{2}$$

$$\pi_i(\arg\max_z \{U_i(z;\sigma) \mid \alpha(s,z;\sigma) = 1\}) = 1. \tag{3}$$

Note that two refinements are built in the equilibrium notion: first, voters cast their vote as if they are *pivotal*. This is a standard refinement, precluding uninteresting equilibria where, for example, all possible proposals are unanimously approved. Second, strategy profiles satisfy *proposer success*: for all $s \in X$ and all i, $\int \alpha(s,z;\sigma)\pi_i(s)(dz) = 1$. Given focus on pure voting strategies, there is no loss in focusing on strategy profiles that satisfy *proposer success*: for any profile in which the support of $\pi_i(s)$ contains proposals that fail at status quo s, there is a payoff equivalent strategy profile in which these proposals are replaced by the status quo.

Besides these mild (and standard) refinements, I now introduce a number of criteria that distinguish a focal set of strategy profiles. The first criterion is that of symmetry, which is respected in the setup considered here and constitutes a natural focal property of equilibrium. Say that strategy profile σ is *symmetric* if $U_1(x;\sigma) = U_3(-x;\sigma)$ and $U_2(x;\sigma) = U_2(-x;\sigma)$. The second criterion satisfies a central feature of equilibria characterized in Baron (1996). In particular, a strategy profile σ satisfies *dynamic single-peaked* preferences if for all i there exist $\hat{x}_i$ such that $U_i(x;\sigma)$ is strictly increasing for $x \leq \hat{x}_i$ and strictly decreasing for $x \geq \hat{x}_i$. It turns out that these first two properties are not jointly consistent with equilibrium in the present setup, as shown in Proposition 1. This prompts consideration of a third property, that is, strategy profile σ satisfies *dynamic single-plateaued* preferences if for each i there exists $\hat{x}_i^\ell$ and $\hat{x}_i^r$ such that $U_i(x;\sigma)$ is strictly increasing for $x \leq \hat{x}_i^\ell$, constant for $\hat{x}_i^\ell \leq x \leq \hat{x}_i^r$, and strictly decreasing for $x \geq \hat{x}_i^r$. Finally, say that the equilibrium is *continuous* if proposal strategies are continuous in the status quo.[3]

3 Symmetry and single-peakedness

Before establishing the main result, I establish that there does not exist a symmetric equilibrium satisfying the single-peakedness property in this section. This argument paves the way for the construction of a symmetric equilibrium in mixed strategies that satisfies the weaker single-plateau property and facilitates the transition to this latter equilibrium construction. The non-existence of a symmetric equilibrium satisfying single-peakedness can be established by contradiction. Suppose there exists a symmetric equilibrium σ that satisfies dynamic single-peakedness. By symmetry, it follows that dynamic ideal points satisfy $\hat{x}_2 = 0$ and that $\hat{x}_1 = -\hat{x}_3$ and $|\hat{x}_i| = x^*, i = 1,3$, for some x^*. Single-peakedness also implies that for any status quo s such that $|s| \leq x^*$ and any $Y \subseteq X$, $\pi_i(s)(Y) = \mathbb{1}_Y(|s|)$ if $\hat{x}_i = x^*$ and $\pi_i(s)(Y) = \mathbb{1}_Y(-|s|)$ if $\hat{x}_i = -x^*$, $i = 1,3$. With these strategies, the payoff of i from any x, $|x| \leq x^*$, is obtained as:

$$(4) \qquad U_i(x;\sigma) = (1-\delta)u_i(x) + \tfrac{\delta}{3}(U_i(x;\sigma) + U_i(-x;\sigma) + U_i(0;\sigma)), |x| \leq x^*.$$

Using (4) setting $x = 0$ we solve for $U_i(0;\sigma) = u_i(0)$, and further using the same equation evaluated at x and $-x$ and solving for $U_i(-x;\sigma), U_i(x;\sigma)$, we obtain:

$$(5) \qquad U_i(x;\sigma) = (1-\delta)u_i(x) + \tfrac{\delta}{3-2\delta}(u_i(0) + (1-\delta)(u_i(-x) + u_i(-x))), |x| \leq x^*.$$

On the other hand, for status quo s such that $|s| > x^*$, the non-median players can successfully propose their ideal point since $\sum_{j=1,2,3} \alpha_j(s, x^*) \geq 2$ and $\sum_{j=1,2,3} \alpha_j(s, -x^*) \geq 2$, so that $\pi_i(s)(Y) = \mathbb{1}_Y(\hat{x}_i)$ for all s such that $|s| > x^*$, all $Y \subseteq X$, and all i. It follows that:

$$(6) \qquad U_i(x;\sigma) = (1-\delta)u_i(x) + \tfrac{\delta}{3}(U_i(x^*;\sigma) + U_i(-x^*;\sigma) + U_i(0;\sigma)), |x| > x^*.$$

After substitution for $U_i(x^*;\sigma), U_i(-x^*;\sigma), U_i(0;\sigma)$ from (5) in equation (6) we conclude that when $|x| > x^*$, $U_i(x;\sigma)$ depends on x only through the stage payoff. Thus, it follows that it cannot be that $x^* < 1$, because in that case U_3 is increasing with x if $x^* < x < 1$ contradicting single-peakedness of U_i with peak $\hat{x}_i \in \{-x^*, x^*\}$, $i = 1,3$. On the other hand, if $x^* \geq 1$ then by differentiating $U_3(x;\sigma)$ at x with $|x| < x^*$ using equation (5) we find that

$$\frac{\partial U_3(x;\sigma)}{\partial x} = (1-\delta)(2 - \frac{6x}{(3-2\delta)}) \qquad \text{and} \qquad \frac{\partial^2 U_3(x;\sigma)}{\partial x \partial x} = -\frac{6(1-\delta)}{(3-2\delta)} < 0.$$

But $\frac{\partial U_3(x;\sigma)}{\partial x} = 0 \Rightarrow x = 1 - \frac{2\delta}{3}$, contradicting the single-peakedness of U_3 with peak $\hat{x}_3 \notin (-1,1)$.

From the last contradiction it follows that:

Proposition 1. *There does not exist a* symmetric *equilibrium strategy profile that satisfies* dynamic single-peaked *preferences.*

Symmetric equilibria with single-peakedness engender incentives for moderation on both non-median players. Such incentives are documented in Baron (1996) and induce (provisional)

[3] Here continuity is with respect to the weak$*$ topology, that is, for all i, all s, and all sequences $\{s^n\}$ converging to s, $\int_{x \in X} f(x) d\pi_i(s^n) \to \int_{x \in X} f(x) d\pi_i(s)$ for all bounded continuous f. This is also the notion of continuity used in Proposition 2 of Kalandrakis (2004).

dynamic ideal points $-x^*, x^*$ that are closer to the median compared to these players' static ideal points. But, at the same time, such moderate proposals attenuate the incentive for moderation when the status quo is outside the interval of these provisional dynamic ideal points. In combination, these two forces render the existence of symmetric equilibria with single-peakedness impossible. Symmetry is essential for both of these forces to be simultaneously present in the three player model considered in this study. Indeed, the present model does admit (two) asymmetric pure strategy equilibria featuring dynamic single-peakedness. These equilibria are consistent with the characterization of Baron (1996), and have been independently derived by Zapal (2014) where the reader can find the details for this and more general settings that admit pure strategy equilibria with quadratic preferences.

Proposition 2. *There exist two pure strategy equilibrium strategy profiles that satisfy* dynamic single-peakedness*, one with peaks:*

$$\hat{x}_1 = -1 + \tfrac{2}{3}\delta, \hat{x}_2 = 0, \hat{x}_3 = 1,$$

and the other with peaks

$$\hat{x}_1 = -1, \hat{x}_2 = 0, \hat{x}_3 = 1 - \tfrac{2}{3}\delta.$$

In the asymmetric equilibria of Proposition 2, only one of the two non-median players moderates her proposal when the status quo is extreme. The asymmetry preserves the moderating incentives of the player whose dynamic ideal point moves closer to the median (compared to her stage ideal point). In turn, this moderation confers no advantage to moderation for the other non-median player. Despite the existence of such single-peaked equilibria, the analysis in Zapal (2014) strongly suggests that versions of the game with more players may not admit any such equilibria, even when symmetry is not (or cannot) be imposed.

4 Single-plateaus and Pareto (sub)optimality

Proposition 1 leaves open the possibility that symmetric equilibria exist in mixed strategies, though they cannot satisfy single-peakedness. Such a symmetric equilibrium that features single-plateaued preferences is established in this section. This is a natural generalization of the single-peakedness property, and is especially apt in this context because it provides the necessary indifference in order to support an equilibrium in mixed strategies. Indeed, the equilibrium partly restores the construction of the previous section using proposer mixing to induce plateaus in non-median players' dynamic preferences starting from the provisional ideal points $x^*, -x^*$ of the previous section. In particular, consider strategy profile σ with dynamic single-plateaued preferences characterized by

$$\hat{x}_3^{\ell} = -\hat{x}_1^{r} = x^* = 1 - \frac{2\delta}{3},$$
$$\hat{x}_3^{r} = -\hat{x}_1^{\ell} = x^{**} = 1 + \frac{2\delta}{3},$$

and $\hat{x}_2^\ell = \hat{x}_2^r = \hat{x}_2 = 0$, and proposal strategies given by

$$\begin{aligned}
\pi_1(s)(Y) &= \mu(s)\mathbb{1}_Y(-|s|) + (1-\mu(s))\mathbb{1}_Y(-x^*),\\
\pi_2(s)(Y) &= \mathbb{1}_Y(0),\\
\pi_3(s)(Y) &= \mu(s)\mathbb{1}_Y(|s|) + (1-\mu(s))\mathbb{1}_Y(x^*),
\end{aligned}$$

for all $Y \subseteq X$, where the mixing probability function μ is continuous and takes the form:

$$\mu(s) = \begin{cases} 1 & \text{if } s \in [-x^*, x^*],\\ \frac{1}{2} + \frac{3(1-|s|)}{4\delta} & \text{if } s \in (-x^{**}, -x^*) \cup (x^*, x^{**}),\\ 0 & \text{if } s \in (-\infty, -x^{**}] \cup [x^{**}, +\infty). \end{cases} \tag{7}$$

These proposal strategies involve non-degenerate mixing by the non-median players placing mass on two proposals when the status quo is in the intervals $(-x^{**}, -x^*), (x^*, x^{**})$ where the dynamic preferences of the respective two players feature plateaus. These strategies exactly coincide with the symmetric strategies characterized in the previous section in the interval $[-x^*, x^*]$ and are in fact identical in the entire domain if $x^* = x^{**}$.

Using these strategies, player i's expected payoff from implemented agreement $x \in X$ satisfies

$$U_i(x;\sigma) = (1-\delta)u_i(x) + \frac{\delta}{3}\begin{pmatrix} U_i(0;\sigma) + \mu(x)(U_i(-x;\sigma) + U_i(x;\sigma)) \\ + (1-\mu(x))(U_i(-x^*;\sigma) + U_i(x^*;\sigma)) \end{pmatrix}. \tag{8}$$

As in the previous section, solving (8) evaluated at $x = 0$ we obtain $U_i(0;\sigma) = u_i(0)$, and using the system of equations obtained from (8) evaluated at x and $-x$ we are able to solve for

$$U_i(x;\sigma) = (1-\delta)u_i(x) + \frac{\delta}{3-2\delta\mu(x)}\begin{pmatrix} u_i(0) + \mu(x)(1-\delta)(u_i(-x) + u_i(x)) \\ + (1-\mu(x))(U_i(-x^*;\sigma) + U_i(x^*;\sigma)) \end{pmatrix}. \tag{9}$$

Equation (9) evaluated at $x \in \{-x^*, x^*\}$ (using the fact that $\mu(-x^*) = \mu(x^*) = 1$) yields an expression for $U_i(-x^*;\sigma), U_i(x^*;\sigma)$ in terms of model primitives. Upon substitution back into equation (9) we finally obtain

$$U_i(x;\sigma) = (1-\delta)u_i(x) + \delta\begin{pmatrix} \dfrac{u_i(0)}{3-2\delta} + \dfrac{\mu(x)(1-\delta)(u_i(-x) + u_i(x))}{(3-2\delta\mu(x))} \\ + \dfrac{(1-\mu(x))3(1-\delta)(u_i(-x^*) + u_i(x^*))}{(3-2\delta\mu(x))(3-2\delta)} \end{pmatrix}. \tag{10}$$

These payoffs are plotted in Figure 1.

Note that the payoffs U_i computed in (10) are continuous in x. They are also differentiable in x except at $-x^{**}, x^{**}$ and, after substitution from (7), we can compute these derivatives as

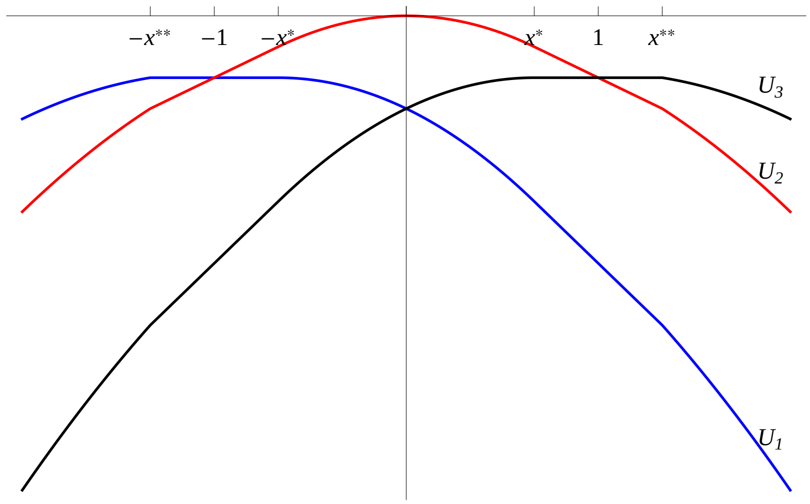

Figure 1: Dynamic payoffs $U_i(x;\sigma)$.

Equilibrium payoffs $U_i(x;\sigma)$ in a symmetric equilibrium with non-median player preferences that feature single-plataues in the intervals $[-x^{**},x^{*}]$ (player 1) and $[x^{*},x^{**}]$ (player 3). Median (player 2) has single peaked-preferences with peak at 0. *Source:* equation (10).

follows:

$$\frac{\partial U_i(x;\sigma)}{\partial x}=\begin{cases}(1-\delta)2(i-1) & \text{if } x\in(-x^{**},-x^{*}),\\ (1-\delta)2(1-i) & \text{if } x\in(x^{*},x^{**}),\\ (1-\delta)(\frac{\partial u_i(x)}{\partial x}+\frac{\delta}{3-2\delta}(\frac{\partial u_i(-x)}{\partial x}+\frac{\partial u_i(x)}{\partial x})) & \text{if } |x|<x^{*},\\ (1-\delta)\frac{\partial u_i(x)}{\partial x} & \text{if } |x|>x^{**}.\end{cases} \tag{11}$$

A plot of the derivative functions reported in (11) is depicted in Figure 2. It is now straightforward to verify the single plateau property by noting that the derivative of U_i with respect to x has the correct sign to the left and right of the respective plateaus.

These arguments establish the main result:

Proposition 3. *There exists a* continuous, symmetric *equilibrium strategy profile that satisfies* dynamic single-plateaued *preferences. It is such that in an open set of status quo, Pareto dominated alternatives are proposed with positive probability and are approved.*

Mixing is essential for the counter-intuitive property of the equilibrium in Proposition 3, as it exactly balances the gain and loss from a proposal outside the interval $[-x^{*},x^{*}]$ inducing the necessary indifference for the non-median players. A Pareto dominated agreement becomes palatable for these players because proposals that are not Pareto dominated entail a smaller probability (but less than probability zero) of the symmetric proposal on the other side of the median prevailing. The continuity of the equilibrium is an added bonus, made possible by continuously varying the mixing probability of the most extreme proposals from zero to one as the status quo spans the interval of the non-median players' plateaus.

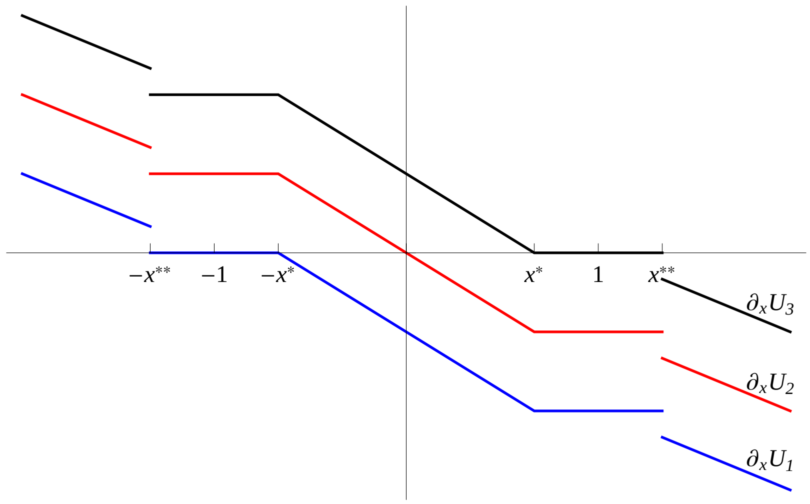

Figure 2: Derivative of dynamic payoff functions $U_i(x;\sigma)$.

Equilibrium payoffs $U_i(x;\sigma)$ are differentiable in $\mathbb{R} \setminus \{-x^{**}, x^{**}\}$. U_i is increasing to the left and decreasing to the right of the plateaus (ideal point in the case of player 2). *Source:* equation (11).

5 Conclusion

As already follows from Proposition 2, the equilibrium in Proposition 3 is not unique. Furthermore, it is not obvious how or whether the equilibrium in Proposition 3 generalizes in asymmetric contexts. But this study establishes that even in the simplest spatial model of dynamic bargaining under majority rule, Pareto dominated alternatives cannot be ruled out as possible outcomes in *continuous* equilibria for an open set of status quo, even in the presence of a (static and dynamic) Condorcet winner.

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