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Are World Leaders Loss Averse?

Abstract

We focus on the preferences of an extremely salient group of highly-experienced individuals who are entrusted with making decisions that affect the lives of millions of their citizens, heads of government. We test for the presence of a fundamental behavioral bias, loss aversion, in the way heads of government choose decision rules for international organizations. If loss aversion disappears with experience and high-stakes it should not exhibited in this context. Loss averse leaders choose decision rules that oversupply negative (blocking) power at the expense of positive power (to initiate affirmative action), causing welfare losses through harmful policy persistence and reform deadlocks. We find evidence of significant loss aversion (λ = 4:4) in the Qualified Majority rule in the Treaty of Lisbon, when understood as a Nash bargaining outcome. World leaders may be more loss averse than the populous they represent.

JEL-Codes: D030, D810, D720, C780.

Keywords: loss aversion, behavioral biases, constitutional design, voting, bargaining, voting power, EU Council of Ministers.

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1 Introduction

Harking to Kahneman and Tversky (1979), people are more sensitive to perceived losses than to commensurate gains (loss aversion). Loss aversion can explain an extraordinary variety of otherwise puzzling phenomena: important examples are the equity premium puzzle (Benartzi and Thaler, 1995), asymmetric price elasticities (Hardie *et al.*, 1993), downward-sloping labor supply (Dunn, 1996; Camerer *et al.*, 1997; Goette *et al.*, 2004), inefficient renegotiation (Herweg and Schmidt, 2015), contract design (de Meza and Webb, 2007; Dittmann *et al.*, 2010; Herweg *et al.*, 2010), taxpayer filing behavior (Engström *et al.*, 2015; Rees-Jones, 2018), the play of game-show contestants (Post *et al.*, 2008), the putting strategy of Tiger Woods (Pope and Schweitzer, 2011) and the buying strategies of hog farmers (Pennings and Smidts, 2003). Lakshminarayanan *et al.* (2006) experiment with monkeys and suggest that loss aversion is a basic evolutionary trait that extends beyond humans. Reflecting this evidence, Rabin (2000, p. 1288) calls loss aversion the "most firmly established feature of risk preferences."[1]

In this paper we focus on the preferences of a very small, but nonetheless extremely salient, group of individuals who are entrusted with making decisions that affect the lives of millions of their citizens: heads of government. In particular, we focus on the role of heads of government in international decisionmaking. If indeed loss aversion is a basic evolutionary trait then we should expect to observe it within heads of government. On the other hand, heads of government are an unrepresentative sample of the human race. They are, for instance, substantially more cognitively able than average (Dal Bó *et al.*, 2017). Perhaps unsurprisingly, therefore, there is growing evidence that these individuals (and other "elite" decisionmakers) possess superior, or at least different, faculties of decisionmaking to a more representative sample of the population and, in particular, to the undergraduate students upon which most experimental estimates of loss aversion are based (e.g., Alevy *et al.*, 2007; Hafner-Burton *et al.*, 2013).

If loss aversion goes away with experience and large-stakes, as supposed by some economists (e.g., List, 2003, 2011; List and Mason, 2011; Levitt and List, 2008), then world leaders, who

[1] For other studies that take a more critical stance see, e.g., Plott and Zeiler (2005), who call into question the general interpretation of gaps between the willingness to pay and the willingness to accept as evidence for loss aversion. Gal and Rucker (2018) question other evidence traditionally interpreted as evidence of loss aversion and argue that loss aversion appears to be best understood as a psychological phenomenon that is dependent on contextual factors, rather than as a stable universal trait.

make high-stakes decisions on a daily basis, should not be prone to loss aversion. Furthermore, political leaders also are known to have higher than average educational attainment (e.g., Dal Bó *et al.*, 2009; Dal Bó and Rossi, 2011), and education is frequently negatively associated with the strength of loss aversion (Gächter *et al.*, 2007; Booij and van de Kuilen, 2009; Hjorth and Fosgerau, 2011). Inesi (2010) reports experimental findings indicating that powerful people exhibit less loss aversion.

If world leaders exhibit loss aversion this could affect their voting behavior in potentially undesirable ways. In particular, heightened attention to potential losses might lead a head of government to oppose an action that would, in expectation, be gainful to their citizens. While important, we do not focus on voting behavior, but rather on the prior role that loss aversion plays when heads of government choose the decision rule they subsequently use to determine whether policies are implemented or not.

To investigate how loss averse, if at all, are world leaders we build on the idea that leaders with differing degrees of loss aversion will prefer different decision rules. Participation in international organizations forces a trade-off on world leaders: the need to coordinate on cross-border issues versus the incumbent necessity to pool national sovereignty (Hooghe and Marks, 2015). If, in particular, the national veto is conceded, a leader may experience a loss if they are required to implement a motion that is harmful to their interests.

We therefore distinguish two distinct types of power within international institutions: the power to initiate actions that an actor supports (positive power), and the power to prevent actions that an actor opposes (negative power). From a purely objective, disinterested viewpoint – i.e., in the absence of loss aversion – the positive and negative notions of power seem of equal import. In the presence of loss aversion, however, heads of government are induced to care more strongly about preventing bad outcomes (negative power) than about initiating positive outcomes (positive power). Accordingly, when called to design voting systems for international organizations, loss averse heads of government will choose decision rules in which the hurdle to pass a motion is higher than to defeat it. Such decision rules are biased towards maintenance of the status quo. Following studies that have observed a preference for the status quo in, e.g., consumer and investment behavior (Samuelson and Zeckhauser, 1988; Knetsch and Sinden, 1984; Hartman *et al.*, 1991) we term this asymmetry in favor of the status quo *status quo bias*.

Why does it matter if political leaders choose decision rules overly biased towards maintaining the status quo? The dynamic costs of this effect are likely to be substantial. The harm from status quo bias manifests in two interrelated phenomena (i) policy persistence, whereby policies remain long after their purpose has been served (Coate and Morris, 1999), and; (ii) reform deadlocks (e.g., Alesina and Drazen, 1991; Heinemann, 2004; Scharpf, 1988).[2] To the extent that loss aversion is pervasive in the electorate heads of government represent, society may be willing to bear some of these harmful effects – indeed status quo bias is a ubiquitous feature of the decision rules used in international organizations. But if heads of government are more loss averse than their electorate, they may cause social harm by inducing these effects at excessive levels. We shall present evidence that suggests heads of government may indeed be more loss averse than the population at large.

In spite of the many normative approaches to the design of decision rules, in practice, international organizations choose their decision rules as the outcome of a bargaining process between heads of government.[3] We, therefore, model the formation of decision rules as the outcome of a Nash bargain between leaders, and show that the ratio of negative power to positive power implied by the chosen rule is a sufficient statistic for measuring loss aversion. In this way, we seek to reveal the coefficient of loss aversion of world leaders from the adoption of a new Qualified Majority (QM) decision rule for the European Union (EU) Council of Ministers (CoM) in 2007. Precisely, we look for the level of loss aversion that leads to a coincidence between the ratio of negative power to positive power implied in the observed rule adopted by EU heads of government and the corresponding ratio at the Nash bargaining solution (NBS).

The QM decision rule adopted by EU heads of government in 2007 is a majority rule for decision-making in a subset of policy domains.[4] It requires that, to pass, 55 percent of member states must vote in favor of a motion, and those in favor must also represent at least 65 percent of EU citizens. Alternatively, a motion also passes if three or fewer countries vote against it. To rationalize as a bargaining outcome the ratio of negative power to positive power implied by this choice of decision rule requires a coefficient of loss aversion of

[2] Consistent with these points, use in the EU of a QM rule (rather than a unanimity rule) is associated with speedier legislative responses, and thereby reduced such instances of persistence and deadlock. See, e.g., Golub (2007) and König (2007).

[3] As such, the decision rules agreed through bargaining often depart from normative principles. See, e.g., Hosli and Machover (2004) for a (despairing) discussion of the Nice QM rule in this regard.

[4] The EU is by no means unique among international organizations in adopting a majority rule for making at least a subset of decisions. For systematic analyses of the decision rules of international organizations see Posner and Sykes (2014) and Blake and Payton (2015).

$\lambda = 4.4$. This implies that losses loom approximately four and a half times as large as gains: world leaders are loss averse. Consistent with our finding, Axel Moberg, a witness to the earlier negotiation of the Nice QM rule as a member of the Swedish delegation, documents how member states were largely preoccupied with "...the ability of groups of like-minded states to block decisions" (Moberg, 2002: 261), i.e., a negative concept of power.[5] Given that estimates for λ generally cluster around two, leaders seem more loss averse than the populations they represent. If leaders were loss neutral ($\lambda = 1$) a considerable number of policy domains currently utilizing the unanimity rule in EU would instead be predicted to utilize a majority rule.

Our model is intended as a descriptive, rather than normative, account of the process by which decision rules are selected. As such, we follow a vast economic literature in interpreting the (generalized) NBS as the outcome of a strategic bargaining process.[6] The NBS, however, also has desirable normative properties (Nash, 1950). In particular, the outcome of the Nash bargain we consider yields an outcome that is Pareto efficient in an ex-ante sense (i.e., from behind a veil of ignorance concerning the motion to be decided). This feature of the model connects, therefore, with a literature that advocates ex-ante utility maximization as a normative criterion for decision rule design (Barberà and Jackson, 2006; Maggi and Morelli, 2006; Rae, 1969).[7]

Our paper contributes to what is presently a relatively thin literature on elite decisionmaking. As Hafner-Burton *et al.* (2013) explain, elites are difficult to study directly because "...they are generally busy, wary of clinical poking, and skittish about revealing information about their decisionmaking processes and particular choices." By inferring preferences from observed choices, we skirt these problems. We also provide a further exploration of the role of behavioral economics in the nexus of economics and politics (see, e.g., Levy, 2003; Boettcher, 2004; Baekgaard, 2017; Stein, 2017; Vis and Kuijpers, 2018). Our analysis also

[5] A further inside account of these negotiations that buttresses this point is Galloway (2001, Ch. 4).

[6] Binmore *et al.* (1986) show that the NBS is an approximation to the perfect equilibria in both time-preference and exogenous-risk strategic models. These results are extended to non-expected utility preferences in Rubinstein *et al.* (1992). Harsanyi (1956) shows that the NBS coincides with the predictions of some earlier strategic bargaining models, in particular that of Zeuthen (1930). This solution equivalence between seemingly disjoint approaches explains, at least in part, the extensive use of the NBS in empirical settings.

[7] For the further implementation of this normative criterion to decision rule design see, e.g., Beisbart *et al.* (2005), Beisbart and Bovens (2007), and Laruelle and Valenciano (2010). Aghion *et al.* (2004) also consider a normative approach to setting voting quotas, but from the perspective of optimally constraining political leaders.

connects to the wider formal analysis of the QM rule of the CoM (e.g., Felsenthal and Machover, 1997, 2001, 2004, 2009).[8] As our findings suggest that the strength of loss aversion exhibited by leaders may exceed that representative of the population at large, our findings also have implications for the literature on the optimal selection of representatives in delegated democracies (e.g., Harstad, 2010).

The plan of the paper is as follows: Section 2 develops a theoretical framework for understanding positive and negative power under a given decision rule, and constructs a bargaining model over the choice of a decision rule. Section 3 describes our implementation of the bargaining model to the 2007 negotiation of the Lisbon QM rule, and Section 4 gives the results. A discussion of our findings is given in Section 5. Proofs are located in Appendix 1, and the figures appear at the very rear.

2 Model

In this section we model the adoption of a decision rule by an international organization as the outcome of a grand bargain between its member states. We consider a voting body $\mathcal{N}$ comprised of $N > 1$ member states, to which motions are submitted. The set of voting possibilities is $\{for, against\}$ and the outcome space is $\{pass, fail\}$.[9] For a given motion, F denotes the set (coalition) of members voting for.

Proceeding in the spirit of Laruelle and Valenciano (2010) we assume, for simplicity, that no country is indifferent between voting for or *against* on any issue, and voting is not costly. In these conditions, countries will vote for or *against* a motion according to whether the motion is gainful or harmful to them, relative to the maintenance of the status quo. Before the motion to be voted on is known, each country belongs to one of two possible types: a for-country, which stands to gain a monetized amount $W^F > 0$ if the motion passes, or an *against*-country, which stands to lose a monetized amount $W^A > 0$ if the motion passes. Accordingly, a for-country, i, will vote for, hence $i \in F$. For an *against*-country j, $j \notin F$. If the motion fails, then the status quo position is maintained, so no country gains or

[8]Further notable contributions to this literature include Le Breton *et al.* (2012), Beisbart *et al.* (2005), Leech (2002), Bindseil and Hantke (1997), Widgrén (1994), and Hosli (1993).

[9]We shall apply our model to the EU CoM, in which abstention is a third possible voting outcome. Under the QM decision rule we study in this paper, however, abstention is formally indistinguishable from a vote against. Hence, it can be omitted without any loss of generality.

loses any amount. We assume that each country is of for-type with probability $p \in (0,1)$, independently of the others, but countries only learn their type once the motion is known.

2.1 Decision Rules

Formally, a decision rule is a mapping, w, from the set F of countries voting for to the set of voting outcomes that satisfies the following axioms:

Axiom 1 $w(\emptyset) \mapsto fail.$

Axiom 2 $w(\mathcal{N}) \mapsto pass.$

Axiom 3 *If* $w(F) \mapsto pass$ *then* $w(T) \mapsto pass$ *for any* T *satisfying* $F \subseteq T \subseteq \mathcal{N}$*.*

Axiom 4 *If* $w(F) \mapsto pass$ *then* $w(\mathcal{N} \setminus F) \mapsto fail.$

Axioms 1 and 2 together guarantee the existence of a non-empty coalition of countries that can pass a motion when voting for. Axiom 3 is a monotonicity requirement. Decision rules satisfying Axiom 4 are termed *proper*, and are otherwise termed *improper*. If the rule is improper then multiple (and contradictory) outcomes are possible – making such rules inherently unsuitable to making decisions of substance in international organizations. Hence we restrict attention to proper rules.

The QM decision rule of the EU CoM, as enshrined in the Treaty of Lisbon, Article 9c, is a special case of a class of decision rules we denote by $QM(q_A, q_F, q_P)$. Let the proportion of the total population of countries $i \in \mathcal{N}$ belonging to country i be denoted by ρ_i, with $\min\{\rho_i\}_{i \in \mathcal{N}} = \underline{\rho}$. A motion passes under the decision rule $QM(q_A, q_F, q_P)$ when (i) either at least a proportion $q_F \in (0.5, [N-1]/N]$ of members representing a proportion $q_P \in (0.5, 1-\underline{\rho}]$ or more of the total EU population votes for; or (ii) the number of members voting *against* is less than $q_A \in \{1, \ldots, \lfloor N/2 \rfloor\}$.

The decision rule chosen by EU leaders in the Treaty of Lisbon is the special case of $QM(q_A, q_F, q_P)$ given by $QM(4, 0.55, 0.65)$. The set of winning coalitions under this rule is depicted graphically as the light-shaded space in Figure 1. As is apparent in the Figure, a motion may pass under the Lisbon QM rule without the population threshold having been satisfied if the size of the coalition voting *against* is less than four.[10]

Figure 1 – see p. 31

It is straightforward to observe that (i) $QM(q_A, q_F, q_P)$ satisfies Axioms 1-4 and (ii) that $QM(q_A, q_F, q_P)$ is distinct from the unanimity rule, under which, for a motion to $pass$, all countries must vote for.

2.2 Power: Positive and Negative

We now construct formal measures of power – both positive and negative – in a voting body, extending earlier work in Coleman (1971). Positive power is the extent to which a country i can initiate action. Hence, it is intimately related to the probability, conditional on i having voted for, that a motion will $pass$, $\Pr(pass|i \in F)$. Negative power – the power to prevent action – is similarly related to the probability, conditional on i having voted *against*, that a motion will $fail$, $\Pr(fail|i \notin F)$. A difficulty with using these probabilities as direct measures of power, however, is that they mix power with luck. In particular, if the unconditional probability of a motion passing is denoted by $\Pr(pass) \equiv \omega$, then it is only the differential $\Pr(pass|i \in F) - \omega$ that reflects genuine positive power separate from luck. Similarly, pure negative power is reflected in the differential $\Pr(fail|i \notin F) - [1 - \omega]$. Rescaling these differentials linearly to the unit interval, we arrive at a pure measure of positive power (β_i^+) and of negative power (β_i^-):

$$\beta_i^+ = \frac{\Pr(pass|i \in F) - \omega}{1 - \omega}; \qquad \beta_i^- = \frac{\Pr(fail|i \notin F) - [1 - \omega]}{\omega}. \tag{1}$$

Under the twin assumptions that (i) all countries vote independently; and (ii) that each country votes for and *against* with equal probability, β_i^+ corresponds to Coleman's (1971) "power to initiate action", β_i^- to Coleman's "power to prevent action", and ω to Coleman's "power of a collectivity to act" ("power to act"). We generalize the setting of Coleman (1971), however, for although we retain assumption (i) above, we relax assumption (ii) by

[10] In the case of $QM(4, 0.55, 0.65)$ it is apparent from Figure 1 that each of the three thresholds $\{q_A, q_F, q_P\}$ actively shape the set of winning coalitions. More generally, however, one or more of the thresholds may become redundant. For instance, if $N - q_A \leq q_F$, then the threshold for members voting for, q_F, plays no role.

allowing the probability of voting *for* to differ from that of voting *against*.[11] Our measures of positive and negative power are also closely related to the concept of criticality: country i is *critical* ($i \in C$) when it is able to change the outcome of a vote by switching its vote. The probability that a country is critical in a given vote, $\Pr(i \in C)$, is equivalently represented as ω-weighted average of β_i^+ and β_i^-,

$$\Pr(i \in C) = \omega\beta_i^- + [1-\omega]\,\beta_i^+,$$

or as the p-weighted harmonic mean of $\beta_i^+$and β_i^-:

$$\Pr(i \in C) = \left\{\left[p/\beta_i^-\right] + [1-p]\,/\beta_i^+\right\}^{-1}.$$

The formal measures of positive and negative power permit an understanding of the constraints facing EU leaders when choosing a QM rule. Strengthening any one of the thresholds $\{q_A, q_F, q_P\}$ reduces positive power by lowering the probability $\Pr\left(pass|i \in F\right)$, but increases negative power by raising the probability $\Pr\left(fail|i \notin F\right)$. As, however, strengthening a threshold also affects the power to act, ω, the overall effect of a threshold change on $\left\{\beta_i^-, \beta_i^+\right\}$ is complex, and potentially non-monotonic. Importantly, however, heterogeneity in country populations drives heterogeneity in the responses of the individual $\left\{\beta_i^-, \beta_i^+\right\}$ to changes in the voting thresholds. This implies that, when countries differ in population, they will have different preferences regarding the setting of these thresholds. Accordingly, we shall represent the collective choice of $\{q_A, q_F, q_P\}$ by EU leaders as the outcome of an underlying bargaining process.

2.3 Utility

Following prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) we suppose that countries form preferences over monetized gains and losses relative to the status quo. In particular, we write utility as

$$U(W) = V(W); \qquad U(-W) = -\lambda V(W); \tag{2}$$

where $V : \mathbb{R}_{\geq 0} \mapsto \mathbb{R}_{\geq 0}$ is everywhere increasing and possesses the "set point" property that $V(0) = 0$. Kahneman and Tversky (1979) propose that preferences display loss aversion

[11] Although we know of no previous study to relax Coleman's measures in this way, the related absolute Banzhaf index (Banzhaf, 1968) has been relaxed similarly. Our generalization of Coleman's measures corresponds to a special case of the way in which the absolute Banzhaf index is generalized in the "empirical Banzhaf indices" of Heard and Swartz (1998) and the "behavioral power index" of Kaniovski and Leech (2009).

when $-U(-W) > U(W)$ for all $W > 0$.[12] In our framework this condition is equivalent to the restriction $\lambda > 1$. Hence, λ is interpreted as a coefficient of loss aversion. A mass of research into the coefficient of loss aversion is summarized in Booij *et al.* (2010: Table 1) and Abdellaoui *et al.* (2007: Table 1), with estimates belonging to the range $\lambda \in [1.07, 4.8]$ and centering around $\lambda = 2$.[13] Accordingly, the estimate $\lambda = 2.25$ of Tversky and Kahneman (1992) is commonly employed in applications of prospect theory.

Using (2), the expected utility of country i, before the motion is known, writes as

$$\mathbb{E}(U_i) = \Pr(i \in F \cap pass)\, U\left(W^F\right) + \Pr(i \notin F \cap pass)\, U\left(-W^A\right) + \Pr(fail)\, U(0). \quad (3)$$

To properly understand the role of positive and negative power in generating expected utility we rewrite (3) in a more informative manner:

Proposition 1 *The expected utility of country i, before the motion is known, is given by*

$$\mathbb{E}(U_i) = p\left\{\omega + [1-\omega]\,\beta_i^+\right\} V\left(W^F\right) - \lambda\,[1-p]\,\omega\left[1-\beta_i^-\right] V\left(W^A\right).$$

Proposition 1 relates the expected utility of country i to its positive power, β_i^+, and its negative power β_i^- in an intuitive way. Possession of positive power increases expected utility by increasing the probability that the gain utility $U\left(W^F\right) = V\left(W^F\right)$ is achieved. Negative power also increases expected utility, but by reducing the probability that the loss utility $-\lambda V\left(W^A\right) < 0$ is incurred. To see how loss aversion interacts with positive and negative power note that the cross derivatives of expected utility are

$$\frac{\partial^2 \mathbb{E}(U_i)}{\partial \beta_i^+ \partial \lambda} = 0; \qquad \frac{\partial^2 \mathbb{E}(U_i)}{\partial \beta_i^- \partial \lambda} = [1-p]\,\omega V\left(W^A\right) > 0. \quad (4)$$

We stress in interpreting (4) that heads of government can, in actuality, only choose the thresholds $\{q_A, q_F, q_P\}$. Movement of a threshold typically alters all elements $\left\{\beta_i^-, \beta_i^+, \omega\right\}$

[12] This definition of loss aversion is the original one of Kahneman and Tversky (1979), and may be interpreted as applying to "large stakes". A related definition of loss aversion for "small stakes" is given by Köbberling and Wakker (2005), according to which $U(\cdot)$ displays loss aversion if and only if $\lim_{W\uparrow 0} \partial U(W)/\partial W > \lim_{W\downarrow 0} \partial U(W)/\partial W$. As designing decision rules for international organizations is inherently a large stakes context, we do not dwell on the small stakes case. We note, however, that these two definitions of loss aversion are complementary, and both are commonly assumed together in axiomatic models (see, e.g., Bowman *et al.*, 1999; Kőszegi and Rabin, 2007). For other related discussions of concepts of loss aversion see Wakker and Tversky (1993), Schmidt and Zank (2005) and Zank (2010).

[13] A notable later study, Tanaka *et al.* (2010), reports an average estimated value of λ of 2.63, consistent with much of the earlier evidence.

simultaneously in an analytically complex way. This caveat notwithstanding, the thought-experiment of separately increasing β_i^- and β_i^+ for a fixed ω is instructive. Importantly, λ interacts positively negative power, but not with positive power. It follows that, as λ is increased, negative power becomes relatively more potent as a means to increase expected utility relative to positive power.

2.4 Bargaining over Decision Rules

The Lisbon QM rule, $QM\,(4, 0.55, 0.65)$, was adopted as the consensual outcome of negotiations among all EU leaders. The consensual nature of the outcome not withstanding, the negotiations were intense in nature, with countries robustly defending their interests. Accordingly, we model the outcome of these negotiations as the solution of a (generalized) Nash bargain among EU member states.

The formulation of a general bargaining problem over the set of all decision rules satisfying A0-A3 is analytically intractable. Instead, we exploit the observation in Cameron's (2004) account of the preparatory negotiations that countries first agreed on the "double-majority" scheme inherent in the Lisbon rule, before then proceeding to negotiate over the setting of the thresholds. We therefore focus on the second stage bargain over the three threshold quantities $\{q_A, q_F, q_P\}$ defined within the QM rule.[14]

What would have been the outcome if EU leaders had been unable to agree on a QM rule? Here we suppose that, in the absence of an agreement, EU leaders resort to the unanimity decision rule, under which a motion passes if and only if all countries vote for. Although the unanimity rule is typically Pareto dominated by majority decision rules (see, e.g., Bouton *et al.*, 2017, 2018) it is focal as the disagreement outcome as it is already used in the EU for decisionmaking in some domains. Also, uniquely among decision rules, the unanimity rule ensures that no country can ever experience a loss: collective action is taken only if it is a Pareto improvement over the status quo (Buchanan and Tullock, 1962).

If the unanimity decision rule is adopted, each country obtains a (common) expected utility

$$\mathbb{E}\,(U_D) = p^N V\left(W^F\right), \tag{5}$$

[14] For a theoretical contribution in which complex decision rules with multiple thresholds emerge as an equilibrium outcome, see Harstad (2005).

where equation (5) follows from the observation that only in the event that all countries vote for, which occurs with probability p^N, is an affirmative outcome reached. In all other instances, the motion fails and the status quo is preserved.

While the unanimity rule maximizes negative power (giving full insurance against the adoption of harmful motions), it comes at the cost of minimizing positive power. A head of government who is sufficiently loss averse will be willing to make this sacrifice, but a less loss averse leader will not. Comparing (3) and (5), country i prefers the unanimity rule to $QM(q_A, q_F, q_P)$ if

$$\lambda > \frac{p\left\{\omega + [1-\omega]\,\beta_i^+\right\} - p^N}{[1-p]\,\omega\left[1-\beta_i^-\right]}\frac{V\left(W^F\right)}{V\left(W^A\right)} \equiv \tilde{\lambda}_i\left(q_A, q_F, q_P\right). \tag{6}$$

Let $\overline{\lambda}_i \equiv \max_{\{q_A,q_F,q_P\}} \tilde{\lambda}_i\left(q_A, q_F, q_P\right)$ be the maximum value of $\tilde{\lambda}_i\left(q_A, q_F, q_P\right)$, such that if $\lambda > \overline{\lambda}_i$ there is no choice of thresholds $\{q_A, q_F, q_P\}$ that would make country i prefer a QM rule. Defining $\underline{\lambda} \equiv \min_{j\in\mathcal{N}}\left\{\overline{\lambda}_j\right\}$ as the smallest such $\overline{\lambda}_i$ across countries, we then have:

Proposition 2

(i) If $\lambda < \underline{\lambda}$ the bargaining outcome is described by the solution to the problem

$$\max_{\{q_A,q_F,q_P\}} \prod_{j\in\mathcal{N}} \left[\mathbb{E}\left(U_j\right) - \mathbb{E}\left(U_D\right)\right]^{\tau_j}; \qquad \sum_{j\in\mathcal{N}} \tau_j = 1; \tag{7}$$

where $\tau_j > 0$ is the bargaining weight of country j.

(ii) If $\lambda \geq \underline{\lambda}$ the bargaining outcome is the unanimity rule (disagreement outcome).

Proposition 2 establishes the predicted bargaining outcomes. If $\lambda < \underline{\lambda}$ there exists a decision rule $QM(q_A, q_F, q_P)$ that yields a Pareto improvement relative to the disagreement outcome, in which case countries are predicted to bargain to the NBS. Conversely, if $\lambda \geq \underline{\lambda}$ then, for every set of thresholds $\{q_A, q_F, q_P\}$ there exists at least one country that is better-off under the unanimity rule than under $QM(q_A, q_F, q_P)$. In this case, any such country will force implementation of the unanimity rule.

3 Estimation

In this section we use the model of the previous section to analyze the choice by EU leaders of the QM rule contained in the 2007 Treaty of Lisbon, and which entered into force on 1st November 2014.

3.1 Identification of λ

To motivate our approach to measuring the coefficient of loss aversion, we now prove a Lemma:

Lemma 1 *The ratio β_i^- / β_i^+ is independent of i.*

Lemma 1 establishes that the ratio $R \equiv \beta_i^- / \beta_i^+$ is common across countries. Thus, R captures in a single statistic the collective preference of EU leaders for negative relative to positive power. Formally, let $R(\lambda)$ be the value of R at the NBS for a given λ. As higher values of λ increase the marginal utility associated with negative power, but not with positive power, $R(\lambda)$ is a monotone increasing function. Via this link from λ to R, we are able to infer the value of λ held by EU leaders from the observed R implied by their choice of decision rule. We look for the unique value of λ (denoted λ^*) at which $R(\lambda)$ corresponds to the observed R of the Lisbon QM rule chosen by EU leaders (R_{Lisbon}):

$$R(\lambda^*) = R_{Lisbon}.$$

3.2 Implementation

Bargaining weights

The outcome of a bargaining process may be affected by a range of factors in addition to those captured by the decision rule. As Bailer (2010) discusses in the EU context, a range of other factors, including bargaining skill, economic might, domestic constraints, information, and institutional power, plausibly play a role. Our model allows for these features to be captured within the set of bargaining weights, $\{\tau_j\}_{j \in \mathcal{N}}$. We now describe how we infer these weights from the observed choice behavior of EU leaders:

Lemma 2 *At the NBS define by (7) it holds that*

$$\tau_i \approx \frac{\mathbb{E}(U_j) - \mathbb{E}(U_D)}{\sum_{j \in \mathcal{N}} [\mathbb{E}(U_j) - \mathbb{E}(U_D)]}.$$

Lemma 2 states that the bargaining weight of a member corresponds to their share of the surplus at the NBS. The proof of Lemma 2 demonstrates that, were all the variables in the bargaining problem in (7) defined on the set of real numbers, the approximation given in the Lemma would hold exactly. The approximation in the Lemma arises, therefore, as the measures of positive and negative power can take values on only the rational numbers. In our context, however, the approximation is extremely close – the maximum relative deviation across $i \in \mathcal{N}$ is a mere 0.083 percent. Accordingly, precise estimates of the bargaining weights that applied in the Lisbon negotiations can be inferred from the set of expected surpluses $\{\mathbb{E}(U_j) - \mathbb{E}(U_D)\}_{j \in \mathcal{N}}$ arising under the Lisbon QM rule actually chosen by EU leaders. As, however, Proposition 1 makes clear that expected utility is a function of λ, the inferred surpluses depend on the assumed level of loss aversion. Hence, at every value of λ, we compute an estimate of each τ_i, denoted $\hat{\tau}_i$, as

$$\hat{\tau}_i(\lambda) = \frac{\mathbb{E}_{Lisbon}(U_i(\lambda)) - \mathbb{E}(U_D)}{\sum_{j \in \mathcal{N}} [\mathbb{E}_{Lisbon}(U_j(\lambda)) - \mathbb{E}(U_D)]}.$$

Voting probabilities

From behind a veil of ignorance as to the motion to be voted on and the preferences of the voters, it is assumed frequently that a voter is equally likely to vote for or $against$ ($p = 0.5$). In this context, however, we believe there are a-priori grounds to suppose that, under the QM rule, countries are more likely to support a motion than to oppose it ($p > 0.5$). The argument here is one of selection: as well as choosing a QM rule EU leaders also choose the policy areas to which it will apply. In particular, it is an established practice within the EU that, in some policy areas, the CoM votes under the unanimity rule.[15] Consistent with this observation, for a fixed λ Proposition 2 implies that a QM rule is applied in those areas with a sufficiently high a-priori expectation of consensus (i.e., p high enough that $\lambda < \underline{\lambda}(p)$), while the unanimity rule (disagreement outcome) is chosen for policy areas expected to achieve sufficiently little consensus (i.e., p low enough that $\lambda \geq \underline{\lambda}(p)$).

EU voting records indeed show very high levels of consensus in voting under a QM rule. Using data provided by VoteWatch Europe (http://www.votewatch.eu), an independent not-for-profit organization, we examine voting outcomes under the QM rule that applied at the time EU leaders were negotiating the Lisbon Treaty. This was the QM rule in the Treaty of Nice that applied between February 2003 and October 2014.[16] For the motions covered by the

[15] Policy areas currently subject to the unanimity rule include common foreign and security policy, EU membership, the granting of new rights to EU citizens, and the harmonization of national legislation in the field of social security and social protection.

[16] The QM rule in the Nice Treaty entails three thresholds for motions to *pass*. It requires that 74 percent of member states' weighted votes be cast in favor, and a majority of member states to vote in favor. Last, those in favor are required to represent at least 62 percent of the EU's total population.

data – all 600 voted on by the CoM under the Nice QM rule beyond 7th July 2009 – the proportion of votes cast that were votes *for* stands at 97.29 percent.[17] Hosli (2007) reports a similarly high rate of 97.96 percent in data on CoM votes covering 1995-2004, and (our) initial estimates under the Lisbon QM rule (based on VoteWatch data between 1st November 2014 and 27th April 2018) put the proportion of *for* votes at 97.80 percent.[18]

We use the observed rates of voting *for* under the Nice QM rule to estimate the parameter p, which is the a-priori probability that a motion is gainful to a country. Here we suppose that EU leader's beliefs concerning the future value of p (under the QM rule they were seeking to negotiate) reflect the empirical frequency of *for*-voting observed under the QM rule at the time the negotiations were taking place.[19] A naïve approach to the estimation of p is to equate it directly to the observed proportion of *for*-votes. A notable feature of our data that augurs against such an approach, however, is that no vote in the CoM is observed to *fail* under the QM rule (Nice or Lisbon). This appears indicative of a tendency within the EU Commission (and other international bodies) to bring forward only proposals that are expected to *pass* under the relevant decision rule. By contrast, our model envisages an environment in which motions are not filtered endogenously in the shadow of the decision rule. Accordingly, to align the model with actual practice in the EU, we interpret the empirical proportion of votes that are *for* as an estimate of the conditional probability $\Pr(i \in F|pass)$ rather than of the unconditional probability $\Pr(i \in F)$. Under the Nice QM rule some 97.29 percent of votes are *for* votes. We use this statistic to back-out the implied value of $p \equiv \Pr(i \in F)$. In particular, p is the solution to the equality

$$\frac{p}{1-\omega_{Nice}(p)} = \Pr(i \in F|pass) = 0.9729. \tag{8}$$

We compute the solution to the equality in (8) as $p = 0.97287$. We use this estimate in what follows.

[17] In practice the CoM will sometimes (6.3 percent of motions) vote more than once on a motion. The majority (99 percent) of the uses of the QM rule in our data occur under the ordinary legislative procedure (previously co-decision) under which the European Parliament may propose amendments to legislation passed by the CoM at first reading, thereby requiring further rounds of voting in the CoM. Where multiple rounds of voting occur we restrict attention to the final round of voting, for in earlier rounds of voting the vote was over legislation not in its final form. We also exclude a small number of motions (55) on which not all CoM members participated in voting (e.g. acts adopted only by Euro area or Schengen member states).

[18] For further discussion of voting patterns in the CoM see Hosli *et al.* (2018).

[19] Implicitly, therefore, we assume that EU leaders expected that rates of *for*-voting would remain unchanged (relative to under the Nice QM rule) under the new Lisbon QM rule they were in the business of negotiating. As empirical rates of *for*-voting in the CoM have indeed been virtually identical under the Nice and Lisbon QM rules, such an expectation was rational.

Monetary payoffs

From behind a veil of ignorance as to the motion to be decided, the monetary payoffs are set equal, $W^F = W^A = W$, so that the loss from implementing an unfavorable motion is equivalent in magnitude to the gain from implementing a favorable motion. This is not to deny the existence of payoff variability across motions, but rather harks to Bernoulli's principle of insufficient reason, according to which, in the absence of a compelling a-priori reason for assigning different values, equality should be presumed.

A notable implication of this specification is that the sub-utility function, $V(W)$, enters both the expected utility in Proposition 1, and the disagreement payoff in (5), as a multiplicative factor. It therefore enters the Nash product as a multiplicative factor, and consequently plays no role in the determination of the NBS. Our estimate of the coefficient of loss aversion is, therefore, independent of assumed risk preferences.

Computational approach

We solve the problem in (7) using numerical methods. For a given choice of λ we perform initially a grid search over $11 \times 13 \times 13$ unique points in $\{q_A, q_F, q_P\}$-space, from which a set of potential local maxima are identified.[20] To locate each local maximum exactly, and ultimately infer which of these local maxima is the global maximum, we employ a direct search (compass) algorithm around each potential local maximum (see Kolda *et al.*, 2003, for a review of these methods).[21]

Proceeding in this way, to obtain $R(\lambda)$ for a given λ we must compute $R(q_A, q_F, q_P)$ over 8000 times. Moreover, the results we present in the next section are based on computing $R(\lambda)$ for some 223 unique values of λ. For this approach to be feasible, therefore, standard approaches to the computation of $\left\{\beta_i^-, \beta_i^+, \omega\right\}$ cannot be employed: a single brute-force computation of either β_i^- or β_i^+ for the then 27-member CoM requires checking the outcome of some 2^{27} possible vote configurations.[22] Accordingly, we develop a novel approach to this computational problem (Appendix 2).[23]

[20] The grid search computes the Nash product in (7) for $q_A \in \{1, 2, \ldots, 13\}$, $q_F \in \{14, 15, \ldots 27\}$, and $q_P \in \{0.5, 0.55, \ldots, 1\}$.

[21] We employ the method in Lewis *et al.* (2007) when searching close to one or more parameter boundaries.

[22] Croatia, currently the newest member of the now 28-state EU, did not join until July 2013.

[23] The scale of the population data thwarts the efficiency of generating functions (see Bilbao *et al.*, 2000) as an alternative exact approach. Although we do not dwell on this methodological development here, we note that the approach to the computation of $\{\beta_i^-, \beta_i^+\}$ outlined in Appendix 2 has applicability to the study of a range of other large-N voting games for which existing approaches are inefficient.

4 Results

Our findings for the coefficient of loss aversion are depicted in Figure 2. Panel (a) of the figure shows the function $R(\lambda)$ for λ on a broad domain encompassing all points such that $\lambda \leq \underline{\lambda}$. Panel (b) of the Figure "zooms in" on $R(\lambda)$ around the point $\lambda = \lambda^*$. In panel (a) we see that $R(\lambda)$ increases in λ in a largely stepped fashion. The critical value $\underline{\lambda}$ is found as $\underline{\lambda} = 25.9$, at which point Malta (the least populous EU member) is sufficiently loss averse that it prefers the unanimity rule to any QM rule. Accordingly, for $\lambda \geq \underline{\lambda}$ the unanimity rule applies.

Figure 2 – see p. 32

To obtain an estimate of λ we look for the intersection of $R(\lambda)$ with R_{Lisbon}, where the latter computes as $R_{Lisbon} = 0.0045$. As seen in panel (b), the intersection arises at $\lambda = \lambda^* = 4.40$. This finding implies that the potential for losses arising from the passing of a motion are given around 4.4 times as much psychological weight as are the potential for gains. EU leaders are loss averse. Moreover, given that evidence on loss aversion in the population at large places λ at around two, it appears EU leaders may actually be more loss averse than their average citizen.

5 Discussion and Conclusion

In this study we used the way in which world leaders choose voting systems for international institutions to infer their coefficient of loss aversion. In particular, we consider the design of the QM rule in the Treaty of Lisbon, which was negotiated by EU leaders in 2007. Our approach models the negotiations over the Lisbon rule as a (Nash) bargain, and estimates the coefficient of loss aversion independently of risk preferences. Given that EU leaders ringfenced the use of their QM rule to policy domains known a-priori to have high levels of agreement between members, the thresholds chosen for motions to pass suggests a very strong concern for blocking power.[24] Accordingly, our findings suggest that world leaders are

[24] Moreover, EU member states, as well as ringfencing use of the QM rule, also have access to a number of constitutional arrangements – notably the "Luxembourg Veto" and "Ioannina Compromise" – that aim to provide safeguards to countries who face being outvoted under the QM rule (see, e.g., Reestman and Beukers, 2017). Article 50 of the Lisbon Treaty, which provides for member states to leave the EU, can also be viewed as an ultimate form of insurance against realizing a loss (Huysmans, 2018).

heavily loss averse: the potential for losses are given around 4.4 times as much psychological weight as is the potential for equivalent gains.

Designing decision rules for international organizations inherently entails high-stakes, and heads of government are highly experienced decisionmakers. These features might suggest that heads of government would not exhibit loss aversion. Our findings go contrary this suggestion, however. Indeed, to the extent that our estimate of the coefficient of loss aversion is higher than is typically found in the literature, heads of government may be more prone to loss aversion than is the population at large. Our findings are instead consistent with the literature arguing that even experts remain prone to behavioral biases (Foellmi *et al.*, 2016; Pope and Schweitzer, 2011). Professional golfers, for instance, are significantly less accurate with birdie putts than when they attempt otherwise similar putts for par. It is also possible, however, that heads of government might be more prone than usual to loss aversion in the pressure-cooker atmosphere surrounding the negotiation of an international decision rule. There is evidence that even experienced decisionmakers may "choke" when faced with making highly consequential decisions, and thereby exhibit greater behavioral bias than they would over more routine decisions with lower stakes (Baumeister, 1984; Ariely *et al.*, 2009; Dohmen, 2008).

Loss aversion leads to the design of decision rules that set the bar for affirmative action inefficiently high. Welfare improving policies that would be enacted in a counterfactual world without loss aversion (i.e., loss neutrality) may not be enacted in a world with loss aversion. In the EU context two distinct effects are discernible, which align conceptually with the notions of intensive and extensive margins. First, at the intensive margin, our analysis predicts that, if EU heads of government were loss neutral, they would have designed a QM rule with less stringent thresholds for motions to pass. Second, at the extensive margin, under loss neutrality, EU heads of government would have been willing to utilize the QM rule for decisionmaking over range of policy issues that are at present subject to the unanimity rule. Taking these effects in turn, under the conditions of our stylized model, 0.023 percent of motions are predicted to fail under the Lisbon QM rule. Were EU leaders loss neutral the predicted fail rate falls to less than 0.0001 percent under the QM rule they would hypothetically choose. While this difference is significant in relative terms, in absolute terms the effect is small. This is simply because QM is only utilized in domains with very high rates of consensus, so there is limited scope to further reduce already tiny predicted failure rates.

The second (extensive) effect is plausibly much larger. To see this we reinterpret Proposition 2. Proposition 2 is predicated on the existence of a known p, and proceeds to characterize the nature of the bargaining outcome as a function of λ. It is equally possible, however, to fix λ (at $\lambda = \lambda^* = 4.4$) and then characterize the bargaining outcome as a function of p. This leads to a threshold level of p, $\underline{p}(\lambda^*) \in (0, 1)$, such that for policy domains with $p \leq \underline{p}(\lambda^*)$ the unanimity rule is adopted, and a QM rule is adopted otherwise. Intuitively, a lower value of p implies an increased probability that a country will face motions that, if passed, would cause it harm. This increases the attractiveness of the unanimity rule relative to all other decision rules. For a sufficiently low p, i.e., $p \leq \underline{p}(\lambda^*)$, there exists no QM rule that is a Pareto improvement relative to the disagreement outcome.

We compare $\underline{p}(\lambda^*)$ with $\underline{p}(1)$ – the latter being the threshold p that applies under loss neutrality. Using the computational approach described in section 3.2 we obtain $\underline{p}(1) = 0.5$ and $\underline{p}(\lambda^*) = 0.82$. Accordingly, under loss aversion, policy areas with $p \in (0.82, 1)$ are predicted to utilize a QM rule, and policy areas with $p \leq 0.82$ are predicted to use the unanimity rule. Under loss neutrality, the model predicts that policy areas with $p \in (0.5, 1)$ would utilize a QM rule, and policy areas with $p \leq 0.5$ would use the unanimity rule. It follows that policy areas for which $0.5 < p < 0.82$ are those in which loss averse EU leaders are predicted to choose the unanimity rule, whereas loss neutral EU leaders are predicted to choose a QM rule. Thus, the interval for p on which a QM rule is predicted to be used almost triples (178 percent increase) in size under loss neutrality. Thus, many domains which presently use the unanimity rule might be predicted to use a QM rule in a loss neutral world, with potentially profound implications for European cooperation in areas such as taxation, social security or social protection, foreign and common defence policy and operational police cooperation.

Of course, when EU leaders arrived to negotiate and sign the final agreement, much preparatory work had already been performed by their officials. Thus, one may ask whether the Lisbon bargaining outcome reflects the preferences of world leaders or the preferences of their officials. After all, officials will sometimes (i) possess greater expertise; (ii) have powers of agenda setting; (iii) influence the flow of information to political decisionmakers; and (iv) affect decisionmaking through their choice of framing (see, e.g., Blom-Hansen *et al.*, 2017 and the references therein). Although the adverse consequences of loss aversion in the choice of decision rules apply irrespective of whether such loss aversion resides with the appointed bureaucrats or the heads of government, we suspect that in the high-stakes case we consider, in which their personal political reputation was on the line, the EU heads of government themselves played a pivotal role, and had the final say. Moreover, heads of government have ultimate control over the selection of the officials to whom they delegate responsibilities. In personal correspondence, Axel Moberg, a witness to the earlier Nice QM rule negotiations, describes how "high-ranking officials were often indisposed to enter into discussion of the merits of various proposals since this was a matter for "higher up"."

From a broader perspective, given that decision rules are not only a feature of EU decisionmaking, but are pervasive in other international, national and local contexts, the wider public policy implications of our analysis are potentially very significant. In an effort to prevent behavioral biases distorting the design of such decision rules we echo the call of Hosli and Machover (2004) for a dialogue between academics and practitioners in order to allow for more informed choices.

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Appendix 1

Proof of Proposition 1. Using (2) in (3) gives

$$\mathbb{E}(U_i) = \Pr(i \in F \cap pass)\, V\left(W^F\right) - \lambda \Pr(i \notin F \cap pass)\, V\left(W_i^A\right).$$

By the multiplication axiom of conditional probabilities, we then have

$$\begin{aligned}\mathbb{E}(U_i) &= \Pr(i \in F)\Pr(pass|i \in F)\, V\left(W^F\right) - \lambda \Pr(i \notin F)\Pr(pass|i \notin F)\, V\left(W^A\right)\\ &= \Pr(i \in F)\Pr(pass|i \in F)\, V\left(W^F\right) - \lambda \Pr(i \notin F)\left[1 - \Pr(fail|i \notin F)\right] V\left(W^A\right).\end{aligned}$$

Substituting $\Pr(i \in F) = p$, this reduces to

$$\mathbb{E}(U_i) = p\Pr(pass|i \in F)\, V\left(W^F\right) - \lambda\left[1-p\right]\left[1 - \Pr(fail|i \notin F)\right] V\left(W^A\right).$$

Finally, using (1) to replace the terms $\Pr(pass|i \in F)$ and $\Pr(fail|i \notin F)$, we obtain the proposition. ■

Proof of Lemma 1. Define

$$\beta_i = \omega\beta_i^- + [1-\omega]\,\beta_i^+. \tag{A.1}$$

According to (A.1), β_i is constructed as the sum of (i) the probability a country can turn an otherwise winning coalition into a losing one by switching its vote from *for* to *against* ($\omega\beta_i^-$); and (ii) the probability that a country can turn an otherwise losing coalition into a winning one by switching its vote from *against* to *for* ($[1-\omega]\,\beta_i^+$). When country i is able to change to outcome of a vote by switching its vote, it is said to be *critical* ($i \in C$). Thus β_i is simply the probability that i is critical: $\beta_i = \Pr(i \in C)$.

We now construct expressions for $\Pr(pass|i \in F)$ and $\Pr(fail|i \notin F)$. By Bayes' rule we have

$$\Pr(pass|i \in F) = \frac{\Pr(pass)\Pr(i \in F|pass)}{\Pr(i \in F)} = \frac{\omega\Pr(i \in F|pass)}{p}; \tag{A.2}$$

$$\Pr(fail|i \notin F) = \frac{\Pr(fail)\Pr(i \notin F|fail)}{\Pr(i \notin F)} = \frac{[1-\omega]\Pr(i \notin F|fail)}{1-p}. \tag{A.3}$$

Then, again by Bayes' rule,

$$\Pr(i \in F|pass) = \frac{\Pr(i \in (C \cap F) \cap pass) + \Pr(i \in (F \setminus C) \cap pass)}{\Pr(pass)}. \tag{A.4}$$

Noting that $\Pr(i \in (C \cap F) \cap pass) = \Pr(i \in C \cap F)$, and that $i \in C$ and $i \in F$ are statistically independent events, (A.4) reduces to

$$\Pr(i \in F|pass) = \frac{\Pr(i \in F)\left[\Pr(i \in C) + \Pr(i \notin C \cap pass)\right]}{\Pr(pass)} = \frac{p\left[\beta_i + \Pr(i \notin C \cap pass)\right]}{\omega}. \tag{A.5}$$

Using analogous steps we also obtain

$$\Pr(i \notin F|fail) = \frac{[1-p]\left[\beta_i + \Pr\left(i \notin C \cap fail\right)\right]}{1-\omega}. \tag{A.6}$$

Substituting (A.5) into (A.2) and (A.6) into (A.3) we obtain

$$\begin{aligned}
\Pr\left(pass|i \in F\right) &= \frac{\omega \Pr(i \in F|pass)}{p} = \beta_i + \Pr\left(i \notin C \cap pass\right); && \text{(A.7)} \\
\Pr\left(fail|i \notin F\right) &= \frac{[1-\omega]\Pr(i \notin F|fail)}{1-p} = \beta_i + \Pr\left(i \notin C \cap fail\right). && \text{(A.8)}
\end{aligned}$$

By definition, we have

$$\begin{aligned}
\Pr\left(pass\right) &\equiv \Pr\left(i \notin C \cap pass\right) + \Pr\left(i \in (C \cap F) \cap pass\right) + \Pr\left(i \in (C \setminus F) \cap pass\right) \\
&= \Pr\left(i \notin C \cap pass\right) + \Pr\left(i \in C \cap F\right) \\
&= \Pr\left(i \notin C \cap pass\right) + \Pr\left(i \in F\right)\Pr\left(i \in C\right). && \text{(A.9)}
\end{aligned}$$

So, rearranging (A.9),

$$\Pr\left(i \notin C \cap pass\right) = \Pr\left(pass\right) - p\beta_i = \omega - p\beta_i. \tag{A.10}$$

By analogous steps we obtain

$$\Pr\left(i \notin C \cap fail\right) = \Pr\left(fail\right) - [1-p]\,\beta_i = 1 - \omega - [1-p]\,\beta_i. \tag{A.11}$$

Substituting (A.10) into (A.7) and (A.11) into (A.8) we obtain

$$\begin{aligned}
\Pr\left(pass|i \in F\right) &= \beta_i + \Pr\left(i \notin C \cap pass\right) = \omega + [1-p]\,\beta_i; && \text{(A.12)} \\
\Pr\left(fail|i \notin F\right) &= \beta_i + \Pr\left(i \notin C \cap fail\right) = 1 - \omega + p\beta_i. && \text{(A.13)}
\end{aligned}$$

Substituting (A.12) and (A.13) into (1) we obtain

$$\beta_i^+ = \left[\frac{1-p}{1-\omega}\right]\beta_i; \qquad \beta_i^- = \left[\frac{p}{\omega}\right]\beta_i; \tag{A.14}$$

such that positive and negative power, β_i^+ and β_i^-, are seen to be directly proportional to β_i. We then have that

$$\frac{\beta_i^-}{\beta_i^+} = \frac{\left[\frac{p}{\omega}\right]\beta_i}{\left[\frac{1-p}{1-\omega}\right]\beta_i} = \frac{p}{1-p}\frac{1-\omega}{\omega},$$

which does not depend on i. ■

Proof of Lemma 2. We begin by assuming (falsely), that the variables in the bargaining problem are all defined on the set of real numbers (such that we can always increment and decrement at the margin). At a Nash bargaining solution, a marginal increase in $\mathbb{E}\left(U_i\right)$ and an offsetting decrease in $\mathbb{E}\left(U_j\right)$, $j \neq i$, must leave the value of the Nash maximand unchanged. Hence, denoting $\mathbb{E}\left(U_i\right) - \mathbb{E}\left(U_D\right)$ as just $\mathbb{E}\left(\Delta U_i\right)$ we have:

$$\frac{\tau_i}{\mathbb{E}\left(\Delta U_i\right)} - \frac{\tau_j}{\mathbb{E}\left(\Delta U_j\right)} = 0; \qquad j \neq i. \tag{A.15}$$

The $N-1$ equations given by setting $i=1$ and $j=2,\ldots,N$ in (A.15), coupled with the equality $\sum_{k\in\mathcal{N}}\tau_k=1$, together give a system of N equations in N unknowns, $\{\tau_k\}_{k\in\mathcal{N}}$, with a unique solution given by

$$\tau_i=\frac{\mathbb{E}\left(\Delta U_i\right)}{\sum_{k\in\mathcal{N}}\mathbb{E}\left(\Delta U_k\right)}. \tag{A.16}$$

Thus, for real variables, at a Nash bargaining solution, the weight τ_i corresponds to i's share of the utility surplus. Noting that $\left\{\beta^-,\beta^+,\omega\right\}$ are not defined on the real line, but instead are restricted to a subset of the rational numbers, the equality in (A.16) does not hold exactly in our context. The closeness of the approximation is a function of the density of $\left\{\beta^-,\beta^+,\omega\right\}$ on the set of rational numbers. As we consider a (large) 27-player game, $\left\{\beta^-,\beta^+,\omega\right\}$ are dense: at the estimate of $\lambda=4.4$ the maximum relative deviation from (A.16) is only 0.083 percent. ■

Appendix 2: Computing Positive and Negative Power

We describe here an efficient approach to the computation of the measures $\left\{\beta_i^-, \beta_i^+\right\}_{i\in\mathcal{N}}$ for the Lisbon QM rule. Whereas the brute force approach to the computation of these measures is of order 2^N complexity, our approach reduces this to a complexity of order $2^{N/2}$. The method computes exact (machine precision) values with a large proportion of the computation occuring only once at the start. We compute$\left\{\beta_i^-, \beta_i^+\right\}_{i\in\mathcal{N}}$ via (A.14), which therefore requires us to compute the set of measures $\left\{\beta_i\right\}_{i\in\mathcal{N}}$, where β_i is the a-priori probability that country i is critical. The crux of the problem is to count (in a weighted fashion) how often a given country is critical, the most difficult part of which is determining whether or not P_F lies in a specified range.

Let $\{\rho_i\}_{i\in\mathcal{N}}$ denote the set of population proportions, and $\widetilde{\rho}$ denote its median. Let $P_F = \sum_{i\in F}\rho_i$ denote the population share of the members of F. We then bifurcate $\mathcal{N}$ into two subsets: $\mathcal{N}^- = \{i\colon \rho_i \leqslant \widetilde{\rho}\}_{i\in\mathcal{N}}$ and $\mathcal{N}^+ = \{i\colon \rho_i > \widetilde{\rho}\}_{i\in\mathcal{N}}$. That is, $\mathcal{N}^-$ is the least populous half of EU member states and $\mathcal{N}^+$ the most populous. For a given set $\mathcal{M} \subseteq \mathcal{N}$ and $P \in [0,1]$, define

$$\mathcal{S}^k(P,\mathcal{M}) \equiv \{F\colon F \subseteq \mathcal{M}, |F| = k, P_F \leqslant P\}.$$

Note that each element of $\mathcal{S}^k(P,\mathcal{M})$ is equally likely; each occurs with probability $p^k(1-p)^{|\mathcal{M}|-k}$. Now let

$$s(k,P,\mathcal{M}) \equiv \left|\mathcal{S}^k(P,\mathcal{M})\right| p^k (1-p)^{|\mathcal{M}|-k}; \tag{A.17}$$

$$t(k,P,\mathcal{M}) \equiv \sum_{j\geqslant k} s(j,P,\mathcal{M}). \tag{A.18}$$

The function s in (A.17) gives the probability that a coalition of $\mathcal{M}$ with k members voting for and the sum of the population proportions of those k members being no more than P. The function t in (A.18) gives the same probability as s, but for a coalition of $\mathcal{M}$ where k or more members vote for. As s and t do not depend on $QM(q_F, q_P, q_A)$ one can, in practice, compute (for each $i \in \mathcal{N}$) the set $\{s(k,P,\mathcal{M}), t(k,P,\mathcal{M})\}_{k\in[0,|\mathcal{M}|],P\in\{P_F\colon F\subseteq\mathcal{M}\},\mathcal{M}\in\{\mathcal{N}^-\setminus\{i\},\mathcal{N}^+\setminus\{i\}\}}$ once at the outset. These data are then used in the remainder of the approach.

A member $i \in \mathcal{N}$ is critical for a given $F \in \mathcal{N}\setminus\{i\}$ if and only if any one of the following four conditions holds:

1. $q_P - \rho_i \leqslant P_F < q_P$ AND $N_F \geqslant q_F - 1$ AND $N_F \leqslant N - q_A$;
2. $q_P \leqslant P_F$ AND $N_F = q_F - 1$ AND $N_F \leqslant N - q_A$;
3. $N_F < q_F - 1$ AND $N_F = N - q_A$;
4. $P_F < q_P - \rho_i$ AND $N_F \geqslant q_F - 1$ AND $N_F = N - q_A$.

We use s and t to determine the probability weight of coalitions in which a given member is critical under each condition. First, for brevity, define

$$\begin{aligned}
\mathcal{N}_i^{\#} &\equiv \mathcal{N}^{\#} \setminus \{i\}; \\
s_i^{\#}(k, P) &\equiv s\left(k, P, \mathcal{N}^{\#} \setminus \{i\}\right); \\
t_i^{\#}(k, P) &\equiv t\left(k, P, \mathcal{N}^{\#} \setminus \{i\}\right);
\end{aligned}$$

where $\# \in \{-, +\}$. We then compute the probability that member i is critical under condition j, Π_{ij}, as

$$\Pi_{ij} = \sum_{F \subseteq \mathcal{N}_i^{+}} \pi_{ij}(F);$$

where

$$\begin{aligned}
\pi_{i1}(F) &= t_i^{-}\left(q_F - |F|, q_P - P_F - \rho_i\right) - t_i^{-}\left(N - q_A + 1 - |F|, q_P - P_F - \rho_i\right) \\
&\qquad - \left\{t_i^{-}\left(q_F - |F|, q_P - P_F\right) - t_i^{-}\left(N - q_A + 1 - |F|, q_P - P_F\right)\right\}; \\
\pi_{i2}(F) &= s_i^{-}(q_F - 1 - |F|, 1) - \lim_{\varepsilon \downarrow 0} s_i^{-}(q_F - 1 - |F|, q_P - \varepsilon - P_F); \\
\pi_{i3}(F) &= s_i^{-}(N - q_A - |F|, 1); \\
\pi_{i4}(F) &= s_i^{-}(N - q_A - |F|, q_P - \rho_i - P_F).
\end{aligned}$$

We may then compute

$$\beta_i = \sum_{j=1}^{4} \Pi_{ij}.$$

Figures

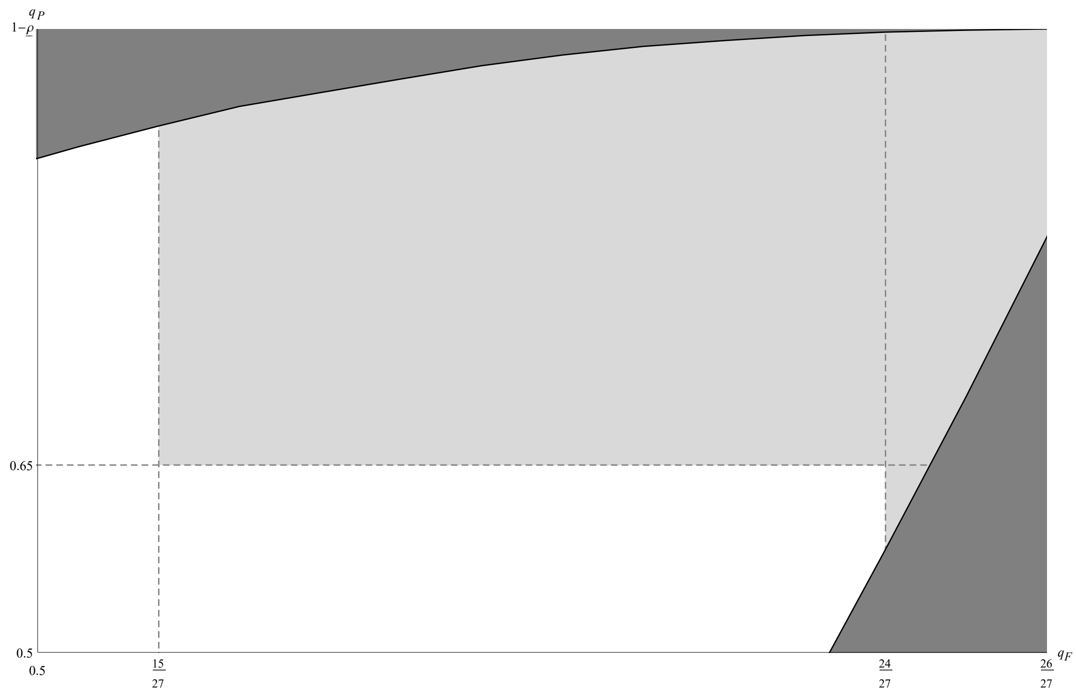
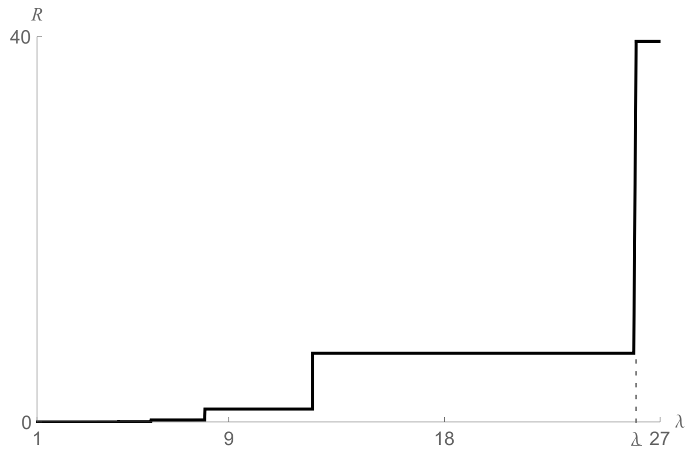
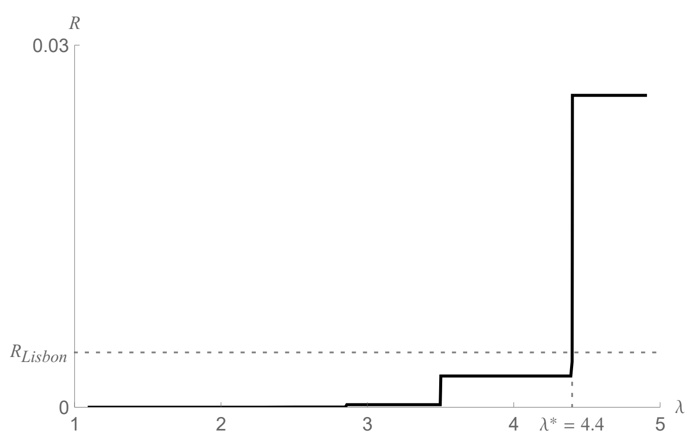


Figure 1: Visual representation of the set of winning coalitions under the Lisbon QM decision rule. The heavy-shaded region is infeasible. The light-shaded region is the set of winning coalitions.



(a) R at the bargaining outcome, as a function of λ.



(b) R at the bargaining outcome in the neighborhood of $\lambda = \lambda^*$.

Figure 2: The bargaining outcome for different values of λ.