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Abstract. We model public choice in a number of cases where a government, since it cannot design an optimal policy as a whole, resorts to a sequential, myopic approach; and which is not free of error. We use this framework to explore governmental budgeting and welfare economics. We develop various examples that clarify how the introduction of such subjective and imperfect characteristics affect predictions concerning public choice. We then provide a model which integrates bounds errors and systematic (astray) errors. We argue that bounds errors and astray errors are inextricably intertwined—some level of bounded rationality is required for astray errors to emerge. We further extend this model to explore information lobbying and other types of external pressure; and we show that choosing leaders with high ability to choose, or with Madison's *wisdom to discern,* is important, especially in the case of policy decisions concerning dangerous products (e.g. assault rifles) and environments (e.g. Covid 19).

JEL Codes: D90, H11

Key Words: Behavioural Economics, Public Choice

1. Introduction

1.1. Imperfect Choices. Only a few decades ago economic models assumed in general that economic agents have unlimited information–processing capacity. Given what economic agents knew and what was feasible, they could solve their choice problems in a strictly optimal manner irrespectively of how difficult that problem was. At the same time, evidence existing primarily in the psychology literature, indicated that individuals have only limited information–processing capacity. Simon [49, 1955, 99–118] wrote about the search for alternatives, satisficing, and aspiration adjustment. There has also been evidence for decades that different people have different abilities to solve complex decision problems, which was based on the quality

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of choice procedures used and outcomes achieved. The emerging point of view among behavioural scientists was that, in order to decide among alternative courses of action, agents re–evaluate and re–adjust their allocation according to their preferences and their ability to be consistent with those preferences. Along this sequence, agents use simple, local and myopic choice procedures called heuristics which adapt choice behaviour to their own level of competence (see, for example, Newell and Simon [35, 1972]). The quality of heuristics they use reflects, among other things, their ability to choose.

Information–processing theories of choice were also developing in the behavioural sciences forty years ago (see, for example, Bettman [9, 1979] and Kaneman et al. [31, 1982]. In those theories, individuals acquire information from various sources in their environment, which they perceive, interpret, and evaluate drawing upon past experience and upon the context in which they obtained it. Thus information–processing theories are not just about what individuals know, but also about how individuals use what they know. In economics, such processing–capacity limitations were expressed early on as the 'competence–difficulty' gap of Heiner [29, 1983, 560–595], whereby the competence of individuals to solve a choice problem does not match the difficulty of that problem. Errors made in that context have been labeled 'bounds errors' by Rabin [43, 2013, 528–543].[1] It is only in the last couple of decades that there is wide interest among economists and growing economic evidence about these issues. Conlisk [19, 1996, 669–700] and Selten [46, 1998, 191–214] (with reference to a 1962 German language version), were early advocates for bounded rationality. Harstad and Selten [27, 2013, 496–511] discuss experimental evidence on the pervasiveness of preference reversals, speculative bubbles, and violations of standard predictions from auction theory. Selten et al. [47, 2012, 443–457] provide experimental evidence about individuals working sequentially on self–selected sub–goals, one at a time, without subsequently making the trade–offs across sub–goals which are necessary in order to solve the overall problem. Harstad and Selten note that only economists would find this omission to be strange (p. 506).

1.2. Perfect Public Choice and Imperfect Individual Choice. Early formal models in economics began to study cases where paternalistic public policy could be explicitly considered (Samuelson and Zeckhauser [45, 1988, 7–59] and de Palma et. al. [22, 1994, 410–440]). For example, when errors in consumption choice exist and can be biased, a natural application is image advertisement. Up to that point,

[1] The label 'bounds' was to distinguish these from 'astray' errors, which Rabin describes as arising not from the complexity of a problem but rather from human intution that leads choices sytematically astray. Three types of astray errors described by Rabin [43, p. 538] are *narrow bracketing errors* (where agents do not consider the complete choice set), *present bias* errors (where agents overweight current utility) and *projection bias errors* (where agents do not judge the future well).

advertisement in economics has been modeled as a good that yields either information (Milgrom and Roberts [34, 1986, 796–821]) or utility (Becker and Murphy [4, 1993, 941–964]). These were powerful theories, but biased choice errors as in sections 8 and 9 of de Palma et. al. [22, 1994] shift the focus to the potential manipulative and harmful effects of image advertisement and so provided a rationale for policy against false advertisement, for the regulation of advertisement of commodities for which errors can become dangerous, and for advertisement aimed at particularly low–ability groups such as children. For discussions on paternalism–based economic policy and the complexity of the issues see Camerer et. al. [14, 2003, p. 1211-1254], O'Donoghue and Rabin [36, 2003, 186–191], and Thaler and Sunsteen [50, 2003, 175–179].

The last decade or two has seen an explosion in theoretical and empirical work on behavioural economics (see Bernheim et. al. [5, 2018]). This has spawned many models explicitly built to explore various policy issues when citizens make astray errors. Bernheim and Rangel [6, 2004, 1558–1590] explore welfare and policy with addiction, and Bisin et. al. [11, 2015, 1711–1737] also study self-control. O'Donoghue and Rabin [37, 2006, 1825–1849] look at present bias and optimal sin taxes. Chetty et. al. [18, 2009, 1145–1177] study the importance of salience of a tax for taxation policy. Heidhues and Koszegi [28, 2010, 2279–2303] work on behavioural savers and credit market policy, O'Donoghue and Rabin [38, 2015, 273–279] on present bias and policy, and Campbell [15, 2016, 1–30] on the need for paternalistic intervention in financial markets with behavioural agents. Chetty [17, 2015, 1–33] provides an interesting and pragmatic perspective on the importance of behavioural economics for policy. A take on the quickly evolving state of the art is captured in Bernheim and Taubinsky's [7, 2018, 381–516] chapter on Behavioral Public Economics in the Handbook of Behavioral Economics. It comprises four sections: foundations of behavioural welfare economics; commodity taxes; policy on savings; and optimal labour taxation.

Potential roles for government in the face of citizens with an imperfect ability to choose brings to mind the pre–Second World War debate between those pushing for more centralised planning, such as Lerner, and those arguing that individual consumers and producers in private markets would outperform central planning, such as von Hayek (see Besley [8, 2006]). The new arguments for a paternalistic role for a government with imperfect individuals was bound to bring a response.

1.3. Imperfect Public Choice. A natural bridge from imperfect individuals to imperfect public choice is provided by voters who play a central role in public choice and have an imperfect ability to choose.[2] Caplan [16, 2007] forcefully makes that case. In formal modeling, the typical approach considers voters making astray errors. Bischoff and Siemers [10, 2011, 163–180] model retrospective voters with biased beliefs, Ortoleva and Snowberg [39, 2015, 504–535] model the importance

[2] Ostrom [40, 1998, 1–22] is an early paper in political science on behavioural collective choice.

of over–confident voters on policy outcomes; Piguillem and Riboni [41, 2015, 901–949] model voters with present bias, Bo et. al. [13, 2018, 964–998] model voters under–appreciating equilibrium effects, and Lockwood and Rockey [32, 2020] voters susceptible to loss aversion. How to constrain imperfect voters is also a natural step. Attanasi et. al. [3, 2017, 129–137] work on constitutional design and voting rules (for example, super majorities with behavioural voters). Finally, there are early signs of a response from a more traditional public choice perspective in Viscussi and Gayer [51, 2015, 973–1008].

1.4. Boundedly Rational, Imperfect Public Choice. Our paper develops models of imperfect public choice in the context of bounded rationality. As discussed above, there is a growing literature on policy, voters and, consequently, governments making astray errors. By contrast, we begin with a government making bounds errors and we then formally consider the interaction between bounds and astray errors. We argue that in many circumstances some level of bounded rationality will be required for the emergence of astray errors.[3]

Choices in general are made amidst a complex web of intertwined effects. In the public domain, choices are made not only by single individuals, but also by different agents with different objectives and abilities. Some of these are elected, others are stakeholders and others are civil servants. Pressure groups and lobbies exist to influence political decisions, and so on. Taking into account this complexity, we adopt a kind of mid–field approach which recognises explicitly the stochastic aspects of public choice processes. Rather than describing them in detail, we analyse their emerging final decisions, i.e., their allocation of public funds.

The core of our models is based on a simple theoretical framework developed by de Palma et al. [22, 1994], who applied it to imperfect *individual* choice in the context of bounded rationality. We consider a collective agent, the *government*, which lacks the information–processing capacity required for a direct comparison of all feasible alternatives. Instead of finding at once a best allocation, the government myopically adjusts the current allocation toward more desired policies. The government makes bounds errors inversely proportional to its ability to choose. We compare the stationary state of this process with traditional models of public choice and welfare economics. We see how an imperfect ability to choose modifies both positive predictions and normative prescriptions of standard models, and how optimisation can

[3]Consider, Herrnstein's [30, 1991, 360–364] experiments. Many experimental subjects facing a somewhat complex dynamic problem fell back choosing on the basis of current costs and benefits, a present bias astray error. However, this was not true of all experimental subjects. Some individuals used the same information to fully solve the same dynamic problems. It is as if their tendency to make astray errors was mitigated according to their ability to choose. We will formally model this below.

be obtained from our model as a special case corresponding to a perfect ability to choose.

In Section 2 we discuss a rather general allocation problem of a high–level government which is an imperfect instrument of choice and which aims to distribute a resource among a number of public sectors. We show that if there is no ability to choose, all government choices are equiprobable irrespectively of existing differences in the true value of alternatives. Higher ability to choose tightens the choices around better alternatives until at the limit where the ability to choose is perfect, the outcome is exactly analogous to the solution of a standard constrained optimisation problem where a government makes no errors. We also show that in our model a larger dispersion in the social impact of choices, for example, in the presence of possibly dangerous policy choices, increases the importance of making good choices, in other words it increases the value of talented, high–ability public servants.[4]

In Section 3 we provide a concrete interpretation of Section 2 as a model of *incremental budgeting.* This is a common budgeting approach for governments and other bureaucracies (for example, university administrations) which aim to allocate annually their expected operating revenue among ministries or bureaus. We argue that the nature of this very common budgeting methodology can only be explained in a world of imperfect ability**.** We identify specific components of the model representing elements of incremental budgeting that fit Simon's [49, 1955] search for alternatives, satisficing, and aspiration adjustment. This is also consistent with the experiments in Selten et al. [47, 2012, 443–457].

In Section 4 we focus on a government concerned with the problem of distributive justice using the traditional welfare–economics approach as in Atkinson and Stiglitz [2, 2015], chapter 12. In our simple model we show that, for any degree of aversion to inequality, the outcome under perfect inability corresponds to that of a Fair outcome (see Foley [23, 1967, 45–98]). We also conclude that welfare is increasing in the public sector's ability and that total utility is decreasing with increasing aversion to inequality. Finally, we show that a public sector's ability is more important when implementing more extreme theories of justice, for example, Bentham's zero aversion or Rawls' infinite aversion to inequality.

In Section 5 we provide a number of examples based on Sections 2, 3 and 4.

We conclude our paper with Section 6, where we focus on errors and pressures which arise in the previous Sections. We first provide a formal model which integrates bounds errors and systematic perception (astray) errors. We argue that bounds errors

[4] Besley [8, 2006] starts his book with a quote by Madison, framer of the American Constitution (1788): "The aim of every political Constitution, is or ought to be, first to obtain for rulers men who possess most wisdom to discern, and most virtue to pursue, the common good of society; and in the next place, to take the most effectual precautions for keeping them virtuous whilst they continue to hold their public trust." Besley focuses on virtue, while our work focuses on wisdom.

and astray errors are inextricably intertwined—some level of bounded rationality is required for astray errors to emerge. We then expand our framework of systematic perception errors to consider external pressure types with imperfect public choices. We model informational lobbying as a attempt to build and exploit systematic bias towards particular policies.[5] We show that with imperfect public choice there is a rationale for optimally restricting political information lobbying and advertisement, especially when lobbying influences policy regarding dangerous products such as policy about assault rifles or global pandemics, and especially with governments of low ability. Expenditure on creating a highly–trained and highly–valued civil service is rational in managing lobbying effects. A further prerequisite for the effective management of lobbying is the choice of leaders with high ability, in other words, leaders with the 'wisdom to discern'.

2. A Basic Public Choice Problem

We consider a government that allocates a resource among a number k of *sectors* such as health, education, public works, the military and so on. The search for an *optimal* public policy mix requires global comparisons of detailed feasible distributions of the resource among sectors and, furthermore, a mapping back from each feasible allocation to a single, all encompassing objective function (see Harstad and Selten [27, 2013, p. 505.]). We assume that the government does not have the ability to make such global comparisons in order to determine an optimal public policy. We use the adjustment process in de Palma et. al. [22, 1994] to portray in a simple manner what seems essential to applied public choice, namely, that public choice is about a sequence of myopic decisions aiming to change allocation parts rather than about determining at once a final, best allocation. For example, along this sequence, the government may conclude that health needs to be provided with an amount sufficient to maintain its condition and public works need to expand.

2.1. Myopic Behaviour. A resource is accumulated by the government at a fixed *accumulation rate* R per unit of time. We partition time into a sequence of *periods* each having the same length Δt, such that $R\Delta t = 1$. We begin at a particular period $[t, t + \Delta t)$. We assume that the government knows the amounts of the resource available to each one of the k sectors at the end of the previous period. Let $S_{i,t}$ denote the *stock* of resource available to sector $i = 1, ..., k$ at the beginning of the period. The flow of services generated by the utilisation of the stock determines the value of the stock to society in that period. Let $\omega_{i,t} = r_i S_{i,t}$ be that uniform *service*

[5] While the regulation of campaign contributions is pervasive, the regulation of informational lobbying is considered less of an issue. For example, a ruling by the US Supreme Court in Citizen's United v. Federal Election Commission (130 US 876 (2010)) allows corporations to spend unlimited amounts on political advocacy advertisement during US election campaigns.

flow for sector i from a fixed *utilisation rate* r_i, $i = 1, ..., k$. Let $\Upsilon_t = \upsilon\left[\omega_{1,t}, ..., \omega_{k,t}\right]$ be the *impact* of the service flows to society from a *public policy mix* $(\omega_{1,t}, ..., \omega_{k,t})$.

In principle, there may be an infinite number of feasible ways in which the resource could be allocated among the k sectors. We assume that the government's decisions are based on a simplified version of this public choice problem where the government allocates the single–unit of the accumulated resource at the beginning of the period to one and only one sector. This leads to the government considering only k public policy mixes in any period. The policy mix where sector i is allocated the single unit in period $[t, t+\Delta t)$ is denoted $\Omega_{i,t} = (r_1 S_{1,t}, ..., r_i(S_{i,t}+1), ..., r_k S_{k,t})$ for $i = 1, ..., k$. We assume that the government estimates the k impact increments $\Delta\Upsilon_{i,t}$ corresponding to $\Omega_{i,t}$ at the beginning of every period or,

$$\Delta\Upsilon_{i,t} = \upsilon(r_1 S_{1,t}, ..., r_i(S_{i,t}+1), ..., r_k S_{k,t}) - \upsilon(r_1 S_{1,t}, ..., r_i S_{i,t}, ..., r_k S_{k,t}).$$

It then allocates the unit of the resource accumulated during the previous period to a single alternative i such that

$$\Delta\Upsilon_{i,t} = \max\left\{\Delta\Upsilon_{j,t} \text{ for } j = 1, ..., k\ \right\}. \tag{1}$$

Thus public choice here unfolds using a sequence of myopic local public policy problems, each involving a single unit of the resource to be allocated to a single public policy alternative, by comparing k estimated aggregate impact increments. It is as if the government aims to employ a gradient strategy in order to climb along the steepest slope of the perceived impact surface toward a peak of that surface—a strategy that represents the government's heuristic.

2.2. Perception Errors. The strict application of (1) as a model of public choice presumes that the government is perfectly capable to determine the incremental effect of using one unit of the resource on the alternative policy chosen. Nevertheless, in realistically complex situations where cognitive limits exist, it is well-established that people, and so governments, do make bounds errors while taking decisions based on choice procedures such as (1). We now introduce those errors through

$$\Delta\mathcal{Y}_{i,t} - \Delta\Upsilon_{i,t} = \varepsilon_{i,t}, \tag{2}$$

where $\Delta\mathcal{Y}_{i,t}$ and $\Delta\Upsilon_{i,t}$ stand for the *perceived* and the *experienced* impact increments derived by the application of public policy i. We assume that those errors are random because they arise in a wide variety of unpredictable ways and that they are i.i.d. Gumbel distributed across time and sectors with zero mean. We can therefore write them as

$$\varepsilon_{i,t} \sim \frac{\varepsilon}{\mu} \text{ for } \mu > 0 \text{ and } \varepsilon_{i,t} \to 0 \text{ as } \mu \to \infty, \tag{3}$$

where ε is zero mean and μ^{-1} is the dispersion parameter of the random errors $\varepsilon_{i,t}$. Since those errors become smaller as μ increases, we say that μ portrays the government's *ability to choose*, where larger μ corresponds to higher ability.

By replacing experienced with perceived impact increments in (1), we obtain our intended description of the sequence of myopic choice procedures used by the government in its effort to determine best public policy. Namely, we imagine that the government allocates at the beginning of every period the unit of the resource accumulated during the previous period to a single sector i which satisfies

$$\Delta\Upsilon_{i,t} + \varepsilon_{i,t} = \max\left\{\Delta\Upsilon_{j,t} + \varepsilon_{j,t} \text{ for } j = 1,..k\right\}. \tag{4}$$

The errors imply that government choices based on (4) can only be determined up to a corresponding probability distribution which, following McFadden [33, 1974, 105–142], is given by the multinomial logit model as

$$\mathbb{P}_{i,t} = \frac{\exp\left(\mu\Delta\Upsilon_{i,t}\right)}{\sum\limits_{j=1}^{k}\exp\left(\mu\Delta\Upsilon_{j,t}\right)} \tag{5}$$

where $\mathbb{P}_{i,t}$ is the probability that the government allocates the unit of resource to sector i at the beginning of the period $[t, t+\Delta t)$.

2.3. Equilibrium. We expect that the adjustment process (4) may lead to some equilibrium. Recall that the government accumulates resource at a constant rate R, such that over the length of any period Δt the amount of accumulated resource is precisely one unit. Thus for every sector i, the *expected amount of the resource* received during any period $[t, t+\Delta t)$ is given by $R\Delta t\mathbb{P}_{i,t}$. Furthermore, also recall that the amounts of the resource previously applied to various alternatives are utilised and so depleted at constant utilisation rates r_i per unit of the stock, which also determines the flow of services $\omega_{i,t} = r_i S_{i,t}$. It follows that the expected change $\Delta S_{i,t}$ in the stock of resources for sector i during t is given by

$$E\left(\Delta S_{i,t}\right) = \left(R\mathbb{P}_{i,t} - \omega_{i,t}\right)\Delta t.$$

Since the government aims to improve the policy mix, $R\mathbb{P}_{i,t}$ is the currently desired service flow for sector i. Then the expected change in the stock can be thought of as an adjustment that aims to close the gap between desired and realized service flows. Since the dynamics of expected change for every alternative depends on the entire history of public policy decisions, they may or may not lead to an equilibrium, that is, to a steady–state of the system where there is no longer any expected change in the stocks. However, taking into account proposition 4 in Ginsburgh et al. [24, 1985], we know that such a steady state is stable. And using our previous remarks, we also know that it can be expressed by the time–invariant system

$$R\overline{\mathbb{P}}_i = \overline{\omega}_i \text{ for } i = 1, ..., k \tag{6}$$

where, from now on, the bar above a symbol denotes its equilibrium value. Dividing (6) by the same for $i = 1$, and introducing (5) in the result, we obtain

$$\Delta\overline{\Upsilon}_i - \Delta\overline{\Upsilon}_1 = \frac{1}{\mu}\ln\frac{\overline{\omega}_i}{\overline{\omega}_1} \text{ for } i > 1. \tag{7}$$

Let us now define a simple expression for the experienced (true) impact increments at equilibrium. We consider the allocation of the resources to sector i at the beginning of a period and its consequences for all future periods along the stationary path. Denote the initial change in the stock for i as $(R\Delta t)_i^{(0)} = 1$. Taking into account that the rate of resource utilisation determines the corresponding rate of decline in the stock, the impact of public policy i at the beginning of the next period is reduced to $\Delta S_i^{(1)} = \left((R\Delta t)_i^{(0)} - r_i\Delta t\right) = (1 - r_i\Delta t)$. Therefore $\Delta S_i^{(q)} = (1 - r_i\Delta t)^q$ is the portion of the original stock still available from the application of alternative i after q periods, while

$$\Delta\omega_i^{(q)} = r_i\,(1 - r_i\Delta t)^q \tag{8}$$

is the corresponding change of the service flow.

The *experienced impact increment* must take into account all future consequences of the initial spending decision on policy i:

$$\Delta\Upsilon_i = \sum_{q=0}^{\infty}\Delta\Upsilon_i^{(q)}.$$

We also assume that the function $\upsilon[\omega_1, ..., \omega_k]$ which determines the true current aggregate impact Υ generated by the k service rates, is differentiable, strictly increasing, and strictly quasi-concave. If we expand $\upsilon[\cdot]$ in Taylor series around ω_i and retain only linear terms, we show in Appendix 1 that we can express experienced impact increments as

$$\Delta\Upsilon_i \cong \frac{\partial\upsilon}{\partial\omega_i}/\Delta t \tag{9}$$

provided that $r_i\Delta t < 1$. From now on we treat (9) as an equality and we introduce it in (7) to obtain

$$\frac{\partial\upsilon}{\partial\overline{\omega}_i} - \frac{\partial\upsilon}{\partial\overline{\omega}_1} = \frac{\Delta t}{\mu}\ln\frac{\overline{\omega}_i}{\overline{\omega}_1} \text{ for } i > 1. \tag{10}$$

Also, by summing up (6) over the k alternatives, we know that

$$\sum_{i=1}^{k} \overline{\omega}_i = R \tag{11}$$

in equilibrium for all μ. Thus the solution to the system of k equations represented by (10) and (11) determines the equilibrium mix of public policies as described by the corresponding mix of the equilibrium service flows $(\overline{\omega}_1, ..., \overline{\omega}_m)$. According to our interpretation above, equilibrium service flows also represent desired service flows: since, in this case, the aspirations of the government match its experiences, there is no need for further change in the service levels.

2.4. Ability and Public Choice. The structure of probabilities (5) implies that, if there is no ability to choose ($\mu = 0$), all government choices are equiprobable irrespective of existing differences in the true value of alternatives: $\overline{\omega}_i = \overline{\omega}_1$ for $i = 2, ..., k$. Higher ability to choose tightens the distribution of marginal allocation probabilities around better alternatives. At the limit, where the ability to choose is perfect ($\mu \to \infty$), (10) implies that at least one of the following conditions must hold: 1) $\overline{\omega}_i = 0$; 2) $\overline{\omega}_1 = 0$; 3) both $\overline{\omega}_i = 0$ and $\overline{\omega}_1 = 0$; and 4)

$$\frac{\partial \upsilon}{\partial \overline{\omega}_i} = \frac{\partial \upsilon}{\partial \overline{\omega}_1} \text{ for all } i \tag{12}$$

which, together with (11), represent the necessary conditions for

$$\max_{\overline{\omega}_1,...,\overline{\omega}_k} \upsilon[\overline{\omega}_1,...,\overline{\omega}_k] \text{ subject to } \sum_{i=1}^{k} \overline{\omega}_i \leq R. \tag{13}$$

It follows that *the equilibrium public policy mix becomes exactly analogous to the solution of a standard constrained optimisation problem if the government makes no errors* whatsoever along its myopic public choice path.

2.5. Ability and Impact. In this Section we examine the effects of ability to choose on the equilibrium level of the aggregate impact. Using (6), we can express the equilibrium level of aggregate impact $\overline{\Upsilon}$ achieved by the government as

$$\overline{\Upsilon} \;=\; \upsilon[R\overline{\mathbb{P}}_1, ..., R\overline{\mathbb{P}}_k]. \tag{14}$$

Since any equilibrium distribution of the utilisation rates $\overline{\omega}_i$ is equivalent to a standard optimisation problem with adjusted resource rate R, we can use the envelope theorem on (14). In Appendix 2, we obtain

$$\frac{d\overline{\Upsilon}}{d\mu} \;=\; \sum_{i=1}^{k} \left(\frac{\partial \upsilon}{\partial \overline{\omega}_i}\right)^2 \overline{\mathbb{P}}_i - \left(\sum_{i=1}^{k} \frac{\partial \upsilon}{\partial \overline{\omega}_i} \overline{\mathbb{P}}_i\right)^2. \tag{15}$$

And since the RHS of (15) represents the variance of a discrete random variable with realizations $\partial v/\partial\overline{\omega}_i$ which occur with probability $\overline{\mathbb{P}}_i$, we conclude that *the equilibrium level of aggregate impact increases with the government's ability to choose.* Thus the equilibrium level of aggregate impact remains below the corresponding feasible maximum if the ability to choose is imperfect. In that sense the government's choice behaviour is strongly related to Simon's [49, 1955] concept of *satisficing.* Notice how the increase in aggregate impact caused by an improvement of the ability to choose depends on the distribution of experienced impact increments: larger differences among the elements of this distribution imply larger gains caused by higher ability. Expressed differently, a larger dispersion in the impact of choices, for example in the presence of dangerous possible outcomes, increases the importance of making good choices. This justifies the presence of a highly trained and highly valued civil service—especially in unsettled times as today.

3. AN INCREMENTAL BUDGETING PROBLEM

Each year a government must allocate resources over a number of ministries or bureaus to establish their budgets for the year. The primary annual budgeting approach for governments and other bureaucracies (e.g. universities) is incremental budgeting (see Curry et. al. [21, 2013]). Under incremental budgeting a government does the allocation by making incremental adjustments to existing budgets. Well in advance of the next fiscal year, a central committee estimates fiscal–year revenue and costs and often decides to apply an across–the–board cut in order to create a desired pool for incremental adjustments. The pool is often relatively small. The committee asks for proposals from the bureaus, evaluates them one bureau at a time, ranks them, and then makes choices until the pool is exhausted.

In other words the backbone of incremental budgeting is small sequential decisions, one bureau at a time, and ongoing every year. They do not compare all possible feasible budgeting possibilities broadly defined across all commodities, space, and time as in an unboundedly rational story. The incremental budgeting process and procedures could not be understood without errors and the quality of decisions depending on the committee's ability to choose. The hope in the committee is that incremental adjustment over the years will allow for an acceptable outcome while managing workload and mitigating risks. This is consistent with Simon's work [49, 1955] on aspiration adjustment. The committee, not knowing the best use for funds, invites the bureaus to submit proposals for incremental adjustments as in Simon's search for alternatives.

We formalise this complexity by assuming that government decisions are taken in a series of gradual steps. We begin with the current *fiscal year,* $t-1$, and consider the incremental budgeting decisions which will determine the final budget for year t to be applied at the beginning of that year. We assume that the total amount of resources available at the beginning of any year is fixed and equals B; and that the final allocation of resources among the m bureaus in the year $t-1$ is given by the vector

$$\mathbf{B}_{t-1} \equiv (B_{1,t-1}, ..., B_{j,t-1}, ..., B_{m,t-1})$$

where B_j represents the *budget* of bureau j and where

$$\sum_{j=1}^{m} B_{j,t-1} = B.$$

We assume that the external environment does not change over the years, including revenue and costs, so that the pool is created solely by the across–the–board cut which we also assume to be fixed over the years. Well in advance of the next fiscal year t, the central committee in the current year $t-1$ decides to apply an *incremental adjustment cut* equal to w. Collecting this amount requires an across–the–board *cut rate* of c, defined by $w = cB$, and which reduces the budget of each bureau proportionally. Given the size of the incremental adjustment cut, incremental adjustment starts with a preliminary stage allocation $\mathbf{B}_t^{(0)}$ with elements that correspond to the final allocation of resources in the previous year net of their across–the–board cuts:

$$B_{j,t}^{(0)} = (1-c)B_{j,t-1} \quad \text{for} \quad j = 1, ..., m. \tag{16}$$

The decisions about how w will be allocated among bureaus is taken in the current year using a sequence of w one–unit steps. The government calls for the bureaus to submit proposals, which can be changed between steps, evaluates them and allocates the unit to a single best in each step. If the first resource unit is allocated to bureau j, the re–allocated government's budget at the first step will be given by

$$\mathbf{B}_{j,t}^{(1)} = ((1-c)B_{1,t-1}, ..., (1-c)B_{j,t-1} + 1, ..., (1-c)B_{m,t-1}). \tag{17}$$

Following Section 2, the impact of this decision can be expressed as $\Upsilon_{j,t}^{(1)} = \upsilon_j[\mathbf{B}_{j,t}^{(1)}]$, while the corresponding *impact increment* as

$$\Delta\Upsilon_{j,t}^{(1)} = \upsilon_j[\mathbf{B}_{j,t}^{(1)}] - \upsilon_j[\mathbf{B}_t^{(0)}].$$

We assume that the government estimates all such impact increments and allocates the first unit to a bureau that satisfies

$$\Delta\Upsilon_{j,t}^{(1)} = \max\{\Delta\Upsilon_{i,t}^{(1)} \text{ for } j = 1, ..., m\}.$$

In all subsequent steps $l = 1, ...w$ the government reconsiders the submitted proposals in order to decide where to allocate the unit at the next step. The impact increment of bureau i at the second step amounts to $\Delta\Upsilon_{i,t}^{(2)} = \upsilon_i[\mathbf{B}_{i,t}^{(2)}] - \upsilon_i[\mathbf{B}_{j,t}^{(1)}]$, where $\mathbf{B}_{j,t}^{(1)}$

is given by (17) provided it was bureau j that received the unit of resource in the previous step. In general, the calculation of impact increments is exactly analogous to that of step two,

$$\Delta\Upsilon_{j,t}^{(\ell)} = \upsilon_j[\mathbf{B}_{j,t}^{(\ell)}] - \upsilon_j[\mathbf{B}_{i,t}^{(\ell-1)}], \tag{18}$$

provided that bureau i was awarded the resource unit in the preceding step $\ell - 1$.

Once the w decision steps are complete in a year's incremental budgeting process then the year's consumption happens and we arrive at the beginning of next year and the next budgeting process. Next year's starting point is $\mathbf{B}_{t+1}^{(0)} \equiv \mathbf{B}_t^{(w)}$. In this way there is a long sequence of decision steps going off into the future. The model here is strongly connected to Section 2 above allowing for use of those results with appropriate revision below.

3.1. Equilibrium. If we take into account the discussion about perception errors in Section 2.2, recall that at every step $\ell = 1, ..., w$ the government's evaluation of a best bureau proposal can be determined only up to a probability distribution given by (5), modified for the steps during t or

$$\mathbb{P}_{j,t}^{(l)} = \frac{\exp\left(\mu\Delta\Upsilon_{j,t}^{(l)}\right)}{\sum_{i=1}^{m}\exp\left(\mu\Delta\Upsilon_{i,t}^{(l)}\right)}. \tag{19}$$

with experienced impact increments given by (18). We expect that this adjustment process (19) may lead to some equilibrium over the budgeting years. In every step bureau j receives one unit of the resource with probability $\mathbb{P}_{j,t}^{(l)}$. On the other hand, the corresponding amount of the one unit cut in the resource during that step paid by bureau j is given by $B_{j,t-1}/B$, its budget share, due to the proportionality of the cut. It follows that the expected change $\Delta B_{j,t}$ in the budget for bureau j for one step in a year is given by

$$E\left(\Delta B_{j,t}\right) = \mathbb{P}_{j,t}^{(l)} - B_{j,t-1}/B.$$

Since the government aims to improve the policy mix, and $B_{j,t-1}/B$ is the expenditure share for sector j at the budgeting time, then $\mathbb{P}_{j,t}^{(l)}$ can be thought of as the desired budget share for sector j. The expected change in bureau $j's$ budget can then be thought of as an adjustment that aims to close the gap between desired and actual budget shares. Since the dynamics of expected change for every alternative depends on the entire history of public policy decisions, they may or may not lead to an equilibrium, that is, to a steady–state of the system where there is no longer any expected change. As discussed in Section 2.3, an equilibrium does exist. It can be expressed by the time-invariant system

$$\overline{\mathbb{P}}_j = \overline{\mathbf{B}}_j/B \text{ for } j = 1, ..., m. \tag{20}$$

Dividing (20) by the same for $i = 1$, and introducing (19) in the result, we obtain

$$\Delta\overline{\Upsilon}_i - \Delta\overline{\Upsilon}_1 = \frac{1}{\mu}\ln\frac{\overline{B}_i}{\overline{B}_1} \text{ for } i > 1. \tag{21}$$

in equilibrium for all μ.

We now adjust the procedure used in Section 2.3 in order to define a simple expression for the experienced impact increments at equilibrium in the case of incremental budgeting. We consider the decision of allocating a unit of resource to the budget of bureau i in a step of a budget year and its consequences for all future years along the stationary path. Denote the initial change in the budget available for utilization during year t for bureau i when it achieves an award $(\Delta w)_i^{(0)} = 1$. That budget will be fully consumed during that consumption year, but the budget year at $t+1$ will start with that unit still playing a role in year $t+1$ consumption according to $\Delta B_i^{(1)} = \left((\Delta w)_i^{(0)} - c\right) = (1-c)$. Therefore,

$$\Delta B_i^{(q)} = (1-c)^q$$

is the portion of the original one-unit budgeting award still playing a role in budgeting decisions for bureau i after q years.

As in Section 2.3, we require that experienced (true) impact increments must take into account all future consequences of the initial budgeting decision:

$$\Delta\Upsilon_i = \sum_{q=0}^{\infty}\Delta\Upsilon_i^{(q)}.$$

We also assume that the function $\upsilon[B_{1,\ldots,}B_k]$ which determines the true current aggregate impact Υ generated by the m budgets, is differentiable, strictly increasing, and strictly quasi-concave. If we expand $\upsilon[\cdot]$ in Taylor series around B_i and retain only linear terms, following Appendix 1 that we can express experienced impact increments as

$$\Delta\Upsilon_i \cong \frac{\partial\upsilon}{\partial B_i}/c \tag{22}$$

provided that $c < 1$. From now on we treat (22) as an equality and we introduce it in (21) to obtain

$$\frac{\partial\upsilon}{\partial\overline{B}_i} - \frac{\partial\upsilon}{\partial\overline{B}_1} = \frac{c}{\mu}\ln\frac{\overline{B}_i}{\overline{B}_1} \text{ for } i > 1. \tag{23}$$

Finally, taking the sum of (20) over the m bureaus, we obtain

$$\sum_{j=1}^{m}\overline{B}_j = B \tag{24}$$

Thus the solution to the system of m equations represented by (23) and (24) determines the equilibrium mix of public policies as described by the corresponding mix of the equilibrium budgets $\left(\overline{B}_1, ..., \overline{B}_m\right)$. According to our interpretation above, equilibrium budgets also represent desired budgets: since, in this case, the aspirations of the government match its experiences, there is no need for further change in the budgets.

All our results in Section 2 go through here but with $\overline{\omega}_i$ replaced by $\overline{B}_i$. In particular (23) under zero ability to choose implies equiprobable government choices which lead to equal bureau budgets over time. At the other extreme, when ability to choose is perfect, (23) implies $\partial v/\partial \overline{B}_i = \partial v/\partial \overline{B}_1$ for $i > 1$, that is, all equilibrium impact increments must be equalized (with appropriate qualifications) as in (12).

4. A Distributive Justice Problem

A government deals with people. It is therefore essential to recognise that the government may take into account issues of distributive justice when it decides on a public policy. Governments decide on public policy which affects the distribution of resources across citizens through income taxation or social policy. Here we re–interpret and modify the model of Section 2 in a way that, while retaining the myopic behaviour and perception errors of government, it allows us to study distribution. Following Atkinson and Stiglitz [2, 2015, chapter 12] we will model a government's theory of justice which can range from a complete indifference regarding the distribution of individual utility levels to an almost absolute preoccupation with equity matters.

In order to focus on the interaction between the government's ability to choose and aversion to inequality we study a very simple model. We retain the myopic behaviour of Section 2.1. We assume that the government allocates a fixed amount of *income* among a fixed number k of people with first–best lump–sum taxes and subsidies. In principle there are a continuum of possible distributions across the k people. We restrict the number of possible distributions by imposing that policies are distinguished only by the possible single–unit addition of the accumulated income to any single one of the k individuals. Income/revenue is accumulated by the government at a fixed accumulation rate r per unit of time. We partition time into a sequence of periods each having the same length Δt, such that $r\Delta t = 1$. We begin at a particular period $[t, t + \Delta t)$. We assume that the government knows the after-tax income available to each one of the k individuals at the end of the previous period. Let $M_{i,t}$ denote the income available to individual $i = 1, ..., k$ at the beginning of the period. The flow of income/consumption to i is $\omega_{i,t} = r_i M_{i,t}$. That generates a utility level for individual i of $U_{i,t} = u_i [\omega_{i,t}]$ for $i = 1, ..., k$.[6] Let $W_t = w [u_i [\omega_{1,t}], ..., u_k [\omega_{k,t}]]$

[6] Following standard public economics one can think of this as indirect utility, that is, a function of after tax and transfer prices and income. Or alternatively as a single–good model. Also as usual we assume no interdependance in utility across individuals.

be the welfare function from a public policy mix $(\omega_{1,t}, ..., \omega_{k,t})$. We denote the policy mix where individual i receives the unit of income in t as $\Omega_{i,t}$ for $i = 1, ..., k$.

We next recognise a fundamental distinction between individual utility levels $u_i[\omega_i]$ and corresponding *publicly evaluated utility levels* $V_i[\omega_i]$. Since the amounts of the income available to each person $M_{i,t}$ are known at the beginning of a period, also known are the *publicly evaluated utility increments*, $\Delta V_{i,t}$, caused by the possible single-unit addition of the accumulated resource to any single individual. We assume that the government allocates the new resource unit to person i if and only if

$$\Delta V_{i,t}[\Omega_{i,t}] = \max\{\Delta V_{j,t}[\Omega_{j,t}] \text{ for } j = 1, ..., k\}. \tag{25}$$

We also retain the perception errors of Section 2.2 together with their properties, and introduce the *perceived publicly evaluated utility levels* $\mathcal{V}_{i,t}$ to write

$$\Delta\mathcal{V}_{i,t} - \Delta V_{i,t} = \varepsilon_{i,t},$$

leading directly to the description of the periodic sequence of government choices

$$\Delta V_{i,t} + \varepsilon_{i,t} = \max\{\Delta V_{j,t} + \varepsilon_{j,t} \text{ for } j = 1, ..., k\} \tag{26}$$

and the corresponding probabilities which, for this Section, are re–written as

$$\mathbb{P}_{i,t} = \frac{\exp(\mu\Delta V_{i,t})}{\sum_{j=1}^{k}\exp(\mu\Delta V_{j,t})}. \tag{27}$$

4.1. Aversion to Inequality. In order to express the government's range of attitudes toward distributive justice, we use a welfare function. We assume that utility is fully measurable and comparable across individuals. Further, we assume that the government's welfare function depends on the individual's own view of their well–being (non–paternalism) and nothing else (welfarism); it values neither inequality nor ethically arbitrary accidents of birth like race and gender (anonymity). We follow Atkinson [1, 1970, 244–263] and assume that $W = \sum V_i$ with the publicly evaluated utility levels written as $V_i = v[U_i, \alpha]$, where $\alpha \geq 0$ is a parameter that reflects the government's *aversion to inequality.* We require that as the aversion to inequality increases, the public valuation of individual utility decreases relatively faster for relatively higher utility, that is, the government shows an increasing bias in favour of the less advantaged. These ideas can be expressed by using the utility elasticity of the change in the publicly evaluated utility and assuming it is a constant, namely

$$\eta_{v_i:U_i} \equiv \frac{d}{dU_i}\left(\frac{dv}{dU_i}\right) \div \left(\frac{1}{U_i}\frac{dv}{dU_i}\right) = -\alpha,$$

which has a solution

$$V_i = \begin{cases} \dfrac{U_i^{1-\alpha}}{1-\alpha} & \text{for } \alpha \neq 1 \\ \\ \ln U_i & \text{for } \alpha = 1. \end{cases} \tag{28}$$

provided that $U_i \geq 1$.[7]

Under zero aversion to inequality, the government adheres to the utilitarian principle of Bentham. At the other extreme, under infinite aversion to inequality, the government applies the second principle of Rawls [44, 1971]: its preoccupation is to distribute the resource so that the resulting inequalities are to the benefit of the least advantaged.

4.2. Equilibrium. The expected amount received by person i in t is $r\Delta t\mathbb{P}_{i,t}$. At the same time, income is consumed by individuals at constant rates $\omega_{i,t}$, so that the corresponding amount of the income consumed during that period is $\omega_{i,t}\Delta t$ and the expected change in the amount of the resource available to person i at the end of the period as

$$\mathrm{E}\left(\Delta M_{i,t}\right) = \left(r\mathbb{P}_{i,t} - \omega_{i,t}\right)\Delta t.$$

Since an adjusted argument for existence continues to apply here, the equilibrium

$$r\overline{\mathbb{P}}_i = \overline{\omega}_i \text{ for } i = 1, ..., k \tag{29}$$

does exist. Dividing once again the same expression for $i = 1$, and introducing (27) in the result, we obtain

$$\Delta\overline{V}_i - \Delta\overline{V}_1 = \frac{1}{\mu}\ln\frac{\overline{\omega}_i}{\overline{\omega}_1} \text{ for } i > 1. \tag{30}$$

Following the corresponding steps in Section 2.3, we evaluate the sequence of resource–increment decline as $\Delta M_i^{(0)} = 1$, $\Delta M_i^{(1)} = (1 - r_i\Delta t)$, ..., $\Delta M_i^{(q)} = (1 - r_i\Delta t)^q$; which implies that the change in the consumption flow in alternative i after q periods is given by $\Delta\omega_i^{(q)} = r_i\left(1 - r_i\Delta t\right)^q$. Since people here derive utility only if they use/consume what they have, $U_i = u_i\left[\omega_i\right]$, the publicly evaluated utility increment in alternative i after q periods is $\Delta V_i^{(q)} = V_i\left[\Delta\omega_i^{(q)}\right]$. Finally, taking into account all future consequences of the initial spending decision on utility, we write the *true utility increment* as $\Delta V_i = \sum_{q=0}^{\infty}\Delta V_i^{(q)} = \Delta V_i = \sum_{q=0}^{\infty} V_i\left[r_i\left(1 - r_i\Delta t\right)^q\right]$. If we expand the true utility increment in Taylor series, follow the steps in Appendix 1 and take into account (28) we conclude that

$$\Delta V_i \cong U_i^{-\alpha}\frac{du_i}{d\omega_i}/\Delta t \tag{31}$$

[7] In (28), we omit the constants of integration.

provided that $|1 - r_i \Delta t| < 1$. Replacing (31) in (30) with an equality sign we get

$$\overline{U}_i^{-\alpha} \left(\frac{du_i}{d\overline{\omega}_i} - \left(\frac{\overline{U}_i}{\overline{U}_1} \right)^{\alpha} \frac{du_1}{d\overline{\omega}_1} \right) = \frac{\Delta t}{\mu} \ln \frac{\overline{\omega}_i}{\overline{\omega}_1} \quad for\ i > 1. \tag{32}$$

This, together with the summation of (29), determines the equilibrium public policy $(\overline{\omega}_1, ..., \overline{\omega}_k)$.

From Section 2.5, for any given level of aversion to inequality and using the generality of the υ function there, we know that the equilibrium level of welfare increases as the government's ability increases. We also know that the result of Section 2.4 applies here for $\alpha = 0$ and $\mu \to \infty$, namely, that total utility $W = \sum U_i$ is maximised in equilibrium subject to (29). When $\alpha \to \infty$ and $\mu \to \infty$, (32) implies $\overline{U}_i = \overline{U}_1$ for $i > 1$. From the structure of probabilities (27) in conjunction with (31), we know that $\mu = 0$ implies equiprobable government choices for any α. It is noteworthy that the equilibrium solutions under perfect inability correspond to that of a Fair outcome (see Foley [23, 1967, 45–98]) under any aversion to inequality.[8]

	$\mu = 0$	$0 < \mu < \infty$	$\mu \to \infty$
$\alpha = 0$	$\overline{\omega}_i = \overline{\omega}_1$		Maximum Total Utility
$0 < \alpha < \infty$	$\overline{\omega}_i = \overline{\omega}_1$		
$\alpha \to \infty$	$\overline{\omega}_i = \overline{\omega}_1$		$\overline{U}_i = \overline{U}_1$

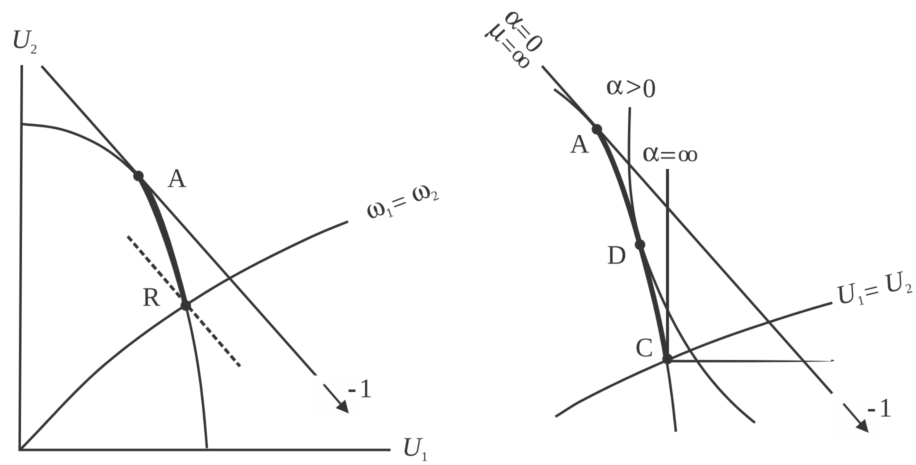
Table 1: Extreme–Valued Equilibrium Solutions

A summary of these conclusions appears in Table 1. All outcomes in that table are Pareto efficient.

5. Examples

In this Section we provide various examples in the simple case of two alternatives allowing for a graphical illustration of the implications for welfare economics. Although these examples are based on the problem of Section 4, their conclusions also apply to Sections 2 and 3 under zero aversion to inequality and corresponding notation adjustments.

[8] This is defined as an allocation which is efficient and involves no envy, in the sense that no one prefers another's consumption possibilities.



(a) Zero Aversion Equilibria (b) Variable Aversion Equilibria

Figure 1: Aversion Equilibria

5.1. Equilibria On the Utility–Possibility Frontier. In the simple case of two alternatives, using (28), social indifference curves are determined by

$$\frac{dU_2}{dU_1} = -\left(\frac{U_2}{U_1}\right)^{\alpha} \tag{33}$$

for any given ω and for any α and μ.

For zero aversion to inequality, according to(33), social indifference curves become straight lines with slope -1 for any level of ability to choose. For zero aversion and perfect ability, (12) and (33) yield

$$\frac{d\overline{U}_2}{d\overline{U}_1} = -1 = -\frac{du_2}{d\overline{\omega}_2} / \frac{du_1}{d\overline{\omega}_1} \tag{34}$$

in equilibrium. Consider an asymmetric utility–possibility frontier with diminishing marginal utility, where individual 2 transforms a given amount of resource into higher utility than individual 1. For example, assume

$$U_1 = u(\omega_1) \text{ and } U_2 = au(\omega_2) \text{ with } a > 1$$

The solution that satisfies (34) is shown as point A in figure 1(a), where the highest feasible social indifference curve is tangent to the utility–possibility frontier. It will involve $\overline{\omega}_1 < \overline{\omega}_2$ to equalize marginal utilities. This portrays the equilibrium public policy as a solution to our analog of a constrained optimisation problem (13). Holding zero aversion fixed and letting ability decline, equilibrium solutions move from point

A toward point R along the segment AR. Every point in the interior of this curve corresponds to the intersection between the utility–possibility frontier and a lower social indifference curve, parallel to the highest feasible, which determines the equilibrium solution for a particular level of ability to choose under zero aversion to inequality. Lower ability implies a lower equilibrium level of social welfare. Under zero ability to choose, the equilibrium solution reaches its lowest level of social welfare at point R where $\overline{\omega}_1 = \overline{\omega}_2$. Also note that at R $\overline{U}_1 < \overline{U}_2$ for our $a > 1$. Thus the curve AR in that diagram contains all equilibrium solutions for $\alpha = 0$ and $0 \leq \mu \leq \infty$. Notice that (32), under $\mu \rightarrow 0$, also implies $\overline{\omega}_1 = \overline{\omega}_2$ for any degree of aversion to inequality: when there is no ability to choose, even at infinite aversion, the unique outcome is an equal distribution of the consumption flows.

Now begin with the straight–line social indifference curve that corresponds to $\mu \rightarrow \infty$ and $\alpha = 0$ in figure 1(a) and raise aversion gradually while holding ability fixed at its highest level. Using (33) once more, with perfect ability and rising aversion, social indifference curves become increasingly curved as indicated in figure 1(b), which shows part of the utility–possibility frontier. At the limit, where aversion to inequality becomes infinite, the social indifference curves become right angles. Starting at A with $\alpha = 0$ and letting aversion increase, equilibrium solutions move from point A toward point C along the curve AC of the utility– possibility frontier. Every point D in the interior of this curve is determined by the tangency between the utility–possibility frontier and the highest among a group of social indifference curves with fixed curvature, in other words, with a given degree of aversion. Holding ability fixed, higher aversion implies a lower maximum feasible equilibrium level of total utility. Under infinite aversion to inequality, the equilibrium solution maximises a Rawlsian social welfare function and reaches its lowest level of total utility at point C where $\overline{U}_1 = \overline{U}_2$ according to (12). Finally notice that the zero ability equilibrium for any aversion to inequality, where $\overline{\omega}_1 = \overline{\omega}_2$, will be some intermediate point to A and C, like D. In general, lower ability moves a government further away from its welfare maximum towards the intermediate point where $\overline{\omega}_1 = \overline{\omega}_2$ for all degrees of aversion to inequality except for the aversion $0 < \alpha < \infty$ which makes $\overline{\omega}_1 = \overline{\omega}_2$ the welfare maximum.

As shown in figure 2, the equilibria that correspond to perfect ability with zero aversion (point A) and infinite aversion (point C) and zero ability with any aversion (point R) respectively, do not coincide in general except in the special case where the utility–possibility frontier is symmetric and convex, that is, where $a = 1$. Then, under any degree of aversion to inequality and any level of ability to choose, the government maximises total utility by distributing the resource equally—which also implies the equal–utility outcome: with $a = 1$, points A, R, and C coincide. Otherwise, for any pair (α, μ) which represents an equilibrium point on the curve AR, there corresponds an α'' such that (α'', ∞) has the same equilibrium allocation as the initial pair. Thus

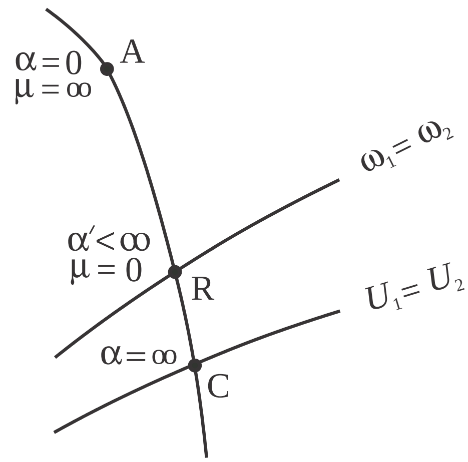


Figure 2: Equilibrium Range Overlaps

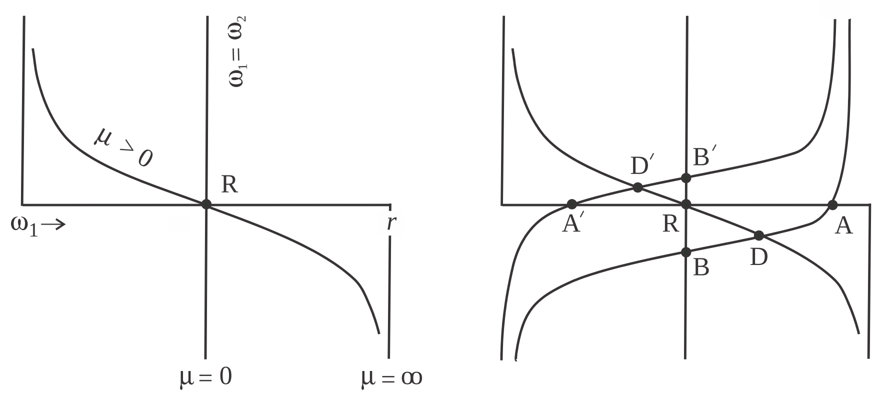
all equilibrium public policies within the overlapping ranges of ability and aversion can be made identical to policies arising from an extreme value of ability combined with an appropriate degree of aversion. In this manner, it becomes clear that public ability to choose is more important in implementing the more extreme theories of justice, for example, $\alpha = 0$ or $\alpha \to \infty$.

5.2. Equilibrium Solutions. In this Section we investigate public policy equilibria directly from the equilibrium condition (10). With two alternatives and with $\alpha = 0$ this condition becomes

$$\frac{du_2}{d\overline{\omega}_2} - \frac{du_1}{d\overline{\omega}_1} = \frac{\Delta t}{\mu} \ln \frac{\overline{\omega}_2}{\overline{\omega}_1}. \tag{35}$$

Diagram (a) in figure 3 represents the graph of the right–hand side of (35).[9] When $\mu \to \infty$, this function equals zero for any value of ω_1 that satisfies $0 < \omega_1 < r$. At both ends of this interval, where $\omega_1 = 0$ and $\omega_1 = r$ respectively, this conclusion no longer applies. At $\omega_1 = 0$ the right–hand side equals ∞/∞, which is represented by the positive half of the vertical line at $\omega_1 = 0$; and at $\omega_2 = 0$ it equals $-\infty/\infty$, which is represented by the negative half of the vertical line at $\omega_1 = r$. As the ability to choose gradually falls from μ from ∞, the graph of the right–hand side is transformed into a series of continuous, downward–sloping curves one of which is shown in diagram (a). Notice that the right–hand side of (35) equals zero at $r/2$ for any μ that satisfies $\mu > 0$. In consequence, all such right–hand side curves of (35) rotate on the midpoint

[9] In the remaining figures 4 and 5, ω_1 is on the horizontal axis as in figure 3. All these figures are based on numerical examples available upon request.



(a) RHS of (35)

(b) LHS and RHS of (35)

Figure 3: Zero Aversion Equilibria

R of the horizontal ω_1–axis. Finally, when $\mu = 0$, the right–hand side of (35) equals $0/0$ at $r/2$: its graph becomes a vertical straight line that crosses the horizontal ω_1–axis at $\omega_1 = \omega_2$.

Diagram (b) in figure 3 shows the graphs of both sides of (35). The two increasing curves on that diagram correspond to the left–hand side of (35). The lower curve is for the case of individual 1 being the better utility machine and the upper curve is for the reverse. Recall that these two imply zero aversion to inequality. When ability is perfect as well, (35) determines solutions to the standard public choice problem (13) which are represented by points A and A′ in diagram (b). The former corresponds to point A in figure 1(a). At the other extreme, when zero ability is reached, the equilibrium solutions B and B′ determine $\overline{\omega}_1 = \overline{\omega}_2$ as an equilibrium public policy for any value of the left–hand side of (35). These correspond to point R in figure 1(a). In–between, as ability declines from $\mu = \infty$ with aversion held constant at zero, equilibrium solutions D and D′ move closer to the middle of the curve $(0, r)$ on the horizontal ω_1–axis. Notice that the gradual displacement from A to B and from A′ to B′ in diagram (b) exactly corresponds to the move of such equilibria from A to R along the curve AR in figure 1(a).

When we treat aversion to inequality as a variable, using (10) once more, (35) is replaced by

$$\overline{U}_2^{-\alpha} \left(\frac{du_2}{d\overline{\omega}_2} - \left(\frac{\overline{U}_2}{\overline{U}_1} \right)^{\alpha} \frac{du_1}{d\overline{\omega}_1} \right) = \frac{\Delta t}{\mu} \ln \frac{\overline{\omega}_2}{\overline{\omega}_1}. \tag{36}$$

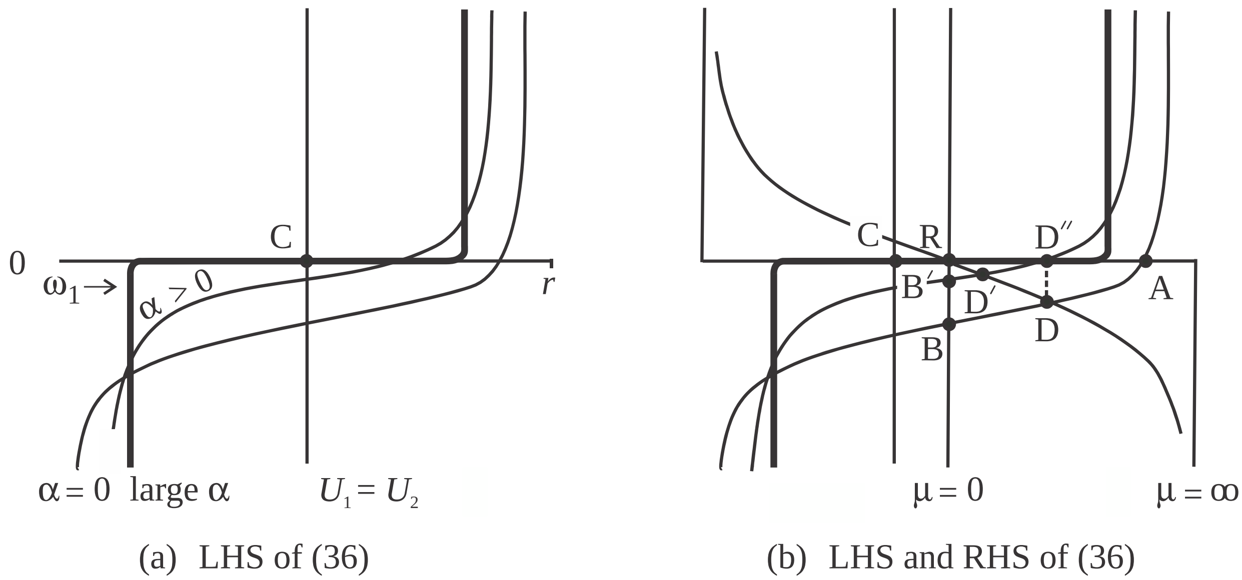


Figure 4: Variable Aversion Equibria

Figure 4(a) represents the left–hand side of (36). In this example, the graph with $\alpha = 0$ corresponds to the lower of the two graphs in figure 3(b). Increasing aversion to inequality generates a continuum of upward–shifting curves, one of which is shown in that diagram as corresponding to $\alpha > 0$. All such curves approach the horizontal ω_1–axis from below and cross it inside the interval CR. When α is large, the graph of the left–hand side extends close to the horizontal ω_1–axis as indicated by the bold line of diagram (a).

Figure 4(b) shows both sides of (36). The intersection of the two sides at point A, where the left–hand side graph is determined by $\alpha = 0$ and the right–hand side by $\mu = \infty$, corresponds to point A in figure 1, as well as in figure 3(b). The intersections at points R, B and B′, where the left–hand side graphs are determined by $0 \leq \alpha \leq \infty$ and the right–hand side by $\mu \rightarrow 0$, correspond to point R in figure 1(a) and points R, B and B′ in figure 3(b). These are consistent with our conclusion in Section 4.2 that zero ability to choose implies equal allocation of the resource for any degree of aversion to inequality. In–between, as aversion increases from zero with ability held constant, the equilibrium solution shifts closer to the mid–point R from D to D′.[10]

We next turn to the sequence of equilibrium solutions as both ability and aversion

[10] In the discussion following figure 2, it was mentioned that for any pair (α, μ) which represents an equilibrium point within the range AR of ability in 2(b), there corresponds an α'' such that (α'', ∞) has the same equilibrium allocation as the initial pair. In figure 4(b), the equilibrium solution at point D which corresponds to $(0, 0 < \mu < \infty)$ has the same solution at point D″ which corresponds to $(0 < \alpha < \infty, \infty)$.

increase from zero. First notice that the intersection between LHS curves of (36) and the ω_1–axis approaches R from the right as aversion increases from zero. Consider now the equilibrium at D′. Holding ability fixed, increasing aversion to inequality shifts D′ toward R and then away from it as it moves above the ω_1–axis toward the vertical line crossing C. Imagine a sequence where both α and μ steadily grow in tandem bringing an equilibrium solution closer to C. Eventually, the equilibrium solution becomes arbitrarily close to C. Taking into account the discussion following (32), we conclude that infinite aversion to inequality as an equilibrium located at C requires a perfect ability to choose: if you aim to achieve precisely equal utility levels at equilibrium, you cannot afford making any mistakes.

The equilibrium level of inequality in this example is defined as $|\overline{U}_1 - \overline{U}_2|$. Let the equilibrium at R correspond to a particular aversion level $\overline{\alpha}$. Then start with any α and $\mu = 0$, in other words start at R in figure 4. For $\alpha > \overline{\alpha}$, increasing μ moves the equilibrium away from R towards C (equal utility) and reduced inequality. For $\alpha < \overline{\alpha}$ increasing μ moves the equilibrium away from R in the opposite direction towards the Bethamite equilibrium A and increased inequality. Now hold ability fixed at $\mu > 0$ and let aversion to inequality increase from $\alpha = 0$. As it increases the equilibrium solution moves toward C, so that inequality decreases. Under zero ability, the equilibrium corresponds to R for any value of α, that is, the equilibrium level of inequality is fixed for any degree of aversion.

6. Errors and Pressures

6.1. Systematic Perception Errors. Efforts to systematically influence the government in favour of a particular policy alternative are pervasive in the realm of public choice and clearly important for understanding public policy. Lobbying, political contributions, public advertisement by interest groups, and the very prospect of an election are examples of external pressure facing a government. We consider such external pressures as efforts to produce and exploit internal systematic perception errors in public choice in the manner of Rabin [43, p. 538], who argues that

> "... not all limits to rationality are based on computational unmanageability. Many of the ways humans are less than fully rational are not because the right answers are so complex. They are instead because the wrong answers are so enticing. Human intuition leads us astray in all sorts of ways that are simply not well described in terms of the difficulty or complexity of problems that bounded-rationality models seem best suited for. The pervasiveness of bounds errors where people are daunted by the task of optimization, or are simply not geared to it, should not be doubted. But astray errors, as one might call them, likewise seem pervasive, and especially amenable to neoclassical modeling."

We agree with Rabin. And so does the profession, as evidenced by the large and growing public choice literature on voters and governments making astray errors which was noted in the introduction. Nevertheless, while we agree with Rabin about the utility of making a distinction, as well as about the importance of astray errors, we do not believe that these two types of error are independent of each other: indeed, as we argue below, some level of bounded rationality is required for the emergence of astray errors.

We model systematic perception errors using the concept of *bias* $\beta_i > 0$ which draws equilibrium government choices toward a particular choice, here the choice of sector i. We assume that random errors (3) are modified as,

$$\Delta \mathcal{Y}_{i,t} - \Delta \Upsilon_{i,t} = \varepsilon_{i,t} \sim \frac{1}{\mu}(\varepsilon + \beta_i). \tag{37}$$

Thus although the bias directly affects random errors by introducing a positive expectation favouring the biased sector, we assume that its impact on the errors decreases as the government's ability increases, and it is completely eliminated when the government's ability becomes perfect. This is analogous to the highest–ability person overcoming the tendency to be led astray. The probabilities (5) are now re–written as

$$\mathbb{P}_{i,t} = \frac{\exp(\mu \Delta \Upsilon_{i,t} + \beta_i)}{\sum_{j=1}^{k} \exp\left(\mu \Delta \Upsilon_{j,t} + \beta_j\right)}. \tag{38}$$

If we introduce these probabilities into the equilibrium definition (6), solve the result for $\Delta\overline{\Upsilon}_i - \Delta\overline{\Upsilon}_1$ and use (9), we obtain

$$\frac{\partial \upsilon}{\partial \overline{\omega}_i} - \frac{\partial \upsilon}{\partial \overline{\omega}_1} = \frac{\Delta t}{\mu}\left(\ln \frac{\overline{\omega}_i}{\overline{\omega}_1} - (\beta_i - \beta_1)\right) \text{ for } i > 1 \tag{39}$$

which, together with (11), provides the equilibrium solution in the case of systematic perception errors. When $\mu \to \infty$, following the argument in Section 2.4, (39) implies that the equilibrium solution becomes equivalent to corresponding equilibria of the constrained optimization model (13) and the biases play no role. At the other extreme, when $\mu = 0$, probabilities (38) yield systematically biased, instead of equiprobable government choices.

Why is the right specification of internal systematic errors one where the systematic bias decreases as the government's ability increases and is completely eliminated when the government's ability becomes perfect? By now there are many empirically relevant examples of astray errors. For each one it is difficult, if not impossible, to imagine an astray error which could not be overcome by a person with sufficient cognitive ability. This is for the simple reason that if we can imagine and understand an astray error we should be able to imagine a strategy which could be utilised by individuals with perfect ability to overcome the astray error. Consider the following illustrative examples.

In Herrnstein's [30, 1991] experiments, many subjects facing an even somewhat complex dynamic problem fell back to choosing on the basis of current costs and benefits: a present–bias astray error. This was not true, however, of all experimental subjects. Some individuals facing the same dynamic problem used the same information to solve the dynamic problem. In Selten and Stoecker's [48, 1986] repeated prisoner dilemma experiments the players, instead of rationally defecting throughout, cooperate until some point close to the final period. Crawford [20, 2013] argued that this may be due to some individuals with 'inappropriately' short time horizons. He explained the heterogeneity in the behaviour across individuals as being driven by differing cognitive abilities. Another example can be found in Rabin's [42, 2002] work on the law of small numbers. There are people who seem to really believe in and behave according to the 'law' while others, who 'believe' in statistics, will presumably not make this astray error. Finally, in the case of narrow bracketing, we would expect relatively narrower brackets to be associated with people with relatively lower cognitive ability. These examples suggest that bounds and astray errors are inextricably intertwined, in particular, that some level of bounds errors are necessary for a manifestation of astray errors. In some sense, an inability to overcome an astray error, becomes a bounds error.

Example. The right–hand side of (39) represents the family of curves which determine the impact of ability to choose on equilibrium public policies. In the case of two alternatives, this function equals zero when either $\mu \to \infty$ (in which case the right–hand side of (39) collapses over the interior of the interval $(0, r)$), or when $\ln(\omega_2/\omega_1) = (\beta_2 - \beta_1)$ which, in conjunction with $\omega_1 + \omega_2 = r$, yields

$$\omega_1 = \frac{r}{1 + \exp(\beta_2 - \beta_1)}. \tag{40}$$

Consider figure 5(a). The three decreasing, right–hand side curves in this diagram denote the same level of ability. Two are at opposite net bias levels, while the third corresponds to $\beta_1 = \beta_2$ which by (40) implies $\overline{\omega}_1 = r/2$ for any $\mu > 0$. Thus when external pressures cancel, right–hand side curves of (40) rotate on the midpoint of the horizontal ω_1–axis as explained in the discussion following figure 3(a); and the vertical straight line that crosses the horizontal ω_1–axis at $r/2$ represents the right–hand side of (39) when $\mu \to 0$. But when $\beta_1 \neq \beta_2$, this vertical shifts away from $\omega_1 = r/2$. Using (40), the shift size is given by

$$\omega_1 - \frac{r}{2} = \frac{r}{2}\left(\frac{1 - \exp(\beta_2 - \beta_1)}{1 + \exp(\beta_2 - \beta_1)}\right),$$

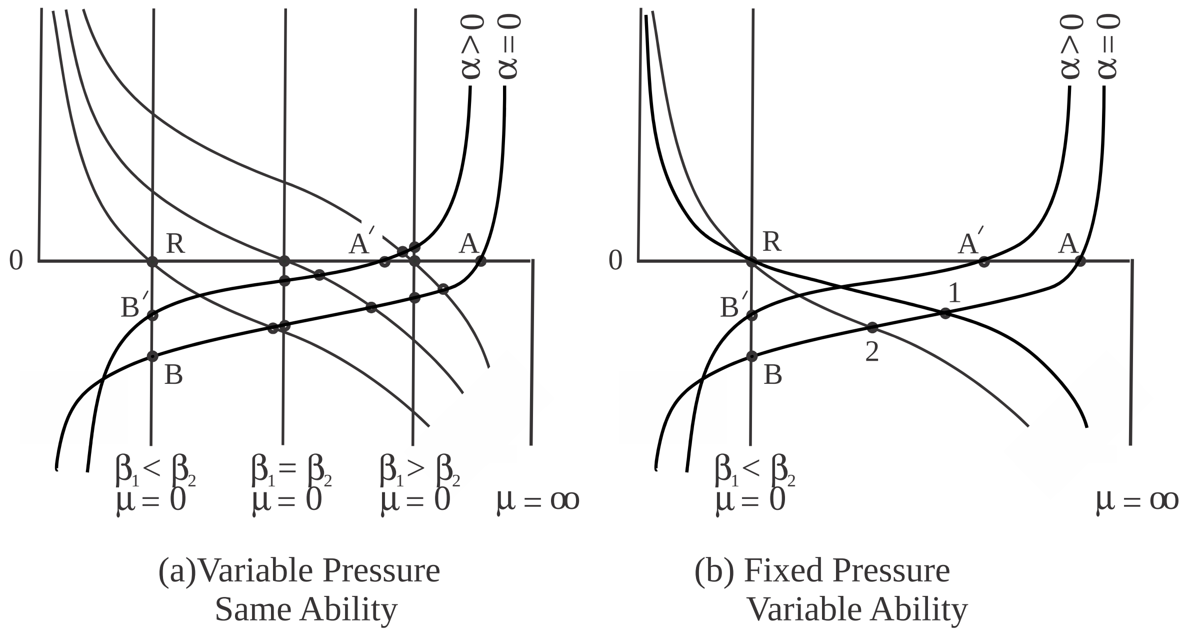


Figure 5: Pressure Equilibria

which is positive when $\beta_1 > \beta_2$ and negative when $\beta_1 < \beta_2$. Therefore, when $\beta_1 > \beta_2$ the intersection shifts to the right and when $\beta_1 < \beta_2$ it shifts to the left. The intersection of those shifted verticals with the ω_1–axis marks the rotation points of the three right–hand side curves. One of these rotation points is marked R in both parts of figure 5.

The left–hand side of (39) is represented by two increasing curves. The solution to the constrained optimisation model (13) is found at point A under perfect ability to choose and zero aversion to inequality. This point is where the impact of net bias on equilibrium public policy is completely eliminated. In any other case, the impact of net bias increases as ability declines and it is maximised under zero ability to choose. Such an equilibrium solution which, for example, arises under $\beta_1 < \beta_2$ corresponds to point B. In figure 5(b), where ability to choose varies under the same level of net bias, the sequence A,1,2, B shows explicitly the growing impact of net bias on the equilibrium solution.

6.2. Political Lobbying. Lobbying in economics was traditionally modelled as a 'black box' influence function.[11] Grossman and Helpman [25, 1994], with a major

[11] Beyond lobbying there are other public choice literatures which immediately come to mind as areas where an extension to imperfect public choice with bounds errors would be potentially interesting. For example, citizen candidates with an imperfect ability to choose, earmarking for a policy involving safety issues when an incumbent is concerned about the ability of the subsequent

step forward, expressed the problem for campaign contributions as 'policy favours' being sold in a political market. In other words, bias away from the societal interest and towards the interest of a lobby group's preferred position becomes a rational economic exchange between the organized lobby group and the policy–maker. There is also work on informational lobbying, where a special interest group has information which is not available to the policy–maker. Then, given the divergent interests of the policy–maker and the lobbyist, whether the information can be trusted becomes an informational issue (see for example Grossman and Helpman [26, 2001]). A natural extension to those literatures is about the management of that problem, for example, through Madison's 'choosing leaders with the virtue to pursue the common good of society'; and in the next place, by taking the most effectual precautions 'for keeping them virtuous'. The work of Besley [8, 2006] with references within, and its focus on the political selection of virtuous leaders who are then faced with good incentives, provide important contributions towards that end. Precautions against 'buying' policy outcomes through campaign contributions are pervasive throughout the world.

We shall argue, however, that even if policy–makers were perfectly virtuous and precautions were perfect, society's potential problem with lobbying would not be eliminated if policy makers do not have Madison's "wisdom to discern". Further, the provision of 'information' to policy–makers and public advertisement by special interest groups has been seen as less of a threat than campaign contributions in some countries.[12] After all, the credibility of the information can be rationally examined and it can be freely discarded if it is not informative or useful.

In Section 6.1 we modeled systematic perception errors using the concept of bias $\beta_i > 0$ which drew equilibrium policy choices toward a particular choice—the choice to provide more resources to sector i. There we assumed that bias was exogenous. Here we assume that bias is a function of lobbying effort in the sense of political information and advertisement. In Section 2.5 we have shown that a larger dispersion in the impact of choices, for example in the presence of dangerous possible outcomes, increases the importance of making good choices and avoiding bias. We also have shown that the impact of bias on the errors decreases as the government's ability increases. At the limit, where the ability to choose is perfect, the individual should not rely any longer on biased information, but only on the intrinsic character of the choice.

Putting these results together, consider the lobbying of the National Rifle Associa-

policy maker, or the importance of civil servants learning by doing with an imperfect ability especially when decisions on optimal training are imperfect.

[12] A recent ruling by the US Supreme Court in Citizen's United v. Federal Election Commission (130 US 876 (2010)) allows corporations to spend unlimited amounts on political advocacy advertisement during election campaigns.

tion in the US or the Trump administration's response to the Covid 19 pandemic. Our model provides a rationale for optimally restricting political information lobbying and advertisement, especially when lobbying influences policy about dangerous products such as assault rifles or global pandemics, and especially with governments of lesser ability. The expenditure on resources to generate a highly–trained and highly–valued civil service in order to manage lobbying effects becomes appropriate. And an aspect to the management of lobbying is through choosing leaders of high ability, in other words, leaders with the 'wisdom to discern'.[13]

7. CONCLUDING REMARKS

> "The power and the success of perfectly rational behavior as a model of choice is to be found in the observation that many real events can be explained by assuming that economic actors behave as if they have a perfect ability to choose. Yet there are phenomena for which explanations alternative to those provided within the context of perfectly rational behavior might appear closer to experience in important respects" (de Palma et. al. [22, 1994, p. 433]).

There are, by now, many examples in the economics literature of phenomena where the 'as if' principle fails. Here we explore some instances of the 'as if' failure using a basic public choice problem developed in Section 2. We first consider the usual for governments incremental budgeting approach. We argue that the very nature of this common budgeting methodology, incremental, sequential, using one at a time decisions on solicited proposals, ongoing, off to an indefinite future, only makes sense under an imperfect ability to choose. Our model fits Simon's [49, 1955] search for alternatives, satisficing, and aspiration adjustment. We then extend the basic problem to study the decisions of a government concerned with social justice. In the last section of the paper we build a framework which integrates bounds errors and systematic perception (astray) errors. We argue that bounds errors and astray errors are inextricably intertwined—some level of bounded rationality is required for astray errors to emerge. The systematic perception errors allowed us to consider informational lobbying as a attempt to build and exploit systematic bias towards particular policy choices. We show there is a rationale for optimally restricting political information lobbying. This is especially true in a policy environment with a larger dispersion in the potential social impact of policy choices, for example, in the

[13]For better or worse, with a citizenry characterised by an imperfect ability to choose, there is also a scope for the public manipulation of bias (see de Palma et. al. [22, 1994, Section IX]). For example, in the presence of environmental externalities, correction could involve public advertisement instead of Pigouvian taxes and subsidies. On the negative side of public manipulation rests the propaganda of both democratic and authotitarian regimes.

presence of possibly dangerous choices, such as policies regarding assault rifles or Covid 19 and with administrations of lower ability. In these cases, the importance of making good choices is critical and consequently increases the societal value of talented, high–ability public servants and leaders with the 'wisdom to discern'.

It is not surprising that the introductory quotation above applies perfectly well to both individual and public choices. Our basic premise, that 'as if' failures arise because choice behaviour is significantly affected by human cognitive limits, provides the foundation for both levels.

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Appendices

1. Proof of (9). We introduce the change in the consumption flow after k periods, $\Delta R_i^{(k)}$, to express the corresponding impact increment as $\Delta\Upsilon_i^{(k)} = \upsilon_i\left[\Delta R_i^{(k)}\right]$. Using (8), the experienced impact increment is

$$\Delta\Upsilon_i = \sum_{k=0}^{\infty}\upsilon_i\left[r_i\left(1 - r_i\Delta t\right)^k\right].$$

Expand $\Delta\Upsilon_i$ in MacLaurin series and retain only linear terms:

$$\Delta\Upsilon_i \cong \sum_{k=0}^{\infty}\left(\Delta\Upsilon_i^{(k)}\Big|_0 + \frac{d}{dR_i}\left(\Delta\Upsilon_i^{(k)}\Big|_0\right)r_i\left(1 - r_i\Delta t\right)^k\right). \tag{A1}$$

Notice that

$$\Delta\Upsilon_i^{(k)}\Big|_0 \equiv \Delta\Upsilon_i^{(k)}\Big|_{\Delta R_i^{(k)}=0} = 0 \tag{A2}$$

because there are no impact increments in the absence of the initial resource increment. Furthermore, that

$$\frac{d}{dR_i}\left(\Delta\Upsilon_i^{(k)}\Big|_0\right) = \frac{d\Upsilon_i}{dR_i} \tag{A3}$$

because, at the beginning of resource increments, the corresponding increase of the impact level is given by the effect of the current resource consumption R_i just before the increment. If we replace (A2) and (A3) in (A1) we get

$$\Delta\Upsilon_i \;\cong\; \frac{d\upsilon_i}{dR_i}r_i\sum_{k=0}^{\infty}\left(1 - r_i\Delta t\right)^k \tag{A4}$$

Then (9) follows because the summation in (A4) represents a geometric series which converges to $1/r_i\Delta t$ provided that $r_i\Delta t < 1$.

2. Proof of (15). Taking into account (14), we have

$$\begin{aligned} \frac{d\overline{\Upsilon}}{d\mu} &= \sum_{i=1}^{m}\frac{\partial\upsilon}{\partial\overline{\omega}_i}r\frac{\partial\overline{\mathbb{P}}_i}{\partial\mu} \\ &\underset{\text{by (9)}}{\cong} \sum_{i=1}^{m}\Delta\overline{\Upsilon}_i(r\Delta t)\frac{\partial\overline{\mathbb{P}}_i}{\partial\mu} \\ &= \sum_{i=1}^{m}\Delta\overline{\Upsilon}_i\frac{\partial\overline{\mathbb{P}}_i}{\partial\mu}. \end{aligned} \tag{A5}$$

We next differentiate (5):

$$\frac{\partial \overline{\mathbb{P}}_i}{\partial \mu} = \left(\Delta \overline{\Upsilon}_i - \sum_{j=1}^{m} \Delta \overline{\Upsilon}_j \overline{\mathbb{P}}_j \right) \overline{\mathbb{P}}_i. \tag{A6}$$

Replacing (A6) into (A5) we obtain (15).