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**ON THE (SEQUENTIAL) MAJORITY  
CHOICE OF PUBLIC GOOD  
SIZE AND LOCATION**

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***PUBLIC POLICY***



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## **ABSTRACT**

### **On the (Sequential) Majority Choice of Public Good Size and Location**

In this paper, we lay the first building blocks of a positive theory of nation formation where national choices consist of the size and location of a public good. Individuals differ both in income and in their preferences for the public good location. Public expenditures are financed either by a lump sum tax or by a proportional income tax. We study both the simultaneous and the sequential determinations of the public good size and location. We show that, while the choice of the type of public good follows the traditional median logic, the majoritarian determination of the taxation rate need not coincide with the choice of a median income citizen.

With lump sum financing, income heterogeneity plays no role and the sequential equilibrium consists of the median location together with the public good level most-preferred by the individual located at the median distance from the median. This policy bundle also constitutes an equilibrium with simultaneous voting in the special case of a uniform bivariate distribution of individuals' income and location. With proportional taxation, there is no policy equilibrium with simultaneous voting. We offer a complete characterization of the equations describing the sequential equilibrium in the general case and we show why and how our results depart from those obtained with the lump sum case. The public good level is lower than the one emerging under lump sum taxation when the income distribution is concave and when the correlation between individuals' income and location is positive but not perfect.

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# 1 Introduction

Our main objective in this paper is to lay the first building blocks of a positive theory of nation formation where the policy space of each nation is multidimensional. This is an essential and difficult departure from most existing models. A first branch of the literature deals with the case where the policy is horizontal, with citizens selecting the location of their capital (Alesina and Spolaore (1997, 2003), Le Breton and Weber (2003)) or the proportion of a fixed budget to be allocated to a specific public good (Alesina, Baqir and Easterly (1999), Alesina Baqir and Hoxby (2004)). A second branch of the literature studies the setting of a vertical policy, with citizens typically selecting the quantity of a public good (Bolton and Roland (1997), Jehiel and Schotchmer (1997, 2001)). Within these different frameworks, the literature has explored several questions. Many papers aim at determining the optimal number of nations. Large countries display significant economies of scale in the financing of the public good but are also more heterogeneous. It may happen then that border citizens feel unhappy with the national policy choice and threaten to secede. The optimal size of a nation results from a balance between these two forces. The question of the stable number of nations has also been extensively investigated. Stability refers to the equilibrium of a game describing both the constitutional rules restricting how nations are formed or dissolved and how policies are selected within each nation. Regarding the latter, a special attention has been devoted to the case where the national choice is made by majority voting. This is quite natural since a majority equilibrium exists and is easy to characterize with a one dimensional policy space and regular utility functions.

Moving to more than one dimension leads to a discontinuous leap in complexity, as it is well known that simultaneous majority voting on multidimensional policy spaces generically has no equilibrium. More precisely, the set of regular (in particular convex) preference profiles with a majority equilibrium in multidimensional policy spaces is generically empty (Banks and Austen-Smith (1999)).<sup>1</sup> As a consequence, the few papers (Alesina, Baqir and Easterly (1999), referred to as ABE hereafter, Etro (2006), Gregorini (2007), Perroni and Scharf (2001))<sup>2</sup> which extend the existing models to multidimensional universes make a number of very specific assumptions to guarantee the existence of a majority voting equilibrium. They

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<sup>1</sup>The proof of this result is based on an explicit characterization of the properties that must be satisfied by the citizens' preferences for policy  $x$  to be a majority equilibrium. There are many different versions of these properties. When the number of citizens/voters is finite, these are the celebrated *Plott's symmetry conditions* (Plott (1967)). If we rather consider a continuous distribution of citizens with Euclidean preferences, these properties require  $x$  to be a *total median* – i.e., a median in all directions (Davis, DeGroot and Hinich (1972)). See also Banks, Duggan and Le Breton (2006).

<sup>2</sup>See also Alesina, Baqir and Hoxby (2004).

consider a two-dimensional policy space and assume that majority voting is sequential. At first glance, a sequential mechanism looks safe from the point of view of existence as soon as preferences are regular enough (in particular, single-peaked on each dimension) since each vote is unidimensional. Note however that unless it is assumed that the two components are totally separable, the backward resolution will lead to a reduced utility function in the first stage which need not be single-peaked. In order to circumvent this difficulty, existing papers make additional assumptions. First, they put the following structure on the policy set : one dimension is horizontal (such as the public good location) while the other is vertical (the aggregate public good expenditure, raised through taxation). Second, all papers<sup>3</sup> restrict themselves to lump sum taxation, so that citizens' income does not matter and the only source of heterogeneity among voters lies in their taste for the public good. Third, in this setting where ultimately citizens are described by one parameter, they consider an ordering of the votes which guarantees the existence of an equilibrium: ABE recognizes for instance that "this assumption is made for tractability, in order to avoid issues of multidimensional voting, which is not our focus." Finally, all papers except ABE further assume that the distribution of the voters' unique trait is uniform over its support.

In this paper, we keep the utility specification considered by this emerging branch of the literature but depart from these contributions in three ways. First, we assume that voters differ in both income and preference for the location of the public good, with the latter financed through an affine income tax. Such an assumption is much closer to observed practice than the lump sum financing studied in the existing literature. Observe that citizens' income does matter in such a context, as people differing in income favor different quantities of public good even if they have the same preference for its location. Second, as people differ in two dimensions, we describe the polity by a two-dimensional statistical distribution that need not be uniform on any dimension.<sup>4</sup> Assuming uniformity is indeed a very special case and makes it difficult for the reader to assess which results (such as the features of the equilibrium policy) may be generalized to other distributions. Also, assuming uniformity eliminates the possibility of discussing the impact of some societal characteristics like for instance polarization (Haimanko, Le Breton and Weber (2005)) or correlation between taste and income on the policy outcome. Finally, we consider both the simultaneous and the sequential determinations of the location and size of the public good. This allows us to understand under which circumstances (i.e., characteristics of the bivariate distribution of

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<sup>3</sup>Except Gregorini (2007) who only considers two classes of income together with proportional income taxation.

<sup>4</sup>We follow the same approach as the one adopted by Le Breton and Weber (2003) in the traditional unidimensional model.

individual traits) a simultaneous equilibrium exists and whether it differs from the sequential equilibrium.

We now summarize our main results. Section 3 focuses on the case of lump sum taxation in order to shed light on the existing literature. We show that, if a simultaneous equilibrium policy exists, it corresponds to the sequential equilibrium identified by ABE where the location of the public good is the median most-preferred one while the size of the budget is the one most-preferred by the individuals with the median distance to the median. We then obtain that a simultaneous equilibrium only exists if very stringent symmetry assumptions are satisfied by the distribution of location preferences (the income distribution plays no role with lump sum financing). The uniform distribution satisfies these assumptions. Section 4 then studies the more ambitious case of proportional income taxation. In that case, there is no simultaneous equilibrium even with a bivariate uniform distribution of traits. We characterize the equilibrium sequential policy and study in section 5 how it is impacted by the shape of the income distribution and by its correlation with the location distribution. We show that, while the choice of the type of public good follows the traditional median logic, the majoritarian choice of the taxation rate is more subtle and need not coincide with the choice of a citizen with a median trait. More precisely, the sequential equilibrium identified by ABE (median location together with public good amount favored by the individual with the median distance to the median location and the median income level) carries through to the case of proportional taxation if (i) the distributions of income and of location are independent from each other, (ii) the location distribution is uniform, and (iii) the income distribution is symmetrical. If only the first two assumptions are satisfied, then the size of the public good is smaller (resp., larger) than the level identified by ABE if the income distribution is everywhere concave (resp., convex). For instance, if income follows a Beta distribution that is positively skewed (as in all OECD countries), then the equilibrium public good level is lower than the one identified by ABE. As for the correlation between income and location preferences, we investigate numerically the case where both distributions are uniform. We obtain that the ABE rule corresponds to the case where they are either perfectly correlated or independent from each other. In the case where both traits are positively but imperfectly correlated, the equilibrium public good level is lower than the one identified by ABE.

We now turn to the setting of our model.

## 2 The Model

We consider a country populated by a continuum of citizens of unitary mass: we normalize the size of the jurisdiction to one as we are not interested in determining its optimal size. This country has to select a public policy consisting of two components : a *horizontal* component, which is described as a continuous variable in the interval  $[0, 1]$ , and a *vertical* component described as a continuous variable in  $\mathfrak{R}_+$ . While the model can accommodate several alternative interpretations, it is useful to think of the public policy as a decision on both the type  $p$  of a pure public good, facility or service to produce (the horizontal dimension) and on the quantity or size  $g$  of this particular public good (the vertical dimension). A nice illustration is the case where the horizontal dimension is simply the *location* of the public good.

Citizens are heterogeneous in two dimensions. First, they differ according to their preferences for the different types of public goods. In that respect, each citizen is described by a parameter  $\alpha$  in  $[0, 1]$ . Second, each citizen is described by his/her private income  $y$  in the interval<sup>5</sup>  $[0, \bar{y}]$ . The statistical distribution of types across citizens is described by a joint distribution  $F$  on  $[0, 1] \times [0, \bar{y}]$  which is assumed to be absolutely continuous with respect to the Lebesgue measure on  $\mathfrak{R}^2$ . We will denote by  $f$  its density and by  $F_\alpha$  and  $F_y$  the marginal of  $F$  on  $[0, 1]$  and  $[0, \bar{y}]$ , respectively.

The payoff of an individual of type  $(\alpha, y)$  when the policy  $(p, g)$  is selected is equal to

$$V(g) [\lambda - |\alpha - p|] + y - t(y)$$

where  $V' > 0, V'' < 0, V(0) \geq 0$  and where  $\lambda \geq 1$  is a parameter and  $t(y)$  denotes the tax paid by such a citizen. Therefore, the parameter  $\alpha$  represents the most-preferred type of public good by a citizen with type  $\alpha$ , irrespective of his/her income. Note also that preferences are quasi-linear with respect to income which is implicitly assumed to be equivalent to private consumption.<sup>6</sup> We focus on the case where the tax is an affine function of income – i.e.,

$$t(y) = ay + b,$$

where  $a \in [0, 1]$  and  $b \in [0, \bar{b}]$ . The technology used to produce the public good in quantity  $g$  is assumed to exhibit constant returns to scale irrespective of the type of public good which is selected – i.e., up to a normalization,  $g$  units of numeraire are needed to produce  $g$  units

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<sup>5</sup>This is without loss of generality since we can set  $\bar{y} = +\infty$ , for instance to consider popular income distributions such as the Pareto and Beta distributions.

<sup>6</sup>Most contributions in the nation formation literature consider a quasi-linear setting.

of public good. However, the linear part of the tax system is distortionary. We follow the existing literature (see e.g. Bolton and Roland (1997)) by assuming that there is a small quadratic cost that decreases each individual's tax proceeds by  $\delta \frac{a^2}{2} y$  where  $\delta$  is a positive parameter.<sup>7</sup> The government budget constraint is then given by

$$\begin{aligned} g &= \int_0^1 d\alpha \int_0^{\bar{y}} \left( t(y) - \delta \frac{a^2}{2} y \right) f(\alpha, y) dy \\ &= b + (a - \delta \frac{a^2}{2}) y_M \end{aligned} \tag{1}$$

where

$$y_M \equiv \int_0^1 d\alpha \int_0^{\bar{y}} y f(\alpha, y) dy$$

is the average income in the economy.

Combining all these elements, we deduce that the (indirect) utility of a citizen of type  $(\alpha, y)$  for the policy  $(p, a, b)$  is

$$V(b + (a - \delta \frac{a^2}{2}) y_M) [\lambda - |\alpha - p|] + (1 - a) y - b.$$

We restrict ourselves to two categories of tax functions belonging to the affine family: pure lump sum taxation ( $b > 0, a = 0$ ) and pure proportional taxation ( $b = 0, a > 0$ ).<sup>8</sup> We start with the simpler case, lump sum taxation, which is the one used in the literature (see Etro (2006), ABE, Perroni and Scharf (2001)). We then move to proportional taxation, where additional effects crop up. In both cases, we first assume that individuals vote simultaneously over the type and the size of the public good. We show that the conditions (on the distribution of traits) to have an equilibrium (a Condorcet winning policy pair –i.e., a policy pair that is preferred by a majority of voters to any other feasible policy pair) are very restrictive. We next introduce a sequential way to choose the two policies, assuming that people vote first over the tax policy and then over the type of public good. This sequence of votes seems reasonable and is indeed the one most often studied in the literature.<sup>9</sup> We identify the equilibrium policy pair under this sequence of votes, and we study how it is affected by the bivariate distribution of voters' traits.

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<sup>7</sup>We could have assumed, as in Etro (2006) for instance, that the distortion also affects the lump sum part of the tax function. This would not have affected our qualitative results. The assumption that lump sum taxes do not generate distortions seems more natural to us.

<sup>8</sup>We leave the analysis of the (simultaneous or sequential) determination of the more general 3-parameter ( $a, b$  and  $p$ ) model for future research.

<sup>9</sup>ABE motivate the order of this sequence by arguing that it “resembles common budget procedures in which the size of the budget is decided before its composition.”

### 3 Lump sum taxation

In this section, we consider the case analyzed by ABE, Etro (2006) and Gregorini (2007) where  $t(y) = b$  – i.e., a tax which is the same for all citizens. The (indirect) utility of a citizen of type  $(\alpha, y)$  for the policy  $(p, b)$  is<sup>10</sup>

$$U(p, b) = V(b) [\lambda - |\alpha - p|] + y - b. \quad (2)$$

We see immediately that the individual's income plays no role in determining his preferences for either  $b$  or  $p$ . Obviously, individuals' most-preferred policy position  $p$  corresponds to their own position  $\alpha$ . As for their most-preferred lump sum tax  $b$ , conditional on  $p = \alpha$ , it is given by the following first-order condition

$$\lambda V'(b) = 1,$$

and is thus the same for all individuals. Figure 1 illustrates the preference upper contour sets of four individuals, when  $V(b) = \sqrt{b}$  and  $\lambda = 3/2$ . Comparing the top left panel with the two bottom ones (where individuals differ in income but share the same position  $\alpha$ ) confirms that the upper contour sets are not affected by the individual's income level. Comparing the two top panels allows to see the impact of modifying the individual's position  $\alpha$  on his preferences.

Insert Figure 1 around here

We first study the simultaneous determination of  $p$  and  $b$ .

#### 3.1 Simultaneous vote over both policy dimensions

Our objective in this section is to assess under which circumstances (i.e., distributions of individuals' traits) a Condorcet winning pair  $(p, b)$  exists when voting simultaneously over  $p$  and  $b$ . We proceed as follows. Whenever the (indirect) utility functions of the citizens are strictly quasi-concave, an alternative  $(p, b)$  is a Condorcet winner if and only if there exists a neighborhood centered on  $(p, b)$  which does not contain an alternative defeating  $(p, b)$  –i.e.,  $(p, b)$  is a Condorcet winner if and only if  $(p, b)$  is a local or differential Condorcet winner (Banks and Austen-Smith (1999)). We show in Appendix 1 that a sufficient condition for the

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<sup>10</sup>We assume that individuals have enough income or (unmodelled) wealth to pay any lump sum transfer lower than or equal to  $\bar{b}$ .

indirect preferences to be quasi concave is that  $V$  is concave enough and/or  $\lambda$  is large enough. In this section, we assume that the indirect utility functions are strictly quasi-concave.

We first characterize the set of voters who would favor a policy change in the generic direction  $d$  to some given policy bundle. By looking at a specific direction, we show that any equilibrium policy must entail the provision of the public good with the median most-preferred location. Using this information, we characterize the tax component of the equilibrium policy as well. Finally, by looking at all possible deviations, we show that the conditions that the bivariate distribution of characteristic  $F$  must satisfy for a Condorcet winner to exist are very restrictive, and satisfied mainly by the uniform distribution.

Starting from a generic policy bundle  $(p, b)$ , the individuals who (weakly) favor a deviation in the direction  $d$  are such that

$$\left\langle d, \left( \frac{\partial U(p, b)}{\partial p}, \frac{\partial U(p, b)}{\partial b} \right) \right\rangle \geq 0,$$

where  $\langle \cdot, \cdot \rangle$  denotes the scalar product and where<sup>11</sup>

$$\begin{aligned} \frac{\partial U(p, b)}{\partial b} &= V'(b) [\lambda - |\alpha - p|] - 1, \\ \frac{\partial U(p, b)}{\partial p} &= V(b) \text{ if } \alpha > p, \\ &= -V(b) \text{ if } \alpha < p, \\ &= 0 \text{ if } \alpha = p. \end{aligned}$$

If we denote by  $d_p$  the horizontal component of the vector  $d$ , and by  $d_b$  its vertical component, we obtain that the set of individuals favoring the direction  $d$  (starting from  $(p, b)$ ) is given by<sup>12</sup>

$$\begin{aligned} &\{(\alpha, y) \text{ such that } \alpha > p \text{ and } d_p V(b) + d_b [V'(b) [\lambda - \alpha + p] - 1] \geq 0\} \\ &\cup \{(\alpha, y) \text{ such that } \alpha < p \text{ and } -d_p V(b) + d_b [V'(b) [\lambda - p + \alpha] - 1] \geq 0\}. \end{aligned}$$

If we take a direction such that  $d_p > 0$  and  $d_b = 0$  (i.e., an increase in  $p$  without modification of  $b$ ), we obtain the straightforward result that all individuals with  $\alpha < p$

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<sup>11</sup>Strictly speaking, the function  $U$  is not differentiable with respect to  $p$  when  $p = \alpha$ , but since  $p = \alpha$  corresponds to the peak of the function, we set its derivative equal to zero. Not having to deal explicitly with the non-differentiability at one point allows us to simplify a lot the exposition of the results, without of course affecting them.

<sup>12</sup>The assumption that  $F$  is absolutely continuous with respect to the Lebesgue measure guarantees that the set of individuals with  $\alpha = \alpha_{med}$  has zero measure. To simplify notation and save space, we restrict ourselves to the description of sets with strictly positive measure.

oppose this move while all those with  $\alpha > p$  favor this move. We then obtain that, to be immune to deviations in this direction, the starting pair must be such that  $p = \alpha_{med}$ , with  $\alpha_{med}$  the unique solution of the equation

$$F_\alpha(x) = \frac{1}{2}.$$

In words, any public good location different from the median most-preferred one in the population would be defeated by a proposal moving this location closer to the median.

From now on, we assume that  $p = \alpha_{med}$  as initial location and we focus on the tax component of the policy bundle. If we consider a deviation  $d$  such that  $d_b > 0$ , we obtain that the set of individuals (weakly) favoring this deviation from  $(\alpha_{med}, b)$  is given by

$$\begin{aligned} & \left\{ (\alpha, y) \text{ such that } \alpha > \alpha_{med} \text{ and } \alpha \leq \alpha_{med} + \lambda + \frac{d_p V(b)}{d_b V'(b)} - \frac{1}{V'(b)} \right\} \\ \cup & \left\{ (\alpha, y) \text{ such that } \alpha < \alpha_{med} \text{ and } \alpha \geq \alpha_{med} - \lambda + \frac{d_p V(b)}{d_b V'(b)} + \frac{1}{V'(b)} \right\}. \end{aligned} \quad (3)$$

It is convenient to denote by  $\beta$  the variable  $\lambda - |\alpha - \alpha_{med}|$ . Loosely speaking, this variable measures how much an individual located at  $\alpha$  values a public good of type  $\alpha_{med}$ . Note that  $\beta$  varies in the interval  $[\eta, \lambda]$  where  $\eta \equiv \lambda - \text{Max}(\alpha_{med}, 1 - \alpha_{med})$ . Formally, let  $H$  denote the joint distribution of  $(\beta, y)$  in  $[\eta, \lambda] \times [0, \bar{y}]$  and let  $H_\beta$  and  $H_y$  be the corresponding two marginal distributions. We have

$$H_\beta(x) = F_\alpha(x - \lambda + \alpha_{med}) + [1 - F_\alpha(\lambda + \alpha_{med} - x)]$$

leading to the first marginal density

$$h_\beta(x) = f_\alpha(x - \lambda + \alpha_{med}) + f_\alpha(\lambda + \alpha_{med} - x).$$

We can now express (3) in a more concise way:

$$\begin{aligned} & \left\{ (\alpha, y) \text{ such that } \alpha > \alpha_{med} \text{ and } \beta \geq \frac{1}{V'(b)} - \frac{d_p V(b)}{d_b V'(b)} \right\} \\ \cup & \left\{ (\alpha, y) \text{ such that } \alpha < \alpha_{med} \text{ and } \beta \geq \frac{1}{V'(b)} + \frac{d_p V(b)}{d_b V'(b)} \right\}. \end{aligned}$$

If  $d_p = 0$  and  $d_b > 0$ , we obtain that the individuals who favor the direction  $d$  are characterized by

$$\beta \geq \frac{1}{V'(b)}. \quad (4)$$

It is easy to interpret this inequality. Observe from (2) that the utility of individual  $(\beta, y)$  when  $p = \alpha_{med}$  is

$$U(\alpha_{med}, b) = \beta V(b) + y - b.$$

The first-order condition for  $\beta$  is then given by

$$\beta V'(b) - 1 = 0.$$

Condition (4) then means that all individuals whose most-preferred lump sum tax is larger than  $b$  support a move in any direction  $d$  that increases  $b$  with  $p$  constant ( $d_p = 0, d_b > 0$ ). By contrast, individuals whose most-preferred lump sum tax is strictly lower than  $b$  would support a move in the opposite direction,  $-d$ . For a majority of voters to prefer  $b$  to a move in either direction  $d$  or  $-d$ , we must have

$$\begin{aligned} \beta_{med} V'(b) &= 1 \\ \Leftrightarrow b &= V'^{-1}\left(\frac{1}{\beta_{med}}\right), \end{aligned}$$

where  $\beta_{med}$  is the median value of  $\beta$ :

$$H_\beta(\beta^*) = \frac{1}{2}.$$

We have thus proved the following:

**Proposition 1** *Assume that  $t(y) = b$  and that individuals vote simultaneously over  $p$  and  $b$ . Then, if a Condorcet winning pair  $(p, b)$  exists,  $p = \alpha_{med}$  and  $b$  is the most-preferred lump sum tax of the individuals with the median distance to the median  $\alpha$ .*

It is interesting to note that the most-preferred lump sum tax of the median individual (such that  $\alpha = \alpha_{med}$ , or  $\beta = \lambda$ ) is not part of the Condorcet winning policy pair. Indeed, it is easy to see that voters (other than  $\alpha_{med}$ ) unanimously support a decrease in taxation from the policy  $(\alpha_{med}, V'^{-1}(\frac{1}{\lambda}))$ . The reason for this is intuitive: since  $p = \alpha_{med}$ , the median individual  $\alpha_{med}$  obtains exactly the kind of public good he most prefers. He is then the individual whose marginal valuation of the public good is the largest in the polity. In other words, if this voter has his say on the lump sum tax, everyone would like to decrease this tax because they all value the public good less (at the margin) than him.

We now turn to the conditions under which the policy pair  $(\alpha_{med}, V'^{-1}(\frac{1}{\beta_{med}}))$  is a Condorcet winner. A first necessary condition is that, whatever  $d_p$  and for any  $d_b > 0$ , the set

of people who (weakly) favor a move in the direction  $d$  has a measure at most equal to one half. This set of individuals is given by (3) where we replace  $b$  by  $V'^{-1}(\frac{1}{\beta_{med}})$  to obtain

$$\begin{aligned} & \{(\alpha, y) \text{ such that } \alpha > \alpha_{med} \text{ and } \alpha \leq \phi_1(d_p, d_b)\} \\ & \cup \{(\alpha, y) \text{ such that } \alpha < \alpha_{med} \text{ and } \alpha \geq \phi_2(d_p, d_b)\}, \end{aligned} \quad (5)$$

where

$$\begin{aligned} \phi_1(d_p, d_b) &= \text{Max} \left( \alpha_{med} + (\lambda - \beta_{med}) + \beta_{med} \frac{d_p}{d_b} V(V'^{-1}(\frac{1}{\beta_{med}})), \alpha_{med} \right), \\ \phi_2(d_p, d_b) &= \text{Min} \left( \alpha_{med} - (\lambda - \beta_{med}) + \beta_{med} \frac{d_p}{d_b} V(V'^{-1}(\frac{1}{\beta_{med}})), \alpha_{med} \right). \end{aligned}$$

The first necessary condition is then that the measure of this set equals at most one half:

$$F_\alpha(\phi_1(d_p, d_b)) - F_\alpha(\phi_2(d_p, d_b)) \leq \frac{1}{2}. \quad (6)$$

To shed some light on this condition, we first assume that  $d_p = 0$ . In that case, condition (6) simplifies to

$$F_\alpha(\phi_1(0, d_b)) - F_\alpha(\phi_2(0, d_b)) \leq \frac{1}{2},$$

where

$$\begin{aligned} \phi_1(0, d_b) &= \alpha_{med} + (\lambda - \beta_{med}) > \alpha_{med}, \\ \phi_2(0, d_b) &= \alpha_{med} - (\lambda - \beta_{med}) < \alpha_{med}. \end{aligned}$$

In that case, the set of voters who prefer the direction  $d$  (i.e., an increase in  $b$  without change in the location) is given by an interval of people centered on the individual with the median most-preferred location. Recall that people close to the median location have the highest willingness to pay for this kind of good – it is thus no surprise that an interval of people around that median prefer a higher value of  $b$ . The fact that this interval is exactly centered on  $\alpha_{med}$  crucially depends on the assumption that  $d_p = 0$ : in that case, people equidistant from  $\alpha_{med}$  have exactly the same preference for an increase in  $b$ .

If we rather consider that  $d_p > 0$  (together with  $d_b > 0$ ), the interval of people who prefer an increase in  $b$  moves to the right: distance from  $\alpha_{med}$  is not the only thing that matters anymore, since people to the right of  $\alpha_{med}$  benefit from  $d_p > 0$  while people to the left of  $\alpha_{med}$  dislike this component of  $d$ . As  $d_p$  becomes large compared to  $d_b$ ,  $\phi_2(d_p, d_b)$  becomes larger than  $\alpha_{med}$  and the only people favoring such a move have a larger-than-average value of  $\alpha$ . Similarly, if we consider  $d_p < 0$  (together with  $d_b > 0$ ), the interval of people who

favor direction  $d$  shifts to the left, and as  $d_p/d_b$  becomes sufficiently large (in absolute value),  $\phi_1(d_p, d_b)$  becomes smaller than  $\alpha_{med}$  and only people with lower-than-average values of  $\alpha$  are in favor of direction  $d$ .

When  $d_b < 0$ , the set of people who (weakly) favor a move in the direction  $d$  is given by

$$\begin{aligned} & \{(\alpha, y) \text{ such that } \alpha > \alpha_{med} \text{ and } \alpha \geq \phi_1(d_p, d_b)\} \\ & \cup \{(\alpha, y) \text{ such that } \alpha < \alpha_{med} \text{ and } \alpha \leq \phi_2(d_p, d_b)\}, \end{aligned} \quad (7)$$

which is the complement to set (5). The necessary and sufficient condition for  $(p, b)$  to be a Condorcet winning pair is then that both sets (5) and (7) have a measure at most equal to one half, which translates to

$$F_\alpha(\phi_1(d_p, d_b)) - F_\alpha(\phi_2(d_p, d_b)) = \frac{1}{2}. \quad (8)$$

By definition of  $\beta_{med}$ , condition (8) is satisfied when  $d_p = 0$ . On the other hand, this measure will generically move away from one half as  $d_p$  is increased (for any constant  $d_b$ ), except in very special circumstances. Note that condition (8) can be reformulated as

$$F_\alpha(\alpha_{med} + \widehat{d} + d) - F_\alpha(\alpha_{med} - \widehat{d} + d) = \frac{1}{2} \text{ for all } d \in ]-\widehat{d}, \widehat{d}], \quad (9)$$

where  $F_\alpha(\alpha_{med}) = \frac{1}{2}$  and  $\widehat{d}$  is such that  $F_\alpha(\alpha_{med} + \widehat{d}) - F_\alpha(\alpha_{med} - \widehat{d}) = \frac{1}{2}$ . When  $d = \widehat{d}$ , this implies  $F_\alpha(\alpha_{med} + 2\widehat{d}) - F_\alpha(\alpha_{med}) = \frac{1}{2}$  and therefore  $F_\alpha(\alpha_{med} + 2\widehat{d}) = 1$ . Similarly, when  $d = -\widehat{d}$ , this implies  $F_\alpha(\alpha_{med}) - F_\alpha(\alpha_{med} - 2\widehat{d}) = \frac{1}{2}$  and therefore  $F_\alpha(\alpha_{med} - 2\widehat{d}) = 0$ . Hereafter, the distributions satisfying (9) are called median uniform. We have then proved:

**Proposition 2** *Assume that  $t(y) = b$  and that individuals vote simultaneously over  $p$  and  $b$ . A Condorcet winning pair  $(p, b)$  exists only if the distribution of  $\alpha$  is median uniform.*

The uniform distribution is of course median uniform, but there are other examples. Take for instance any function  $h$  on  $[\frac{1}{4}, \frac{3}{4}]$  such that  $h(t) = h(1-t)$  for all  $t \in [\frac{1}{4}, \frac{1}{2}]$  and  $\int_{\frac{1}{4}}^{\frac{3}{4}} h(t) dt = \frac{1}{4}$ . Let  $f$  be the function defined on  $[0, 1]$  as

$$f(\alpha) = \begin{cases} h(\frac{1}{2} - t) & \text{for all } t \in [0, \frac{1}{4}] \\ h(t) & \text{for all } t \in [\frac{1}{4}, \frac{3}{4}] \\ h(\frac{3}{2} - t) & \text{for all } t \in [\frac{3}{4}, 1] \end{cases}$$

It is straightforward to check that  $f$  is the density of a median uniform distribution.

Despite some flexibility, it should however be clear that median uniformity is not generic – i.e., the condition is violated for some small perturbations of any median uniform distribution. Since a Condorcet winning pair  $(p, b)$  generically does not exist, we consider in the next section a sequential determination of the two policy dimensions.

## 3.2 Sequential vote

In this section, we proceed as in ABE and consider a sequential majority procedure where citizens vote first on the lump sum tax  $b$  and then on the type  $p$ . It is immediate to see from (2) that there is a majority equilibrium in the second stage which is independent of the decision on  $b$  in the first stage. This majority equilibrium corresponds to the median value  $\alpha_{med}$  of  $\alpha$ .

Solving backward, in the first stage the individuals anticipate the value of  $p$  that will be chosen in the second stage and vote according to their utility function (2) where we make use of  $p = \alpha_{med}$  and of the definition of  $\beta$  to obtain

$$U(\alpha_{med}, b) = \beta V(b) + y - b.$$

This utility function is concave in  $b$ , and individual  $\beta$ 's most-preferred value of  $b$  (given that  $\alpha = \alpha_{med}$ ), which we denote by  $b^*(\beta)$ , is the solution to

$$\beta V'(b) - 1 = 0$$

in the case of an interior solution. We have that

$$\begin{aligned} b^*(\beta) &= 0 \text{ if } \beta V'(0) < 1 - \text{i.e., if } \beta \text{ is low enough and} \\ b^*(\beta) &= \bar{b} \text{ if } \beta V'(\bar{b}) > 1 - \text{i.e., if } \beta \text{ is large enough.} \end{aligned}$$

Using the implicit function theorem, we obtain that

$$\frac{\partial b^*(\beta)}{\partial \beta} = -\frac{V'(b)}{\beta V''(b)} = \frac{1}{\beta A(b)} > 0,$$

where  $A(b)$  is the absolute risk aversion coefficient (describing the shape of the utility function). The sensitivity of the most-preferred tax of an individual to his distance to the median type decreases with risk aversion.

Figure 2 illustrates the iso-tax lines in the  $(\beta, y)$  space. They are vertical, since the income dimension does not play any role here.

Insert Figure 2 around here

Applying the usual median voter theorem, we obtain that the result of the vote is  $b = b^*(\beta_{med})$  – i.e., the lump sum tax most-preferred by the individuals located at the *median distance from the median*, which is the rule derived by ABE. Note that, in stark contrast

with the preceding section, a sequential equilibrium always exists, whatever the distribution  $F$ .

We have obtained the following proposition.

**Proposition 3** *Assume that  $t(y) = b$  and that individuals vote sequentially, first over the lump sum tax  $b$  and then over the public good type  $p$ . The unique equilibrium of this voting procedure is given by  $p = \alpha_{med}$  and  $b = b^*(\beta_{med})$  – i.e., the chosen type is the median one, while the lump sum tax is the one most-favored by the individuals with the median distance from the median on the location dimension.*

**Corollary 1** *The Condorcet winning pair  $(p, b)$  obtained with simultaneous voting over  $p$  and  $b$ , if it exists, is identical to the equilibrium of the sequential voting game where  $b$  is chosen first and  $p$  second.*

When the public good is financed with a lump sum transfer, the income heterogeneity among individuals plays absolutely no role. We now turn to the richer case where proportional income taxes are used.

## 4 Proportional income taxation

In the case of a proportional income tax  $t(y) = ay$ , the (indirect) utility of a citizen of type  $(\alpha, y)$  for the policy  $(p, a)$  is

$$W(p, a) = V(g(a)) [\lambda - |\alpha - p|] + (1 - a) y, \quad (10)$$

where  $g(a)$  is given by the government budget constraint (1) when  $b = 0$ . We proceed as in the previous section: we first show that there is in general no Condorcet winner when individuals vote simultaneously over  $p$  and  $a$ . We then study the sequential game where individuals vote first over  $a$  and then over  $p$ . We provide in Appendix 2 the proof that indirect utilities are quasi-concave with proportional income taxation if  $V$  is concave enough and/or  $\lambda$  is large enough. We then assume quasi-concavity of indirect utility preferences in this section.

### 4.1 Simultaneous vote over $p$ and $a$

We start by looking at the optimal policy  $(p^*(\alpha, y), a^*(\alpha, y))$  of a citizen of type  $(\alpha, y)$ . Clearly,  $p^*(\alpha, y) = \alpha$ : whatever the size of the public good, the individual would like its

avored type to be provided. We then obtain that  $a^*(\alpha, y)$  is solution to the following first-order condition

$$V'(g(a))(1 - \delta a) = \frac{y}{\lambda y_M}. \quad (11)$$

It is immediate to see from (11) that the most-preferred tax rate of an individual now depends on his income, in sharp contrast with the lump sum financing case. Figure 3 depicts the preference upper contour sets of four individuals when  $V(b) = \sqrt{b}$  and  $\lambda = 3/2$ . Unsurprisingly, the most-preferred tax rate is decreasing with the individual's income, since taxes owed increase with income.

Insert Figure 3 around here

We proceed as in the previous section, starting from a generic policy bundle  $(p, a)$  and looking for necessary conditions that its components have to satisfy in order for the pair to be a Condorcet winner. Starting from  $(p, a)$ , the individuals who favor a deviation in the direction  $d$  are such that

$$\left\langle d, \left( \frac{\partial W(p, a)}{\partial p}, \frac{\partial W(p, a)}{\partial a} \right) \right\rangle \geq 0,$$

where

$$\begin{aligned} \frac{\partial W(p, a)}{\partial a} &= V'(g(a))(1 - \delta a)y_M [\lambda - |\alpha - p|] - y, \\ \frac{\partial W(p, a)}{\partial p} &= V(g(a)) \text{ if } \alpha > p, \\ &= -V(g(a)) \text{ if } \alpha < p, \\ &= 0 \text{ if } \alpha = p. \end{aligned}$$

We denote as previously by  $d_p$  the horizontal component of the vector  $d$ , and by  $d_a$  its vertical component. The set of individuals favoring the direction  $d$  (starting from  $(p, a)$ ) is given by

$$\begin{aligned} &\{(\alpha, y) \text{ such that } \alpha > p \text{ and } d_p V(b) + d_a [V'(g(a))(1 - \delta a)y_M [\lambda - \alpha + p] - y] \geq 0\} \\ &\cup \{(\alpha, y) \text{ such that } \alpha < p \text{ and } -d_p V(b) + d_a [V'(g(a))(1 - \delta a)y_M [\lambda - p + \alpha] - y] \geq 0\}. \end{aligned}$$

We use the same argument as in the preceding section to show that a Condorcet winning policy pair must involve  $p = \alpha_{med}$ : if it were not the case, a majority of voters would like to deviate in the direction of the median  $\alpha$  while keeping the tax rate  $a$  constant.

From now on, we assume that  $p = \alpha_{med}$  and focus on the tax component of the policy bundle. If we consider a deviation  $d$  such that  $d_a > 0$ , we obtain that the set of individuals favoring this deviation from  $(\alpha_{med}, a)$  is given by

$$\left\{ (\alpha, y) \text{ such that } \alpha > \alpha_{med} \text{ and } y \leq \beta V'(g(a))(1 - \delta a)y_M + \frac{d_p}{d_a}V(g(a)) \right\} \quad (12)$$

$$\cup \left\{ (\alpha, y) \text{ such that } \alpha < \alpha_{med} \text{ and } y \leq \beta V'(g(a))(1 - \delta a)y_M - \frac{d_p}{d_a}V(g(a)) \right\}.$$

If  $d_p = 0$ , we obtain that all individuals who (weakly) favor the direction  $d$  (an increase in  $b$  while keeping  $p$  constant) are such that

$$y \leq \beta V'(g(a))(1 - \delta a)y_M. \quad (13)$$

Observe that the first-order condition for an individual  $(\beta, y)$  faced with  $p = \alpha_{med}$  is given by

$$y = \beta V'(g(a))(1 - \delta a)y_M. \quad (14)$$

To illustrate the joint effect of  $y$  and  $\beta$  on the optimal choice, we denote by  $\tilde{y}(\beta, a)$  the income level that satisfies (14) –i.e., the income of an individual of type  $\beta$  who most prefers a proportional tax rate of  $a$  when faced with  $p = \alpha_{med}$ . Condition (13) shows that all individuals who have an income lower than  $\tilde{y}$  are in favor of an increase in  $a$  (i.e.,  $d_a > 0$ ). Figure 4 (a) illustrates condition (13) in the  $(\alpha, y)$  space. Assume that we start with the value of  $a$  that is most-preferred by the individual with the median income and the median location, so that  $\tilde{y}(\lambda, a) = y_{med}$ . Among individuals located at  $\alpha_{med}$ , those who favor an increase in  $a$  are those whose income is lower than the median income in the population. Individuals located further from  $\alpha_{med}$  on the horizontal axis have a lower marginal valuation of the public good. As the benefit from this good decreases with the distance between individual location  $\alpha$  and median location, so does the threshold value of income below which voters favor an increase in the tax rate. To satisfy the optimal behavior described by (14),  $\beta$  and  $y$  must be comonotonic (in other words, they must change in the same direction).

Insert Figure 4 around here

One immediately infers from this figure that the policy bundle composed of  $\alpha_{med}$  and of the most-preferred tax rate of the individual with both the median location and the median income is always defeated by a majority of voters who prefer a lower tax rate (and the

same location). The intuition is similar to the one exposed in the lump sum case, and is based upon the observation that individuals with the median location are those who have the largest direct benefits from the public good. Consequently, a move to decrease the tax rate from their most-preferred level is favored not only by all individuals with above-median income, but also by poorer-than-median individuals who are located far enough from the median location. This holds true whatever the distribution function  $F$  or  $H$ .

Let us denote by  $(\alpha_{med}, a^\circ)$  the policy pair that is such that exactly one half of the polity is in favor of an increase in the tax rate when the location of the public good is kept unchanged. It is clear from above that this policy is the most-preferred one of an individual with median location and with a larger-than-median income:  $\tilde{y}(\lambda, a^\circ) > y_{med}$ . For instance, in the case where the distributions of locations and of income are both uniform (and independent), the tax rate  $a^\circ$  is given by

$$\int_{\eta}^{\lambda} \beta V'(g(a^\circ)) \frac{(1 - \delta a^\circ)}{\lambda - \eta} y_M d\beta = 1/2.$$

Making use of the first-order condition of the individual  $\tilde{y}(\lambda, a^\circ)$ , we obtain that

$$\tilde{y}(\lambda, a^\circ) = \frac{\lambda}{\lambda + \eta} = \frac{\lambda}{2\lambda - \frac{1}{2}},$$

i.e. that  $\tilde{y}(\lambda, a^\circ) > y_{med}$  as explained above.

It is interesting to note that, in the case of the uniform and independent distributions of  $\beta$  and  $y$ , the tax rate  $a^\circ$  is also the most-preferred tax of an individual with the average income  $y_M$  and with the median distance to the median location,  $\beta_{med}$ :  $\tilde{y}(\beta_{med}, a^\circ) = y_M$ . To prove this, it is enough to observe that the first-order condition for an individual with  $\beta = \lambda$  and  $y = \tilde{y}(\lambda, a^\circ)$ ,

$$\lambda V'(g(a))(1 - \delta a) y_M = \frac{\lambda}{2\lambda - \frac{1}{2}},$$

is the same as the first-order condition for individual with  $\beta = \beta_{med}$  and  $y = y_M$

$$\left(\lambda - \frac{1}{4}\right) V'(g(a))(1 - \delta a) y_M = y_M.$$

We summarize our results so far in the next Proposition.

**Proposition 4** *Assume that  $t(y) = ay$  and that individuals vote simultaneously over  $p$  and  $a$ . Then, if a Condorcet winning pair  $(p, a)$  exists, it is such that  $p = \alpha_{med}$  and that  $a$  is the most-preferred proportional tax of individuals with median location and with a larger-than-median income. In the special case of uniform and independent distributions of  $\alpha$  and  $y$ , this policy  $a$  is also the one most-preferred by an individual with the average income  $y_M$  and the median distance to the median location,  $\beta_{med}$ .*

We now look at the set of people who prefer an increase in taxation coupled with an increase in the location of the public good (i.e., a move  $d_p > 0$  and  $d_a > 0$ ), starting from  $(\alpha_{med}, a)$ . This set is defined in (12) and is represented on Figure 4 (b). The threshold income below which individuals favor a move in the direction  $d$  remains decreasing in the distance between individual's location and policy location, as in Figure 4 (a), but we now observe a discontinuity for  $\alpha = \alpha_{med} = p$ . To the left of  $\alpha_{med}$ , individuals do not favor an increase in  $p$  as it moves the location of the public good further away from their bliss point, while to the right of  $\alpha_{med}$  individuals do favor such a move. The size of the discontinuity increases with  $d_p$ , the horizontal component of the move considered (for a given  $d_a$ ). More precisely, as  $d_p$  increases the threshold income level decreases by  $V(g(a))/d_a$  to the left of  $\alpha_{med}$  and increases by the same amount  $V(g(a))/d_a$  to the right of  $\alpha_{med}$ .

The conclusion we draw from Figure 4 is that the existence of a Condorcet winning policy pair when voting simultaneously over the two dimensions is extremely unlikely. Even if we start from a policy pair  $(\alpha_{med}, a^\circ)$  such that exactly one half of the polity would like to increase the tax rate while keeping the location constant, when we consider directions where both dimensions are modified simultaneously, Figure 4 (b) shows that the bivariate distribution of  $\alpha$  and  $y$  must exhibit a lot of symmetry for the policy pair to remain immune to these deviations. Moreover, even in the case of the uniform independent distributions, there is no Condorcet winner. This can be seen from the fact that the income distribution is bounded above and that  $\tilde{y}(\lambda, a^\circ) > y_M$ . This last observation means that, if  $d_p$  is large enough, then the threshold income of an individual who is located immediately to the right of  $\alpha_{med}$  reaches the upper bound of the distribution. As is shown on Figure 4 (c), we obtain in that case that a majority of voters favor a decrease in  $p$  coupled with a decrease in the tax rate. We then obtain

**Proposition 5** *Assume that  $t(y) = ay$  and that individuals vote simultaneously over  $p$  and  $a$ . There is no Condorcet winning pair  $(p, a)$ , even in the case of uniform and independent distributions of  $\alpha$  and  $y$ .*

We now turn to the sequential determination of both policy dimensions.

## 4.2 Sequential vote

In what follows, we consider a sequential majority procedure where citizens vote first on the tax rate  $a$  and then on the type  $p$ . We see immediately from (10) that there is a majority equilibrium in the second stage which is independent of the decision on  $a$  in the first stage.

This majority equilibrium, which we denote by  $p_2$ , corresponds to the median value of  $\alpha$ :

$$p_2 = \alpha_{med}.$$

Solving backward, citizens are aware that their choice of  $a$  has no influence at all on the result of the second stage vote. Their most-preferred value of  $a$ , denoted by  $\tilde{a}(\beta, y)$ , is then obtained as a solution to the following first-order condition

$$V'(g(a)) (1 - \delta a) = \frac{y}{\beta y_M}. \quad (15)$$

This first-order condition is sufficient since the second derivative of the indirect utility function

$$V''(g(a)) (1 - \delta a)^2 - \delta V'(g(a))$$

is negative. If

$$\beta V'(0) y_M - y \leq 0, \text{ then } \tilde{a}(\beta, y) = 0$$

and if

$$\beta V'\left(\left(1 - \frac{\delta}{2}\right)y_M\right) (1 - \delta) y_M - y \geq 0, \text{ then } \tilde{a}(\beta, y) = 1.$$

From the implicit function theorem and the second order conditions, we deduce immediately that, if  $\tilde{a}(\beta, y)$  is an interior solution, then

$$\frac{\partial \tilde{a}(\beta, y)}{\partial \beta} = -\frac{V'(g(a)) (1 - \delta a) y_M}{\beta V''(g(a)) (1 - \delta a)^2 - \beta \delta V'(g(a))} > 0, \quad (16)$$

and

$$\frac{\partial \tilde{a}(\beta, y)}{\partial y} = \frac{1}{\beta V''(g(a)) (1 - \delta a)^2 - \beta \delta V'(g(a))} < 0. \quad (17)$$

Not surprisingly, citizens endowed with a large income or distant from the median type of public good have a low most-preferred proportional tax rate. It is easy to see from (16) that the sensitivity of the most-preferred tax rate to the distance from the median type is inversely related to the absolute coefficient of risk aversion. Risk aversion mitigates the effect of the individuals' characteristics on their tax choices.

Figure 5 depicts the iso-tax curves in the type space  $[\eta, \lambda] \times [0, \bar{y}]$  –i.e., the locus of types  $(\beta, y)$  whose most-preferred tax policy is  $a$ .

Insert Figure 5 around here

From (16) and (17), we deduce that the slope  $dy/d\beta$  of an iso-tax curve corresponding to  $a = \tilde{a}(\beta, y)$  is equal to

$$V'(g(a))(1 - \delta a)y_M,$$

which does not depend on  $\beta$  nor on  $y$  – i.e., the iso-tax curves are affine functions. In order to find the equilibrium tax rate emerging from the first stage vote, we have to find the median iso-tax line – i.e. the iso-tax line that separates the set of types into two halves, with one half located above the line (and favoring a smaller tax rate) and the other half located below (and supporting a lower tax rate).<sup>13</sup> Formally, the equilibrium first stage tax rate, which we denote by  $a_1$ , is the solution to

$$\Psi(a) = \int_{\eta}^{\lambda} d\beta \int_0^{\beta\varphi(a)} h(\beta, y)dy = \frac{1}{2}, \quad (18)$$

where

$$\varphi(a) \equiv y_M V'(g(a))(1 - \delta a).$$

**Proposition 6** *Assume that  $t(y) = ay$  and that individuals vote first over  $a$  and then over  $p$ . The equilibrium policy pair is composed of the median policy location  $\alpha_{med}$  together with the proportional rate  $a_1$  as defined in equation (18).*

In the next section, we compare the sequential equilibrium  $(p_2, a_1)$  with a natural benchmark, and we assess the role played by the bivariate distribution of voters' types.

## 5 Comparison with benchmark

The equilibrium policy pair when individuals vote first over the proportional tax rate and then over the type of public good results in the median policy location to be proposed, together with a proportional tax rate  $a_1$ . This proportional tax rate is given by formula (18), which is not very transparent. In this section, we would like to investigate the determinants of this formula, and particularly how it is affected by the properties of the bivariate distribution function  $H(\beta, y)$ . In order to do this, we first define a natural benchmark for the proportional tax rate. This benchmark, which we denote by  $a_{med}$ , is defined as the most-preferred tax rate of citizens with a median income  $y_{med}$  and a median distance to the median,  $\beta_{med}$ . It is the solution to the equation

$$V'(g(a))(1 - \delta a) = \frac{y_{med}}{\beta_{med}y_M}$$

---

<sup>13</sup>Given the continuity of  $F$  with respect to the Lebesgue measure, the set of individuals located exactly on the median iso-line has zero measure.

where  $\beta_{med}$  and  $y_{med}$  are defined as

$$H_\beta(\beta_{med}) = \frac{1}{2} \text{ and } H_y(y_{med}) = \frac{1}{2}.$$

This benchmark is attractive because it corresponds to the equilibrium obtained in ABE.<sup>14</sup> It also corresponds to the equilibrium obtained with a sequential vote over a lump sum tax first and then over the type of public good (see Proposition 3).

We first study the circumstances under which  $a_1$  and  $a_{med}$  differ when the distributions of income and of location are independent from each other. We then lift this assumption in order to try and understand the role played by the correlation between types.

## 5.1 Independent distributions

The simplest case we examine (which is also the one most of the literature has focused on, such as in Etro (2006), Gregorini (2007) and Perroni and Scharf (2001)) assumes that the bivariate distribution  $H$  is uniform (this is of course a -very- special case of independent distributions  $H_\beta$  and  $H_y$ ). Formula (18) then simplifies to

$$\Psi(a_1) = \frac{1}{\bar{y}(\lambda - \eta)} \varphi(a_1) \int_\eta^\lambda \beta d\beta = \frac{\lambda + \eta}{2\bar{y}} \varphi(a_1) = \frac{1}{2},$$

which implies that

$$\varphi(a_1) = \frac{\bar{y}}{(\lambda + \eta)},$$

i.e.,

$$V'(g(a_1))(1 - \delta a_1) = \frac{\bar{y}}{y_M(\lambda + \eta)}.$$

By contrast, the most-preferred tax rate of an individual of type  $(\frac{\lambda + \eta}{2}, y_{med})$  when  $p = \alpha_{med}$  is solution to the equation

$$V'(g(a_{med}))(1 - \delta a_{med}) = \frac{y_{med}}{\beta_{med} y_M}. \quad (19)$$

It is straightforward to see that  $a_{med} = a_1$  since  $y_{med} = \bar{y}/2$  and  $\beta_{med} = (\lambda + \eta)/2$ .

**Proposition 7** *Assume that  $t(y) = ay$  and that individuals vote first over  $p$  and then over  $a$ . If the bivariate distribution of types is uniform, then the equilibrium proportional tax rate is the tax rate most-preferred by the individual with the median income and the median distance to the median when faced with  $p = \alpha_{med}$ .*

<sup>14</sup>In ABE, voters' income plays no role as the public good is financed with a lump sum transfer. In our extension to proportional taxation, income does play a role so we choose the natural benchmark of the median income voter.

We then turn to the more general case where the two types are independent but not both uniformly distributed:

**Assumption 1:**  $h(\beta, y) = h_\beta(\beta)h_y(y)$

Under Assumption 1,  $a_{med}$  is solution to the equation

$$\int_{\eta}^{\lambda} h_\beta(\beta)H_y(\beta\varphi(a_1))d\beta = \frac{1}{2}. \quad (20)$$

First note that, if instead of being continuous, as assumed here,  $H_\beta$  was concentrated<sup>15</sup> on a unique value  $\beta$ , then the above equation would simplify to

$$\begin{aligned} H_\beta(\beta\varphi(a_1)) &= \frac{1}{2} \\ \Leftrightarrow \varphi(a_1) &= \frac{y_{med}}{\beta}, \end{aligned}$$

from which, together with (18) and the definition of  $\varphi(a)$ , we conclude that  $a_1 = a_{med}$ .

Rather than assuming a concentrated distribution  $H_\beta$ , we make the following assumption:

**Assumption 2:**  $H_\beta(\beta)$  is the uniform distribution over  $[\eta, \lambda]$ .

In that case,<sup>16</sup>  $a_1$  solves

$$\int_{\eta}^{\lambda} H_y(\beta\varphi(a))d\beta = \frac{\lambda - \eta}{2} \quad (21)$$

while  $a_{med}$  is such that

$$H_y\left(\frac{\lambda + \eta}{2}\varphi(a_{med})\right) = \frac{1}{2}.$$

The two tax rates do not coincide in general. It is of interest to identify the properties of  $H_y$  which would lead to  $a_1$  being smaller than, equal to, or larger than the benchmark  $a_{med}$ .

We have that, if  $H_y$  is concave (respectively, convex), then

$$\int_{\eta}^{\lambda} H_y(\beta\varphi(a))d\beta \leq (\text{respectively, } \geq) H_y\left(\frac{\lambda + \eta}{2}\varphi(a)\right).$$

Since

$$\varphi'(a) \equiv y_M^2 V''(g(a)) (1 - \delta a)^2 - \delta y_M V'(g(a)) < 0,$$

and  $H_y$  is increasing, we deduce from above that

**Proposition 8** *Assume that Assumptions 1 and 2 hold. Then, (a) If  $H_y$  is concave then  $H_y\left(\frac{\lambda + \eta}{2}\varphi(a_1)\right) \geq \frac{1}{2}$  and therefore  $a_{med} \geq a_1$ ; (b) If  $H_y$  is convex then  $H_y\left(\frac{\lambda + \eta}{2}\varphi(a_1)\right) \leq \frac{1}{2}$  and therefore  $a_{med} \leq a_1$ ; (c) If  $H_y$  is linear (i.e., the income distribution is uniform), then  $a_{med} = a_1$ .*

<sup>15</sup>A so-called Dirac mass.

<sup>16</sup>which results from the uniformity of the distribution  $F_\alpha$  of  $\alpha$ .

The case where  $H_y$  has concave and convex sections is also important as reflected by the standard assumption of single-peaked density. We now make the following assumption.

**Assumption 3:**  $h_y$  is symmetrical around  $y_M = \bar{y}/2$ .

In that case,  $a_{med}$  is given by

$$\frac{\lambda + \eta}{2} \varphi(a_{med}) = \frac{\bar{y}}{2} = y_M.$$

Replacing  $a$  by  $a_{med}$  in (21), and using the symmetry of  $H_y$ , we obtain

$$\begin{aligned} \int_{\eta}^{\lambda} H_y\left(\frac{\beta}{\beta_M} y_M\right) d\beta &= \int_{\eta}^{\frac{\lambda+\eta}{2}} H_y\left(\frac{\beta}{\beta_M} y_M\right) d\beta + \int_{\eta}^{\frac{\lambda+\eta}{2}} \left[1 - H_y\left(\frac{\beta}{\beta_M} y_M\right)\right] d\beta \\ &= \int_{\eta}^{\frac{\lambda+\eta}{2}} d\beta = \frac{\lambda - \eta}{2}, \end{aligned}$$

i.e., we have proved

**Proposition 9** *Assume that Assumptions 1-3 hold. Then, the equilibrium proportional tax rate is the tax rate most-preferred by the individual with the median income and the median distance to the median (when faced with  $p = \alpha_{med}$ ) :  $a_{med} = a_1$ .*

Observe that Proposition 7 is a special case of Proposition 9. Propositions 8 and 9 have not exhausted the set of possible (and interesting) distributions of income. We now provide numerical illustrations of the difference between  $a_1$  and  $a_{med}$  when  $H_\beta$  is uniform while  $H_y$  is a Beta distribution. Figure 6 (a) shows  $a_{med}$  and  $a_1$  as functions of the skewness of the income distribution for the family of Beta distributions with linear frequencies (i.e., when either the first or the second parameter of the distribution is equal to 1). A skewness of zero corresponds to the uniform distribution (Beta(1,1)), for which, according to Proposition 8,  $a_{med} = a_1$ . We see from Figure 6 (a) that, when the skewness is negative, we have that  $a_1 > a_{med}$  while the opposite relationship occurs with a positive skewness. This result is indeed a special case of Proposition 8, since a negatively skewed linear  $h_y$  generates a convex  $H_y$ , while a positively skewed linear  $h_y$  generates a concave  $H_y$ . From the figure, we also obtain that the gap between  $a_{med}$  and  $a_1$  is increasing in skewness, even though  $a_1$  is not monotone in skewness (it first decreases, then increases in skewness).

Insert Figure 6 around here

Figure 6 (b) performs the same exercise for another family of Beta income distribution functions, namely those with single-peaked and non-linear frequencies.<sup>17</sup> We obtain the same qualitative results as in panel (a):  $a_1 > a_{med}$  when skewness is negative,  $a_1 < a_{med}$  when skewness is positive, and the gap between  $a_{med}$  and  $a_1$  is monotone increasing in skewness. Observe that the fact that  $a_1 = a_{med}$  when the skewness is nil is an illustration of Proposition 9, since the Beta distribution studied is symmetrical around one half.

We know that empirical distributions of income are positively skewed. Figure 6 (b) then suggests that generalizing indiscriminately the “median distance to the median” result of ABE to the real world leads to an over-estimation of the equilibrium proportional tax rate.

In the next section, we go beyond Assumption 1 and study the impact of the correlation between income and location.

## 5.2 Correlation between income and location

When the two marginal distributions are correlated, the picture becomes more complex. To assess the intrinsic role of independence, it is useful to introduce a measure of departure from independence. From Sklar’s theorem (Sklar (1959)), there exists a joint distribution  $C$  on  $[0, 1]^2$ , called a *copula*, such that its two marginals are uniform on  $[0, 1]$  and

$$H(\beta, y) = C(H_\beta(\beta), H_y(y)).$$

As an illustration, we now assume that both  $H_\beta$  and  $H_y$  are uniformly distributed, and that the distribution  $H$  is obtained using the Archimedean copula

$$H(\beta, y) = \Phi^{-1}(\Phi(H_\beta(\beta)) + \Phi(H_y(y))),$$

where  $\Phi$  is called the generator function. We provide an example with the so-called Gumbel copula, where the generator function is given by

$$\Phi(x) = (\ln(x))^{-c}.$$

Increasing  $c$  results in an increase in the correlation between  $\beta$  and  $y$ : the correlation is equal to zero (independence) when  $c = 0$ , and increases to one as  $c$  becomes large enough. Figure 7 shows both  $a_{med}$  and  $a_1$  as functions of the correlation between  $\beta$  and  $y$  when the Gumbel copula is used and  $H_\beta$  and  $H_y$  are uniform. We already know from Proposition 8

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<sup>17</sup>More precisely, we study Beta( $c, d$ ) distributions where one parameter is equal to 2. Negatively skewed distributions correspond to  $c > 2$  and  $d = 2$  while positive skewness corresponds to  $c = 2$  and  $d > 2$ . The case with zero skewness corresponds to Beta(2,2).

that  $a_{med} = a_1$  when the distributions  $H_\beta$  and  $H_y$  are uniform and independent. Figure 7 shows that  $a_{med} = a_1$  also when the correlation between income and position is perfect; a simple look at Figure 5 should convince the reader that this is so, since the median iso-tax line remains the same in both the cases of perfect correlation and of independence. We further learn from Figure 7 that  $a_{med} > a_1$  when the correlation is strictly in between zero and one. This means that generalizing without discrimination the “median distance to the median” result from ABE to a setting like the one depicted in Figure 7 leads to over-estimate the equilibrium proportional tax rate.

Insert Figure 7 around here

## 6 Conclusion

In this paper, we lay the first building blocks of a positive theory of nation formation where national choices consist of the size and location of a public good. Individuals differ both in income and in their preferences for the public good location, so that the polity is summarized by a bivariate distribution of these two traits. Public expenditures are financed by affine income taxation: we consider both the case of a lump sum tax and of a proportional income tax. We study both the simultaneous and the sequential determinations of the public good size and location. We show that, while the choice of the type of public good follows the traditional median logic, the majoritarian determination of the taxation rate is more subtle and need not coincide with the choice of a median income citizen. With lump sum financing, income heterogeneity plays no role and the sequential equilibrium consists of the median location together with the public good level most-preferred by the individual located at the median distance to the median (as in ABE). This policy bundle also constitutes an equilibrium with simultaneous voting in the special case of a median uniform bivariate distribution. With proportional taxation, there is no policy equilibrium with simultaneous voting even if the bivariate distribution is uniform. We offer a complete characterization of the equations describing the sequential equilibrium in the general case (no assumption on the bivariate distribution of traits). We show why and how our results depart from those obtained by ABE, where the public good level chosen is the one most-preferred by the individual with the median distance to the median and the median income. We obtain a lower public good level than this benchmark when the income distribution is concave, such as with positively

skewed Beta distributions, and when the correlation between income and location is positive but not perfect.

This paper is a first step towards a more general and integrated analysis of the sequential majoritarian decision process when the policy set is multidimensional. Further research would shed additional light on the robustness of the conclusions established in the present paper. First, we would like to know to which extent these results remain valid for a broader class of settings and of utility functions. The specific utility functions used in this paper are common in the nation formation literature which has motivated us, but we conjecture that some features of the equilibrium outcome can be extended to more general formulations. A second promising direction of research would consist in comparing the equilibrium reached under sequential voting with another popular solution due to Kramer (1972) and Shepsle (1979), in which separate committees vote on the various issues at hand. De Donder, Le Breton and Peluso (2009) contain some preliminary answers to these two questions. A third direction of research would consist in integrating the majority voting approach described in this paper to a more general game of nation formation.

## 7 Appendix

In the two following subsections, we investigate the conditions under which the indirect utility functions of the citizens in the lump sum case and in the proportional case are strictly quasi-concave. The developments are based on a straightforward application of the classical differential test of strict quasi-concavity as exposed for instance in Green, Mas-Colell and Whinston (1995)).

### 7.1 Appendix 1

In this first appendix, we demonstrate that, under some appropriate conditions, the (indirect) utility  $U$  of a citizen of type  $(\alpha, y)$  in the case of lump sum taxation

$$U(p, b) = V(b) [\lambda - |\alpha - p|] + y - b$$

is strictly quasi-concave. Without loss of generality, consider the case where  $\alpha > p$ . The bordered Hessian matrix  $D^2U(p, b)$  attached to  $U$  is here

$$\begin{pmatrix} V''(b)(\lambda - \alpha + p) & V'(b) & V'(b)(\lambda - \alpha + p) - 1 \\ V'(b) & 0 & V(b) \\ V'(b)(\lambda - \alpha + p) - 1 & V(b) & 0 \end{pmatrix}$$

The utility function is strictly quasi-concave if and only if the determinant of this matrix is positive –i.e., if

$$2(V'(b)(\lambda - \alpha + p) - 1)V(b)V''(b) - (V(b))^2 V''(b)(\lambda - \alpha + p) > 0,$$

which is equivalent to the inequality

$$2(V'(b))^2 - V(b)V''(b) > \frac{2V'(b)}{\lambda - \alpha + p}.$$

The right hand side is decreasing in  $p$ . Therefore, it is enough to check this inequality for  $p = 0$  – i.e.,

$$\frac{2(V'(b))^2 - V(b)V''(b)}{2V'(b)} > \frac{1}{\lambda - \alpha}.$$

The relevant (i.e., Pareto) range of values of  $b$  is the interval  $[V'^{-1}(\frac{1}{\lambda-1}), V'^{-1}(\frac{1}{\lambda})]$ . The above inequality is tighter to satisfy when  $\alpha = 1$  and  $V'(b)$  is small. Therefore, it will hold true for all  $b \in [V'^{-1}(\frac{1}{\lambda-1}), V'^{-1}(\frac{1}{\lambda})]$  and all  $\alpha \in [0, 1]$  if

$$\frac{1}{\lambda} - \frac{V(b)V''(b)}{2V'(b)} > \frac{1}{\lambda - 1},$$

i.e. if

$$-\frac{V(b)V''(b)}{2V'(b)} > \frac{1}{\lambda(\lambda - 1)},$$

which holds true when  $V$  is concave enough or/and  $\lambda$  is large enough. For the sake of illustration, consider the isoelastic case<sup>18</sup>  $V(b) = b^\delta$  with  $\delta \in ]0, 1[$ . The above condition simplifies to

$$\frac{(1 - \delta)}{2} b^{\delta-1} > \frac{1}{\lambda(\lambda - 1)}.$$

Since  $b^{\delta-1} \geq \frac{1}{\lambda^\delta}$ , the inequality will hold true if

$$\frac{(1 - \delta)}{2\delta} > \frac{1}{\lambda - 1},$$

or equivalently if

$$\delta < \frac{\lambda - 1}{\lambda + 1}.$$

---

<sup>18</sup>In the isoelastic case, the sufficient condition can be improved to the condition  $\frac{(1+\delta)}{2\delta} > \frac{\lambda}{\lambda-1}$  or even to the condition  $\frac{(1+\delta)}{2\delta} > \frac{\lambda}{\lambda-\alpha}$  if we don't look for a condition uniform with respect to  $\alpha$ .

## 7.2 Appendix 2

In this second appendix, we prove that under appropriate conditions, the (indirect) utility  $W$  of a citizen of type  $(\alpha, y)$  in the case of proportional taxation,<sup>19</sup>

$$W(p, a) = V(ay_M) [\lambda - |\alpha - p|] + (1 - a)y,$$

is strictly quasi-concave. Without loss of generality, we consider the case where  $\alpha > p$ . The bordered Hessian matrix  $D^2W(p, a)$  attached to  $W$  is here

$$\begin{pmatrix} V''(ay_M)(y_M)^2(\lambda - \alpha + p) & V'(ay_M)y_M & V'(ay_M)y_M(\lambda - \alpha + p) - y \\ V'(ay_M)y_M & 0 & V(ay_M) \\ V'(ay_M)y_M(\lambda - \alpha + p) - y & V(ay_M) & 0 \end{pmatrix}$$

The utility function is strictly quasi-concave if and only if the determinant of this matrix is positive –i.e., if

$$2(V'(ay_M)y_M(\lambda - \alpha + p) - y)V(ay_M)V'(ay_M)y_M - (V(ay_M))^2V''(ay_M)(y_M)^2(\lambda - \alpha + p) > 0,$$

which is equivalent to

$$2(V'(ay_M)y_M(\lambda - \alpha + p) - y)V'(ay_M) - V(ay_M)V''(ay_M)y_M(\lambda - \alpha + p) > 0,$$

and, after some rearrangements, to

$$y_M \left[ 2(V'(ay_M))^2 - V(ay_M)V''(ay_M) \right] > \frac{2V'(ay_M)y}{\lambda - \alpha + p}.$$

As in Appendix 1, the right hand side is decreasing in  $p$ . Therefore, it is enough to check this inequality for  $p = 0$  –i.e. that

$$\frac{y_M}{y} \frac{2(V'(ay_M))^2 - V(ay_M)V''(ay_M)}{2V'(ay_M)} > \frac{1}{\lambda - \alpha},$$

or equivalently that

$$\frac{y_M}{y} V'(ay_M) - \frac{y_M}{y} \frac{V(ay_M)V''(ay_M)}{2V'(ay_M)} > \frac{1}{\lambda - \alpha}.$$

The relevant range of values of  $ay_M$  is the interval  $\left[ V'^{-1}\left(\frac{\bar{y}}{(\lambda-1)y_M}\right), V'^{-1}\left(\frac{\bar{y}}{\lambda y_M}\right) \right]$ . The above inequality is tighter to satisfy when  $\alpha = 1$  and  $V'(ay_M)$  is small. Therefore, it will hold true for all  $ay_M \in \left[ V'^{-1}\left(\frac{\bar{y}}{(\lambda-1)y_M}\right), V'^{-1}\left(\frac{\bar{y}}{\lambda y_M}\right) \right]$  and all  $\alpha \in [0, 1]$  if

$$-\frac{y_M}{y} \frac{V(ay_M)V''(ay_M)}{2V'(ay_M)} > \frac{1}{\lambda(\lambda - 1)},$$

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<sup>19</sup>We assume that  $\delta = 0$  in order to simplify the already complex calculations, but this assumption is without loss of generality.

which, as in the lump sum case, holds true when  $V$  is concave enough or/and  $\lambda$  is large enough. In the isoelastic case  $V(ay_M) = (ay_M)^\delta$  with  $\delta \in ]0, 1[$ , and since  $(ay_M)^{\delta-1}y_M \geq \frac{y}{y_M} \frac{1}{\lambda\delta}$ , the inequality will hold true if

$$\frac{(1-\delta)}{2\delta} > \frac{1}{\lambda-1},$$

as in appendix 1.

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Figure 1 : Preference contour sets in (p, b) space with lump sum taxation

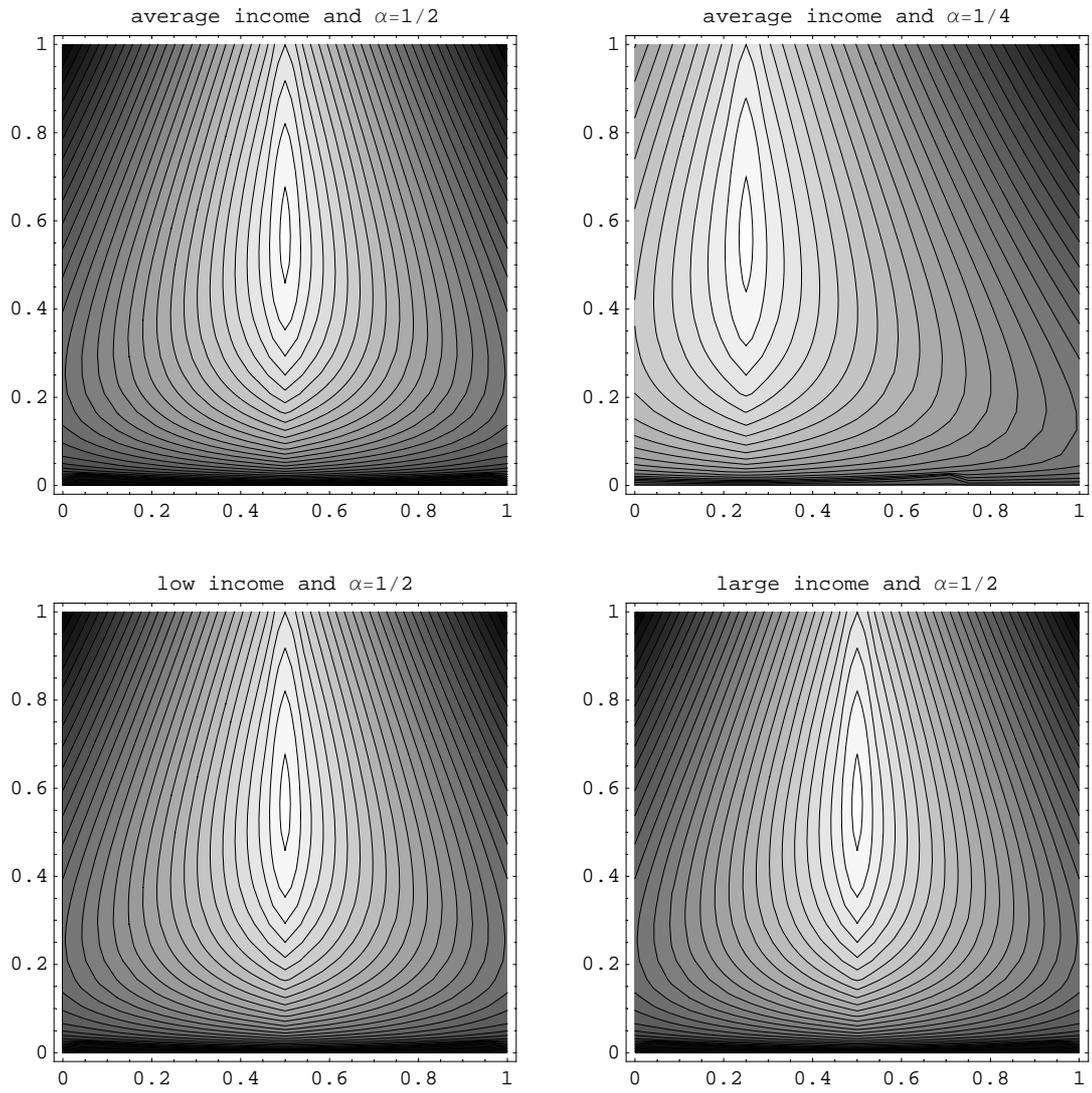


Figure 2: Iso-tax curves with lump-sum taxation

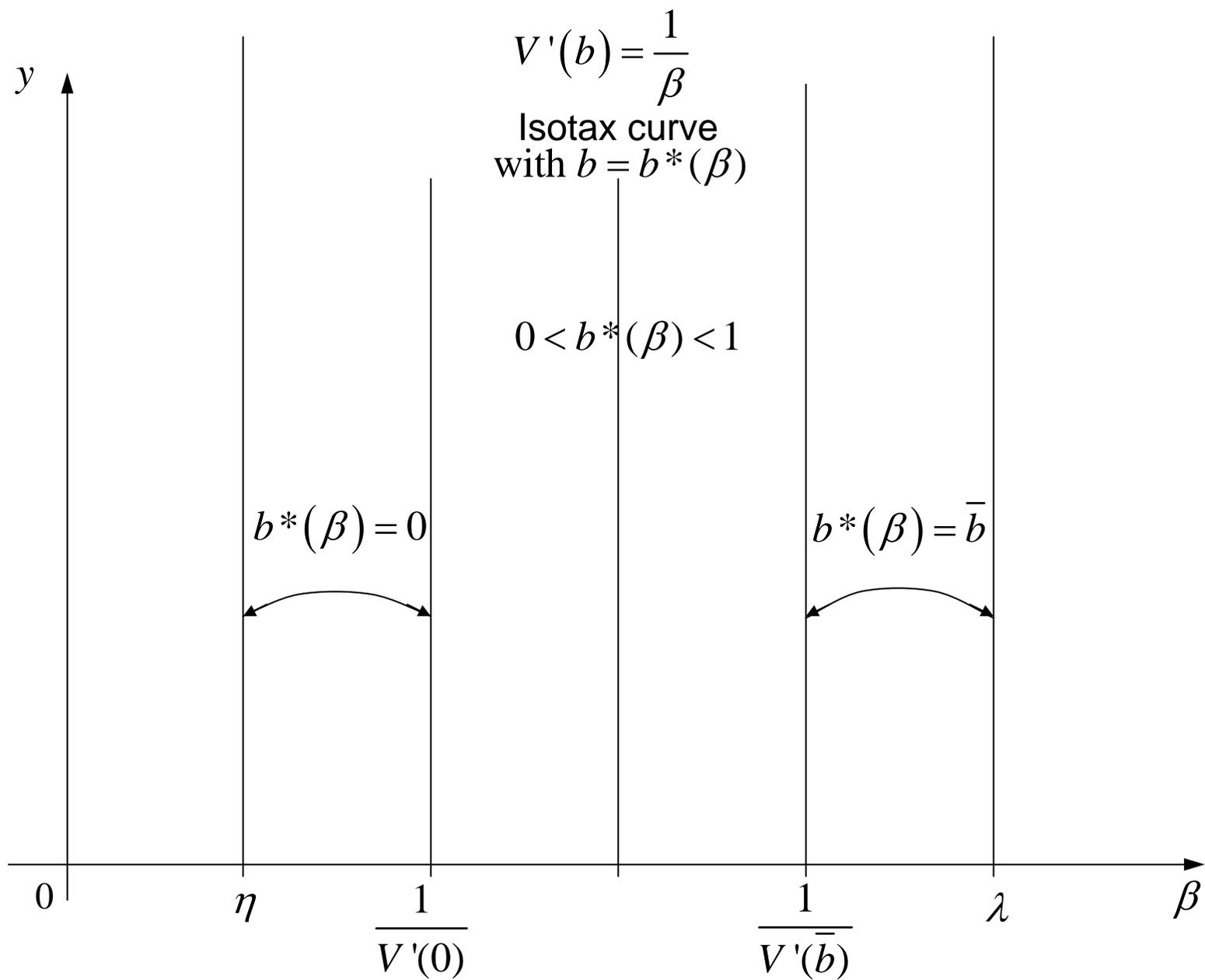


Figure 3 : Preference contour sets in (p, a) space with proportional taxation

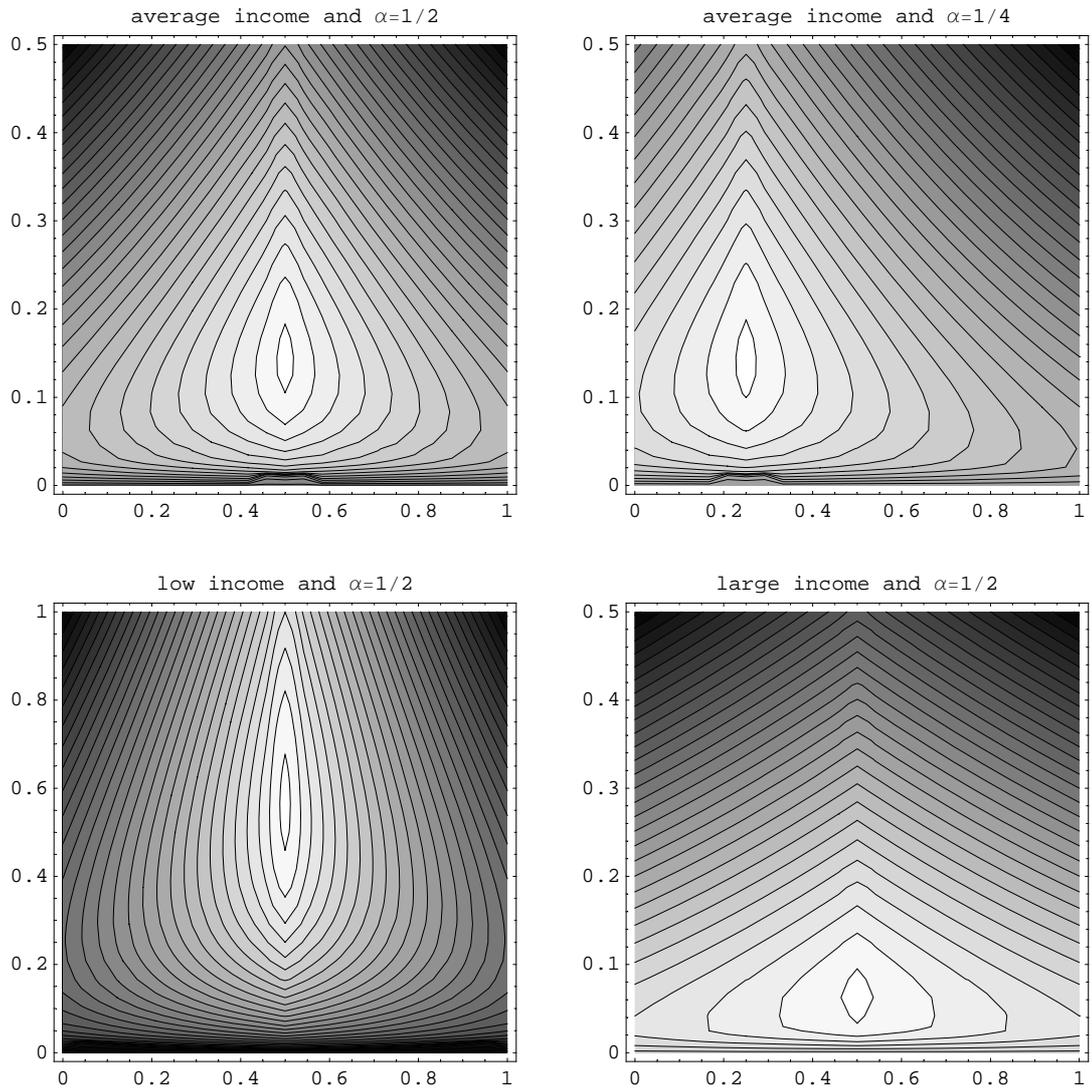


Figure 4: Set of individuals favoring a move in direction  $d$ , starting from  $(\alpha_{med}, a)$

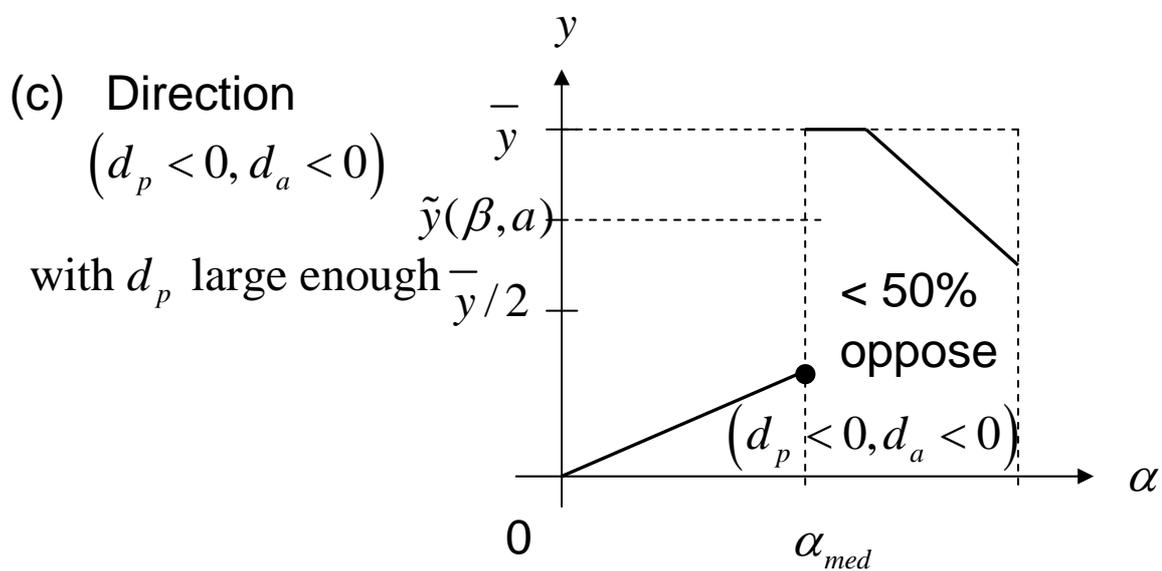
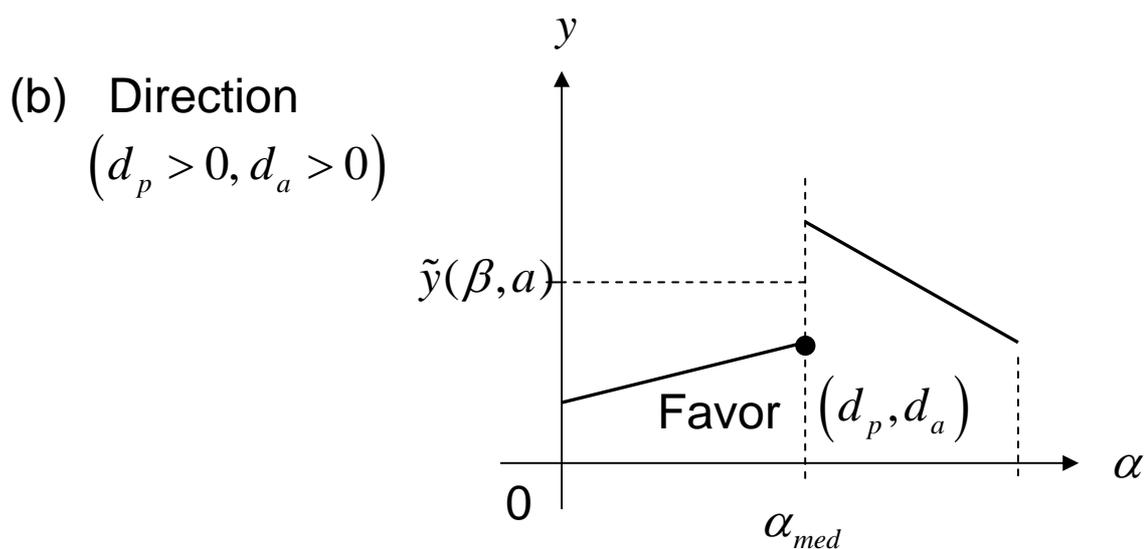
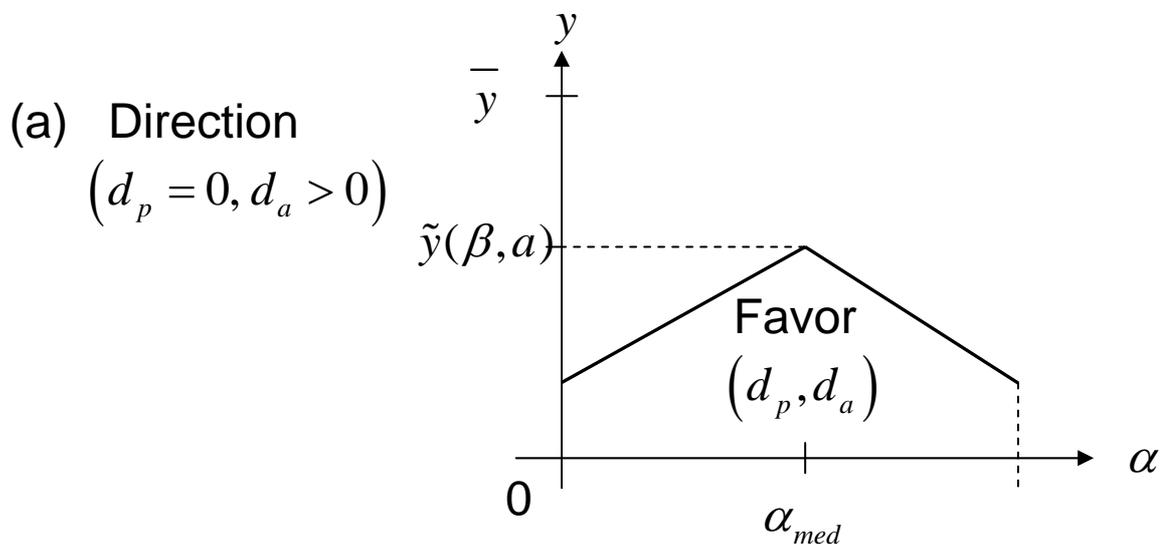


Figure 5: Iso-tax curves with proportional taxation

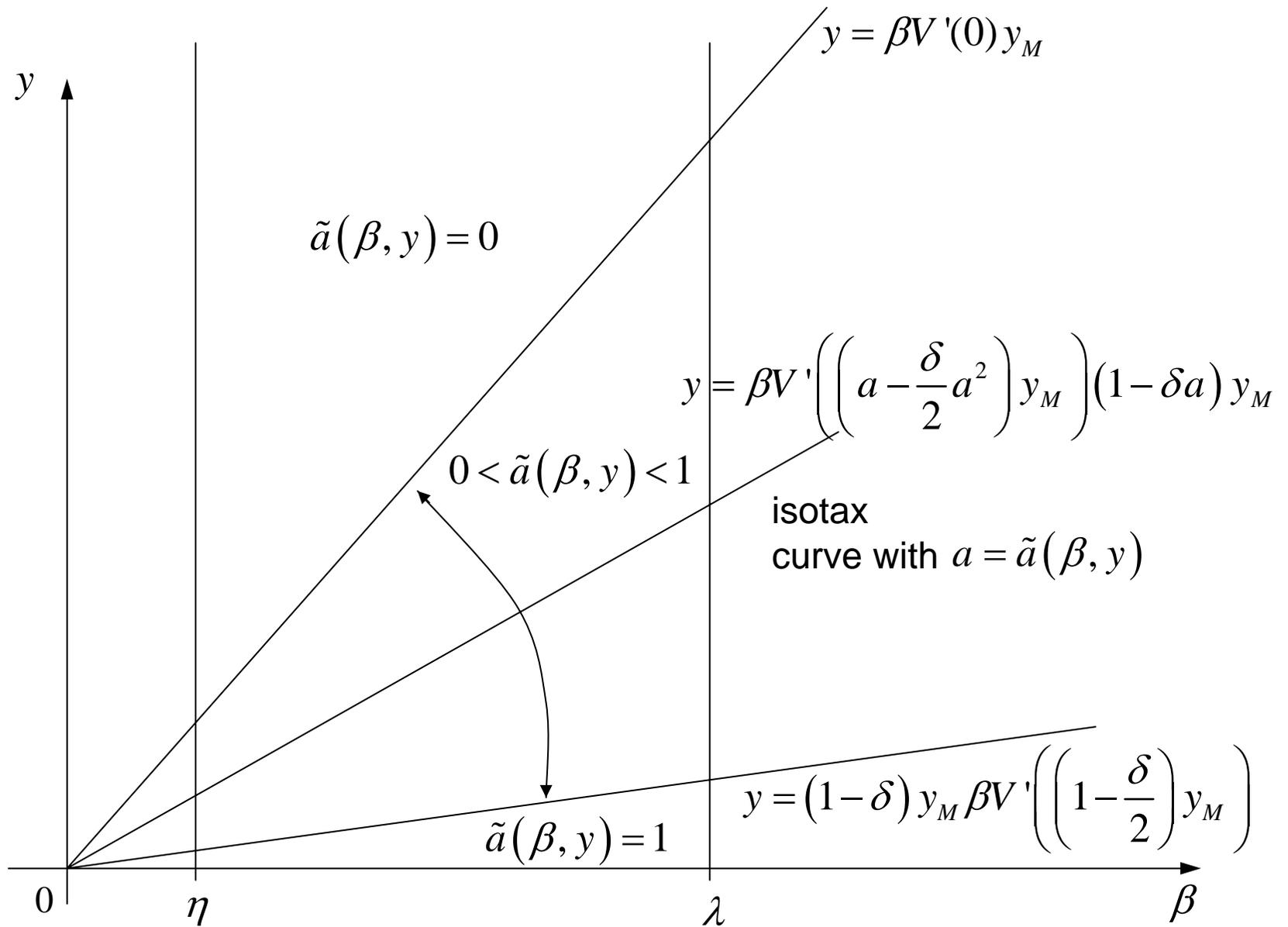
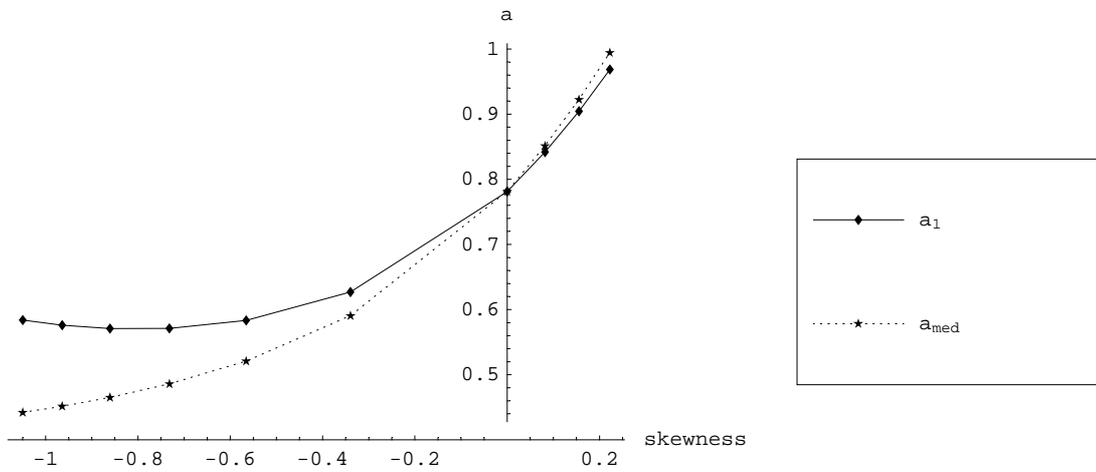


Figure 6 :  $a_{med}$  and  $a_1$  as a function of skewness for Beta distributions

Panel (a) : Beta income distributions with linear frequency



Panel (b) : Beta income distributions with single - peaked non - linear frequency

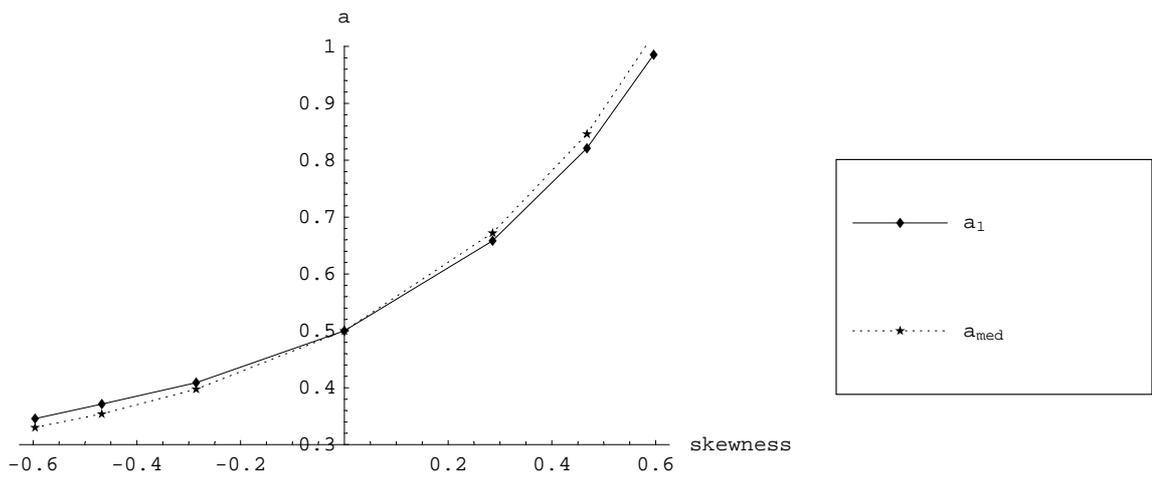


Figure 7 : Gumbel copula with  $H_\beta$  and  $H_y$  uniform

