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A positive model of overlapping income taxation in a federation of states

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Abstract

This paper develops a positive theory of overlapping income taxation in a federation of states. The analysis provides a complete characterization of the equilibrium federal and states tax rates as functions of the level of total productivity dispersion between the states. The federal rate is increasing in the level of total productivity dispersion between the states, even if the income of the decisive voter at the federal level is above the mean income. Given that the individuals' income is endogenously determined there exists a negative trade-off between the implemented federal tax rate and the resulting states' tax rates, regardless of the pre-tax income of the decisive voter at the state level. Thus, high levels of productivity dispersion between the states cause a higher than optimal federal tax rate together with low states' tax rates. It is also shown that a system of overlapping income taxation is not efficient. The resulting inefficiency might be exacerbated by the implementation of a federal matching grants program, contradicting previous results in the related normative literature.

JEL classification: D72; H23; H77
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1. Introduction

In all OECD countries central governments levy a tax on personal income. But this is not the only income tax levied in those countries. In 22 out of 29 OECD countries income

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earners also pay local, regional, provincial or state income taxes (Bronchi and de Kam, 1999). Regional income tax rates (or state income tax rates in federations) are, in a vast majority of OECD countries, significantly lower than central income tax rates. In the U.S., for instance, in the last 25 years the average effective marginal income tax rate at the federal level oscillates around 30% whereas, for a majority of states, the average effective state income tax rate is below 5%, with nine states during this period exhibiting a zero income tax rate.[1] Local taxes exhibit a similar pattern in Canada, France, and Germany, just to name a few additional examples.

From a political economy standpoint the extremely low income tax rates enacted at the state level are somewhat puzzling. It is well established in the positive literature of income taxation that if the income of the median voter is below the mean (this is the case for every region in every OECD country) then a majority of voters should prefer large scale expropriation and redistribution. Several explanations exist for the fact that, in practice, the rich are not expropriated through the tax system. The two most prominent are related to the deadweight loss from taxation and tax competition between lower level governments when tax bases are mobile. But even if voters take into account the deadweight loss from taxation and the losses from tax competition, the low levels of state income tax rates exhibited in a majority of countries are difficult to explain.[2]

This paper presents a new rationale to explain the observed regularity of high federal income tax rates together with low state income tax rates, even in the absence of mobile individuals.[3] The analysis shows that in a federal system where tax bases are joint property there is a negative relationship between the levels of the federal and state income tax rates. This negative relationship exists because both taxes have the same impact on the individuals' labor supply. Federal and state taxes, however, have an opposite effect on the utility level of individuals living in different states, since states income taxes redistribute income among individuals *within* each state whereas the federal tax implicitly redistributes income *between* the states. Consequently, regardless of their income, individuals living in relatively poor states exhibit a preference for a high federal income tax rate. (Thus a high federal tax rate constitutes an equilibrium if these individuals comprise a majority of the federal population.) Given the trade-off between federal and state taxes, the equilibrium states' income tax rates are relatively low, even when the income of the decisive voter at the state level equals zero.

The paper builds a simple model of taxation and redistribution in a two-tier federal system consisting of a single federal government and two state governments. The federation's political agenda works as follows. In the first stage individuals vote for a federal tax schedule that applies to all the residents of the federation. At a second stage residents of each state vote over local tax schedules. Governments at all levels use only

[1] The data referred to was obtained from the TAXSIM model and is available at http://www.nber.org/~taxsim.

[2] This is especially the case for states that having the constitutional right to implement a positive income tax rate choose not to do so.

[3] The formal analysis below abstracts from mobility of individuals between states. This assumption allows me to highlight a complementary mechanism influencing central and local income tax schedules. See the conclusions for a detailed discussion of the influence of mobility on the results of the paper.

linear tax-transfer schedules to redistribute income. The political mechanism considered for all the elections is majority rule.

In the model, individuals are endowed with a productivity level and choose the amount of labor they supply as a function of the selected tax schedules. This introduces a trade-off between the level of output and its distribution, as was first modeled in a political economy context by Romer (1975), Roberts (1977), and Meltzer and Richard (1981). The point of departure of this paper is that individuals, who are assumed immobile, reside in two different states and face overlapping taxes on their income. This framework introduces a new source of heterogeneity whereby individuals differ not only with respect to their productivity level, but also with respect to their state of residence. As a consequence, the individuals' preferences over tax schedules are not entirely determined by their own income.

The results show that residents of the relatively rich state always oppose a positive federal tax rate. Individuals with low productivity residing in the rich state prefer a zero federal income tax rate in order to maximize redistribution at the state level. Individuals with high productivity in this state also oppose federal taxation but simply because taxation, no matter its source, reduces their utility. In contrast, residents of the poor state favor a positive federal tax rate, its level depending on each individual's productivity level.[4]

Since individuals' preferences over the federal tax schedule are not a monotonic function of their productivity level, a coalition of poor individuals (which constitute a majority of the federal population) never emerges. In fact, the income of the decisive voter at the federal level is always above the median federal income and might even be above the mean federal income. This voter's preferred federal tax rate is an increasing function of productivity dispersion between the states. Hence, if this relatively rich individual is from a relatively poor state she supports a positive federal income tax rate. The objectives of this individual are twofold. First, a positive federal tax rate redistributes income toward the individual's state. And second, the demand for state redistribution decreases as the federal tax rate increases. This trade-off between the federal tax rate and the state tax rate thereby provides another reason for high productivity individuals in the poor state to support a high federal tax rate, ultimately bringing a low state tax rate.

From an efficiency standpoint, a federal social contract allowing a two-tier income taxation system is, in general, not optimal.[5] Simply put, this is because the impact of the federal tax rate on both states' income tax schedules is partially ignored under a decentralized system of decision-making. Obviously, a policy that takes this externality into consideration may achieve a welfare improvement for all the residents of the federation, with greater redistribution and lower taxation.

This provides a possible role for the federal government: to implement policies that undo the non-optimal outcome that arises from decentralization. Gordon (1983) and Wildasin (1991) propose the implementation of a system of federal matching grants. Under

[4] Persson and Tabellini (1996) obtain similar results in a different framework. In a model where the federal policy achieves two main goals (risk sharing and redistribution) they find that transfers between the regions exacerbate interregional conflict, in the sense that residents of the rich region tend to prefer lower federal tax rates than residents of the poor region.

[5] A similar conclusion was obtained in the related normative literature (see Gordon, 1983; Johnson, 1988; Wildasin, 1991; Boadway et al., 1998).

that system the federal government shares a proportion of the cost of redistribution at the state level, reducing the cost of state redistribution paid by the state's residents. Consequently, individuals support higher states income tax rates to finance greater redistribution at the state level. This increases the federal expenses on the matching grants program, bringing about high federal tax rates to cover federal expenses. Thus, the implementation of this system causes higher levels of taxation and lower levels of redistribution; that is, a federal matching grant system would tend to decrease rather than increase total welfare of the federation's residents.[6]

The next section presents the model. Section 3 describes the individuals' preferences over the different tax schedules and the resulting equilibrium when taxes are chosen by majority rule. Section 4 conducts an efficiency analysis of a federal system with overlapping income taxes with and without federal matching grants. Concluding remarks appear in the last section of the paper.

2. The model

Consider a federation of two states, A and B (the analysis is easily generalized to any number of states). There is a unit mass of individuals living in the federation, a share p_A of them resides in state A. Individuals cannot move between the states. Each individual is endowed with a productivity level w and has no non-labor wealth. Thus, individuals are heterogeneous with respect to their productivity level and their state of residence. The population of each state is divided into two classes; in each state $i=A$, B there is a mass $n_i^l > 1/2$ of low-productivity individuals (with productivity equal to zero), and a mass $n_i^h = 1 - n_i^l$ of high-productivity individuals with $w > 0$.

Individuals choose the amount of labor they provide on a competitive market. Income is measured in units of consumption and is produced using a constant returns to scale technology. Hence, an individual with productivity $w > 0$ who supplies y/w units of labor earns pre-tax income y.

The federation has a two-tier taxation system: there is a federal and a state income tax schedule. Both tiers impose linear taxes that are used to collect revenues. These revenues are redistributed lump sum to the population of individuals that are subject to that particular tax. According to the political agenda of the federation the federal tax is imposed first on the individuals' pre-tax income; later on every state imposes its own tax schedule on the remaining of the individuals' pre-tax income.[7]

[6] This result contrasts with the one obtained in Wildasin (1991). In his paper, a higher-level government using corrective matching grants achieves a welfare improvement. In the present model, however, I assume that all tax schedules are chosen by majority rule. This political mechanism increases the externalities arising from decentralized decision-making, and thus the inefficiency of a system of overlapping income taxation.

[7] Assuming that taxes are paid simultaneously would not change the nature of any of the following results. The adoption of a sequential timing, which is common in the related literature (cf. Boadway et al., 1998), only tries to reflect the strategic considerations of the residents of a given state when choosing their own state tax schedule. When doing so, it is reasonable to suppose that these residents take the federal tax schedule as given.

Formally, the *federal tax schedule* is represented by a tax rate $f \in [0,1]$ and a redistribution level $r_f \in \mathbf{R}_+$ such that the federal budget constraint,

$$r_f = f\left[p_A n_A^{\mathrm{h}} y_A + p_B n_B^{\mathrm{h}} y_B\right],$$

is satisfied. Similarly, the tax schedule of state i is given by the tax rate $s_i \in [0,1]$, where the state redistribution level $r_i \in \mathbf{R}_+$ is obtained from

$$r_i = s_i(1-f)p_i n_i^h y_i.$$

The individuals' net income is

$$c_i = (1-s_i)(1-f)y_i + r_f + \frac{r_i}{p_i}.^{8} \tag{1}$$

Given both tax schedules, an individual with productivity w_i chooses pre-tax income $y_i(w_i, s_i, f)$ to maximize $u(c, (y/w))$ subject to (1). Throughout the paper I assume the following quasi-linear preferences over consumption and labor supply:

$$u\left(c, \frac{y}{w}\right) = c - \frac{\alpha}{\beta+1}\left(\frac{y}{w}\right)^{\beta+1}, \quad c, y \geq 0, \tag{2}$$

where α is a positive constant and $(1/\beta)$ is the (constant) elasticity of labor supply.

While this is a highly restrictive specification of preferences, it captures the incentive effects of taxes (consumption-leisure trade-off). Moreover, this specification removes a source of considerable complication in the analysis that follows. In particular, under a general specification, redistribution may induce productive individuals to refrain from working. If every individual in a state has zero pre-tax income, then a continuum of equilibrium tax rates for this state exists. This indeterminacy complicates the analysis when solving for the equilibrium federal tax rate. Finally, the specification above (which is widely used in studies of income taxation; cf. Diamond, 1999; Bohn and Stuart, 2003; De Donder and Hindriks, 2003) is considerably more tractable than a general one, allowing us to obtain clear, intuitive results.

Under the preferences above the optimal pre-tax income of an individual with productivity $w_i > 0$ is

$$y_i = w_i\left[\frac{(1-s_i)(1-f)w_i}{\alpha}\right]^{\frac{1}{\beta}}. \tag{3}$$

Note that under this class of preferences, redistribution at either governmental level does not affect labor supply decisions and every individual with positive productivity level chooses to work.

[8] This particular specification of the individuals' net income is a consequence of the sequential timing in which the taxes are imposed. Had I assumed instead that both taxes are imposed simultaneously, we would have obtained that $c_i = (1 - s_i - f)y_i + r_f + r_i/p_i$ (see Gouveia and Masia, 1998). As already pointed out, adopting this different specification would not change the nature of any result of this paper.

3. Federal and states' tax schedules

This section first solves for the states' tax schedules and then for the equilibrium federal tax schedule. All the taxes are chosen according to majority rule. Ties are broken by an equal-probability rule.

3.1. Preferences over states' tax schedules

Substituting the individuals' pre-tax income into the federal budget constraint we obtain the federal level of redistribution as a function of the tax rates,

$$r_f = f\left(\frac{1-f}{\alpha}\right)^{\frac{1}{\beta}} \sum_{i=A,B} p_i n_i^h w_i \left[(1-s_i)w_i\right]^{\frac{1}{\beta}}; \tag{4}$$

similarly, state i's level of redistribution is given by

$$r_i = s_i(1-f)p_i n_i^h w_i \left[\frac{(1-s_i)(1-f)w_i}{\alpha}\right]^{\frac{1}{\beta}}. \tag{5}$$

Since individuals with low productivity constitute a majority of the population in each state, they determine their state tax rate. To find her preferred state tax schedule, a low-productivity individual from state i maximizes her indirect utility function over the set of feasible state tax schedules. This individual's indirect utility function is obtained by substituting Eqs. (4) and (5) back into (2):

$$V_i^1 = s_i(1-f)n_i^h w_i \left[\frac{(1-s_i)(1-f)w_i}{\alpha}\right]^{\frac{1}{\beta}} + f\left(\frac{1-f}{\alpha}\right)^{\frac{1}{\beta}} \sum_{i=A,B} p_i n_i^h w_i \left[(1-s_i)w_i\right]^{\frac{1}{\beta}}.$$

The solution to the associated maximization problem follows. All proofs are located in the appendix.

Lemma 1. *State i's equilibrium tax rate si is characterized by*

$$s_i = \begin{cases} \frac{\beta}{\beta+1} - \frac{f p_i}{(1-f)(\beta+1)}, & \text{for } f < \frac{\beta}{\beta+p_i}, \\ 0, & \text{otherwise.} \end{cases}$$

As it is readily seen from Lemma 1, states' tax rates are a decreasing function of the federal tax rate (see Fig. 1). The existing trade-off between state redistribution and federal redistribution is the main reason behind this result. Whereas federal redistribution is decreasing in s_i, the state level of redistribution increases in s_i for any $s_i < \beta/(\beta+1)$. Therefore, only when f (and consequently r_f) is equal to zero low-productivity individuals choose to maximize state redistribution. To choose such a high state tax rate when the federal tax rate is positive is too costly in terms of federal redistribution. Hence as f increases the equilibrium state tax rate decreases, and the federation shifts redistribution from the state level to the federal level. When $f=\beta/(\beta+p_i)$, a positive state tax rate

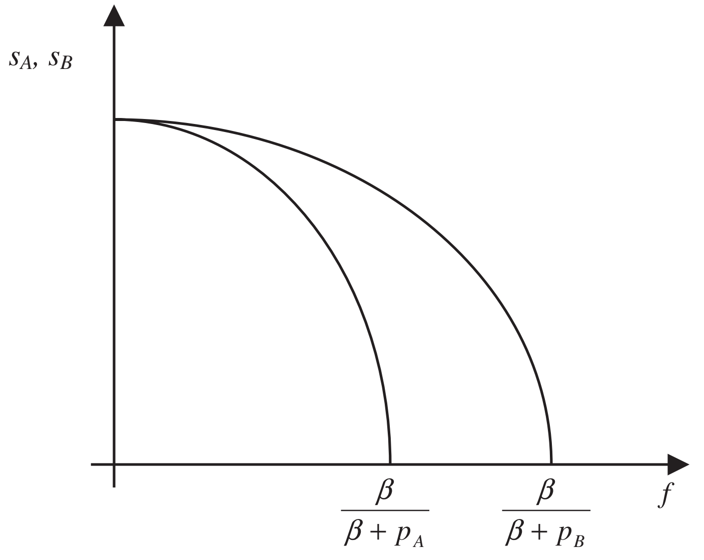

Fig. 1. States' tax reaction functions (for $p_A > p_B$).

decreases federal redistribution more than what it contributes to state redistribution. Thus, when the federal tax rate is above $\beta/(\beta+p_i)$, low-productivity individuals choose a zero state tax rate.[9]

In addition, the state income tax rate decreases with the state's share of the overall population p_i. As p_i increases (for a fixed f) more of the total income in state i is transferred to the federal level and is used for redistribution between the states. Therefore, less income is available for redistribution within the state. A reduction in the state's income tax rate is required to partially offset this disincentive.

Finally, note that s_i is a concave function of f. This is because the taxes are imposed sequentially on the individuals' income. From Eq. (3) it follows that the individuals' optimal pre-tax income is not a linear function of the sum of the tax rates. Due to this multiplicative structure, low-productivity individuals have to compensate high-productivity individuals with more significant decreases in s_i (for a given increase in f) as the level of f increases.[10] Had low-productivity individuals not compensated high-productivity individuals this way, the state's total income would decrease considerably with f, and consequently the state's level of redistribution would decrease as well.

[9] Using general utility functions Boadway and Keen (1996) show, in a normative analysis, that the slope of states' reaction functions to the federal tax rate is ambiguous. Empirically, however, Goodspeed (2000, 2002) and Hayashi and Boadway (2001) point to a downward-sloping reaction function of lower-level governments, using data from OECD countries and Canada, respectively.

[10] Totally differentiating y and setting $\mathrm{d}y = \mathrm{d}w = 0$ we obtain that $(1-s)\mathrm{d}s + (1-f)\mathrm{d}f = 0$, which implies that $\mathrm{d}s/\mathrm{d}f < 0$. From a second differentiation of the last expression it follows that also $(\mathrm{d}^2 s/\mathrm{d}^2 f) < 0$.

3.2. Preferences over the federal tax schedule

The individuals' preferences over the federal tax rate are obtained by maximizing their indirect utility function over the set of feasible federal tax schedules, subject to the states' reaction functions. The resulting preferences over f are a function of the total productivity dispersion between the states. Let us define

$$x \equiv \frac{n_B^h}{n_A^h}\left(\frac{w_B}{w_A}\right)^{\frac{\beta+1}{\beta}} \tag{6}$$

as the measure of dispersion in total productivity between the states. When x is close to one, productivity dispersion between the states is relatively low. The farther away x is from one, the more unequal the states' total productivity levels.

The dispersion index x combines the original inequality in productivity between the states together with the elasticity of labor supply. For high values of β the relative importance of the individuals' pre-tax income is low, and dispersion between the states is mainly determined by the ratio of the share of high-productivity individuals. As the elasticity of labor supply increases, the difference between the individuals' productivity plays a more significant role in the resulting dispersion between the states. Whenever both states impose the same tax rate, x is equal to the ratio of the states' total income.[11]

The proposition below presents the preferred federal tax rate for low-productivity individuals from state A when the population is evenly distributed between the two states.[12]

Proposition 1. *The preferred federal income tax rate for low-productivity individuals from state A, f_l^A, is*

$$f_l^A = \begin{cases} 0, & \text{for } x \le 1, \\ \frac{2\beta(x-1)}{x+\beta(x-1)}, & \text{for } 1 < x \le \frac{\beta+1}{\beta}, \\ \frac{2\beta}{2\beta+1}, & \text{for } \frac{\beta+1}{\beta} < x. \end{cases}$$

Fig. 2 depicts these preferences and the resulting state tax rate according to Lemma 1. Note that the federal income tax rate has two opposite effects on the utility of low-productivity individuals. On the one hand, a positive federal tax rate implies a positive level of federal redistribution. On the other, more federal redistribution through an increase in f implies less state redistribution. Therefore, low-productivity individuals evaluate which tax rate they prefer to increase, knowing that in equilibrium the other tax rate will decrease.

[11] When the analysis is extended to m states, state j's relevant measure of productivity dispersion is $x_j \equiv \left(\sum_{i=1}^m n_i^h w_i^{\frac{\beta+1}{\beta}} - n_j^h w_j^{\frac{\beta+1}{\beta}}\right) / (m-1) n_j^h w_j^{\frac{\beta+1}{\beta}}$.

[12] I adopt this simplifying assumption from now on because it allows me to obtain closed-form solutions that highlight the basic forces at work in the model. The basic intuition behind Propositions 1 and 2 continues to hold without this assumption. Consequently, the results summarized below in Corollary 1 are robust for any p_A and p_B such that $p_A + p_B = 1$, provided that none of the four groups of individuals comprises a majority of the population at the federal level.

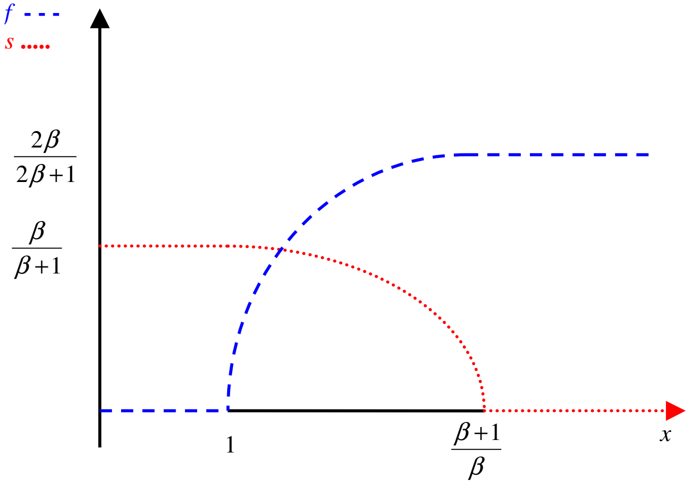

Fig. 2. Preferred federal tax rate for low-productivity individuals from state A.

Suppose, for example, that the total productivity dispersion between the states is less than one. If the federal tax rate is positive, low-productivity individuals residing in A receive federal redistribution. A positive federal tax rate, however, has two negative effects on these individuals' utility. First, it implicitly transfers income from state A to state B; and second, it lowers their state's redistribution level. If instead the federal tax rate equals zero, low-productivity individuals in A appropriate to themselves part of the transfer between the states through their state income tax schedule. Low-productivity individuals in state A prefer this last alternative as it maximizes their total income. If it is the case that $x > 1$, low-productivity individuals in A are now the recipients of redistribution between the states. Thus, they prefer a positive federal tax rate.

The level of their preferred federal tax rate is determined by the productivity dispersion between the states. As x increases, the gains from redistribution between the states for low-productivity individuals residing in A increase as well.[13] This explains why f_l^A is increasing in x. The cost that this group pays for these gains is a lower redistribution at the state level. Eventually s_A reaches zero and there is no more room to trade-off an increase in the federal rate for a decrease in their state's rate of income taxation, even for greater levels of productivity dispersion between the states. A further increase of the federal tax rate above this level (without an accompanying decrease in s_A) has a large disincentive effect, lowering federal redistribution. This defines the second threshold value of x, above which both the federal and state income tax rates are constant—namely $f_l^A = 2\beta/(2\beta+1)$ and $s_A = 0$.

[13] Total productivity at the federal level ($n_h^A w_A + n_h^B w_B$) is assumed constant when analyzing the implications of changes in x.

Due to the symmetry of the analysis, the preferences of low-productivity individuals in state B are the mirror image of the ones presented in Proposition 1. Their preferred federal income tax rate, f_l^B, is decreasing in x and the relevant threshold values of productivity dispersion are the inverse of the ones found for f_l^A. In particular, f_l^B reaches a maximum of $2\beta/(2\beta+1)$ for $x<\beta/(\beta+1)$, and a value of zero when productivity dispersion is greater than or equal to one. In the intermediate range $f_l^B=2\beta(1-x)/[1+\beta(1-x)]$.

From the previous argument it follows that preferences over f are not a monotonic function of the individuals' productivity level; i.e., individuals with the same productivity level residing in different states have opposing preferences over the federal tax rate.[14] Consequently, low-productivity individuals (which constitute a majority of the population) never form a coalition to extract as much income as possible from high-productivity individuals. It is then necessary to study high-productivity individuals' preferences over f to find out whether or not a consensus may emerge between the different groups in the federation. Only under such a consensus a federal tax rate able to reach the required support of at least half of the population against any other feasible tax rate exists. The preferences of high-productivity individuals from state A appear next.

Proposition 2. *The preferred federal income tax rate for high-productivity individuals from state A,* f_h^A*, is*

$$f_h^A = \begin{cases} 0, & \text{for } x \le \underline{x}, \\ \frac{2\beta(x-\underline{x})}{x+\beta(x-\underline{x})}, & \text{for } \underline{x} < x \le \bar{x}, \\ \frac{2\beta}{2\beta+1}, & \text{for } \bar{x} < x. \end{cases}$$

where $\underline{x} \equiv 1 + \frac{1}{(\beta+1)n_A^h}$ and $\bar{x} \equiv \frac{\beta+1}{\beta} + \frac{1}{\beta n_A^h}$.

The preferences of high and low productivity individuals residing in state A over the federal tax rate are very similar. High-productivity individuals also derive a benefit and suffer a cost from the federal tax schedule. Unlike low-productivity individuals, the federal tax bill of high-productivity individuals is positive when the tax rate is positive—this is the cost. The benefits are both experienced at the state level (from a decrease of their state's tax rate) and at the federal level (from federal redistribution). For a high enough dispersion level the benefits exceed the costs, thus the preference for positive federal tax rates.

The main difference between f_l^A and f_h^A is their threshold values. Whereas f_l^A is positive for any x above one, f_h^A remains equal to zero until x reaches a higher value. Since s is a concave function of f, for low levels of x the gains that high-productivity individuals in state A obtain from a positive federal tax rate are small compared to the losses they suffer in terms of higher overall taxation. As productivity dispersion between the states increases, the gains that these individuals accrue from federal redistribution increase as well. Eventually, benefits outweigh costs, defining the threshold value $\underline{x}$ above one.

[14] This is the case even though the individuals' preferences over the federal tax rate are single-peaked. Single-peakedness of the individuals' preferences follows from the observation that the individuals' indirect utility function is strictly quasiconcave in f.

Combining Propositions 1 and 2 follows that $f_l^B \geq f_h^B \geq f_h^A \geq f_l^A$ for $x<1$ and $f_l^B \leq f_h^B \leq f_h^A \leq f_l^A$ for $x>1$.[15] This means that the federal tax rate proposed by a high-productivity individual always obtains a majority over a tax rate proposed by a low-productivity individual.

Corollary 1. *The decisive voter over the federal income tax schedule is a high-productivity individual. Consequently, the equilibrium federal income tax rate is given by $f_h^i(x)$.*

According to this corollary the decisive voter's productivity level is above the median productivity. This result stands in sharp contrast to the one obtained in related models with only one tier of income taxation (Romer, 1975; Roberts, 1977; Meltzer and Richard, 1981). In those models, each individual's preferred tax schedule is a monotonic decreasing function of her productivity level. Thus, under universal suffrage, the decisive voter is the individual with the median productivity level. This is not the case in a federal system of income taxation. Rather, in a federal system the decisive voter is a relatively productive individual who, for a wide range of parameter values, chooses to implement a positive federal income tax rate.[16]

More strikingly, an interesting situation may arise whereby the decisive voter's productivity is above the federation's mean productivity, yet this voter selects a positive federal income tax rate. The following proposition formalizes this observation for individuals in state A.

Proposition 3. *If $\underline{x}<x<(2-n_A^h)/n_A^h$ then the decisive voter's productivity is above the federation's mean productivity level, yet the equilibrium federal tax rate, f_h^A, is positive.*

The analysis developed in this section has direct empirical implications. Several studies using data from the states within the U.S. concluded that there is no empirical support to the claim that a positive relation between income inequality and government redistribution exists.[17] As the present paper shows, however, the implications of Meltzer and Richard (1981) are not maintained in a federation of states with overlapping income taxation. Consider, for example, the predictions of the current model when w_A decreases while w_B increases. Those changes increase the productivity dispersion between the states. Hence, when the implemented federal income tax schedule is f_h^A the resulting federal tax rate increases as well. This leads to a decrease of both states' income tax rates, even though income inequality in state A increases whereas in state B decreases; that is, either a positive

[15] For $x<1$ we obtained in Propositions 1 and 2 that $f_l^A = f_h^A = 0$. When $x>1$ it is simple to show that

$$\frac{2\beta(x-1)}{x+\beta(x-1)} > \frac{2\beta(x-\underline{x})}{x+\beta(x-\underline{x})} \text{ if only if } x>0,$$

which is always the case.

[16] In a federation with m states, the equilibrium federal income tax rate is positive whenever the decisive voter resides in a relatively poor state. This is likely to be the case when the distribution of total productivity across states is right skewed. Given that the mean total productivity is greater than the median total productivity at the state level in every OECD country, this might explain the observed high levels of federal taxation and low levels of state taxation.

[17] See for example Gouveia and Masia (1998), and Rodriguez (1999).

or negative relation between the productivity of the decisive voter and the state's level of redistribution could be observed.

4. Efficiency analysis

Although the federal tax rate affects both states' tax rates, an individual in state i ignores the impact of f on the redistribution level of the other state. As a consequence, a two-tier income taxation system leads to an equilibrium on the downward sloping side of the federation's Laffer curve. A policy that takes this externality into account achieves a welfare improvement for all the citizens of the federation, with greater redistribution and lower taxation.

This non-optimal policy of redistribution is reminiscent of Gordon (1983), Johnson (1988), Wildasin (1991) and Boadway et al. (1998). These papers develop a normative analysis of taxation in a federation of states. In those analyses, a benevolent social planner (maximizing a Benthamite welfare function over the utilities of current residents of a state) fails to take into account either vertical or horizontal externalities.[18] These two externalities lead the federation to an inefficient equilibrium.

Several differences between the current paper's approach and the one adopted in the previous literature are worth mentioning. First, the previous papers abstract from political economy considerations, the main focus of the present paper. Second, in this paper the horizontal externality is assumed away since individuals are immobile. Finally, given that individuals (and not a social planner) choose the federal tax rate through majority vote, the vertical inefficiency has an opposed effect to the one obtained in previous papers. Both in Johnson (1988) and in Boadway et al. (1998) states ignoring the effects of their taxes on federal revenues tend to implement a higher than optimal income tax rate. In contrast, in the current paper states' tax rates are low whereas the federal tax rate tends to be higher than optimal.

To formalize matters, let us consider how the federation's total redistribution level reacts to changes in the productivity dispersion between the states. The federation's total redistribution is given by

$$R(x) \equiv r_f + r_A + r_B = \frac{\mathcal{P}}{2}\left[\frac{(1-s)(1-f)}{\alpha}\right]^{\frac{1}{\beta}}[f + s(1-f)], \tag{7}$$

where

$$\mathcal{P} \equiv n_A^h w_A^{\frac{\beta+1}{\beta}} + n_B^h w_B^{\frac{\beta+1}{\beta}}$$

is the total productivity level of the federation, which is constant. When the equilibrium federal tax rate is f_h^A, $R(x)$ is constant for $x < \underline{x}$ and $x > \bar{x}$. For intermediate values of x, however, total redistribution is strictly decreasing in x.

[18] A vertical externality relates to the effects of the states' policies on federal revenues. A horizontal externality is caused by the mobility of individuals between states and the impact of the states' taxes on nonresidents of a particular state.

Lemma 2. *R(x) is strictly decreasing in x for* $\underline{x}<x<\bar{x}$.

In this same range of productivity dispersion, total income taxation on the individuals' income increases with x. That is, for any $\underline{x}<x$ the federation as a whole ends up at the decreasing part of its Laffer curve. This is an inefficient outcome, as a reduction in income taxes would increase total redistribution.

Proposition 4. *If* $x>\underline{x}$ *the equilibrium tax rates of the federation are on the downward sloping side of its Laffer curve.*

The intuition is straightforward. When the federal income tax rate is positive the loss in redistribution in the more productive state (which is not taken into account by the decisive voter) more than offsets the gain in redistribution in the less productive state. Proposition 4 does not state, however, that a decrease in the rate of a given tax results in a Pareto improvement. Rather, the proposition establishes that in equilibrium the combination of taxes selected by the individuals delivers an outcome inside the federation's Pareto frontier.

An important reason behind this inefficiency is that the federal tax schedule is the only available policy instrument that redistributes income between the states. Clearly, a social planner implementing lump-sum transfers between the states and eliminating one layer of taxation would achieve a Pareto improvement. But even abstracting from lump-sum transfers, a Pareto improvement can be achieved for sufficiently high levels of productivity dispersion by eliminating the states' income tax schedules.

Proposition 5. *There exists a critical productivity dispersion level* $x^*<\bar{x}$ *such that for every* $x>x^*$ *eliminating states income tax schedules results in a greater utility level for all the individuals in the federation.*

The individuals' inability to credibly commit to a non-equilibrium strategy drives the federation to this inefficient outcome. Suppose low-productivity individuals promise to choose a state income tax rate equal to zero for any federal income tax rate. In this situation the resulting federal tax rate equals $\beta/(\beta+1)$, the one preferred by low-productivity individuals in both states. Notwithstanding their promise, in the second stage while voting over state taxes low-productivity individuals in both states will select a positive state income tax rate as it allows them to enforce more redistribution. High-productivity individuals anticipate such a deviation in the first period and behave accordingly. Hence, the resulting inefficient equilibrium is inescapable without a commitment mechanism.

But even if a device that outlaws income tax schedules exists only in state A, an efficient outcome is not reached.[19] If a device that outlaws income tax schedules exists only in state A, low-productivity individuals in state B are enjoying the best of both worlds. First, they receive more federal redistribution given that high-productivity individuals in state A have higher incomes due to incentive effects. And second, they also

[19] In some states within the U.S., like Tennessee, the constitution does not allow the implementation of an income tax schedule. In others states a supermajority is required for tax rates increments (this is the case in more than 15 states).

receive redistribution at the state level, which there is no reason to give up by setting the state's tax rate at zero. Thus, for low-productivity individuals the implementation of a state income tax schedule is a dominant strategy that leads the federation to an inefficient equilibrium.

Another policy instrument that may achieve an efficiency improvement is the implementation of a system of federal matching grants.

4.1. Federal matching grants

In models of fiscal competition the federal government may design corrective schemes that undo the inefficient outcomes arising from decentralized regional decision-making. Wildasin (1991), for example, shows that a system of matching grants from the federal government to state governments can neutralize the horizontal externalities created by state policies, leading the federation to an efficient outcome. It is then natural to explore the implications of that system using the current framework, whereby all the taxes are determined according to majority rule equilibrium, rather than by social planners.

Under a federal matching grants program state i's budget constraint is given by

$$\delta r_i = s_i(1-f)p_i n_i^h y_i, \tag{8}$$

where $\delta \in (0, 1)$ measures the state's share of the cost of a dollar's worth of redistribution. The balanced budget constraint condition at the federal level implies that

$$r_f + (1-\delta)(r_A + r_B) = f\left[p_A n_A^h y_A + p_B n_B^h y_B\right]. \tag{9}$$

Under a matching grants program individuals choose to increase state redistribution because states are responsible for only a share of their redistribution expenses. A higher federal tax rate is required to pay for part of this greater redistribution level. As a result we obtain higher income tax rates and lower total redistribution. Thus, a system of federal matching grants in general exacerbates the resulting inefficiencies.[20]

Proposition 6. *Under a federal matching grants program the overall implemented income tax rates are greater and the federations' total redistribution level is smaller than without the matching grants program for*

$$x \leq \underline{x} \text{ or } x \geq 1 + \frac{2\left(\delta + n_A^h\right)}{n_A^h\left[(1+\delta)(\beta+1) - 2\right]}.$$

That is, a federal matching grants program under a democratic system may have the opposite effect than the one obtained when the federal government is represented by a benevolent social planner. This provides a critical assessment to the use of federal

[20] The result in the following proposition cannot be established for any productivity dispersion level without imposing some sufficient conditions on the parameters. For example, notice that the range where the result is not guaranteed is empty for $\beta \geq (1+2n_A^h+\delta)/(1-2n_A^h-\delta)$, with $1-2n_A^h-\delta>0$. Another possibility would be to impose restrictions only on δ. In fact, there exists a critical value δ^* such that the stated inefficiency is obtained for all $\delta<\delta^*$, for any x.

matching grants as a corrective device that undoes externalities arising from decentralized decision making.

5. Conclusions

This paper developed a positive theory of overlapping taxation in a federation of states. The conclusions of the model are consistent with the observation that in a vast majority of OECD countries federal income taxes are significantly higher than state income taxes. Clearly, a different analysis focusing on competition between lower level governments when tax bases are mobile is consistent with that observation as well. My position is that the current paper does not present an alternative, but rather a complementary view. Indeed, this paper's main objective is to formulate a new rationale that may well coexist with the predominant theory of competition between lower level governments when tax bases are mobile.

The main result of the paper shows that the existence of productivity dispersion between the states has a significant impact on the individuals' preferences, bringing otherwise identical individuals to have opposing preferences over the federal tax rate. As a consequence, even though the decisive voter at the federal level has a productivity level above the median, she supports a positive rate of federal income tax. Because of incentive considerations, a high rate of federal income tax brings to a low rate of taxation at the state level.

Another result worth mentioning is that a federal social contract allowing a two-tier income taxation system is, in general, not optimal. The reason for this is that under a decentralized system of decision-making the federal tax schedule creates externalities that are partially ignored. It is also found that a system of federal matching grants may exacerbate the existent inefficiency. This contrasts with previous results obtained in the related normative literature where a system of federal matching grants is welfare improving.

Although it delivers new and interesting results, the model is extremely sparse. Its main restriction is, arguably, the abstraction from mobility of individuals between the states.

Adding mobile individuals to the model introduces another layer to the individual's decision problem. Relatively higher tax rates in one state may lead to the emigration of productive individuals to the other state. Yet, the concentration of rich individuals in one state may lead to the immigration of poor individuals. Given that poor individuals comprise a majority of the population, their immigration will result in higher tax rates. An equilibrium in this framework is a fixed-point in which no individual wishes to move or alter its labor supply, and no state wishes to change its tax rate given the tax rate chosen by the other state. To guarantee the existence of an equilibrium is a challenging task. Using this framework it is very difficult to come up with a set of simple sufficient conditions for existence. A change in policy implies migratory movements that imply a change in the composition of the population and, subsequently, another change in policy. This cycle may continue endlessly.

In any event, my conjecture is that the inclusion of mobility considerations may help us understand the coexistence of high federal income tax rates with low state income tax rates. Simply put, the federal government has a monopoly on the power and ability (however imperfect) to coerce citizens into paying taxes. In the stylized democracy model of this paper, the federal government is nothing more than the aggregation of the preferences of a majority of individuals. Given that poor individuals always constitute a majority of the population at the federal level, federal tax rates will tend to be high. While federal income taxes are inescapable to the rich population, that is not the case with state income tax schedules. Tax competition among the states will emerge and drive states income tax rates to low levels.

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Appendix A. Proofs

Proof of Lemma 1. Low-productivity individuals' decision problem takes the form:

$$\max_{s_i\in[0,1]} s_i(1-f)n_i^h w_i\left[\frac{(1-s_i)(1-f)w_i}{\alpha}\right]^{\frac{1}{\beta}} + f(1-f)^{\frac{1}{\beta}}\sum_{i=A,B} p_i n_i^h w_i\left[\frac{(1-s_i)w_i}{\alpha}\right]^{\frac{1}{\beta}}.$$

Strict concavity in s_i is easily verified on the relevant domain, and the first-order conditions directly yield the stated results. □

Proofs of Propositions 1 and 2. The proof below solves the maximization problem for an individual living in state A. An identical procedure yields the results for a resident of state B.

The individuals' maximization problem takes the form:

$$\max_{s_i}, f\in[0,1] s_A(1-f)n_{\mathrm{h}}^A w_A\left[\frac{(1-s_A)(1-f)w_A}{\alpha}\right]^{\frac{1}{\beta}}$$
$$+\frac{f}{2}(1-f)^{\frac{1}{\beta}}\sum_{i=A,B} n_i^h w_i\left[\frac{(1-s_i)w_i}{\alpha}\right]^{\frac{1}{\beta}} + \gamma\frac{\beta}{\beta+1}\left(\frac{1}{\alpha}\right)^{\frac{1}{\beta}}\left[(1-s_A)(1-f)w_A\right]^{\frac{\beta+1}{\beta}}$$

$$\text{subject to}\quad f\in[0,1]\quad\text{and}\quad s_i=\begin{cases}\dfrac{\beta}{\beta+1}-\dfrac{f}{2(1-f)(\beta+1)}, & \text{for } f<\dfrac{2\beta}{2\beta+1},\\ 0, & \text{otherwise,}\end{cases}$$

where $\gamma=0$ for the preferences of low-productivity individuals (Proposition 1) and $\gamma=1$ for the preferences of high-productivity individuals (Proposition 2).

To simplify the exposition I denote the total weighed productivity in each state by

$$a \equiv n_A^h w_A^{\frac{\beta+1}{\beta}} \text{ and } b \equiv n_B^h w_B^{\frac{\beta+1}{\beta}}.$$

The Lagrangian for the maximization problem above is:

$$\begin{aligned}\mathcal{L}\left(f, s_A, s_B, \lambda_A, \lambda_B, \theta_A, \theta_B, \theta_f; x\right) = {} & s_A(1-f)a\left[\frac{(1-s_A)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} \\ & + \frac{f}{2}(1-f)^{\frac{1}{\beta}}\sum_{i=A,B} n_{\mathrm{h}}^i w_i\left[\frac{(1-s_i)w_i}{\alpha}\right]^{\frac{1}{\beta}} \\ & + \gamma\frac{a\beta}{n_A^h(\beta+1)}\left(\frac{1}{\alpha}\right)^{\frac{1}{\beta}}\left[(1-s_A)(1-f)\right]^{\frac{\beta+1}{\beta}} \\ & + \sum_{i=A,B}\left\{\theta_i s_i - \lambda_i\left[\frac{\beta}{\beta+1} - \frac{f}{2(1-f)(\beta+1)}\right.\right. \\ & \left.\left. - s_i\right]\right\} + \theta_f f.\end{aligned}$$

The corresponding first-order conditions are

1. $\mathcal{L}_f \Rightarrow -s_A\frac{\beta+1}{\beta}a\left[\frac{(1-s_A)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} + \left(\frac{1-f}{\alpha}\right)^{\frac{1}{\beta}}\frac{\beta(1-f)-f}{2\beta(1-f)}\left[a(1-s_A)^{\frac{1}{\beta}} + b(1-s_B)^{\frac{1}{\beta}}\right] - \gamma \times \frac{a(1-s_A)}{n_A^h}\left[\frac{(1-s_A)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} + \sum_{i=A,B}\frac{\lambda_i}{2(\beta+1)(1-f)^2} + \theta_f = 0.$

2. $\mathcal{L}_{s_A} \Rightarrow \frac{(1-f)a}{\beta(1-s_A)}\left[\beta(1-s_A)-s_A\right]\left[\frac{(1-f)(1-s_A)}{\alpha}\right]^{\frac{1}{\beta}} - \frac{af}{2\beta(1-s_A)}\left[\frac{(1-f)(1-s_A)}{\alpha}\right]^{\frac{1}{\beta}} - \gamma\frac{a(1-f)}{n_A^h} \times \left[\frac{(1-s_A)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} + \lambda_A + \theta_A = 0.$

3. $\mathcal{L}_{s_B} \Rightarrow -\frac{bf}{2\beta(1-s_B)}\left[\frac{(1-f)(1-s_B)}{\alpha}\right]^{\frac{1}{\beta}} + \lambda_B + \theta_B = 0.$

4. $\mathcal{L}_{\lambda_i} \Rightarrow s_i \geq \frac{\beta}{\beta+1} - \frac{f}{2(1-f)(\beta+1)}$, $\lambda_i \geq 0$, with complementary slackness.

5. $\mathcal{L}_{\theta_i} \Rightarrow s_i \geq 0, \theta_i \geq 0$, with complementary slackness.

6. $\mathcal{L}_{\theta_f} \Rightarrow f \geq 0, \theta_f \geq 0$, with complementary slackness.

With two inequality constraints and three non-negative variables, there are 32 possible patterns of equations and inequalities. Let us see which ones offer candidates for a maximum.

The first candidate is given by $\theta_f \geq 0$, $\theta_i = 0$, and $\lambda_i \geq 0$. These constraints imply that $f = 0$ and $s_i = \beta/(\beta+1)$. Substituting these values into the FOCs yields that $\theta_f \geq 0$ if and only if $x \leq 1 + \frac{\gamma}{n_A^h(\beta+1)}$. The inequalities $\lambda_i \geq 0$ are satisfied for any value of x.

The second candidate is given by $\lambda_i \geq 0$, and $\theta_i = \theta_f = 0$. This case corresponds to the interior solution where all the tax rates are positive. From the first three FOCs we obtain the following two equations:

$$\lambda_A = \left[\frac{(1-s_A)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} \left[\frac{af}{2\beta(1-s_A)} + \gamma\frac{a(1-f)}{n_A^h} - \frac{a(1-f)}{\beta(1-s_A)}[\beta(1-s_A)-s_A]\right] > 0, \tag{10}$$

$$\lambda_B = \left[\frac{(1-s_B)(1-f)}{\alpha}\right]^{\frac{1}{\beta}} \frac{bf}{2\beta(1-s_B)} > 0 \tag{11}$$

and replacing λ_i and s_i in $\mathcal{L}_f$ according to (10), (11), and Lemma 1 yields

$$\frac{1+x}{2\beta(1-f)}[\beta(1-f)-f] - \left[1-\frac{f}{2\beta(1-f)}\right] - \frac{\gamma(2-f)}{2(\beta+1)(1-f)n_A^h} + \frac{1}{2(\beta+1)(1-f)^2}\left[\frac{f(1+x)(1-f)(\beta+1)}{\beta(2-f)} - \frac{f(1-f)(\beta+1)}{\beta(2-f)} + \frac{\gamma(1-f)}{n_A^h}\right] = 0.$$

Tedious manipulations of the equation above deliver

$$f_l^A = \frac{2\beta(x-1)}{x+\beta(x-1)} \text{ and } f_h^A = \frac{2\beta(x-\underline{x})}{x+\beta(x-\underline{x})},$$

the results stated in Propositions 1 and 2.

Finally, the solution for high levels of productivity dispersion is reached when $\theta_f = 0$, $\lambda_i \geq 0$ and $\theta_i \geq 0$, $i = A, B$. In this case $s_A = s_B = 0$ and $f = 2\beta/(2\beta+1)$. Substituting the values of the tax rates into the FOCs we obtain that $\lambda_i > 0$ for any parameters values but $\theta_i \geq 0$ if and only if $x \geq \frac{\beta}{\beta+1} + \frac{\gamma}{\beta n_A^h}$.

Second order sufficient conditions are satisfied for all the different solutions. I choose to omit these conditions here because they are lengthy and do not provide additional insights. The details can be obtained from the author upon request. □

Proof of Proposition 3. The condition $x < \frac{2-n_A^h}{n_A^h}$ implies that

$$n_A^h w_A^{\frac{1+\beta}{\beta}} + n_B^h w_B^{\frac{1+\beta}{\beta}} < 2w_A^{\frac{1+\beta}{\beta}}$$

which directly yields $y_A > (1/2)(n_A^h y_A + n_B^h y_B)$. Finally, by Proposition 2 we know that f_h^A is positive for $1 + \frac{1}{(\beta+1)n_A^h} < x$. □

Proof of Lemma 2. If $x<\bar{x}$ by Proposition 2 we know that $f<2\beta/(2\beta+1)$, which implies (by Lemma 1) that

$$s=\frac{\beta}{\beta+1}-\frac{f}{2(1-f)(\beta+1)}. \tag{12}$$

Substituting (12) into (7) yields

$$R(x)=\psi(2-f)^{\frac{1}{\beta}}(f+2\beta)$$

where

$$\psi\equiv\frac{a+b}{4(\beta+1)}\left[\frac{1}{2\alpha(\beta+1)}\right]^{\frac{1}{\beta}}$$

is a constant. Differentiating R with respect to x we obtain

$$\frac{\partial R}{\partial x}=\psi(2-f)^{\frac{1}{\beta}}\left[1-\frac{f+2\beta}{\beta(2-f)}\right]\frac{\partial f}{\partial x},$$

which is always negative for $\beta>0$. □

Proof of Proposition 4. From Lemma 2 we know that total redistribution is strictly decreasing in this range. It remains to show that total taxation on the individuals' income is increasing in x.

From Lemma 1 and Proposition 2 it follows that

$$s+f=\frac{\beta}{\beta+1}-\frac{f}{2(1-f)(\beta+1)}+f.$$

Differentiating the previous expression with respect to x we obtain that

$$\frac{\mathrm{d}(s+f)}{\mathrm{d}x}>0 \text{ if and only if } f<1-\frac{1}{4(\beta+1)^2}.$$

The above inequality is always satisfied since the maximum possible value of f in equilibrium, $\frac{2\beta}{2\beta+1}$, is strictly less than $1-\frac{1}{4(\beta+1)^2}$. □

Proof of Proposition 5. When regional taxes are outlawed, low-productivity individuals in both states have the same preferences over the federal tax schedule. Hence, they form a majority at the federal level. Their preferred federal tax rate in this case is

$$\hat{f}=\arg\max_{f} r_f \ s.t. \ s_i=0; i=A,B.$$

When $x \geq \bar{x}$ the equilibrium income tax schedules are $s_i = 0$ and $f_h^A = 2\beta/(2\beta+1)$. Thus, in this range state redistribution is zero. Since $\hat{f}$ is uniquely defined and $\hat{f} < f_h^A$ we obtain that

$$r_f(\hat{f}) > r_f(f_h^A).$$

That is, for $x \geq \bar{x}$, according to the outcome under $\hat{f}$ taxes are lower and redistribution is greater than according to the equilibrium tax rate f_h^A. Thus, for $x \geq \bar{x}$, the utility of all the individuals in the federation is greater under $\hat{f}$ than under f_h^A. In fact, this is the case for every $x > x^*$, where x^* is defined by

$$r_f[f(x^*), s(x^*)] + r_A[f(x^*), s(x^*)] = r_f[f^*, 0]^{21} \quad \square$$

Proof of Proposition 6. Under a federal matching grants program, the indirect utility level of low-productivity individuals in state A is

$$\begin{aligned} V_l^A &= s_A(1-f)n_A^h w_A \left[\frac{(1-s_A)(1-f)w_A}{\alpha}\right]^{\frac{1}{\beta}} \left[\frac{1-(1-\delta)p_A}{\delta}\right] \\ &\quad + f\left(\frac{1-f}{\alpha}\right)^{\frac{1}{\beta}} \sum_{i=A,B} p_i n_i^h w_i [(1-s_i)w_i]^{\frac{1}{\beta}} - \frac{(1-\delta)}{\delta} r_B \end{aligned} \tag{13}$$

obtained by substituting Eqs. (3), (8), and (9) back into (2). The implemented state tax schedule is obtained by maximizing (13) over the set of feasible state taxes. The solution to that maximization problem yields[22]

$$\hat{s_A}(\delta) = \begin{cases} \dfrac{\beta}{\beta+1} - \dfrac{\delta f p_A}{(1-f)(\beta+1)[1-(1-\delta)p_A]}, & \text{for } f < \dfrac{\beta[1-(1-\delta)p_A]}{\beta[1-(1-\delta)p_A]+\delta p_A}, \\ 0, & \text{otherwise.} \end{cases}$$

Substituting $p_i = 1/2$ and solving for the preferred federal tax rate as in Propositions 1 and 2, we obtain

$$f_l^A(\delta) = \begin{cases} 0 & \text{for } x \leq 1, \\ \dfrac{\beta(x-1)(1+\delta)^2}{2x\delta+\beta(x-1)(1+\delta)} & \text{for } 1 < x \leq \dfrac{(1+\delta)(\beta+1)}{\beta(1+\delta)-(1-\delta)}, \\ \dfrac{\beta(1+\delta)}{\beta(1+\delta)+\delta} & \text{for } \dfrac{(1+\delta)(\beta+1)}{\beta(1+\delta)-(1-\delta)} < x, \end{cases}$$

[21] Note that the level of redistribution at both the state and federal level is continuous in x. Furthermore, total redistribution is strictly decreasing in x in the relevant range. Hence, such an x^* exists and is uniquely defined.

[22] The indirect utility function V_l^A is strictly concave in s_A on the relevant domain. Hence, this is the unique solution, obtained directly from the first order conditions.

for low-productivity individuals, and

$$f_h^A(\delta) = \begin{cases} 0 & \text{for } x \leq 1 + \frac{2\delta}{n_A^h(\beta+1)(1+\delta)}, \\ \dfrac{\beta(1+\delta)\left[(\beta+1)n_A^h(x-1)(1+\delta)-2\delta\right]}{[2x\delta+\beta(x-1)(1+\delta)](\beta+1)n_A^h-2\beta\delta} & \text{for } 1+\dfrac{2\delta}{n_A^h(\beta+1)(1+\delta)} < x \leq 1+\dfrac{2\left(\delta+n_A^h\right)}{n_A^h[(1+\delta)(\beta+1)-2]}, \\ \dfrac{\beta(1+\delta)}{\beta(1+\delta)+\delta} & \text{for } 1+\dfrac{2\left(\delta+n_A^h\right)}{n_A^h[(1+\delta)(\beta+1)-2]} < x. \end{cases}$$

for high-productivity individuals.

As it is the case without federal matching funds, preferences are not a monotonic function of w. Therefore, the equilibrium federal tax rate is $f_h^A(\delta)$. Note that $f_h^A(\delta) \geq f_h^A(1)$ for

$$x \leq \bar{x} \text{ or } x \geq 1 + \frac{2\left(\delta+n_A^h\right)}{n_A^h[(1+\delta)(\beta+1)-2]},$$

establishing the desired result. □

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