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Inter-jurisdictional Migration and the Size of Government

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Abstract

This paper develops a model of centralized public spending where decision-makers are the regional median voters instead of the national median voter of the received literature. Regional representatives decide the level of public spending by bargaining in the central legislature. We study how exogenous changes in the composition of the regional electorate either deteriorate or mitigate inter-jurisdictional redistributive conflicts and how these, in turn, influence the size of the government. We find the conditions under which migration-induced inter-regional income convergence (divergence) leads either to a bigger or a smaller government. Finally, the relationship between migration and efficiency is explored within the present framework.

Key words: Demographic Changes; Government Spending; Inequality; Redistribution; Bargaining; Political Economy Theory.

JEL Classifications: D30, D78, H0, H41, H50, R1.

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1 Introduction

Milton Friedman once remarked that a country cannot have both free legal migration and a generous welfare state. One of the reasons for that is unskilled legal migrants receive more welfare benefits than their income tax contribution. Besides, it is commonly believed that a mass of unskilled legal migrants who acquire the right to vote lead to a larger welfare state; that is, more income tax redistribution in their favor. This paper presents a theory that shows this may not necessarily be the case especially when we look at internal migration flows.

The geographical distribution of voters determines the elected representatives of a constituency. Any change in the voting population due, for example, to ageing, migration, relocation in urban areas, the extension of the voting rights and citizenship contributes to shape public policies.

Some examples of changes in the electorate are the migration between East and West Germany as well as its capital Berlin after reunification or between North and South of Spain and Italy after the second world war. There are also policies that impact directly on the voting population such as the extension of the franchise or the recognition of political rights to landed migrants after a certain number of years they have been living and working in the country.

A simple way to deal with this issue is to use the median voter approach. Any change in the voting populace changes the median voter and has, therefore, a direct impact on public policy as explained by Meltzer and Richard (1981). They argue that the extension of the franchise causes the election of a poorer median voter who will increase redistributive public spending. As pointed out in Giuranno (2009), Meltzer and Richard's logic applies to a one-region economy. However, most countries, as well as urban areas, are divided into regions and electoral districts. Therefore, in a multi-region economy the national median voter approach cannot explain public policy as regionally elected representatives have to form a central legislature and set policy through a collegial bargaining mechanism.

The impact on the size of government of demographic changes in a multi-jurisdictional economy has not been adequately studied yet. In this paper we explicitly address this issue by considering a multi-regional economy where policy decisions are made by bargaining by the regional median voters in the central legislature. In this context, whether a group of individuals vote in one or in another jurisdiction may have important policy implications. Inter-regional migrants who acquire the right to vote in their final destination affect the collective choice mechanism by moving the median voters in both the regions where they come from and where they end up.

When people move they may acquire different individual incomes. Therefore, inter-regional mobility affects the distribution of income within and among regions and the average income of the whole economy. Voters' mobility leads to regional pivotal voters who may be either relatively richer or poorer with respect to the per-capita income of the economy. In the collective choice mechanism here developed,

the income gap among regional median voters characterises the dimension of the inter-regional redistributive conflict. We study how inter-regional migration either mitigates or deteriorates both the intra- and inter-regional redistributive conflicts and how the latter influence the size, equity and efficiency of public spending.

Our theory complements the classic theory of the determinants of the size of government and fiscal redistribution which depends on the level of income inequality. Meltzer and Richard (1981, 1983) argued that in a one-jurisdictional polity the more skewed the distribution of income, the larger the difference between the median and the mean income and the higher the size of government. Giuranno (2009) showed that in a multi-jurisdiction structure the larger the inter-regional income inequality, the lower the government size because of the worsening inter-regional redistributive conflicts. Thus, there are two conflicting effects. One is due to intra-regional inequality as in Meltzer and Richard (1981) and the other to inter-regional inequality as in Giuranno (2009). Now, can the two conflicting effects be linked to each other? As discussed in Giuranno (2009) without providing a formal analysis, the two effects interact. In this paper, we address this issue formally and find that what really matters are the two income gaps, one between the income of regional median voters and the second between median voters' income and the average income of the whole economy.

In our framework, migration does not influence the election of the national median voter as in Dolmas and Huffman (2004), it rather influences the election of the jurisdictional median voters that will form the central legislature and set policy by bargaining.

We show that people's mobility, as in general any demographic change, decreases government size when it leads to the election of regional median voters that are simultaneously richer relative to the average income of the whole economy. This may be the case, for example, of the brain-drain that has strongly characterised the migration from the poorer South to the richer North in the last twenty years in Italy, where reducing public spending has become a priority in the political agenda. Di Cintio and Grassi (2011) found empirical evidence that a large number of skilled workers from the poorer Italian regions who just gained their University degree move to richer regions to increase their income. Before migrating, their incomes are lower than the income of the regional median voter. Once they migrate to a rich region, skilled workers can gain a wage above that of the median voter of the destination region. As a result, the brain-drain from a poorer to a richer region alters the composition of the voting populace and may produce regional median voters that are simultaneously richer in all regions. We find that when all regional median voters become simultaneously richer, they will unanimously agree to decrease the size of government. This result can be considered as an extension of Meltzer and Richard's (1981) effect to a multi-region economy.

Similarly, we show that people's mobility increases government size when it produces regional median voters that are simultaneously poorer relative to the per-capita income. This happens, for example, when workers who are richer than the

regional median voter move to a region where they become poorer than the local median voter even if their private income has increased. Davies and Winer's (2011) empirical evidence provides a different example. They showed that the US immigration restrictions that came into effect in 1968 for more than two decades reduced Canadian emigration. This, in turn, may have contributed to increase both economic inequality within provinces and the size of government in Canada.

Migration worsens inter-regional redistributive conflicts when the income gap among regional median voters either increases or decreases. In these cases, the impact of migration on centralised public spending is more ambiguous. To illustrate the case, we consider a two-region economy and first assume that inter-regional mobility leads to a lower income disparity between regional median voters. This happens when voters who live in the poorer region and earn an income below that of the regional median voter migrate and acquire the right to vote in the rich region where they still earn a salary below that of the regional median voter. This is the case, for example, of the massive migration of unskilled workers from the South to the North of Italy during the fifties and sixties. In this case, low income workers left the poorer region to earn a better salary in the rich region. Unskilled workers usually have an income to the left of the regional distribution of wealth and, often, to the left of the median voter income. Therefore, if unskilled workers move from poorer to rich regions and their income increases, but remains below that of the median voter of the destination region, the perturbation in the electorate is such that the median voter of the poorer region becomes relatively richer and the median voter of the rich region relatively poorer. We show that when mobility leads to a smaller income disparity in median voters' incomes, public spending increases if the income effect is more relevant for the median voter of the rich region. This is because the reduction of inter-regional redistributive conflicts makes the median voter of the rich region more willing to increase government spending as her private marginal cost declines. However, if the income effect is more relevant for the poorer region, a smaller income inequality leads to more ambiguous results. Specifically, the median voter of the poorer region is now richer and she may obtain an increase in public spending since this is now also the will of the richer median voter. However, the poorer median voter faces a conflict of interest as she has to balance her will to increase public spending with an increase in her private marginal cost.

Inter-regional migration may also worsen inter-regional redistributive conflicts when the income gap between the resulting median voters increases. This happens when the median voter of the rich region is a richer one and that of the poorer region is a relatively poorer one. This can be the case of migration of skilled workers from the poorer to a richer region when workers do not migrate just as soon as they obtain their graduate or postgraduate degrees. In this case, skilled workers of the poorer region first spend sometime in their region where they gain an income above that of the local median voter and then decide to migrate to a richer region where they still earn a salary above that of the regional median voter. We show that if the income effect on the regional median voters is more relevant for the median voter of the rich

region, then government size declines as the rich region is the one that constraints public spending in this case. On the contrary, if the income effect is more relevant for the median voter of the poorer region, then the policy outcome is ambiguous. In this case, the marginal tax paid by the poorer median voter declines and she would be happy to increase public spending. However, this effect has to be strong enough to convince the richer median voter to increase the size of government.

This paper also studies the relation between migration, equity and the efficiency of public spending. We consider two cases. In the first case, both median voters have an income below that of the average income. While, in the second case, the average income is smaller than the rich median voter's income and higher than the poorer's income. According to empirical evidence (see Meltzer and Richard 1981, 1983 and others) we can rule other hypothesis out of the game. We find over-provision of public goods and services when both median voters are poorer than the average income voter. Instead, when the rich median voter is richer than the average income voter we may obtain either over or under-provision. In any case, when we compare the bargaining outcome with the social optimum, we find that migration leads to efficiency in public spending as the distribution of income becomes uniformly distributed within and among regions. Therefore, in this model there is no trade-off between equity and efficiency as they tend to go together.

1.1 *Related literature*

Papers that study the link between migration and redistributive policies under several aspects are mainly based on the choice of the national median voter. There are a few papers that study the issue within a two-jurisdiction context. Most of these papers look at decentralised policy among independent jurisdictions where local median voters set policy in a Nash equilibrium set-up. We advance the existing literature by explicitly developing a framework where jurisdictional median voters cooperate over policy in a unitary state.

Furthermore, most existing literature considers two discrete levels of income associated to skilled and unskilled workers for both natives and migrants. This in turn implies that, the economy may have only two types of median voters and polices. In our paper the distribution of income is continuous and, therefore, migration always changes the jurisdictional median voters and the resulting redistributive policies.

Besides Migration, there are many phenomena that lead to changes in the voting population, which affect redistributive policies. Razin et al. (2002a) considered the case of population aging that affects median voter's policy choices in an overlapping generation model of intra- and intergenerational transfers. Husted and Kenny (1997) found empirical evidence that the expansion of the voting franchise led to bigger government. Acemouglu and Robinson (2000) and many others focused on the case of the extension of the franchise. During the nineteenth century most Western societies extended voting rights, a decision that led to unprecedented redistributive programs. They argue that these political reforms can be viewed as strategic

decisions by the political elite to prevent widespread social unrest and revolution. Political transition, rather than redistribution under existing political institutions, occurs because current transfers do not ensure future transfers, while the extension of the franchise changes future political equilibria and acts as a commitment to redistribution. In other words, redistribution is an end rather than a direct means for maintaining the political status quo.

Regional governments' public policy may have an effect not only on international migration, but also on inter-regional relocations, as the empirical evidence on Canadian data provided by Day and Winer (2012) suggests. The relation between the welfare state as a magnet for skilled and unskilled migration, which is the opposite kind of problem dealt in this paper, was also addressed by numerous authors as Gramlich and Laren (1984) and Borjas (1999). Gramlich and Laren (1984) and Borjas (1999) found empirical evidence that migrants move mainly towards high benefit states. Cohen and Razin (2008), Razin and Wahba (2011, 2012), Razin et al. (2011 cp. 1 and 2) and others argued that welfare, rather than labor, induced migration constraints the growth of the welfare benefits in rich countries. Therefore, migration policies should be implemented to limit unskilled migration as it inflicts a burden on the welfare state. On the contrary, skilled migration should be encouraged as it may help the finances of the welfare state.

The relation between migration and the welfare state level was addressed by Razin et al. (2011, cp. 3) and Hansen (2003). Razin et al. (2011, cp. 3) showed how the generosity of the welfare state can be affected by exogenous skilled and unskilled migration flows. Hansen (2003) analysed the welfare choice of the median voters of two independent countries under three different set-ups: uncoordinated, coordinated and leader-follower models. Immigrants are influenced in their relocation decision by welfare benefits in host countries and do not acquire the right to vote. Therefore, median voters, who never change, set policy by anticipating the impact on their utility of welfare driven immigration.

Armenter and Ortega (2010) ask whether inter-jurisdictional worker mobility has undermined the ability of U.S. states to redistribute income. They consider a multi-jurisdictional economy where both migration decisions and redistribution policies are jointly determined by local fiscal authorities, which are interested in maximizing regional welfare. Taking into account heterogeneous regions and skilled and unskilled workers with idiosyncratic migration costs, they find that worker mobility has induced substantial convergence, but no downward pressure, in tax rates. A main difference between this paper and Armenter and Ortega (2010) is that we consider policy decision made by the central fiscal authority.

Benhabib (1996) points out that economic models that consider the migration policy chosen by the natives population do not take into account that migrants may acquire the right to vote and contribute to decide future public spending. An economic model where migrants vote was developed by Razin et al. (2002b) who found that an increase in the number of migrants can lead to a lower tax burden depending on whether the median voter is a native-born skilled or unskilled person

or a migrant. They consider the fiscal leakage from native-born to the migrants in a one-region model with exogenous and external migration. Mayer (2007) also examines the effect of immigration on the extend of income redistribution via majority voting when immigrants can vote. The tax outcome depends on the size of the native skilled and unskilled groups. The initial amount of redistribution in the economy determines the skill composition of immigrants, which in turn changes the size of skilled and unskilled voters. In our model, we consider the case of internal migration in a multi-region economy without dividing the voting population into skills or homogenous classes.

Razin et al. (2012) develops a dynamic political-economy theory that highlights how skilled and unskilled migration influences inter- and intra-generation redistribution conflicts of a typical welfare system.

Boerner and Silke (2007) focuses on the power of the non-voter on the welfare state level. They argue that in one-jurisdiction economy with emigration the composition of the constituency changes. This increases the political influence of the less mobile part of the population and, at the same time, reduces tax revenues as less people contribute.

Within the purview of a general equilibrium setting comprising individuals, the local and the central governments, Epple and Romer (1991) study how much redistribution occurs when only the local governments can have tax transfer instruments, individuals can move freely among jurisdictions and voters in each jurisdiction are fully aware of the migration effects of the redistributive policies. Their model predicts that local redistribution induce sorting of the population, with the poorest households located in the communities that provide the most redistribution. While the threat of out-migration affects the potential for redistribution, their results suggest that significant local redistribution is nonetheless feasible.

Wildasin (1994) analyses redistribution policies that transfer income between owners of immobile factors of production and workers in a given region. The menu of income distribution possibilities attainable through tax/transfer policy in the presence of labour mobility is characterized. Simple general equilibrium analysis shows that migration can lead to Pareto-inferior outcomes in the destination region if immigrants are the beneficiaries of redistributive transfers. All residents of the destination region may gain, however, if transfer payments are also paid to workers in the source region so as to reduce the level of immigration.

Dolmas and Huffman (2003) study several general equilibrium models in which the agents in an economy must decide on the appropriate level of immigration into the country. Immigration does not enter directly into the native agents' utility functions, and natives have identical preferences over consumption goods. However, natives may be endowed with different amounts of capital, which alone gives rise to alternative levels of desired immigration. They show that the natives' preferences over desired levels of immigration are influenced by the prospect that new immigrants will be voting in the future, which may lead to higher taxation to finance government spending from which they will benefit.

They also show that changes in the degree of international capital mobility, the distribution of initial capital among natives, the wealth or poverty of the immigrant pool, and the future voting rights and entitlements of immigrants can all have a dramatic effect on the equilibrium immigration and taxation policies. Both their model and the empirical evidence support the notion that inequality can lead to reduced immigration. The results also suggest that opposition to immigration can be mitigated by enhanced capital mobility, as well as from removing some of the benefits that immigrants ultimately receive, either in the form of government transfers, or the franchise to vote.

A reason why immigration policy is such a contested issue is that often immigrants acquire the right to vote and, hence, may affect future policies. With the help of a dynamic, general equilibrium model of immigration policy, Ortega (2004) contends that there is a trade-off between skill-complementary immigration and the resulting shift in political power. In each period, a heterogeneously skilled population chooses an immigration policy by majority vote. Voters anticipate that immigration affects the skill premium and the skill composition of the electorate. Ortega shows that a reasonably parameterized version of the model is consistent with the main features of US immigration.

Salmon (2012) remarks the *"need to devote more attention to the effects of mobility on the composition of the electorate"*. In his recent survey, Salmon addresses the issues of mobility manipulation to shape the electorate, which can occur either between the center and peripheries of a metropolitan area (Mingant and Salmon 1986 and 1988, Glaser and Shleifer 2005, Brueckner and Glaser 2008) or between jurisdictions (Caplan 2001, Brosio and Revelli 2003b). Mingant and Salmon (1986, 1988), Glaeser and Shleifer (2005) and Brueckner and Glazer (2008) provide examples of mobility manipulation, which shapes the distribution of the electorate and the incumbent's probability to be re-elected.

Brosio and Revelli (2003b) study the assignment of income distribution policy in the presence of migration. They built their theory by introducing migration in Brosio and Revelli's (2003a) overlapping generations median voter model in a multi-tiered structure of government. In their framework, jurisdictional median voters change over time. However, current median voters may incentivize migration flows that affect policy choice of future median voters.

To the best of our knowledge there does not exist theoretical literature explaining the relation between migration and the size of the public sector in a multi-regional economy when policy is chosen by bargaining among regional representatives.

The paper is organized as follows. The next section defines the benchmark model and reproduces a standard result first due to Meltzer and Richard (1981). Section three discusses the relation between inter-regional migration and majority voting outcome. Sections four and five present the results and six the conclusions. The appendix contains derivations and proofs.

2 The economic framework without migration

Consider two jurisdictions, or regions, comprising a state.[1] In jurisdiction 1 there are N_1 people and in jurisdiction 2 N_2 people, with $N_1 + N_2 = N$ and N normalized to one. There are two goods in this economy, a public good g and a private good y, which can be thought of as individual income or initial endowment. The central government provides the public good uniformly across regions and levies a proportional income-tax t, bounded by $0 \leq t \leq 1$, on individual income y in order to finance the provision of g. We assume, for simplicity, that the unit cost of g is one, so that if the size is g the cost of the public sector is just one times g. Besides, government spending is provided equally to everyone. The government budget constraint is then simply

$$t\overline{y} = g, \tag{1}$$

where $\overline{y} = \sum_{h=1}^{N} y^h / N$ is the average income of the all economy.

Each citizen h has the same quasi-linear preferences over private consumption, $(1-t)\, y^h$, and publicly provided goods g. We can now write the policy preferences of a citizen h as follows,

$$u^h = (1-t)\, y^h + H(g) = (\overline{y} - g)\, \frac{y^h}{\overline{y}} + H(g), \tag{2}$$

where the public spending benefit function $H(g)$ is increasing, smooth concave and satisfies the endpoint Inada condition.

In what follows, we analyse the social optimum solution, the regional first-best policy under majority voting and finally the legislature equilibrium. Then, we study how a change in the distribution of the electorate due to inter-regional relocations or migration impacts on the legislature equilibrium policy.

2.1 The social optimum

We first study the social optimum that can be interpreted as the policy outcome of a benevolent central planner. We suppose that the central planner maximizes the following additive social welfare function:[2]

$$\max_{g^e} \sum_{h=1}^{N} u^h. \tag{3}$$

The efficient government size, g^e, satisfies the familiar Samuelsonian condition,

$$H'(g^e) = \frac{\sum y^h}{\overline{y}}. \tag{4}$$

[1] Here, we focus on the territorial dimension of the model. Alternatively, we can think about two distinct ethnic, religious, incomes or other kinds of groups.

[2] As in Besley and Coate (2003), we assume that the endowments of the median voters and of all the taxpayers are large enough to meet their tax obligations.

Equation (4) states that the social marginal benefit is equal to the social marginal cost in equilibrium. The Samuelsonian condition leads to the following simple equation

$$H'\left(g^e\right) = 1, \tag{5}$$

which means that, in equilibrium, the marginal benefit is equal to the marginal cost.

Clearly, the distribution of income does not influence the central planner's decision. Therefore, any change in either the inter or intra-regional distribution of income does not influence the social optimum outcome.

2.2 The regional first best under majority voting

Individual preferences are concave in policy, implying that every citizen has a unique preferred policy that satisfies the following first order condition

$$H'\left(g^h\right) = \frac{y^h}{\overline{y}}. \tag{6}$$

We assume that voters vote sincerely. Under majority rule, the voter with median income is decisive. Furthermore, income is the only dimension of heterogeneity among citizens. Therefore, voters with incomes below that of the median voter prefer a higher level of public spending and redistribution. On the contrary, voters with incomes above that of the decisive voter desire less public spending and less redistribution.

The distribution of income differs between the two jurisdictions. We denote by y_i, with $i = 1, 2$, the income of the median voter of region i and, to simplify the exposition, assume that median voter 1 is richer than median voter 2, $y_1 \geq y_2$.[3]

The regional median voters form the centralized legislature, which has to determine the size of the public sector. Once the legislature decides the dimension of g, the government budget constraint is automatically determined by equation (1).[4] Accordingly, the tax paid by median voter i is $ty_i = \frac{y_i}{\overline{y}}g$, with $i = 1, 2$. Thus, we write the utility function of median voter i as follows,

$$u_i = y_i - \frac{y_i}{\overline{y}}g + H\left(g\right), \qquad \text{with } i = 1, 2. \tag{7}$$

Policy is chosen by bargaining by the regional median voters in the centralised legislature. Before looking at the bargaining solution, we first consider the first best policy outcome for a regional median voter, which is the unique solution to the following equation:

$$H'\left(g_i^D\right) = \frac{y_i}{\overline{y}}, \qquad \text{with } i = 1, 2. \tag{8}$$

[3] When this condition is violated, we have a symmetric situation. So the assumption does not have any bearing on the end results.

[4] The model could also be extended by introducing a different tax-rate for the two jurisdiction so that the legislature can bargain over g, t_1 and t_2. In this case, budget constraint would be $g = N_1 t_1 \overline{y}_1 + N_2 t_2 \overline{y}_2$, where $\overline{y}_1$ and $\overline{y}_2$ are the mean income of jurisdiction 1 and jurisdiction 2 respectly.

Solution (8) states that if the median voter of region i is, let us say, a non-benevolent dictator she would choose g_i such that her private marginal benefit is equal to her private marginal cost. The non benevolent dictator is a free-rider. She always reduces public expenditure when her private marginal cost increases; that is, $\partial g_i^D / \partial \frac{y_i}{\overline{y}} < 0$. She increases the provision of g when either the mean income increases or her private income declines because this reduces her marginal cost.

If we compare equations (8) and (5) we can conclude that the regional first best under majority voting equals the social optimum when median and mean incomes are the same. Otherwise, we get over provision when $y_i < \overline{y}$ and under provision when $y_i > \overline{y}$.

2.3 The legislature bargaining equilibrium

In this section we will analyze the public policy outcome when decisions are not made by a central planner or a non-benevolent dictator, but directly by the jurisdictional median voters in the central legislature. Here, median voters form a government and choose policy through negotiation.[5]

We assume that if no agreement is achieved, the government will not be able to implement any public good, i.e., $g = 0$.[6] Therefore, the utility each representative obtains in the event of disagreement is $u_i^d = y_i$, with $i = 1, 2$. That is, everybody consumes entirely his or her private income. In order to reach an agreement both median voters must have positive net gains from implementing g. In formula, it must be $u_i - u_i^d > 0$, which implies $-\frac{y_i}{\overline{y}} g + H(g) > 0$.

We denote the net gain from reaching an agreement of median voter i with the symbol ϕ_i, such that

$$\phi_i = u_i - u_i^d = -\frac{y_i}{\overline{y}} g + H(g). \tag{9}$$

The net gain from reaching an agreement is equal to the net private gain minus the net private cost and represents the private net benefit if an agreement is reached on g. The net gain from cooperating on the provision of g is smaller for the richer median voter; that is,

$$\phi_1 \leq \phi_2. \tag{10}$$

Median voters have the same net gains when they have the same income y_i and, hence, the same marginal cost $\frac{y_i}{\overline{y}}$.

Note that the marginal gain from cooperation is equal to the marginal utility, here denoted as Mu_i; i.e.:

$$\frac{\partial \phi_i}{\partial g} = -\frac{y_i}{\overline{y}} + H'(g) = Mu_i. \tag{11}$$

[5] Note that we assume that voters vote sincerely when they elect the regional representatives. Relaxing this assumption would be an interesting extension of this paper, which we leave out for future research.

[6] For a different threat point hypothesis see Giuranno (2010), where regional governments can set policies if the central government cannot decide.

Representatives choose the government size g by bargaining. We show that by maximizing the following Nash bargaining condition:

$$\max_{g} \left(-\frac{y_1}{\overline{y}}g + H(g)\right)\left(-\frac{y_2}{\overline{y}}g + H(g)\right). \tag{12}$$

The first order condition is:

$$\frac{-\frac{y_1}{\overline{y}} + H'(g)}{-\frac{y_1}{\overline{y}}g + H(g)} + \frac{-\frac{y_2}{\overline{y}} + H'(g)}{-\frac{y_2}{\overline{y}}g + H(g)} = 0. \tag{13}$$

Since the two denominators must be positive, it turns out that $Mu_1 < 0$ and $Mu_2 > 0$ because marginal cost is higher for median voter 1. This shows that the bargaining equilibrium is a compromise between median voters' most preferred policies; that is, in equilibrium, median voter 1 would like a smaller provision of g and median voter 2 would like more public consumption.

Furthermore, the ratio

$$\frac{-\frac{y_i}{\overline{y}} + H'(g)}{-\frac{y_i}{\overline{y}}g + H(g)}, \quad \text{with } i = 1, 2, \tag{14}$$

can be interpreted as the elasticity with respect to g of the net gain from bargaining for median voter i. The elasticity measures the percent change in gain from reaching an agreement relative to public spending. It is easy to verify that as $\frac{y_i}{\overline{y}}$ increases the ratio (14) declines. [7] This means that a median voter becomes more rigid in the negotiation as she becomes richer relative to the mean. Therefore, she will be less willing to reach an agreement over g.

3 Regional median voters and inter-regional migration

What happens to the three equilibrium conditions (5), (8) and (13) when the inter and intra-regional distribution of voters change?

The electorate changes for many reasons such as, migration, inter-regional relocation, aging and so on. A simple way to think about this issue is to consider the case of inter-regional relocation or migration, which alters the composition of the electorate without altering the total population. An individual who relocates, and acquires the right to vote in the region where he or she ends up, causes an electoral perturbation that changes the median voters of the two regions. What matters is who becomes the regional median voter after a perturbation in the electorate has taken place. Actually, from equilibrium conditions (8) and (13), it is evident that what really matters is the income of the new regional median voters and the average income or, simply, their ratio $\frac{y_i}{\overline{y}}$, with $i = 1, 2$. For this reason, we denote by $\gamma_i = \frac{y_i}{\overline{y}}$ the "decisive" ratio between the income of median voter i and the mean income of the whole economy.

[7] To see this, one has to consider that $gH'(g) - H(g) < 0$ as proved in Chiang (1984, pp. 192-3).

Following Razin et al. (2002b), we solve the model by assuming a continuous relation between the level of inter-regional migration or relocation, m, and our key parameter, γ, which determines a change in the regional median voters. The level of migration m may have several interpretations. Razin et al. (2002b) consider m as an exogenous binding quota or simply the number of migrants. We can simply think about m as the number of migrants who move from region 1 to region 2 or vice versa, where they acquire the voting right. Specifically, when $m = 0$ the electorate does not change as none moves between regions. As m increases, the median voters of the two regions change; i.e.: $\frac{\partial \gamma_i}{\partial m} \lesseqgtr 0$, with $i = 1, 2$. The sign of $\frac{\partial \gamma_i}{\partial m}$ depends on the ranking in both regions of the income of the individuals who migrate.

Therefore, as in Dolmas and Huffman (2004), for a given value of m, we need to conjecture the inter- and intra-regional distributions of income. To summarise, when individuals migrate between regions and acquire the right to vote in the region of destination, the following four conceivable analytical cases arise:

$$\begin{aligned}
&1)\ \gamma_1'(m) \geq 0 \text{ and } \gamma_2'(m) \geq 0;\\
&2)\ \gamma_1'(m) \leq 0 \text{ and } \gamma_2'(m) \leq 0;\\
&3)\ \gamma_1'(m) \leq 0 \text{ and } \gamma_2'(m) \geq 0;\\
&4)\ \gamma_1'(m) \geq 0 \text{ and } \gamma_2'(m) \leq 0.
\end{aligned}$$

The central planner's equilibrium condition, represented by equation (5), implies no changes in public policy when the regional composition of the voting populace changes. The reason is that the social marginal cost and benefit do not change. Instead, both the equilibrium condition (8) representing the regional median voters' first best and the bargaining equilibrium (13) are affected substantially.

Now, according to equation (8) if a small increase in m leads to a richer median voter in region i relative to the mean, the first best policy outcome for median voter i results in a lower g. On the contrary, if a small increase in m leads to a poorer median voter in region i relative to the mean, the first best policy outcome for median voter i is represented by a lower g as suggested by Meltzer and Richard (1981).

We now study the impact on centralised public spending when there is a change in the electorate in the four conceivable cases.

4 Centralised public spending under inter-regional migration

So far, we have argued that, in a world where income is the only element of heterogeneity among citizens, changes in the composition of jurisdictional electorates modifies the distribution of income inside jurisdictions leading to the election of different jurisdictional median voters. This, in turn, implies that the redistributive conflict between regions assumes different intensities, which depends on whether the new regional pivotal voters have either a lower or higher median-mean income ratio, γ_i.

The following Lemma provides the key to solve the comparative statics for the four conceivable cases.

Lemma 1 *An increase in m leads to a larger public sector when the following relation holds:*

$$\frac{dg^*}{dm} \geqslant 0 \text{ when } \frac{\gamma_1'(m)}{\phi_1^2} + \frac{\gamma_2'(m)}{\phi_2^2} \leqslant 0. \tag{15}$$

The proof is in the Appendix.

Lemma 1 states that the relation between inter-regional migration and the size of the public sector depends on the sign of expression

$$\left(\frac{\gamma_1'(m)}{\phi_1^2} + \frac{\gamma_2'(m)}{\phi_2^2}\right), \tag{16}$$

which is a function of the marginal change in the median voters' income ratio $\gamma_i'(m)$ due to migration and net gain ϕ_i, with $i = 1, 2$. Obviously, we obtain $dg^*/dm = 0$ when $\gamma_1'(m) = \gamma_2'(m) = 0$. To understand the implications of the Lemma it is necessary to study the four conceivable cases separately. We start from the case in which both median voters have become richer relatively to the mean income voter and the opposite case in which they have become relatively poorer.

Proposition 1 *An increase in m that leads to richer regional median voters relative to the national average causes a decrease in the size of g. Conversely, an increase in m that leads to poorer regional median voters relative to the national average causes an increase in the size g. In formulas,*

$$\frac{dg^*}{dm} \leq 0 \text{ when } \gamma_1'(m) \geq 0 \text{ and } \gamma_2'(m) \geq 0 \tag{17}$$

and

$$\frac{dg^*}{dm} \geq 0 \text{ when } \gamma_1'(m) \leq 0 \text{ and } \gamma_2'(m) \leq 0. \tag{18}$$

The proof is a straightforward application of Lemma 1.

The Proposition considers two cases where the change in the voting populace does not worsen the conflict of interest between regional median voters. In the first case, an increase in the number of individuals who move from one region to the other causes the election of relatively richer regional median voters who are both more rigid with respect to public spending. Therefore, they will certainly agree to reduce the size of the public sector. In the second case, both regional median voters are poorer relative to the mean income. Therefore, they will agree to increase redistributive public spending and have a bigger public sector. This Proposition shows that when there is no substantial conflict of interest between median voters the classical Meltzer and Richard (1981) result is replicated in a multi-juridisction economy.

4.1 Migration and inter-regional convergence

What happens when migration worsen inter-regional redistributive conflicts? We answer this question in Propositions 2 and 3 and in Corollary 1.

Proposition 2 *Consider the case where $\gamma_1'(m) < 0$ and $\gamma_2'(m) > 0$ in which an increase in m leads the richer median voter to be a voter with a lower relative income and the poorer median voter to be one with a higher relative income, the following comparative static results apply:*

$$\frac{dg^*}{dm} > 0 \text{ if } |\gamma_1'(m)| \geq |\gamma_2'(m)|, \tag{19}$$

$$\frac{dg^*}{dm} \lesseqgtr 0 \text{ if } |\gamma_1'(m)| < |\gamma_2'(m)|. \tag{20}$$

Besides, for the residual limit cases that have not been treated above, the following comparative statics results apply:

$$\frac{dg^*}{dm} < 0 \text{ if } \gamma_1'(m) = 0 \text{ and } \gamma_2'(m) > 0, \tag{21}$$

$$\frac{dg^*}{dm} > 0 \text{ if } \gamma_1'(m) < 0 \text{ and } \gamma_2'(m) = 0. \tag{22}$$

The proof is based on Lemma 1. Proposition 2 considers first the case where $\gamma_1'(m) < 0$ and $\gamma_2'(m) > 0$. This, in turn, implies that $\frac{\gamma_1'(m)}{\phi_1^2} < 0$ and $\frac{\gamma_2'(m)}{\phi_2^2} > 0$. Given that relation (10) is always satisfied, as we assumed $y_1 > y_2$, expression (16) is certainly negative when $|\gamma_1'(m)| \geq |\gamma_2'(m)|$. On the contrary, the sign of expression (16) is ambiguous when $|\gamma_1'(m)| < |\gamma_2'(m)|$. Furthermore, cases (21) and (22) are straightforward applications of Lemma 1.

In the case under consideration, the incomes of the median voters of the two regions converge as median voter 1, the richer one by assumption, becomes poorer with respect to the mean and median voter 2 becomes relatively richer. In this situation, median voter 1 would like to increase the size of g because her marginal cost is now lower. But, median voter 2 has a conflict of interest. On the one hand she would like to increase g as she can benefit from redistributive public spending. On the other, her marginal cost is now higher and this reduces redistribution in her favour.

Case (19) in the above Proposition states that if the marginal change in γ is weakly greater for the richer median voter 1 , $|\gamma_1'(m)| \geq |\gamma_2'(m)|$, then g increases. A bigger change in the gamma for median voter i means a bigger change in her marginal cost. Therefore, as the marginal cost of the richer median voter declines, her gain from cooperating ϕ_1 increases and she becomes more willing to agree on a larger provision of g. On the contrary, as the marginal cost of the poorer median voter increases, her gain from cooperation ϕ_2 declines and she becomes less willing to agree on a larger g. Since, the change in the marginal cost is more relevant for

the region with the highest median income, the interest of the richer median voter is dominant in the renegotiation and the size of g will increase.

Case (20) states that if the marginal change in γ is bigger for the poorer median voter 2, $|\gamma_1'(m)| < |\gamma_2'(m)|$, then the change in government spending is ambiguous. In order to understand the ambiguity, we recall that according to equilibrium condition (13) median voter 2 always wants more public good provision than median voter 1, in equilibrium. When median voter 2 is richer, she has to balance her willingness to have more public spending with a higher marginal cost, which decreases her gain from public good provision ϕ_2. Therefore, the final outcome is ambiguous and, as usual, depends on the sign of expression (16).

Case (21), instead, leads to an unambiguous result: $\frac{dg^*}{dm} < 0$ when $\gamma_1'(m) = 0$ and $\gamma_2'(m) > 0$. The latter can be seen as a limit situation of case (20). It states that government size declines if income convergence, induced by migration, does not affect the richer median voter. Case (22), can be read as a limit situation of case (19). As expected, it states that government size unambiguously increases if income convergence does not affect the poorer median voter.

Proposition 2 has an interesting Corollary. We noticed that when $\gamma_1'(m) < 0$ and $\gamma_2'(m) > 0$, median voters' income disparity declines. Now, what happens when they actually equalise? We find the full convergence between median voters' incomes leads to opposite results depending on whether we are in situation (19) or (20), as stated in the following Corollary.

Corollary 1 *Consider the case where $\gamma_1'(m) < 0$ and $\gamma_2'(m) > 0$ in which an increase in m leads to median voters' income equalisation, $y_1 = y_2$, then government size increases when $|\gamma_1'(m)| > |\gamma_2'(m)|$ and declines when $|\gamma_1'(m)| < |\gamma_2'(m)|$.*

The proof of the Corollary is straightforward after considering that median voter's income equalisation also leads to median voters' net gains equalisation, $\phi_1 = \phi_2$, in Lemma 1.

According to case (19), government size increases when inter-regional income equalisation occurs mainly because the median voter of the richer region is a poorer one. In this case, inter-regional net gains equalisation is mainly driven by a lower marginal cost for the richer median voter.

On the contrary, case (20) is not ambiguous anymore as $\frac{dg^*}{dm} < 0$ when $y_1 = y_2$. Thus, government size declines when inter-regional convergence occurs mainly because the median voter of the poorer region is a richer one. In this case, inter-regional net gains from reaching an agreement tend to equalise too, but this equalisation is mainly driven by a higher marginal cost for the poorer median voter. Therefore, since the impact on the marginal cost of the richer median voter is less relevant, it will be mutually convenient to agree on a lower g.

For completeness, we also note that when $|\gamma_1'(m)| = |\gamma_2'(m)|$ then $\frac{dg^*}{dm} = 0$ and that cases (21) and (22) apply to the above Corollary.

4.2 Migration and inter-regional divergence

Now, we turn to the last case in which the gap between median voters' incomes and marginal costs widens.

Proposition 3 *Consider the case where $\gamma_1'(m) > 0$ and $\gamma_2'(m) < 0$ in which an increase in m leads the rich median voter to be a voter with a higher relative income and the poorer median voter to be one with a lower relative income, the following comparative statics results apply:*

$$\frac{dg^*}{dm} < 0 \text{ if } |\gamma_1'(m)| \geq |\gamma_2'(m)|, \tag{23}$$

$$\frac{dg^*}{dm} \lesseqgtr 0 \text{ if } |\gamma_1'(m)| < |\gamma_2'(m)|. \tag{24}$$

Besides, for the residual limit cases that have not been treated above, the following comparative statics results apply:

$$\frac{dg^*}{dm} > 0 \text{ if } \gamma_1'(m) = 0 \text{ and } \gamma_2'(m) < 0, \tag{25}$$

$$\frac{dg^*}{dm} < 0 \text{ if } \gamma_1'(m) > 0 \text{ and } \gamma_2'(m) = 0, \tag{26}$$

The proof is based on Lemma 1. Proposition 3 considers the case where $\gamma_1'(m) > 0$ and $\gamma_2'(m) < 0$. This, in turn, implies that $\frac{\gamma_1'(m)}{\phi_1^2} > 0$ and $\frac{\gamma_2'(m)}{\phi_2^2} < 0$. Given that relation (10) is always satisfied, expression (16) is positive when $|\gamma_1'(m)| \geq |\gamma_2'(m)|$. On the contrary, the sign of expression (16) is ambiguous when $|\gamma_1'(m)| < |\gamma_2'(m)|$. Besides, cases (25) and (26) are straightforward.

In the case under consideration, the incomes of the median voters of the two regions diverge as median voter 1 becomes richer with respect to the mean and median voter 2 becomes relatively poorer. In this situation, median voter 1 would like to decrease the size of g because her marginal cost is now higher. Instead, median voter 2 would like to increase g as she can benefit from increased redistributive public spending at a lower marginal cost. In addition, the poorer median voter has a higher net gain from cooperating. While, the net gain is lower for median voter 1, which restricts the set of possible agreements.

The situation where the change in the marginal cost is weakly greater for the richer median voter, case (23) in the Proposition, is straightforward as it leads unambiguously to a smaller public sector. The richer median voter sees her gains to cooperate becoming smaller and uses this to gain bargaining power in the negotiation, which allows her to impose her preference on public policy.

In case (24), where the change in the marginal cost is greater for the poorer median voter, the impact on policy outcome is ambiguous. However, as case (25) suggests, we can establish the sign of the comparative statics when $\gamma_1'(m) = 0$, which unambiguously leads to $\frac{dg^*}{dm} > 0$. Thus, if the income of the richer median

voters does not change, median voter 2 will be able to renegotiate an increase in g^*. Therefore, in case (24), in order to obtain a decrease in g, the interest of the richer median voter to reduce the implementation of g must be sufficiently strong to win the interest of the poorer median voter to increase it. Furthermore, as expected, condition (26) states that the size of g decreases when the income of the poorer median voter does not change.

5 Inter-regional migration and Efficiency

We conclude with a Proposition that compares the bargaining outcome with the central planner solution. In order to do this, we distinguish two cases. In the first case $\overline{y} \geq y_1 \geq y_2$ and in the second case $y_1 \geq \overline{y} \geq y_2$. When $\overline{y} \geq y_1 \geq y_2$ both median voters have income below the average income of the whole economy. This is a standard assumption based on empirical evidence (see Meltzer and Richard 1981 and 1983 and others). However, since we have a model with two regions and two median voters, this assumption could be violated by the richer median voter. For this reason, we also consider the case where $y_1 \geq \overline{y} \geq y_2$, which could apply to some developing countries situations.[8] Empirical evidence suggests that median income is above average income in Chinese cities and in the West Chinese coast and below the mean in the countryside.

Proposition 4 *Changes in m leads to the social optimum policy outcome when regional median voters' income converges towards the mean income of the all economy; i.e. when $\gamma_1 = \gamma_2 = 1$. On the contrary, when $\overline{y} \geq y_1 \geq y_2$ government spending is over-provided and when $y_1 \geq \overline{y} \geq y_2$ government spending can be either over or under-provided.*

The proof is in the Appendix.

According to Proposition 4, any change in the population that leads to a uniform distribution of income between and within regions generates an optimum policy outcome from the social point of view.

Figures 1 and 2 illustrate the Proposition. The coincidence between the bargaining and the social optimum solution is represented by the two thick curves in figures 1 and 2. The two graphs put government size g on the horizontal axes, the bargaining and the central planner's first order conditions and the regional median voters net gains on the vertical axes. Specifically, the vertical curves are the first order conditions and the parabolic curves the net gains. The thick parabolic curve in figures 1 and 2 represent regional median voter's net gains for the case $\gamma_1 = \gamma_2 = 1$. In this case, the net gains are the same for both median voters. The point where the vertical thick line is zero represents the size of g that maximizes surplus for both median voters. This point coincide with the central planner's solution. Thus,

[8] The other situations are either symmetric or empirically non relevant cases, which we do not tackle. The interested reader could easily derive them.

the vertical thick line represents both the central planner's and the bargaining first order conditions. Now, the thin curves in figure 1 show the bargaining situation for the case $\overline{y} \geq y_1 \geq y_2$. Specifically, the smaller thin parabolic curve is the net gain for the richest median voter and the larger thin curve is the net gain for the poorer median voter. Thus, figure 1 shows what happens when we move away from a situation where $\gamma_1 = \gamma_2 = 1$ to a situation where $\overline{y} \geq y_1 \geq y_2$. As we can see, regional median voters do not have the same gain from cooperating anymore. Now, both median voters have a greater convenience to rich an agreement over public spending, but this convenience is bigger for the poorer median voter 2. The central planner' first order condition and, therefore, the social optimum size of g does not change. Instead, the vertical thin lines represents the new bargaining first order condition. As we can see, there are several points where the bargaining first order condition is zero, but only the first thin line is the unique bargaining solution because it lies within the set where the net gains of both regional median voters intersect. The graph shows that when regional median voters have both an income below the average income, public spending is over-provided.

Graph 2 shows a situation where the bargaining outcome leads to under-provision. This graph shows what may happen when the economy moves from a situation where $\gamma_1 = \gamma_2 = 1$ to a situation where $y_1 \geq \overline{y} \geq y_2$. Again, regional median voters now have a different net gain from cooperating. However, differently from figure 1, median voter 1 has now become not only richer than median voter 2, but also richer than the voter with the average income. Therefore, if her convenience from cooperating becomes small enough compared with the situation of the poorer median voter, the size of the public sector can decline, as shown in the particular simulation in figure 2.

6 Conclusion

Inter-regional migration contributes to shaping geographical redistributive conflicts and influences the nature of public spending. This paper presented a model where migrants are not only treated as tax payers and consumers of public goods and services, but also as voters. We pointed out that inter-regional migration changes the distribution of the electorate in the electoral districts and interferes with centralised policy formation.

This paper considered a multi-regional economy where the jurisdictional median voters form a centralized government and negotiate over a common policy. Demographic variations bring about a change the median voters income relative to the mean income of the economy. We see how this change either mitigates or deteriorates inter-jurisdictional redistributive conflicts and how that in turn affects the size of the government.

Our analysis shows that four conceivable cases are possible under inter-regional migration. The first two cases, where jurisdictional median voters become simultaneously richer or poorer, are trivial as voter relocation does not worsen inter-regional

redistributive conflicts. Here, we found that government size increases when regional median voters become poorer and declines when they become richer relative to the mean income. Therefore, in these cases, Meltzer and Richard (1981) classical result replicates also in a multi-region context.

However, the conflict of interest arises when the income gap between regional median voters declines or increases. In the third case, inter-regional migration leads to convergence in regional median voters' incomes. Policy outcome depends on who has incurred the highest shock in the marginal cost. If income convergence occurs mainly because the income, and consequently the marginal cost, of the median voter of the richer region declines, then government size increases. On the contrary, if income convergence occurs mainly because the income and marginal cost of the median voter of the poorer region increases, then policy outcome is ambiguous. However, in the latter situation, in the limit case where migration leads to income equalization between regional median voters government size declines.

In the fourth case, inter-regional migration leads to divergence in the regional median voters. Here, if divergence occurs because the rich median voter becomes a richer one, then government spending declines. While, the size of the public sector is more ambiguous when the divergence occurs because the poor median voter is a poorer one. In this case, the poorer median voter would like to increase the size of the public sector, while the richer median voter would like to shrink it. The final outcome depends on which one of the two conflicting interests dominates.

The paper also studies whether and when inter-regional migration leads to the social optimum policy outcome. We find that migration leads to efficiency when it causes the election of regional median voters whose incomes not only equalise, but also converge towards the average income of the all economy. This occurs, for example, when migration leads to the equalitarian distribution of income between and within regions. On the contrary, we found under-provision when all regional median voters are poorer then the mean income voter. Besides, when a regional median voter is richer and the other one is poorer than the average income voter, we may get either under- or over-provision of public goods and services.

Furthermore, inter-jurisdictional migration shapes both intra- and inter-jurisdictional distribution of income. In the context of this analysis, what we called Meltzer and Richard's (1981) and Giuranno's (2009) effects represent two very special cases. Specifically, inter-regional migration leads to Meltzer and Richard's "intra-regional inequality effect" when intra-jurisdictional income inequality either increases or decreases simultaneously in both jurisdictions without altering inter-regional inequality. Giuranno's "inter-regional inequality effect" occurs when migration flows affect the inter-jurisdictional distribution of income without altering intra-regional inequality. In all those situations where migration affects simultaneously inter- and intra-jurisdictional inequalities, policy outcome changes in directions that are not predictable by Melter and Richard (1981) and Giuranno (2009). Indeed, this paper demonstrated how inter- and intra-regional inequality effects interact when migration leads to either different marginal change in median voters' incomes or when

these changes take opposite signs; that is, our model generates predictions on policy outcome that cannot be made by Melter and Richard's (1981) and Giuranno's (2009) models alone.

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7 Appendix

Proof of Lemma 1. Denote by F the first order condition (13),

$$F = \frac{-\gamma_1(m) + H'(g)}{-\gamma_1(m)\, g + H(g)} + \frac{-\gamma_2(m) + H'(g)}{-\gamma_2(m)\, g + H(g)} = 0. \tag{27}$$

We want to study $\frac{dg^*}{dm} \equiv -\frac{F_m}{F_g}$. It is straightforward to verify that the second order condition is negative, $F_g < 0$, while the numerator is

$$F_m = \frac{-\gamma_1'(m)\,\phi_1 + \gamma_1'(m)\, g \frac{\partial \phi_1}{\partial g}}{\phi_1^2} + \frac{-\gamma_2'(m)\,\phi_2 + \gamma_2'(m)\, g \frac{\partial \phi_2}{\partial g}}{\phi_2^2}. \tag{28}$$

After rearranging we get

$$F_m = \left(\frac{\gamma_1'(m)}{\phi_1^2} + \frac{\gamma_2'(m)}{\phi_2^2} \right) \left(-H(g) + gH'(g) \right). \tag{29}$$

Here, $(gH'(g) - H(g))$ is negative because the marginal benefit is smaller than the average benefit, i.e. $H'(g) < H(g)/g$.[9] We conclude that F_m is positive when $\left(\frac{\gamma_1'(m)}{\phi_1^2} + \frac{\gamma_2'(m)}{\phi_2^2} \right)$ is negative. This proves the Lemma.

Proof of Proposition 4. In order to prove the proposition, we first show that the bargaining solution leads to the efficient solution when $\gamma_1 = \gamma_2 = 1$. In this case, the bargaining first order condition (13) becomes $2\frac{-1+H'(g)}{-g+H(g)} = 0$. This is satisfied when $H'(g) = 1$, which coincides the social optimum solution (5). Second, consider the case $\overline{y} \geq y_1 \geq y_2$. The social optimum condition (5) does not change when the distribution of the electorate changes between regions. On the contrary, condition (18) shows that the provision increases as the median mean income ratios declines for both median voters. Third, consider the case $y_1 \geq \overline{y} \geq y_2$. The impact on g of moving away from the situation $\gamma_1 = \gamma_2 = 1$ is explained by Proposition 3. Therefore g may either increase or decrease.

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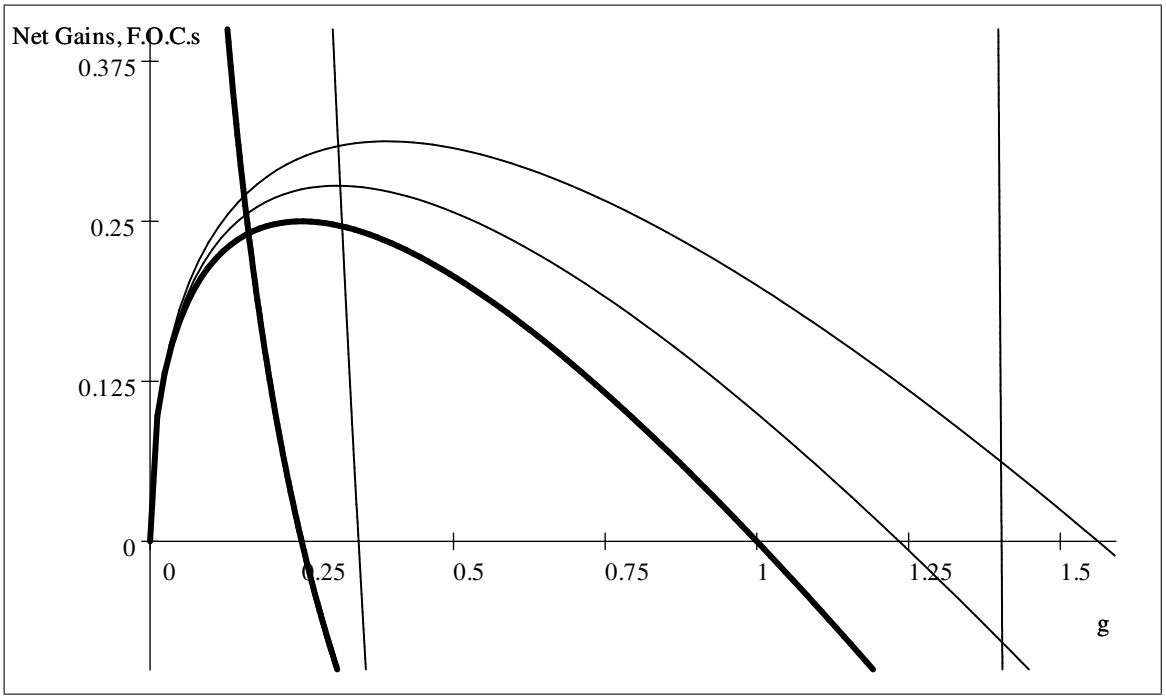

Figure 1: A case of over-provision when $H(g) = \sqrt{g}$; the thick curve shows the bargaining equilibrium and the net gains when $\gamma_1 = \gamma_2 = 1$; the parameters for the thin curves are $\gamma_1 = 0.9$ and $\gamma_2 = 0.8$.

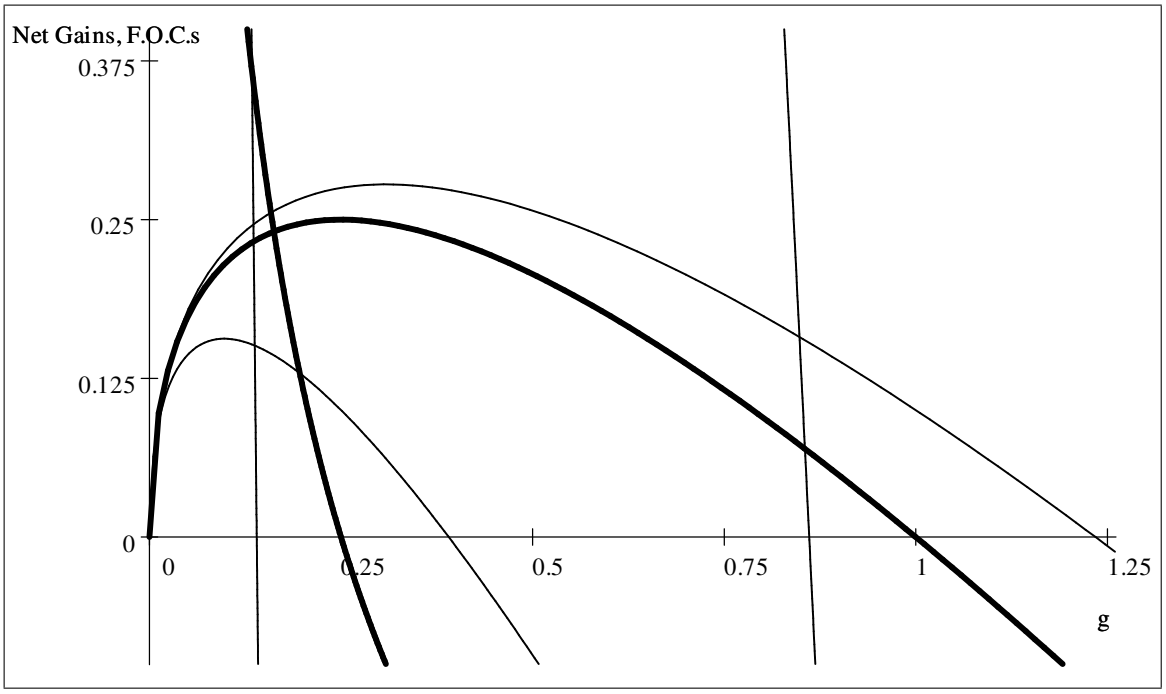

Figure 2: A case of under-provision when $H(g) = \sqrt{g}$; the thick curve shows the bargaining equilibrium and the net gains when $\gamma_1 = \gamma_2 = 1$; the parameters for the thin curves are $\gamma_1 = 1.6$ and $\gamma_2 = 0.9$.