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„Laboratory Federalism: Stability of Social Policy Measures with Asymmetric Countries"

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Contents

Acknowledgements **2**

Contents **3**

1 Introduction **5**

2 The Model **10**

2.1 Structure and Mobility 10

2.2 Redistribution and Migration 10

2.3 Governments' Objectives 12

2.4 The Game 13

3 A Primer in Evolutionary Game Theory **15**

4 Model Analysis **19**

4.1 Properties of Auxiliary Welfare Functions 20

5 Results for the Symmetric Case **23**

5.1 Nash Equilibria 23

5.2 ESS 24

6 Results for the Asymmetric Case **26**

6.1 Nash Equilibria 27

6.1.1 Equal Group Sizes 27
6.1.2 Distinct Group Sizes 31

6.2 ESS 32
6.2.1 Equal Group Sizes 32
6.2.2 Distinct Group Sizes 35

7 A Numerical Example **37**

7.1 Symmetric Equilibria 37
7.1.1 Nash Equilibria 37
7.1.2 ESS 38

7.2 Asymmetric Equilibria 39
7.2.1 Nash Equilibria 39
7.2.2 ESS 40

8 Conclusion **41**

9 German Abstract **43**

References **45**

Curriculum Vitae **46**

1 Introduction

In political debates about the structure of economic entities one approaches the issue of centralism versus federalism very fast. The idea that federalism fosters experimentation, which in turn should result in the finding of good policies is one of the major arguments in this discussion. The following statement by Oates (1999), in which he describes this mechanism, can be seen as the starting point of my investigation:

> *"...[T]here are a variety of policies for addressing social and economic problems. And a federal system may offer some real opportunities for encouraging such experimentation and thereby promoting technical progress in public policy."*

The center of this idea is that diffusion of knowledge and innovations happens without perfect information about the system as a whole. This reasoning is linked very closely to Adam Smith's "invisible hand" that ensures the best allocation of goods and services in a market economy. The decentralized "knowledge" that is inherent in the system as a whole is larger than a single authority's can ever be. And this informational superiority is the reason why a federalist system - at least in theory - is able to find better policies than a central power.

Another feature of laboratory federalism is the minimization of risk. Small scale experimentation ensures that costs of possibly bad policy choices are kept on a low level due to the limited area of influence. Positive effects, on the other hand, are shared by the whole community. This is a text-book example of a positive externality. How large the externality is, depends on the mechanism of knowledge transport. And this is the last important characteristic of laboratory federalism: learning. The importance of how experimental knowledge is passed on to neighbors is highlighted by Schnyder (2011):

> *"I think that the main idea behind the concept of laboratory federalism is that a decentralized system allows to learn more efficiently about the best policies, thanks to a larger sample of small scale experimentation and a larger variety of the politicians' ability, than in centralized states."*

From this we can deduce that the number of experimentation itself is a large promoter of chances to find better policies[1]. The higher the number of "laboratories" the higher are the odds of discovering good policies and also the lower are the costs of experimentation to the whole community. Nevertheless, one has to bear in mind that at some point the smallest size of "laboratories" is reached when it just makes no more sense to further reduce their size without threatening their ability to work as a political entity.

Real world examples of practiced laboratory federalism are Switzerland with its 26 cantons and the Open Method of Coordination (OMC) within the European Union. In both cases we have a large number of independent jurisdictions within an integrated economic area. The current political setup in Switzerland came into existence in 1848. In the federal constitution of 1848 and its amendments and revisions, the cantons' independence from the federal government is defined. Obinger (2002) in his comparative analysis of political systems in Austria and Switzerland summarizes the role of cantons as follows:

> *"The cantons acted as a 'political laboratory' from where the constitutional innovations [...] trickled down to the federal government."*[2]

The result of such experiments in "political laboratories" was that Swiss cantons developed several social policy measures that were not known at the time in other European countries. Amongst these measures were the first public unemployment insurance fund in 1890 and the first pension system for civil servants in 1881[3].

The OMC in the EU even has guidelines on how the experimentation has to be organized, starting from a set of common objectives and indicators to the identification of best practices and adoption of those on the national level. This structure is implemented as an iterative process that ensures constant experimentation, evaluation and implementation of best policies. The OMC has been employed in several areas of social policy measures so far, e.g. European employment strategy, pension, asylum, education, etc.

[1]Schnyder (2011) shows that also the quality of experimentation has a huge impact on the result.

[2]The original German version is: "Die Kantone fungierten damit als 'politisches Labor', von wo aus konstitutionelle Innovationen [...] auf die Bundesebene durchsickerten." See Obinger (2002), page 252.

[3]See Obinger (2002), page 253.

Another very recent example within the European Union is the issue of *Armutsmigration*[4]. As Hans Werner Sinn already pointed out in his 2004 speech at the Munich Economic Summit, the social policy competition in order to avoid attracting all the immigrants from poorer regions in Eastern Europe will lead to the erosion of welfare states in Europe[5]. From his point of view, a competition in social policy measures on a national level will result in an ever decreasing level of social standards since countries do not want to host the poor immigrants. Without taking other considerations into account, the bottom line is that immigrants are too costly. In the end, the welfare state in all of Europe would decrease to a level that only covers basic needs - a condition that none of the current inhabitants can seek to achieve.

This reasoning and the conclusions drawn from it are the starting point of my digging deeper into the matter of competition in social policy measures. What I want to find out is whether the story that Hans Werner Sinn tells is the whole story or whether there can be potential equilibria in a competition that do not require the welfare state to cease to exist.

In order to study this topic it is important to understand how social policy systems behave in the first place. Based on the environment they are embedded in, different outcomes are possible. In other words, one and the same set of policy measures may lead to different results, based on the setting they are placed into. This means that the results of my thesis can provide a benchmark for policy analysis under laboratory federalism. Such an advance of research in the field of Public Economics is one aspect of the motivation for this work.

The other aspect is to advance the knowledge in the field of Evolutionary Game Theory. So far, there has been very little work on evolutionary stability in asymmetric setups with finite populations. It is a pretty new field of research based on the work by Schaffer (1988) and, therefore, it is still open to lots of new insights.

Starting from the hypothesis that laboratory federalism leads to the identification of best policies by means of small scale experimentation and knowledge diffusion, I want to find out how systems of social policies develop and whether they survive in such a competitive environment.

The neoclassical answer to this question would be that starting from an arbitrary system of policies a race to the bottom should follow. Countries would undercut one another in order to achieve higher welfare by saving public money.

[4]This expression captures the problem of poor immigrants trying to settle within the EU in order to take advantage of the high standard of social systems in EU member countries.

[5]See Sinn (2004), page 15.

This money would then be saved by private agents who will see an increase in disposable income and, hence, an increase in utility because of higher consumption.

However, in the Game Theoretic setup that I use, I can show that this does not necessarily have to happen. A moderate level of policy measures will survive - either as a Nash equilibrium or Evolutionarily Stable Strategy (ESS)[6].

The rest of the thesis is organized as follows. In the subsequent section I present the model that I use in order to study the stability of social policy measures in a setup of asymmetric countries. This model is an extension of the model used by Ania and Wagener (2012). In their paper Ania and Wagener (2012) study the stability of social policies in a standard public-finance framework with one symmetric group of countries. My model, in contrast, departs from this symmetric setup. I will introduce two distinct groups of countries that constitute an economic area. All other features of their model remain unchanged. This means that the system of social policy measures is modeled via a framework of redistribution from rich to poor where the welfare recipients are perfectly mobile between the jurisdictions. Due to this mobility, externalities arise from decentralized choices on the level of redistribution. These external effects have an impact on the effectiveness of policy choices in other countries.

Another important feature is that governments are inequality-averse utility maximizers with a preference for redistribution. This seems to be a standard game-theoretic example where players (governments) chose mutually best responses, but *in laboratory federalism* [...] *governments are expected to compare their performance and copy the policy that appears best,* relative *to what other governments do*[7]. The extension to the case of asymmetric groups of countries makes it possible to gain new insights with respect to stability of social policy measures. This means that I can find new Nash equlibria as well as evolutionary equilibria in addition to the ones found by Ania and Wagener (2012). Recent literature on the subject of policy adoption via imitation, such as Coelli *et al.* (2010), has found that competition between states need not necessarily end up in a race to the bottom. This result confirms the predictions of my model.

The next section deals with concepts and definitions that are necessary for the reader to understand the model analysis in section 4.Basically, this means explaining the basic concept of evolutionary stability in finite populations in

[6]To be explained in section 1.3
[7]See Ania and Wagener (2012) p.2

the way that Tanaka (1999) and Schaffer (1988)[8] defined it and relating this concept to the more familiar notion of Nash Equilibrium.

The model analysis is presented in Section 4 and the results in Setions 5 and 6, the most important parts. I will briefly mention the results by Ania and Wagener (2012) in section 5 and then in section 6 focus on the asymmetric case. Instead of one symmetric group of countries, I will consider an economic area consisting of two distinct groups of countries that are symmetric in themselves. Here I will focus on two different cases. In the first scenario both groups will be of equal size and in the other scenario the size of the groups will differ. In order to illustrate that these cases change the results to the symmetric case very much, I will give a short numerical example afterwards.

In the last section I draw my conclusions and summarize the main findings.

[8]This is for the symmetric case. The definition used for the asymmetric case is the one by Tanaka (1999).

2 The Model

As mentioned before, the model that I use in order to study the behavior of social policies under laboratory federalism is an extension of the model used in Ania and Wagener (2012). I will describe the structure of the model in several separate sections. First of all, I want to talk about the structure of the economic area. Then, I will describe process of redistribution and migration between the countries. In the last section, I will describe the governments' objectives and define its utility function (or welfare function) and relate that to the mobility and choices on redistribution in each country.

2.1 Structure and Mobility

The economic system I consider consists of n jurisdictions (or countries) that are divided into two groups $g = h, l$, with $n_g \geq 2$. There is free mobility between any two countries, no matter what group they belong to. Each country is populated by a number of individuals owning immobile assets. This part of the population is called the *rich* and its size is normalized to one. The wealth of the rich is denoted by ω_R^g.

The immobile assets owned by the rich can be taxed by the government. The power of taxation lies with the government of any country and there is no higher power that has influence on taxation in any jurisdiction. The mobile part of the population is called the *poor*. The poor don't own any taxable assets, but they have initial wealth denoted ω_P. It is assumed here that the wealth of rich and poor is the same across countries within a group and that the following holds true: $\omega_R^h > \omega_R^l > \omega_P > 0$.

2.2 Redistribution and Migration

The choice variable of each country $i = 1, 2, ..., n$ is the level of non-negative lump-sum transfer s_i. This transfer is paid to the poor and financed by a lump-sum tax, t_i, on the rich. The amount of mobile poor in country i is denoted by l_i and it is assumed that $0 < l_i < \nu$ holds. $\nu \geq n$ is the aggregate (and constant) size of the poor population in the whole economic area.

Another equation that needs to hold is the following: $s_i \cdot l_i = t_i$, or in other words, governments cannot over- or underspend the money they acquire through the tax on the rich - their budget needs to be balanced. It follows that the spending of disposable income on consumption for the poor and rich in country i takes the following form: $c_i^P = \omega_P + s_i$ and $c_i^{R,g} = \omega_R^g - t_i = \omega_R^g - l_i \cdot s_i$, respectively.

A strategy profile is a vector of policy choices of all countries and it is written as $\mathbf{s} = (s_1, ..., s_n) \in S^n$. This can also be written in the form $\mathbf{s} = (s_i \mid \mathbf{s}_{-i})$, with s_i being the redistribution level chosen by country i and $\mathbf{s}_{-i}$ the vector of policy choices of all other countries or any permutation thereof. Here it is important to introduce another notation as well.

Since all individuals derive their utility solely from consumption, the mobile part seeks to live in the country with the highest level of transfers. When we take i as given, then the highest subsidy chosen by all countries other i is defined as $\overline{s}_i = \max_{j \neq i} s_j$. The set of countries with the most generous transfer scheme excluding country i is written as $M_i(\mathbf{s}_{-i}) = \{j \neq i \mid s_j = \overline{s}_i\}$, given the strategy profile $\mathbf{s} = (s_i \mid \mathbf{s}_{-i})$, and its cardinality is denoted by $m_i(\mathbf{s}_{-i}) = |M_i(\mathbf{s}_{-i})|$.

Due to this structure of mobility and policy decisions, any strategy profile $\mathbf{s}$ causes the poor to relocate. This resulting migration flow vector is denoted by $(l_1(\mathbf{s}), ..., l_n(\mathbf{s}))$. In case of a tie, which means that the highest subsidy is chosen by more than one country, the poor are split equally. Formally, this means that $s_i = s_j \Rightarrow l_i = l_j$. Therefore, the migration flows are captured by the following pattern:

$$l_i(\mathbf{s}) = l(s_i| \, \mathbf{s}_{-i}) := \begin{cases} 0 & \text{if } s_i < \overline{s}_i \\ \frac{\nu}{1+m_i(\mathbf{s}_{-i})} & \text{if } s_i = \overline{s}_i \\ \nu & \text{if } s_i > \overline{s}_i. \end{cases} \tag{1}$$

From this specification it follows that $0 \leq l_i(\mathbf{s}) \leq \nu$ and $\sum_{i=1}^{n} l_i(\mathbf{s}) = \nu$. As long as no s_i changes, the allocation of poor remains unchanged. If some s_i changes, then the mobile poor migrate freely and without any costs between the countries until a state is reached in which equation (1) holds again for the new strategy profile $\mathbf{s}$.

The results of equation (1) with respect to the allocation of poor are the following: In case of equal subsidies in all countries, the poor are shared equally. If some countries choose higher subsidies than other countries, then some countries will host no poor, while those countries with the highest subsidies will host all of them.

Remark: The assumption that the poor are the mobile part of the society in my economic area is arbitrary. One could label them rich and say that those own mobile assets that can flow freely between the countries. Then countries would not decide on the level of subsidies, but would interact in a price competition in taxes on these mobile assets. The story, in this case, is just the other way around and therefore the results would be the same in terms of interpretation.

2.3 Governments' Objectives

The governments I consider are inequality-averse utilitarians who derive utility from consumption only. They are incorporated into the model with a strictly increasing and strict concave utility function $u(c)$ for all $c \geq 0$. Furthermore, this utility function is assumed to be twice continuously differentiable. Two more conditions are that $u(\omega_P) \geq 0$ and that $u(0) < u(\omega_R^g) - \nu \cdot u\left(\omega_P + 1/\nu \cdot \omega_R^g\right)$.

The payoff function for government i which is basically the sum of all its residents' utilities, looks as follows:

$$\pi_i(\mathbf{s}) = l_i(\mathbf{s}) \cdot u(c_i^P) + u(c_i^{R,g}) = l_i(\mathbf{s}) \cdot u(\omega_P + s_i) + u(\omega_R^g - l_i(\mathbf{s}) \cdot s_i). \qquad (2)$$

Taking into account what we know from (1), which is that $l_i(\mathbf{s})$ does not change with permutations of $\mathbf{s}_{-i}$, we can write (2) a little different:

$$\pi_i(\mathbf{s}) = \pi(s_i|\, \mathbf{s}_{-i}) = l(s_i|\, \mathbf{s}_{-i}) \cdot u(\omega_P + s_i) + u(\omega_R^g - l(s_i|\, \mathbf{s}_{-i}) \cdot s_i). \qquad (3)$$

The difference to equation (2) is that (3) is a payoff function for any country i in the argument s_i, given all other governments' choices $\mathbf{s}_{-i}$ or any permutation thereof.

As mentioned before, the poor distribute equally across all countries in the case when all countries choose the same subsidy $s_i = s$ for all i. I see this as the benchmark scenario which can be achieved if countries were able to coordinate and agreed on some common subsidy level s. In this scenario $l_i = \nu/n$, and the optimal level of s would be

$$s^{eff} \quad := \quad \arg\max_{s \in S} \left\{ \frac{\nu}{n} \cdot u(\omega_P + s) + u\left(\omega_R^g - \frac{\nu}{n} \cdot s\right) \right\} = \frac{\omega_R^g - \omega_P}{1 + \nu/n}. \qquad (4)$$

The right-hand side of this equation clearly shows that $s^{eff} < n/\nu \cdot \omega_R^g$ must hold, otherwise the rich would be fully dispossessed. I will call s^{eff} the *efficient symmetric solution*[9] in an egalitarian society. Strategy profiles where the highest subsidy chosen is higher that this benchmark solution of the symmetric income distribution are referred to as states with too much redistribution. Similarly, if $max_{s_i \in \mathbf{s}}\{s_i\} < s^{eff}$, I call this a state with too little redistribution.

2.4 The Game

Taken together, all these model specifications define a game with the following characteristics:

- The players in this game are the countries $i = 1, ..., n$, belonging to group $g = h, l$.
- These countries simultaneously choose subsidies $s_i \in S = [0, k/\nu \cdot \omega_R^g]$.
- Payoffs are determined by migration flows according to equation (1). The payoff functions are given by the governments' utility functions $\pi_i = S^n \rightarrow \mathbb{R}$. For a symmetric representation we can use equation (3) and write $\pi_i(\mathbf{s}) = \pi_i(s_i | \ \mathbf{s}_{-i})$ instead.

Remark: It is important to note that there is an ethical flaw in the governments' payoff function that one cannot leave uncommented. Taking a close look at the expression $l_i(\mathbf{s}) \cdot u(c_i^P) + c(c_i^{R,g})$ in equation (2) makes one realize that it possible to substitute population size for higher welfare. It means that for any given population with some well being, there exists a, usually larger, population of poor only that exhibits a higher payoff. This is the so-called

[9] I leave the label given to this expression by Ania and Wagener (2012) unchanged.

repugnant conlusion[10].The condition $u(0) < u(\omega_R^g) - \nu \cdot u\left(\omega_P + 1/\nu \cdot \omega_R^g\right)$ is a limit to the redistribution that the government wants to have. It ensures that the rich are not being expropriated and, thus, limits the effect of the repugnant conclusion.

An obvious solution to this problem would be to use a welfare function that depends on the average of its inhabitants' utilities. But since I want to compare my results to that of Ania and Wagener (2012), I need to stay with their model specification. The result they get for a welfare function with the average utility in the population leads to a race to the bottom, as the government's focus now lies on the homogeneity and not the size of its population.

[10]See Blackorby *et al.* (2009)

3 A Primer in Evolutionary Game Theory

In order for the reader to follow the model analysis later on, it is important to introduce and explain the notion of evolutionary stability, in particular ESS. The concept of Evolutionarily Stable Strategies was first used in evolutionary biology and is a notion of an equilibrium in games. Introduced by John Maynard Smith and George Robert Price in their 1973 seminal paper *The Logic of Animal Conflict*, the concept was used to describe stability of a continuum population (e.g. bacteria) that is immune to a small fraction of invaders. This means that a strategy is an ESS if, once adopted by a population, it cannot be abandoned if only a sufficiently small fraction of the population chooses any other strategy. In the case of a continuum population, the set of ESS constitutes a subset of Nash equilibria of the same game. Smith and Price (1973) describe the intuition behind an ESS as follows:

> *"... an ESS is a strategy such that, if most of the members of a population adopt it, there is no 'mutant' strategy* [invading the population in a sufficiently small fraction] *that would give higher reproductive fitness."*[11]

In finite populations the case is a little different. Here, one has to consider that those individuals that change their strategy to the mutant strategy[12] necessarily need to leave the group that had adopted the equilibrium strategy. In infinite populations this factor doesn't matter since the group with the equilibrium strategy remains infinite as long as only finitely many individuals change their strategy. In finite populations, the mutant individuals' leaving the group of those that still play the equilibrium strategy has the effect that the notion of ESS becomes a totally different one. In finite populations ESS are, in general, not a subset of the set of Nash equilibria.

The following two definitions of symmetric ESS and Nash equilibria capture the similarity between these two concepts. Superscript d indicates the player choosing a strategy different from the equilibrium strategy, i.e. the mutant player. Technically this looks as follows[13]:

[11] See Smith and Price (1973), page 15.

[12] The biological vocabulary pops up constantly when talking about evolutionary game theory.

[13] See Schaffer (1988).

A strategy is an ESS if:

$$\pi(s|s^d, s, \ldots, s) \geq \pi(s^d|s, s, \ldots, s), \forall s^d \in S. \tag{5}$$

Strategy s is played in a symmetric Nash equilibrium if:

$$\pi(s|s, s, \ldots, s) \geq \pi(s^d|s, s, \ldots, s), \forall s^d \in S. \tag{6}$$

If those two inequalities hold strictly, the profiles are called *strict symmetric* ESS and Nash equilibria, respectively.

Although the concepts seem pretty similar, the difference between these two concepts is also clearly visible. In the case of Nash equilibria, one compares the payoff of a single player before and after a possible deviation. In the case of ESS, only the payoff after a possible deviation matters. Here one compares the payoffs of the deviating player with payoffs of the other players after the deviation has happened[14].

A strategy is an ESS if and only if after a deviation the deviator is not better off compared to the other players after the deviation. Put differently, this means that in the case of ESS, a player maximizes her relative payoff (compared to that of other individuals), while in a Nash equilibrium a player has maximized her absolute payoff given the opponents' strategies.

The next step is to go from the symmetric to the - more general - asymmetric case. Since my model contains only two groups the following definition considers this case only. Although the definitions may look similar to the ones above, the differences are crucial:

[14]The two inequalities can also be seen as the two different aspects a potential deviator has to think about. In the case of a Nash equilibrium, the idea is, "Does a singular change in my strategy benefit me, given the other players' strategies?". In the case of ESS, the reasoning would be of the sort, "How do I affect my and the others' payoffs when I deviate to an alternative strategy, given the other players stay with their strategy? And does it promote my relative performance compared to the others'?".

In a setup of two groups i and j with sizes n_i and n_j, strategy s_i is an ESS if[15]:

$$\pi_i(s_i \mid s_i^d, \underbrace{s_i, \ldots, s_i}_{n_i-2}, \underbrace{s_j, \ldots, s_j}_{n_j}) \geq \pi_i(s_i^d \mid \underbrace{s_i, \ldots, s_i}_{n_i-1}, \underbrace{s_j, \ldots, s_j}_{n_j}) \tag{7}$$

Strategy s is played in a Nash equilibrium if:

$$\pi(s_i \mid s_{-i}) \geq \pi(s_i^d \mid s_{-i}) \tag{8}$$

Equation (7) is directly translated from the definition in Tanaka (1999)[16]. The strategy s^* is an evolutionarily stable strategy. This means that, if all players adopted this strategy[17] it would not be profitable in relative terms for any player to choose an alternative strategy s^d. What is important to note, is that comparison in this case is only done for individuals within the same group. In Tanaka (1999) the whole industry of producing firms is split into two groups, one high-cost and one low-cost group. For the definition in Equation (7), this means that i, j are members of the same group!

In equation (8) superscript * indicates the equilibrium strategy. For the Nash equilibrium definition, this means that s_i^* is a specific strategy (namely, the one that gives this player the highest utility given the strategy profile s_{-i}^*), whereas s_i is any strategy that player i can choose.

Using the same notation, one can one can define Nash equilibria and ESS formally via payoff maximization like this:

Definition 1. *In a game with $\{N, S, \pi\}$, where N is the number of players, S is the common strategy space for all players and π is the payoff function, the strategy profile $\mathbf{s} = (s_1, ..., s_n)$ is said to constitute a* Nash Equilibrium*, if the following holds:*

$$\arg\max_{s_i^d \in S_i} \pi(s_i^d \mid s_{-i}). \tag{9}$$

[15]Once again, the definition shows that for an ESS in a setup with two groups only the intra-group utility comparison is relevant.

[16]Equation (1) in Tanaka (1999)

[17]In general, this strategy is different for the players $i = 1, \ldots, n$, since we assume an asymmetric setup. In this particular example, the profit functions are different for each player - hence the subscript.

This, basically, says that the optimal strategy to choose for player i is the one that maximizes his payoff, given that all the other players choose their optimal strategies. Put differently, in a Nash equilibrium all players simultaneously maximize their absolute payoff.

Starting from equation (7) one can define an ESS strategy as follows:

Definition 2. *An ESS strategy of the game* $\{N, S, \pi\}$ *is the solution to the maximization problem*

$$\arg\max_{s^d \in S} \{\pi(s^d \mid s, \ldots, s) - \pi(s \mid s^d, s, \ldots, s)\}. \tag{10}$$

The maximum of this function is reached when $s^d = s$, where the function takes the value 0. The intuition behind this result is that starting from any ESS profile a mutant player who wants to improve her relative payoff compared to others - which can be achieved by maximizing the difference between payoffs - should as a result of this maximization also play the ESS-strategy. Otherwise, she would be worse off because for any $s^d \neq s \Rightarrow \pi^d < \pi$.

4 Model Analysis

As mentioned above, I will analyze the model with respect to finding Nash equilibria and ESS. Nash equilibria arise when countries simultaneously maximize their payoff function, taking into account the other countries' choices. ESS, on the other hand, will be found when countries compare their relative performance and try to enhance their relative position. This means that they maximize their comparative advantage.

Starting from a Nash equilibrium, a deviator cannot improve her own payoff by single-handedly choosing an alternative strategy $s^d \neq s$. If you start from an evolutionarily stable strategy profile, no deviator can improve her relative payoff compared to the other players.

In order to identify an ESS, one has to compare the payoff of a mutant player, with that of the non-deviating players that stay with their strategy choice. In my asymmetric case with two distinct groups of countries, this means that you compare payoffs only *within a group*. This makes sense, since the deviator seeks to improve his welfare compared to his direct competitors. One further reason for this treatment is that it leaves room for future work, where one can introduce different utility functions, one for each group. In that case it is even more obvious that intra-group utility comparisons have no meaning.

Another characteristic that is important to note is the impact of the small (finite) group size. As mentioned before, a player choosing an alternative strategy has a direct impact on the utility of non-deviators. Thus, a mutant player can improve her relative profit if her own payoff rises by more than that of the other players, or even if she just incurs a smaller loss than the other players. The latter is the reason, why ESS no longer need to be Nash equilibria[18]. This means, that there may exist situations where is it advantageous - in relative terms - to leave a Nash equilibrium.

In order to find Nash equilibria and ESS it is useful to follow the way of Ania and Wagener (2012). Therefore, I introduce families of auxiliary functions, one family for each group of countries:

$$f^g(k,s) = \frac{\nu}{k} \cdot u(\omega_P + s) + u\left(\omega_R^g - \frac{\nu}{k} \cdot s\right), \tag{11}$$

[18]Which is the case in infinite populations - as mentioned above.

where $g = h, l$ is the index for the group of countries considered and $k \in \{1, ..., n\}$ is the number of countries sharing the poor at subsidy level s. Thus, $f^g(k, s)$ can be viewed as the payoff to each one of k countries in group g sharing all the poor. The difference in payoffs for the groups comes via different values for ω_R. In the following I will not prove that the families of these auxiliary functions look as depicted in Figure 1, since this prove is already given in Ania and Wagener (2012).

4.1 Properties of Auxiliary Welfare Functions

Several features of this family of functions are of importance. I will describe them only in the setting of one group of countries - as depicted in Figure (1) - since this environment makes it easier to follow and the properties also hold for two groups of auxiliary functions.

$f^g(k, 0) \geq u(\omega_R^g)$ for every k means that no matter how many countries share all the poor, the baseline utility at $s = 0$ is larger than if any of those countries hosted rich only. This is easy to be explained, since at $s = 0$ all countries set the same subsidy and, thus, we know from (1) that the poor are spread equally across countries. This, in turn, means that every country hosts poor as well as its immobile rich population and since $u(\omega_P) > 0$[19] the sum of the two needs to be larger than $u(\omega_R^g)$.

As shown in Figure 1, $f(k, s)$ is strictly concave in s, given k. At $s = 0$ the functions $f(k, s)$ are strictly increasing at $s = 0$. This is due to the concavity of $u(c)$ and the fact that $w_P < w_R^g$. Taking the first derivative of any such function in the family of auxiliary welfare functions, leads to the first-order condition

$$u'(\omega_P + s_g^*(k)) = u'(\omega_R^g - \frac{\nu}{k} \cdot s_g^*(k)),$$

where

$$s_g^*(k) = \arg\max_{s \geq 0} f^g(k, s).$$

Taken together, these two equations define the value s^* at which each function in the family of $f^g(k, s)$ attains its maximum:

[19]See section 2.3.

$$s_g^*(k) = \frac{\omega_R^g - \omega_P}{1 + \nu/k}. \tag{12}$$

The intuition behind this result is that, if k countries equally share the poor population, their optimal choice[20] would be $s_g^*(k)$. From Figure (1), one can see that the function $s_g^*(k)$ is increasing in k and from equation (12) it follows that the following inequality holds:

$$0 < s_g^*(k) < \frac{k \cdot \omega_R^g}{\nu}.$$

The former property means that redistribution is higher the more countries share the poor population, whereas the latter property ensures that the rich are not fully dispossessed. The value $k \cdot \omega_R^g/\nu$ is the natural border for the level that subsidies can attain when k coordinate their strategy[21]. A special case is when all countries coordinate on the same strategy. In this case we reach the efficient symmetric solution I already characterized in (4), $s_g^*(n) = s^{eff}$.

There are a few last definitions I need to introduce before being able to start the analysis.

Definition 3. *For any $k \in \{1, ..., n\}$ the strictly positive value $\hat{s}_g(k)$ of s is given by*

$$f^g(k, \hat{s}_g(k)) = u(\omega_R^g).$$

Definition 4. *For any $k \in \{1, ..., n\}$ the strictly positive value $\bar{s}_g(k)$ of s is given by*

$$f^g(k, \bar{s}_g(k)) = f^g(1, \bar{s}_g(k)).$$

The values $\hat{s}_g(k)$ identify the subsidy level at which a country is indifferent between hosting ν/k poor or not hosting any poor at all and only receive payoff $u(\omega_R^g)$. The values $\bar{s}_g(k)$ give the levels where a country is indifferent

[20] I.e., the point at which they achieve the highest utility.

[21] This holds as long as countries are required to have a balanced budget.

between paying subsidy $\bar{s}_g(k)$ to ν/k poor and paying the same transfer while hosting all the poor. Ania and Wagener (2012) show that the following order holds true for any group g:

$$s_g^*(1) < \bar{s}(n) < \hat{s}(1) < \hat{s}(2) < ... < \hat{s}(n). \tag{13}$$

This is the chain of critical subsidies that I will refer to later on when calculating the equilibria. Due to the model specifications this ordering needs to hold for any homogeneous group of countries[22].

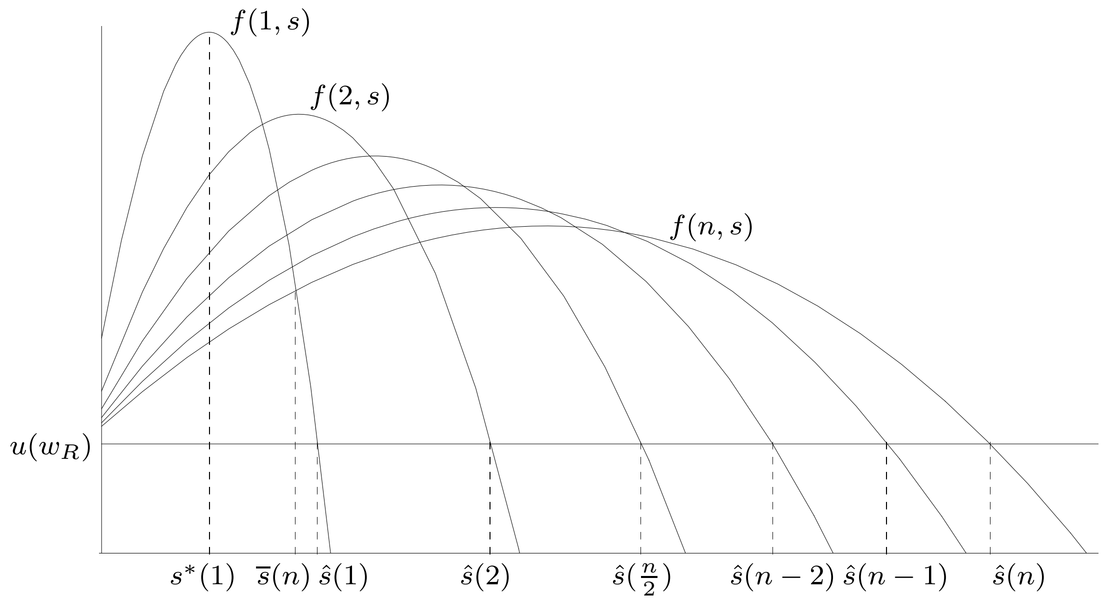

Figure 1: Properties of auxiliary welfare functions $f(k, s)$.

Figure (1)[23] depicts auxiliary welfare functions in the case of a homogeneous group of six countries and clearly indicates the chain of critical subsidies.

[22]See Ania and Wagener (2012).
[23]Source: Ania and Wagener (2012).

5 Results for the Symmetric Case

The following section contains a summary of the results for the case of one homogeneous group of symmetric countries which was studied by Ania and Wagener (2012). This means that $\omega_R^g = \omega_R$ and $n_g = n$. There will be one section with the resuts for Nash equlibria and another one containing results for ESS.

5.1 Nash Equilibria

From Figure (1) one can see that a country's welfare increases at low levels of subsidies and at some point it starts decreasing. This means that at low subsidies the positive welfare effect of attracting immigrants exceeds the costs of redistribution. At some point these costs, however, become too large and the pattern is reversed. One other important feature of the welfare functions is that the more countries coordinate on a given subsidy (the higher k is), the higher is the utility for these countries. I.e. higher levels of subsidy can be sustained, the more countries share the costs of redistribution.

All symmetric pure-strategy Nash equilibria are characterized by the set

$$\Sigma^N = \{\mathbf{s} = (s, ..., s) \mid \bar{s}(n) \leq s \leq \hat{s}(n)\}.$$

The lower limit of the set Σ^N, $\bar{s}(n)$, is the lowest level at which countries can coordinate and where it is not profitable for a single country to deviate. This is easy to prove. If a country were to set a subsidy $s^d > s$, then it would find itself on the line $f(1, s)$ to the right of $\bar{s}(n)$, since it would host all the poor alone. The utility at any point of $f(1, s)$ to the right of $\bar{s}(n)$ is alway below the level $f(n, \bar{s}(n))$. Thus, such a move is never profitable. One important thing to notice is that at all levels $s < \bar{s}(n)$ a one sided increase of the subsidy level is profitable. Thus, $\bar{s}(n)$ needs to be the lower limit of the set of pure-strategy Nash equlibria, i.e. at this point it is not profitable any more for a single country to host all the poor alone.

If, on the other hand, a country would decide to set a subsidy $s^d < s$, it would not host any poor at all. Therefore its utility would be $u(\omega_R)$. Since $f(n, s)$

is always higher than $u(\omega_R)$ to the left of $\bar{s}(n)$ this move is also never profitable.

The upper limit of the set of all pure-strategy Nash equilibria Σ^N is $\hat{s}(n)$. The proof of this is similar to the one above. A single-handed decrease of the subsidy level to $s^d < s$ is not strictly profitable since it earns you the same utility as staying with $\hat{s}(n)$, namely $u(\omega_R)$. Increasing the subsidy to $s^d > s$ will lead to a utility level strictly lower than before. Thus, such a move is also never profitable.

To prove that $\hat{s}(n)$ is the upper limit of the set Σ^N means proving that this level is the last level where it is profitable for all the countries to coordinate. Coordination of all countries means that each country earns utility according to the function $f(n, s)$. At all points to the right of $\hat{s}(n)$ the following holds: $f(n, s) < u(\omega_R)$. This means that countries earn a lower profit at these subsidy levels than they would if they chose a lower level and host no poor at all. At all points to the left of $\hat{s}(n)$ the reverse holds true and at this subsidy level countries are indifferent between hosting no poor or staying with the other countries at $\hat{s}(n)$. I.e. this is the highest level of subsidies that countries would want to coordinate on.

5.2 ESS

For the analysis of ESS it is again very useful to look at Figure (1). The main result is similar to that of Nash equilibria:

All ESS are contained in the interval

$$S^E = [\hat{s}(1), \hat{s}(n-1)].$$

Strategies in this interval also satisfy the criteria for strategies played in a Nash equilibrium. This means that most of the Nash equilibria are also evolutionarily stable, but some of the subsidy levels closer to the border are not contained in S^E. The lower boundary of S^E is $\hat{s}(1)$. At this level a single mutant country cannot destabilize the system. To see why, one needs to compare the payoffs after a deviation to some $s^d \neq s$. If a country chose a subsidy $s^d < s < \hat{s}(1)$ it would not attract any poor at all and, thus, receive payoff $u(\omega_R)$. The other countries would then be left with utility $f(n-1, \hat{s}(1))$, which is higher than $u(\omega_R)$. Therefore, all levels of $s < \hat{s}(1)$ cannot be ESS.

This means that all the Nash equilibria between $\bar{s}(n)$ and $\hat{s}(1)$ are not evolutionarily stable. At these Nash equilibria it does not pay off in absolute terms to deviate to some $s^d > s$, since the costs of hosting all the poor are higher than the rewards of hosting them. But in relative terms the deviating country earns an advantage over the other countries since the costs they bear after this deviation are larger than the loss of the deviant country. At $\hat{s}(1)$ a country is exactly indifferent between hosting all the poor and not hosting poor at all. I.e. from this subsidy level on, it does not even pay in relative terms to deviate to a higher subsidy.

The upper boundary of the set of ESS is $\hat{s}(n-1)$. Starting from any subsidy $s > \hat{s}(n-1)$, a deviant choosing a lower subsidy level will gain a relative advantage over the other countries. Choosing $s^d < s$ earns the deviant a payoff of $u(\omega_R)$ since it will not host any mobile poor. The other countries are then left with utility $f(n-1, s)$ which is lower than $u(\omega_R)$ to the right of $\hat{s}(n-1)$. Thus, at $\hat{s}(n-1)$ countries a single deviant is indifferent between choosing a lower subsidy $s^d < s$ or staying with the others at s. I.e. this is the highest subsidy that can be an ESS[24].

Within S^E no single deviator can increase its relative position. Let's say - starting from $s \in [\hat{s}(1), \hat{s}(n-1)]$ - a country chooses to alter its strategy to some $s^d ys$. This country will now host no poor and receive utility $u(\omega_R)$. All the other countries receive $f(n-1, s) > u(\omega_R)$ after this deviation. Thus, the deviant is strictly worse off than its competitors. If a country would choose a subsidy $s^d > s$, the resulting payoff would be $f(1, s^d) < u(\omega_R)$, while the others receive $u(\omega_R)$. Also in this case the deviant is strictly worse off compared to the other countries.

[24] At $\hat{s}(n-1)$ the ESS is not strict since the payoff of the deviant and that of the other countries are equal.

6 Results for the Asymmetric Case

Compared to the symmetric case, the case of two distinct groups of countries gives rise to more different scenarios. The basic analysis, however, follows the same pattern as in the symmetric case.

First of all I will now define in what way the asymmetry exactly enters the model. In the first part, the asymmetry is generated only via different values of ω_R^g. This means that the two groups of countries only differ with respect to their initial wealth. The utility function and all other features remain unchanged compared to the symmetric case. In addition, also the group size will be equal, i.e. $n_h = n_l$. This is already enough asymmetry in order to achieve all possible orderings of critical subsidies, given the rules on these subsidies described above.

One example of a possible ordering of these values and the corresponding welfare functions for the two groups is given in Figure (2). All other scenarios could also be constructed in the same way by changing the model parameters. Therefore, it is not necessary to also change the utility function for further asymmetry. As long as the properties of the welfare functions remain unchanged, the analysis would lead the same results and further complication is not necessary.

In the second part, I will increase the asymmetry of the two groups by introducing different group sizes, i.e. $n_1 \neq n_2$. Here again, the analysis will be the same as before and the results are a generalization of the results obtained for groups of equal size.

The first result, that is noteworthy is that in a setup with two groups and equal ω_R, no asymmetric equilibria are possible. I.e. it is not possible for some countries to host poor while the other group of countries sets a lower subsidy. This is because equally wealthy countries set the same subsidy in an equilibrium[25]. The reason for this is that it in some scenarios it would be profitable for countries that do not host poor to set the same subsidy as those countries that already set the higher subsidy. In other scenarios, where the countries hosting the poor set too high a subsidy, it is profitable for them to deviate to the lower subsidy.

[25]See Ania and Wagener (2012).

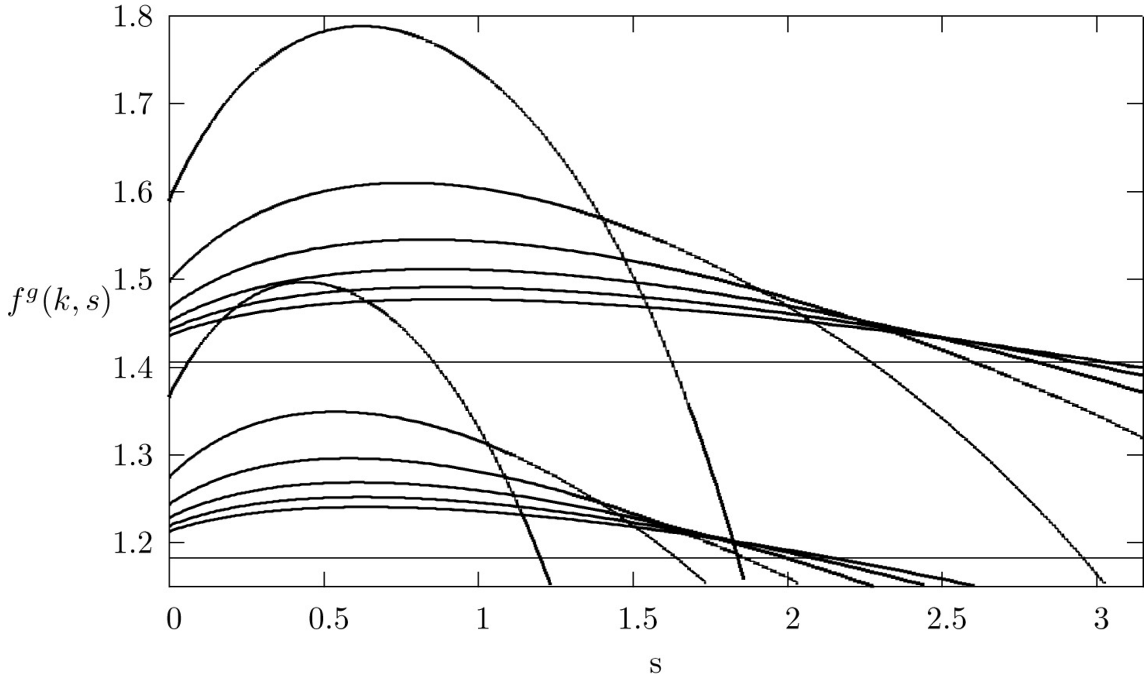

Figure 2: Two groups of countries with $\omega_R^1 \neq \omega_R^2$.

6.1 Nash Equilibria

6.1.1 Equal Group Sizes

This section considers the case where the one homogeneous group studied in Ania and Wagener (2012) is divided into two groups of equal size n but with different values of initial wealth ω_R. The first important result is that all the symmetric Nash equilibria from section (5.1) still exist in this setting. All symmetric profiles where countries set subsidies in S_Y are Nash equilibria. This set is given by

$$S_Y = [\max\{\bar{s}_l(2n), \bar{s}_h(2n)\}, \min\{\hat{s}_l(2n), \hat{s}_h(2n)\}].$$

Proof. Starting from any symmetric strategy profile $\mathbf{s} = (s, \ldots, s)$, countries in group h and l receive utilities $f^h(2n, s)$ and $f^l(2n, s)$, respectively. If one

deviant country in any of the groups, say group h, decided to set a subsidy $s^d < s$, it would now host no poor at all. Thus, its payoff would be $u(\omega_R^h)$. To the left of $\hat{s}_h(2n)$, this value is always smaller than $f^h(2n, s)$ and a move in this direction is,thus, not profitable. The same holds true for the other group. Hence, to the left of $\min\{\hat{s}_l(2n), \hat{s}_h(2n)$ this is not profitable for any country. A deviation of a country in group h to some $s^d > s$ would make it the only host of the poor community with payoff $f^h(1, s^d)$. This is not profitable for subsidies larger than $\bar{s}_h(2n)$. Again, the same is true for group l and taken together, these conditions define the set S_Y.
Strategy profiles outside of this range, cannot be Nash equilibria. Assume that we started from the symmetric profile $\mathbf{s}$, with $s < \bar{s}_i(2n)$ for some i. Then there is the possibility for a country in at least one group to achieve higher utility by a single deviation. This deviation to some $s^d > s$ would make it better off with new payoff $f^g(1, s^d) > f^g(2n, s)$. As long as $s < \max\{\bar{s}_l(2n), \bar{s}_h(2n)\}$, a profitable deviation of one country is possible - namely to some $s < s^d < \max\{\bar{s}_l(2n), \bar{s}_h(2n)\}$. The same line of reasoning applies to symmetric strategy profiles $\mathbf{s}$, with $s > \hat{s}_g(2n)$ for some g. In this case, deviations to $s > s^d > \hat{s}_g(2n)$ of a country in group g are always profitable, i.e. $u(\omega_R^g) > f^g(2n, s)$.

□

In order for these Nash equilibria to exist, S_Y needs to be non-empty. This is the case as long as $\min\{\hat{s}_l(2n), \hat{s}_h(2n)\} > \max\{\bar{s}_l(2n), \bar{s}_h(2n)\}$. Since the asymmetry enters this model only via different values of ω_R for the two groups, this condition simplifies to:

$$\hat{s}_l(2n) > \bar{s}_h(2n).$$

This condition is fulfilled as long as the two groups of countries are not too different, i.e. as long as the expression $\omega_R^h - \omega_R^l$ is not too large[26].

When taking a close look at the auxiliary welfare functions, one finds that critical subsidies of the wealthier group of countries are larger than the respective critical subsidy in the other group. Thus, the set S^Y can be written in a more compact form:

$$S_Y^* = [\bar{s}_h(2n), \hat{s}_l(2n)]. \tag{14}$$

[26]Intuitively, this result is not very striking. It merely says that symmetric Nash equilibria are possible as long as the game itself is not too asymmetric.

Remark 1. The conditions on the border of the set S_Y are not independent. If the lower (higher) border is determined by one group, then the other group determines the higher (lower) border. This is due to the fact that asymmetry only arises from different values of ω_R and utility functions are the same for both groups.

Before describing the set of strategy profiles that constitute an asymmetric equilibrium, one first needs to say something about the structure of these equilibria. Asymmetric equilibria in this model need to be of the form $\mathbf{s} = (\underbrace{s^h, \ldots, s^h}_{n_h}, \underbrace{s^l, \ldots, s^l}_{n_l})$. This means that asymmetric equilibria are asymmetric with respect to the two groups, but intra-group symmetric. This intra-group symmetry is due to the model structure. By considering one group only one is back at the model in Ania and Wagener (2012), where it is shown that Nash equilibria need to be symmetric.

Beside the symmetric Nash equilibria shown above, there also exist asymmetric ones. This means that there are Nash equilibria where some countries host all the poor and the other countries host no poor. I.e. under certain conditions, a strategy profile of the form $\mathbf{s} = (s^h, \ldots, s^h, s^l, \ldots, s^l)$, with $s^h > s^l$, can be a Nash equilibrium.

At such a profile no country has an incentive to deviate, no matter whether it is in the group with the high or the low subsidy. Such a Nash equilibrium is possible if the following condition holds:

$$s_i \in [\max\{\hat{s}_j(n+1), \bar{s}_i(n)\}; \hat{s}_i(n)], s_j \in [0, s_i). \tag{15}$$

Proof. a. There are two groups of countries, l and h, with equal size n. We start from a strategy profile of the form $\mathbf{s} = (s^h, \ldots, s^h, s^l, \ldots, s^l)$ and say that $s^l < s^h$. Countries in group l choose s^l, whereas countries in group h choose s^h and $\omega_R^h > \omega_R^l$. If country i with subsidy s^l chose to deviate to some $s^d < s^l$ the resulting payoff would be the same as before, namely $u(\omega_R^l)$ since country i won't host any poor. In fact, all deviations to some $s^d < s^h$ have the same effect and would not change the payoff of country i. A deviation of country i to $s^d = s^h$ is also not profitable as long as the resulting payoff $f^l(n+1, s^h) \leq u(\omega_R^l)$, which is equivalent to saying $\hat{s}_l(n+1) \leq s^h$ needs to hold. Deviating to some $s^d > s^h$ would mean that country i would host all

the poor. In the case of $s^h \geq \hat{s}_l(1)$ this is never profitable for this country. This condition, however, is already ensured by the previous condition, since $\hat{s}_l(n+1) > \hat{s}_l(n)$.
If country j with subsidy s^h were to deviate to some $s^d < s^h$, its new level of utility would be $u(\omega_R^h)$ which is smaller than or equal to $f^h(n, s^h)$ as long as $s^h \leq \hat{s}_h(n)$ holds. Deviating to $s^d > s^h$ would result in payoff $f^h(1, s^d)$ which is lower than $f^h(n, s^h)$ when $s^h \geq \bar{s}_h(n)$.

b. Given the same parameters, let's assume countries in group l were to choose s^h and countries in group h chose s^l. Since the ordering of critical subsidies would be the same, but the conditions for equilibria to exist would be exactly the opposite as in *a*, it is impossible for asymmetric Nash equilibria to exist in this case. This is because $[\max\{\hat{s}_l(n+1), \bar{s}_h(n)\}; \hat{s}_h(n)]$ and $[\max\{\hat{s}_h(n+1), \bar{s}_l(n)\}; \hat{s}_l(n)]$ cannot be both non-empty at the same time.

□

This proof shows that it is possible for asymmetric Nash equilibria to exist. From *a* and *b* it follows that in an asymmetric Nash equilibrium only one group - namely the one with higher ω_R - can afford to host all the poor and thus pay the higher subsidy s^h. Thus, the conditions in (16) change to:

$$s^h \in [\max\{\hat{s}_l(n+1), \bar{s}_h(n)\}; \hat{s}_h(n)], s^l \in [0, s^h). \tag{16}$$

What is important to note here, is that there is no condition on s^l except for the one that $s^l < s^h$. The interval for subsidies that can constitute an asymmetric Nash equilibrium is non-empty as long as the two groups of countries are asymmetric enough[27].

When comparing the conditions necessary for symmetric and asymmetric Nash equilibria to exist, one can see that they are closely related. In fact, it is possible that the two sets that contain the possible equilibrium strategies can have a common border (either the upper or the lower one)[28]. Another observation is that the subsidy s^h in the asymmetric equilibrium is always higher than the subsidy in the symmetric equilibrium.

[27]See Figure 2. In cases where the asymmetry is not very pronounced, the set can be empty, i.e. $\hat{s}_l(n+1) > \hat{s}_h(n)$. This confirms the intuition that asymmetric equilibria should only arise in a sufficiently asymmetric environment.

[28]But the two sets can never be congruent. See Remark 1.

This means that when going from a symmetric to an asymmetric equilibrium, the subsidy level of the remaining countries hosting the poor needs to rise. In other words, the total sum of money spent on the poor is not directly proportionate to the number of countries hosting the poor. What is remarkable, though, is the fact that there are asymmetric equilibria in which both groups of countries set higher subsidies than in the symmetric equilibrium[29].

When starting from a symmetric setup where only symmetric equilibria are possible and then slightly increasing the degree of asymmetry, the set of possible equilibria is changing. At some critical degree of asymmetry, suddenly asymmetric Nash equilibria are possible in addition to the symmetric ones. As one increases the difference between the two groups further, the symmetric equilibria at some point cease to exist and in very asymmetric environments only the asymmetric equilibria are possible. But, no matter what setup is used, there is always a set of possible Nash equilibria, symmetric, asymmetric or both[30].

Taking a look at Figure 2, one can see that symmetric as well as asymmetric Nash equilibria can coexist. As mentioned in the Proof, only when countries in the group with higher ω_R set s^h can there be an asymmetric equilibrium[31].

6.1.2 Distinct Group Sizes

For $n_h \neq n_l$, the analysis is practically the same as above and the results are merely a general representation of the results for equal group sizes. The first important result is that in this case the symmetric equilibria from the previous sections still hold[32]. From this it follows that in a symmetric Nash equilibrium subsidies need to lie in the interval

$$S'_Y = [\bar{s}_h(n_l + n_h), \hat{s}_l(n_l + n_h)].$$

When it comes to the analysis of asymmetric Nash equilibria, one has to differentiate between two cases. First, when the group of countries with high ω_R

[29] This is due to the fact that countries do not host any poor as long as they choose $s \in [0, s^h)$.

[30] In setups with a huge degree of asymmetry, the set for possible asymmetric equilibria is trivially non-empty since $\hat{s}_l(n+1) < \bar{s}_h(n) < \hat{s}_h(n)$ holds true.

[31] The ordering of critical subsidies allows only for the wealthier countries to set the higher subsidy in an asymmetric equilibrium.

[32] The only difference in this case is that instead of $2n$ the total number of countries is $n_l + n_h$.

is larger, intuition tells us that asymmetric equilibria should still be possible, since the overall wealth advantage over the poor countries is now larger than in the case where $n = n_l = n_h$. The richer countries should in this setup still be able to host the poor on their own and pay for their benefits.

If the group sizes are the other way round, the intuition is not so clear any more. Therefore, a precise analysis is needed.

The set of profiles where rich countries set strategies in the following interval characterizes Nash equilibria in this scenario[33]:

$$s^h \in [\max\{\hat{s}_l(n_h+1), \bar{s}_h(n_h)\}; \hat{s}_h(n_h)], s^l \in [0, s^h). \tag{17}$$

The expression where the difference in group sizes enters is $\hat{s}_l(n_h+1)$. This is a critical subsidy of group l, depending on the number of countries in group h. In cases of "enough" asymmetry in ω_R this expression is smaller than $\hat{s}_h(n_h)$ and asymmetric equilibria are possible, i.e. the above set is non-empty[34].

For $n_h > n_l$ this set is non-empty[35], but for $n_h < n_l$ the case is not so clear. When analyzing Figure 2, one can find that the set is non-empty in cases where the difference is group size is not too large and the difference with respect to ω_R is large enough. The idea behind this result is that the rich countries together need to be sufficiently wealthy to host all the poor on their own in order for asymmetric equilibria to exist.

6.2 ESS

6.2.1 Equal Group Sizes

Results similar to Nash equilibria also hold true for ESS. First of all, the symmetric ESS from section (5.2) survive in a slightly modified way. This new set of symmetric ESS in the case of two groups of countries is given by:

$$E_A = [\max\{\hat{s}_l(1), \hat{s}_h(1)\}; \min\{\hat{s}_l(2n-1), \hat{s}_h(2n-1)\}].$$

[33]The proof is a generalization of the previous proof with equal group sizes.
[34]Note that the case of equal group sizes is a special case of this setup.
[35]See Figure 2.

Proof. Starting from a symmetric profile $\mathbf{s} = (s, \dots, s)$, countries in group l and h receive payoffs $f^l(2n, s)$ and $f^h(2n, s)$, respectively. If some deviant country i in group l were to choose an alternative strategy $s^d < s$, the resulting payoff for this country would be $u(\omega_R^l)$, while all other countries in the same group would be left with payoff $f^l(2n-1, s)$. This move is not strictly profitable as long as $s \leq \hat{s}_l(2n-1)$. Should country i set an alternative strategy $s^d > s$, its new payoff would amount to $f^l(1, s^d)$. Compared to the payoff of the other countries in this group, $u(\omega_R^l)$, country i's payoff is not larger as long as $s \geq \hat{s}_l(1)$. The same conditions also hold true for countries in the other group. Therefore, in the set of symmetric ESS all these conditions need to hold simultaneously. The resulting set is E_A.

□

For symmetric equilibria to exist, this set needs to be non-empty. This is the case when $\min\{\hat{s}_l(2n-1), \hat{s}_h(2n-1)\} > \max\{\hat{s}_l(1), \hat{s}_h(1)\}$. In other words, as long as the two groups of countries are not too different with respect to their initial wealth ω_R, symmetric ESS can exist. Again, as in the analysis of Nash equilibria, the intuition behind this result is that symmetric evolutionary equilibria can only occur in a setup where the two groups are similar enough.

The general description of E_A can be written in a more compact way by indicating the wealthier and the poorer group:

$$E_A^* = [\hat{s}_h(1), \hat{s}_l(2n-1)]. \tag{18}$$

In addition to these symmetric ESS, there are also evolutionarily stable strategies where only one group of countries hosts all the poor. I.e. there exist strategy profiles go the form $\mathbf{s} = (s^h, \dots, s^h, s^l, \dots, s^l)$ with $s^h > s^l$, where all countries in one group set strategy s^h and the countries in the other group set strategy s^l. At such a profile no country can increase its relative performance, compared to members of its own group, by deviating to another strategy.

The conditions for asymmetric ESS with equal group sizes n are given by

$$s_i \in [\max\{\hat{s}_j(n+1), \hat{s}_i(1)\}; \hat{s}_i(n-1)], s_j \in [0; s_i].$$

In order to follow the proof below, it is necessary to keep in mind that only intra-group payoff comparisons are relevant when analyzing ESS[36].

Proof. *a.* We start from a strategy profile of the form $\mathbf{s} = (s^h, \ldots, s^h, s^l, \ldots, s^l)$, where countries in group l choose s^l and countries in group h choose s^h. Both groups are of equal size n. In this scenario the baseline payoffs for countries in the two groups are $u(\omega_R^g)$. A deviation of country i with subsidy s^l to some $s^d < s^h$ would not change any payoffs. A deviation of this country to $s^d > s^h$ would make it the sole host of all the poor and result in payoff $f^l(1, s^d)$ which is smaller or equal to the payoff of all the others after this move, $u(\omega_R^l)$, as long as $s^h \geq \hat{s}_l(1)$. If, on the other hand, country i were to choose $s^d = s^h$ its new payoff would be $f^l(n+1, s^h)$. This value is smaller or equal to $u(\omega_R^l)$ - the payoff of all other countries in group l - as long as $s^h \geq \hat{s}_l(n+1)$. Note that this condition guarantees the above condition $s^h \geq \hat{s}_l(1)$ trivially.
If some country in group h would choose an alternative strategy $s^d < s^h$, the resulting payoff $u(\omega_R^h)$ would be smaller or equal to the payoff of all the other countries in this group - $f^h(n-1, s^h)$ - only if $s^h \leq \hat{s}_h(n-1)$. An alternative deviation to $s^d > s^h$ would give country j a utility level of $f^h(1, s^d) \leq u(\omega_R^h)$. This inequality holds for all $s^h \geq \hat{s}_h(1)$. Taken together, these conditions define the above set of possible ESS.

b. Keeping the setup unchanged, I now assume that countries in group l set s^h and countries in group h choose strategy s^l. Since the ordering of critical subsidies would not change, but the conditions for ESS to exist would be exactly the opposite as in *a*, it is impossible for asymmetric ESS to exist in this case. Not both sets $[\max\{\hat{s}_l(n+1), \hat{s}_h(1)\}; \hat{s}_h(n-1)]$ and $[\max\{\hat{s}_h(n+1), \hat{s}_l(1)\}; \hat{s}_l(n-1)]$ can be non-empty at the same time.

□

a and *b* together with what we know about the chain of critical subsidies from Ania and Wagener (2012) show that ESS can exist only if the wealthier countries set the higher subsidy s^h. Intuitively this makes sense. It merely says that, only the group that can afford to host all the poor will do so in an evolutionary equilibrium. In the case of equal group size this makes it possible to simplify the interval of s^h for ESS to exist:

The interval for s^h can either be empty or non-empty, depending on the model parameters. These parameters define the chain of critical subsidies characterized in section (6) and, thus, tell whether $\hat{s}_h(n-1) > \max\{\hat{s}_l(n+1), \hat{s}_h(1)\}$ holds or not. Since all possible sequences of critical subsidies can be produced via asymmetry in the value of ω_R for the two groups of countries, there are

[36] See section (4).

some scenarios where the interval is non-empty, i.e. there are cases where ESS of the form $\mathbf{s} = (s^h, \ldots, s^h, s^l, \ldots, s^l)$ exist.

When comparing the sets in which asymmetric and symmetric ESS exist, one can see that they are related[37]. In cases where the asymmetry is not very large, asymmetric and symmetric ESS can coexist. The two sets can even have one common border (either the upper or the lower one).

As in the case with Nash equilibria, for asymmetric ESS to exist the two groups of countries need to asymmetric enough with respect to ω_R. Starting from a symmetric environment, only symmetric ESS are possible. By slightly increasing the asymmetry, at some point symmetric and asymmetric equilibria may coexist. As the asymmetry becomes too pronounced, the symmetric ESS cease to exist and only asymmetric ones survive.

Remark 2. Since the only condition on s^l is that $s^l \in [0, s^h)$, there are infinitely many asymmetric equilibria for every s^h that satisfy the criteria for asymmetric ESS. In other words, as long as the higher of the two subsidies satisfies some criteria it does not matter on what the other countries coordinate or whether they coordinate at all. There could even be a spectrum of subsidies that are chosen by countries in group l. As long as all of this subsidies are in the interval $[0, s^h)$, the basic structure of the strategy profile remains unchanged and the proof still holds. The "most asymmetric" ESS would, thus, be the strategy profile $\mathbf{s} = (s_1, s_2, \ldots, s_{n_1}, s^h, \ldots, s^h)$, where all countries in group l choose different subsidies and countries in group h coordinate on s^h.

6.2.2 Distinct Group Sizes

As with Nash equilibria, the analysis of asymmetric ESS for the case $n_1 \neq n_2$ is very similar to the analysis when the two groups are of equal size. In fact, the results when $n_1 = n_2 = n$ are just a special case of the more general results with different group sizes. This means that symmetric ESS also hold in this case, with the set of symmetric ESS given by

$$E'_A = [\hat{s}_h(1), \hat{s}_l(n_l + n_h - 1)].$$

Asymmetric ESS can exist even with distinct group sizes. Here again, one has to differentiate between the case where the wealthier group of countries is larger and the case where this group is smaller. Intuition would suggest

[37] This analysis is again very similar to the analysis of Nash equilibria.

that in the first case, where there are more wealthier than poor countries, the asymmetric equilibria should still exist, since the relative aggregate wealth on group level is more pronounced than in the case of equal group sizes.

For the other case, when the group of poorer countries is larger than the wealthier one, the case is ambiguous. Therefore a more detailed analysis is necessary.

The resulting conditions on subsidies for asymmetric ESS to exist when group sizes differ, are[38]:

$$s^h \in [\max\{\hat{s}_l(n_h+1), \hat{s}_h(1)\}; \hat{s}_h(n_h-1)], s^l \in [0; s^h]. \tag{19}$$

What is interesting to see from the conditions on s^h is that the group size of the poorer countries does not affect the equilibria. It is merely a statement on when the wealthy countries are rich enough to host all the poor. Given any model parameters, the relative wealth of the two groups defines whether asymmetric ESS can exist or not.

Comparing all the conditions of ESS and Nash equilibria, one can see that the intuition behind the results is always the same. As long as the setup is symmetric enough, symmetric equilibria are possible. In an asymmetric setup, new equilibria enter where only the rich group of countries hosts all the poor. As the setup becomes even more asymmetric, the symmetric equilibria vanish and only asymmetric ones remain.

When it comes to group sizes, the actual difference in number is not as important as the difference in wealth[39]. As long as the rich countries can afford to host all the poor, asymmetric equilibria are possible.

[38]The proof here is a generalization of the proof when group sizes are equal.

[39]This difference is a combination if differences in group sizes and the respective values for ω_R.

7 A Numerical Example

The economic area considered in this example consists of $N = 6$ countries. The area is split into two groups of countries with each group containing three countries, i.e. $n_l = n_h = n = 3$. The utility function is the same for all six countries and is given by

$$u(x) = \ln x + 1.$$

The two groups only differ with respect to their initial wealth of the rich population. This difference can be interpreted as the state of development. One group is more advanced than the other and, therefore, richer. Without loss of generality, it is assumed that $\omega_R^l < \omega_R^h$.

The utility function together with the welfare function in equation (11) gives

$$f^g(k, s) = \frac{\nu}{k} \cdot [\ln(\omega_P + s) + 1] + \ln(\omega_R^g - \frac{\nu}{k} \cdot s) + 1.$$

Let the other parameters of this example be: $\nu = 0.6$, $\omega_R^l = 1.2$, $\omega_R^h = 1.5$ and $\omega_P = 0.5$.

Based on these parameters, the critical subsidies I am interested in are:

$$\begin{gathered}\bar{s}_l(n) = 1.144 < \hat{s}_l(1) = 1.202 < \bar{s}_h(n) = 1.551 < \hat{s}_h(1) = 1.628 < \\ \hat{s}_l(n-1) = 2.087 < \hat{s}_l(n) = 2.150 < \hat{s}_h(n-1) = 2.942 < \hat{s}_h(n) = 3.039.\end{gathered}$$

Due to this ordering, the sets for symmetric Nash equilibria, S_Y, and symmetric ESS, E_A, are given by: $S_Y = [1.551, 2.150]$; $E_A = [1.628, 2.087]$.

7.1 Symmetric Equilibria

7.1.1 Nash Equilibria

In order to see whether the calculated borders also hold in this numerical example, I will calculate the payoffs in a symmetric Nash equilibrium $\mathbf{s} = (s, \ldots, s)$, where $s \in S_Y$.

The baseline utility for $s = 1.8$ for countries in group l is $f^l(2n, s) = 1.203$. Countries in group h receive utility $f^h(2n, s) = 1.461$. A deviating country from group one would receive $u(\omega_R^l) = 1.182$ for any $s^d < s$ and $f^l(1, 1.9) = -0.688$ for an move to $s^d = 1.9 > s$. For a deviating country in group h, the utility for reducing the subsidy to some level $s^d < s$ would be $u(\omega_R^h) = 1.405$, which is lower than 1.461. A move to $s^d = 1.9 > s$ would also result in a lower utility, namely $f^h(1, 1.9) = 1.103$.

To show that subsidies outside the interval are not Nash equilibria, let's start from the symmetric profile with $s = 1$. At this profile, countries in the two groups receive utilities $f^l(2n, s) = 1.236$ and $f^h(2n, s) = 1.477$, respectively. But a move of one country in either group to some subsidy $s^d > s$ would profit this country. The utilities in this case are $f^l(1, 1.1) = 1.266$ and $f^h(1, 1.1) = 1.708$.

Also a symmetric profile above the the upper border of S_Y cannot be an equilibrium. Starting from $\mathbf{s}$ with $s = 2.2$, the utilities at this profile for countries in the two groups are $f^l(2n, s) = 1.179$ and $f^h(2n, s) = 1.446$, respectively. A country in group l can increase its payoff by deviating to some $s^d < s$ and receive utility $u(\omega_R^l) = 1.182$. Thus, $\mathbf{s} = (s, \ldots, s)$ is not stable in the sense of Nash.

7.1.2 ESS

When it comes to ESS, the symmetric profile $\mathbf{s}$ with $s = 1.8$ should be evolutionarily stable since $s \in E_A$.

The utilities at this profile are the same as above, namely 1.203 and 1.461. In order to check whether this profile is a symmetric ESS, one has to compare payoffs after the move of a mutant country with members of the mutant's group. Let's say country i, member of group l, moves to $s^d < s$. Its new utility is $u(\omega_R^l) = 1.182$ and the remaining countries of this group receive $f^l(2n-1, s) = 1.204$. This means that the move of country i is not profitable compared to the other members of its group. The same holds true if country i were a member of group h, since $u(\omega_R^h) = 1.405 < f^h(2n-1, s) = 1.470$.

A move of country i to a higher subsidy $s^d = 1.9 > s$ is also not profitable compared to members of its own group. In this case it would be the sole host of all the poor resulting in payoff $f^l(1, s^d) = -0.688 < u(\omega_R^l) = 1.182$. The same holds true for countries in group h, $f^h(1, s^d) = 1.103 < u(\omega_R^h) = 1.405$.

Now I will show that strategy profiles outside E_A are not evolutionarily stable. Let's start from a symmetric profile $\mathbf{s}$ with $s = 1$. The utilities in this case are 1.332 and 1.738, respectively. In this case, a mutant country in group l can increase its payoff compared to members of its group by deviating to $s^d = 1.2 > s$. Although the new payoff, $f^l(1, 1.2) = 1.184$ is smaller than the payoff before, this new payoff is larger than the utility of all the other countries in group l now, namely $u(\omega_R^l) = 1.182$.

With the same line of reasoning, one can show that a symmetric profile with $s > 2.085$ cannot be an ESS. Starting from the profile $\mathbf{s}$ with $s = 2.2$, the payoffs are 1.179 and 1.446, respectively. This profile is no ESS, since country i in group l can improve its relative payoff by deviating to some $s^d < s$. The new payoff $u(\omega_R^l) = 1.182$ is larger than the payoff of the remaining countries in this group, namely $f^l(n-1, s) = 1.173$.

7.2 Asymmetric Equilibria

7.2.1 Nash Equilibria

In order for asymmetric Nash equilibria to exist, the condition on s^h that needs to hold[40] is $s^h \in [\hat{s}_l(n+1), \hat{s}_h(n-1)] = [1.998, 2.604]$. This means that the profile $\mathbf{s} = (s^l, \ldots, s^l, s^h, \ldots, s^h)$ where countries in group 1 set $s = s^l = 1$ and countries in group 2 set $s = s^h = 1.999$ should be a Nash equilibrium.

In order to show that this is true, I will compare payoffs at this profile to potential deviant's payoffs. Starting from the above strategy profile, the payoffs for the two groups are $u(\omega_R^l) = 1.182$ and $f^h(3, 1.999) = 1.451$. Countries in group l have no incentive to deviate. First, for any $s^d < s^h$ the utility would not change. A move to $s^d = 1.9999 > s^h$ would result in payoff $f^l(1, 1.9999) = -7.571$ and setting $s^d = s^h$ gives a utility level of $f^l(n+1, 1.999) = 1.1822 < u(\omega_R^l) = 1.1823$. Both these moves do not increase the deviating country's payoff.

This move here also indicates that the lower border for Nash equilibria, 1.998, is a border indeed. Close to this subsidy level, countries in both groups are almost indifferent between deviating or not.

Also in the other group, there is no incentive do deviate from the proposed strategy profile $\mathbf{s}$. Would a country set $s^d < s^h$ the resulting payoff $u(\omega_R^h) =$

[40]See section 6.2.1.

1.405 would be smaller than the payoff at s^h. Also a move in the other direction is not profitable, since $f^h(1,2) = 0.946 < 1.479$.

All these utility comparisons together show that $\mathbf{s}$ is an asymmetric Nash equilibrium, in which one group of countries hosts all the poor.

7.2.2 ESS

The condition on s^h for asymmetric ESS to exist, is: $s^h \in [1.998, 2.272]$. Thus, the profile $\mathbf{s} = (s^l, \ldots, s^l, s^h, \ldots, s^h)$, where countries in group l set $s^l = 1$ and countries in group h set $s^h = 1.999$, should be an evolutionarily stable strategy profile.

Starting from the above profile, payoffs for the two groups are $u(\omega_R^l) = 1.182$ and $f^h(3, 1.999) = 1.479$, respectively. For countries in group l, there is no possibly profitable deviation. First, any move to $s^d < s^h$ would not change the payoff. Second, A move to $s^d = 1.999 > s^h$ would give the country utility of $f^l(1, 1.9999) = -7.571$ which is lower than the utility of the other countries in the same group, namely $u(\omega_R^l)$. Also the payoff when deviating to $s^d = s^h$, $f^l(n+1, 1.999) = 1.1822$ is lower than payoff of its group members.

Countries in the other group also have no possibility to increase the relative payoff compared to members of the same group by singularly deviating to an alternative strategy. Setting $s^d < s^h$ would give the mutant country a utility of $u(\omega_R^h) = 1.405$ which is smaller than the payoff of the remaining countries in the same group, namely $f^h(2, 1.999) = 1.470$. A move to $s^d = 2 > s^h$ would give the mutant country a payoff of $f^h(1,2) = 0.946$ which is again smaller than $u(\omega_R^h) = 1.405$, the payoff of its group members after the move.

Taken together, all these utility comparisons prove that the profile $\mathbf{s}$ is an asymmetric ESS. From above we know that it is a Nash equilibrium too.

This numerical example shows that symmetric and asymmetric equilibria can coexist within one and the same setup.

8 Conclusion

When talking about the survival of social policy measures in a federal conglomerate of economic entities, recent work[41] has shown that stability of a system of social policy measures and federalism do not mutually exclude one another. The results of this thesis support their findings and with respect to the work of Ania and Wagener (2012) even go one step further. Equilibria in the sense of Nash and also evolutionary equilibria as defined in Schaffer (1988) exist in a federal economic area when all countries within this area are symmetric. This symmetry requires the equilibria to be symmetric, i.e. Nash equilibria and evolutionarily stable strategies (ESS) only exist as strategy profiles where all countries choose the same strategy.

Since this symmetric case was already well studied in the literature, my approach was to study the stability of social policies in an economic area that contains a certain degree of asymmetry. The findings in this setup are, on the one hand, similar to what the symmetric case offers as results. On the other hand, the asymmetry in the new model gives rise to totally new equilibria. These new Nash equilibria and ESS do not require the countries to "coordinate" on the same strategy. It is sufficient that a small group of countries chooses a specified level of subsidies and then the other countries are free to choose any strategy below this level. This means, that in the asymmetric setup a lower degree of coordination is necessary than in the symmetric setup.

In other words, a small group of countries can choose to host all the poor in the entire economic area and the poorer countries do not pay any subsidies at all. From this point of view, the richer constituencies shoulder the whole transfer system whereas the poorer group of countries does not take part in it at all and remains on the baseline level of utility. This leads to the question of a comparison of symmetric versus asymmetric equilibria.

In the case of a symmetric equilibrium all countries achieve welfare of at least the baseline utility level. If we let these countries coordinate on some strategy profile, the outcome is very likely to be one in which all countries are above the initial utility of $u(\omega_R)$. This is not possible at an asymmetric equilibrium. Here only the group of countries hosting the poor can coordinate on a subsidy level that guarantees them a utility level higher than the initial one. All other countries that do not pay into the redistribution system remain at their baseline utility level. In the eyes of an egalitarian, the symmetric equilibrium is

[41] Ania and Wagener (2012) and Oates (1999)

therefore preferable to an asymmetric one.

Despite the debate about what equilibria are preferable on what grounds, the important result is that these asymmetric equilibria can exist under certain circumstances[42]. The asymmetry in my model is very artificial, which means that there are a lot of possible modifications and, hopefully, new insights for further research. One could probably go as far as making each country different from one another and see what would happen to the stability of social policy measures in such an economic area. But these questions are open for future research in this field.

[42] The exact criteria are mentioned in section (6).

9 German Abstract

Die vorliegende Arbeit beschäftigt sich mit der Stabilität von sozialpolitischen Maßnahmen in einem föderalen Staatenverbund. In Anlehnung an das Modell von Ania and Wagener (2012) agieren Staaten auch in meinem Modell als strategische Entscheidungsträger. Sie haben die Hoheit über steuerpolitische Entscheidungen und treffen diese Entscheidungen unabhängig voneinander. Ziel der einzelnen Länder ist es, unter Berücksichtigung der Entscheidung anderer Staaten, die eigene Wohlfahrt zu maximieren. Die Bewohner aller Länder sind in zwei Gruppen - arm und reich - unterteilt.

Es wird angenommen, dass die reiche Bevölkerung nicht mobil ist und immer im Ausgangsland wohnhaft bleibt. Die arme Bevölkerung aller Länder in diesem föderalen Staatenbund wird als mobile Einheit gesehen, die volle Mobilität besitzt. Diese Gruppe siedelt sich immer dort an, wo die Transferquote am höchsten ist. Wenn mehrere sich mehrere Länder für eine hohe Quote entscheiden, teilt sich diese Gruppe in gleiche Teile auf diese Länder auf. Die Wohlfahrt eines Landes berechnet sich nun als Summe der Nutzen der Gruppe der reichen Bevölkerung in diesem Land und einer Funktion der Gruppe der armen Bevölkerung, die abhängig von der Höhe der Transferquote ist.

Die Resultate einer strategischen Interaktion der einzelnen Länder im oben geschilderten Modell sind bereits von Ania and Wagener (2012) beschrieben. Die vorliegende Arbeit ist eine Erweiterung in Hinblick auf die Asymmetrie des Staatenverbundes. Ania and Wagener (2012) untersuchen den Fall vollkommen symmetrischer Länder, währenddessen mein Modell aus zwei unterschiedlichen Gruppen von Ländern besteht. Diese Gruppen unterscheiden sich im Entwicklungsstatus. Eine Gruppe wird als fortgeschritten modelliert, wohingegen die andere als eine Gruppe von Entwicklungsländern gesehen werden kann[43].

Mit dieser Erweiterung des ursprünglichen Modells ändern sich auch die Resultate. Zum einen bleiben zwar die alten Nash-Gleichgewichte und evolutionären Gleichgewichte bestehen[44], doch darüberhinaus entstehen auch neue Gleichgewichte.

[43]Das bedeutet für das Modell, dass die Gruppe von Entwicklungsländern einen niedrigeren Ausgangswert für das Vermögen der reichen Bevölkerungsgruppe hat. Dies mag sonderbar erscheinen, doch die notwendigen Eigenschaften der Wohlfahrtsfunktionen sind dadurch gegeben. Siehe Sektion (6).

[44]Das bedeutet, dass es im neuen Modell Gleichgewichte gibt, die denen aus dem symmetrischen Fall entsprechen. Sie sind jedoch nicht identisch, sondern nur konzeptionell gleich. Siehe ebenso Sektion (6).

Unter bestimmten Voraussetzungen[45] sind auch asymmetrische Strategieprofile stabil. Es könne also sowohl asymmetrische Nash- als auch evolutionäre Gleichgewichte entstehen. Anders formuliert: es gibt Gleichgewichte, in denen nicht alle Länder in ein Transfersystem einzahlen, sondern eine Gruppe von Ländern alle Armen aufnimmt und die andere Gruppe keine Unterstützung leistet. Ungeachtet dessen, ob man solch ein Szenario für wünschenswerter oder besser hält als ein System in dem alle Länder sich an einer Transferpolitik beteiligen, ist es wichtig zu wissen, dass eben unter gewissen Voraussetzungen solch ein Szenario eintreten kann. Genau das ist der Beitrag, den diese Arbeit leisten will.

[45]Das heißt, wenn Modellparameter bestimmte Konstellationen der Wohlfahrtsfunktionen - wie in Sektion (6) beschrieben - erzeugen.

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Sprachen

Deutsch	Muttersprache
Englisch	fließend
Schwedisch	Grundkenntnisse
Italienisch	Grundkenntnisse

EDV-Kenntnisse

OS	alle Windows Versionen, MAC OS X
Programme	MS Office, EViews, Stata, BB, Murex

Interessen

Sport	Fußball (aktiv und passiv), Fitness, Tischtennis, Badminton
Sonstiges	Reisen, Lesen, Freundschaften & Beziehung, Brettspiele