The Economics of River Flood Management: A Challenge for the Federal Organization?

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Chapter 1

Introduction

1.1 Empirical motivation

River floods can be very damaging. Recent large scale flood events, such as the 2002 Elbe flood in Middle and Central Europe, illustrate the vulnerability of societies to flood hazards. Even though such extreme events are rare, there is a long history of damaging floods all around the world. For the last 25 years the average flood damage per year is estimated to be about 3.3 and 4 billion US dollars for Europe and the United States, respectively (see section 2.2). Discussions on an upward trend in flood damages coincide with the observation of increased human encroachment of flood-prone areas near rivers. Such land-use changes increase the value at risk to flooding. The accumulation of wealth in sensitive areas is an ongoing process in Germany. In the nineteen nineties 0.56% of areas near rivers were transformed into human settlements and transport infrastructure, the respective share for the whole of Germany is only 0.48%. These figures suggest that a saturation point of urbanization in flood-sensitive areas has not yet been reached, which is surprising since the share of human settlements and transport infrastructure is traditionally high in these areas. Currently 16.5% of areas near rivers are taken up by human settlements and infrastructure, compared to 7.7% for the whole of Germany (see section 3.3.1).

Flood risk is increasingly seen in the context of climate change. However, for past flood events it is difficult to find a climate change imprint in damage data. This is not surprising, since damaging floods are typically rare events and non-climate related factors have also changed significantly in recent decades. However, confidence has grown that climate change will lead to more extreme weather events in the future, which is most likely to increase flood risk and increase the importance of river flood management (IPCC 2001b).

A wide range of human responses to flood risk are possible. It is the aim of flood management to find the most efficient combination of the different possible measures. This goal is ambitious since the different responses have quite different characteristics and involve different economic issues. Some measures are locally so restricted that they are private goods; an example is flood proof building. Other measures, such as levees, are beneficial for a whole community and are therefore public goods. Public flood defense can have purely local effects, making it to an issue of local public good provision, but it can also have inter-regional spillovers that affect communities downstream. Since water flows from upstream locations to downstream locations, these spillovers are typically unidirectional. This raises the question of how spillovers can be internalized in the decision process on public goods. Depending on the flood defense measure, unidirectional spillovers can be positive (flood basins) or negative (levees that cut off natural flood basins). The topography of watersheds usually allows the distinction between flood-prone areas and areas without flood risk which leads to an uneven distribution of the benefits from flood defense: Citizens located near rivers benefit, whereas citizens further away from a river have no direct advantage from flood defense. This induces spatially heterogeneous preferences for public flood defense.

There is a close interrelation between public and private decisions in flood management. Private locational choices of individuals interact with public flood defense. A high flood protection level can trigger locational choices of individuals and lead to human encroachment on flood-prone areas in natural flood basins.

Floods are uncertain events. Thus, responses to floods can be approached as a form of risk management. While some responses aim to reduce the probability of a damaging flood (measures in the watershed that mitigate flood risk), others try to reduce the damaging impact of floods (flood adaption through appropriate land use). Since chances of an extreme flood associated with catastrophic damages in any given year are low, there may be a misperception of flood risk that leads to inadequate mitigation or adaption efforts.

To focus on key problems of flood management in Germany, its institutional organization is analyzed. Such an analysis can serve as the basis for a formal approach that captures some key problems of flood management in general. A few stylized facts characterize the current situation of flood management in Germany:

- ▷ Public flood defense is provided by all federal levels in Germany. The communal level is responsible for flood defense at small water bodies and for land-use planning. The *Bundesländer*[1] provide flood defense along the major rivers. The federal government introduced central flood protection standards for the whole of Germany. In addition it gave substantial ad hoc disaster relief to affected citizens after major flood events in the past.
- ▷ Improvements in flood protection are often only possible through measures with inter-jurisdictional spillovers. In the current debate on improved flood protection, some measures can only be undertaken at upstream locations. Examples are potential flood basins along the Upper Rhine for a better protection of cities, such as Cologne, on the lower Rhine.
- ▷ It is the exception and not the rule that public flood defense is provided by a jurisdiction that is tailored to flood-prone areas. Usually a jurisdiction also includes citizens in no risk zones. It is also common that a jurisdiction stretches over several watersheds.
- ▷ There is an increasing awareness that high flood damage in recent years correlates

[1]German states are called *Bundesländer*.

with an accumulation of wealth in flood-prone areas. However, so far this accumulation of wealth is largely not seen as a response to the improved public flood defense of recent decades.

These stylized facts can all be interpreted as challenges for the federal organization of public flood defense. Firstly, unidirectional spillovers challenge a decentralized provision of flood protection, because the interests of downstream riparians are neglected by upstream jurisdictions. Secondly, jurisdictions with both risk and no risk areas might be challenged to efficiently provide flood defense, since one group of citizens wants flood protection and another group has no interest in it. Thirdly, the federal organization can be challenged by inter- and intra-jurisdictional migration flows that respond to the level of public flood defense. Public good provision that is efficient for a given population distribution might not be efficient for a jurisdiction of smaller or larger population size.

1.2 Theoretical motivation

The literature on fiscal federalism can serve as a starting point for a study on public flood defense and its challenges to the federal organization. This literature looks at the vertical distribution of public responsibilities with the aim to provide suggestions how to achieve an efficient provision with public goods. It is well established in the literature that first-best solutions are often hard to achieve, even if one assumes a social planner who cares about the utility of all citizens within a jurisdiction (Oates 1999, List and Mason 2001). This draws attention to comparisons of second-best approaches. In his influential contribution "Fiscal Federalism" Oates (1972) postulates in his *decentralization theorem* that the lowest governmental level that internalizes spillovers shall provide the public good. Also, with inter-regional spillovers, the decentralized supply can be superior to the centralized supply because of the possibility to differentiate public goods according to local preferences. This argument relies on the assumption that a centralized provision of public goods is restricted to a uniform supply within the whole jurisdiction. With this assumption, centralization is only superior to decentralization if spillovers are sufficiently large.

Recent contributions challenge this view and emphasize a slightly different trade-off between decentralized and centralized supply of public goods. Besley and Coate (2003) find the uniformity restriction not very plausible, because a central government could theoretically choose a differentiated supply pattern of public goods. Focusing on the decision making process and not on the fiction of a social planner, Besley and Coate see the disadvantage of centralization in inefficient voting decisions. Voters from one region care about public goods in other regions only if they receive spillovers. Public good supply in a central jurisdiction is not required to be uniform but must be approved by a majority of voters. This may result in strong regional differences of public goods if spillovers are weak. For stronger spillovers these differences can be expected to decrease. Thus, also in political-economy approaches, spillovers are the critical parameter determining whether decentralization or centralization is superior. A basic assumption of political-economy approaches on fiscal federalism is a common budget that finances (local) public goods. This financing rule creates common pool incentives that drive the inefficiencies in central jurisdictions. DelRossi and Inman (1999) and Knight (2004) find evidence for the empirical relevance of common pool incentives for federal water and for transportation projects in the United States. Both cases provide evidence that central legislators try to target spending to politically favored states.

Despite the recognition that unidirectional spillovers, which are present in many water issues, are a particular challenge for the federal organization (see for example Oates (2002)), political-economy approaches largely neglect this important special case of public good provision.

There is a distinct spatial pattern of flood defense, since benefits are restricted to flood-prone areas. The spatial distribution of public benefits is the starting point for the literature on the formation of nations (Alesina and Spolaore 2003), where the size of a state influences the cost of preference heterogeneity and the advantage of cost-sharing of public goods. Another approach, of Frey (1997), recognizes that public goods have different spatial characteristics and suggests that a flexible system of overlapping jurisdictions can efficiently provide different bundles of public goods within a nation. The issue of flood defense certainly does not raise such principle issues as the formation of nations, but is does raise the issue of whether jurisdictions shall be tailored to flood-prone areas. This can be done through single issue authorities, which complement an existing federal structure. Such considerations seem important in a political-economy context, where the benefits from public goods drive voting preferences. However, the current literature says little on single issue authorities so that this is another starting point for the formal analysis of flood defense.

There is an extensive literature on local public goods and migration that was inspired by Tiebout (1956). Some authors even see the possibility of locational choices as the crucial feature of local public good economies (Stiglitz 1977). Early contributions investigate purely local public goods, but more recent contributions also incorporated inter-regional spillovers. Wellisch (1993) finds that a decentralized supply of public goods with spillovers can be efficient if transfers are possible. Other, very general approaches search for migration equilibria with voting on public goods and inter-regional spillovers (Konishi 1996). However, these ambitious approaches generally assume a given federal structure and do not address the issue of whether public goods shall be provided by decentralized or centralized decision making. As Nechyba (1997, 278) remarks, the study on intergovernmental relations in the spirit of Oates has been largely separated from the literature on local public goods and migration that was inspired by Tiebout. Since it is well established in the literature that there is a close interrelation between public goods and locational choices, it is promising to apply this insight to the case of public flood defense in a federal state.

1.3 The economic problem

The empirical and theoretical motivation leads to the following economic questions that shall be answered in the dissertation:

- ▷ Shall decentralized or centralized jurisdictions provide local public goods that have unidirectional spillovers?
- ▷ Can single issue authorities, which separate people with unequal public good benefits, improve efficiency in public good provision?
- ▷ What is the linkage between unidirectional spillovers and heterogeneous benefits in the choice of the best federal setting?
- ▷ Taking migration into account, what is the best federal organization, and how does the answer to this question depend on the voting behavior of citizens?

In answering these questions the following analysis relies on some important premises. First, public flood defense is interpreted as the result of voting decisions. Second, free migration is seen as a fundamental force that is of relevance in flood management. Third, it is recognized that other economic issues (such as uncertainty) are also of importance in flood management, however, it is assumed that these factors do not completely invalidate the present analysis.

1.4 The modeling approach

Unidirectional spillovers and spatially heterogeneous benefits of public goods challenge the federal organization of flood defense. Following the lead of recent political-economy contributions to fiscal federalism, both aspects are investigated in a two region model with majority voting. The two regions can be interpreted as an upstream and a downstream region. Within each region there is a group of citizens who benefit from public goods and another group without benefits.

Four different decision-making structures are compared: classical decentralization or centralization (based on jurisdictions containing voters both with and without benefits of the public goods) and decentralized or centralized single issue authorities (whose jurisdictions, by definition, contain only voters with high benefits). Decentralized jurisdictions separate upstream and downstream voters, whereas a centralized jurisdiction comprises both groups.

Based on a comparison of aggregated public good surplus, it turns out that centralized jurisdictions lead to a very low public good surplus and that either classical decentralization or decentralized single issue authorities achieve the best results under most conditions. The centralized provision of public goods is flawed because there is either an extreme over- or an extreme under-provision of the downstream public good. This can, however, be mitigated if there is a common standard for flood protection or if only the upstream provision of the public good is centralized. Whether or not these two solutions are beneficial depends on the magnitude of spillovers and also on the voting majorities in the two regions.

Expanding the model to consider migration leads to a more complex setting. With voting and locational decisions to be made, the analysis is structured as a two stage game. At the first stage of the game there is voting with a given population distribution, and at the second stage citizens decide on their location. Following a wide strand of the literature, see for example Wildasin (1987), free and costless migration is assumed as well as homogeneous preferences within the population. Therefore the migration equilibrium is characterized by the same utility level of the whole population. The provision with public goods depends crucially on the voting behavior. One possibility is that voters are myopic, neglecting potential migration at the second stage. Alternatively non-myopic voters could anticipate migration flows in response to a given level of public good provision. The analysis focuses on a two region setting, with homogeneous benefits from public goods within each region. To compare different federal settings, a functional form of the model is specified.

The result of the model depends crucially on the voting behavior. With myopic voting, centralization suffers from the dominance of the majority, which results in a large population size of the majority region in the migration equilibrium. The impact of spillovers on the population distribution depends on the sign of the spillovers as well as on political-economy conditions. With decentralization, spillovers have a positive impact on the downstream population size. The comparison of both federal settings is in favor of decentralization unless spillovers are very large.

Non-myopic voting leads to very different results, since voters are aware that the final equilibrium utility level is the same for the whole population. Differences between the federal organizations now primarily reflect the different financing schemes of decentralized and centralized supply of public goods. Under certain conditions, centralization can achieve the socially efficient allocation, whereas this is not generally the result under decentralization. However, for both federal settings and sufficiently strong spillovers, the downstream populations increases when spillovers become more extreme (positive or negative). Thus, negative and positive spillovers favor a large downstream population.

1.5 Outline of the dissertation

The structure of the dissertation is as follows. Chapter 2 introduces river flooding and human responses to that hazard. It structures the discussion of flood management with respect to the dimensions 1) private or public action, 2) the scope of inter-regional spillovers, and 3) the three basic responses of risk management. Focusing on public flood defense and spatial spillovers, chapter 3 analyzes flood management in Germany, which leads to the working hypothesis that flood management is a challenge for the federal organization. This is followed by an overview on the economic literature on fiscal federalism and unidirectional spillovers (chapter 4). On the basis of the literature review and the discussion of flood management in Germany, the economic problem is formulated.

Chapter 5 presents the basic model of local public good provision in a federal state. The following chapters are extensions to the basic model by introducing the possibility of free migration. Chapter 6 assumes non-myopic voting, where voters do not anticipate how public good provision influences locational choices. While chapter 7 analyzes the same issues with the assumption that voters are non-myopic and therefore consider potential migration in response to public good provision. The last chapter summarizes the results and discusses their policy implication with respect to flood management.

Chapter 2

Introduction to river flood management

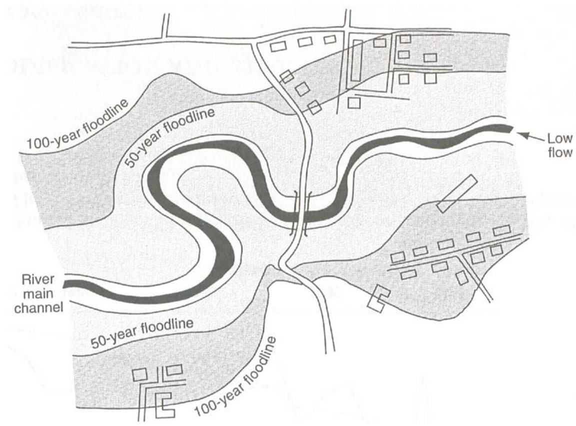
2.1 Physical causes of river floods

Two aspects characterize floods: inundation and damage. The first aspect is emphasized by Smith and Ward (1998, 8). In their book on *'Floods'* they draw on Ward's definition: *"A flood is a body of water which rises to overflow land which is not normally submerged"*. In the same book a more restrictive definition of river floods is given by Chow (1956), *"A flood is a relatively high flow which overtaxes the natural channel provided for the runoff"*. Pielke and Downton (2000) also consider the second aspect of floods. They point to different perspectives on floods of scientists and policy makers. In addition to the above defined hydrological floods there can be damaging floods, which are, *"floods that result in damage to human life or property"* (Pielke and Downton 2000, 3625-3626). In what follows, damaging river floods will be at the center of attention and coastal floods will be neglected. Therefore river floods and floods will be used as synonyms.

Key features of a hydrological flood event are the peak water level and peak discharge, with the latter being the volume of water passing a gage in a certain time. The duration of floods differs as well as the time until peak conditions and the total volume of floodwater. The area of inundation of the peak water level of a flood is called the flood outline. The larger the flood, the greater the flood outline. Usually there is also a distinct seasonal pattern of floods, since the conditions that cause floods in winter months usually differ from those in the summer (Smith and Ward 1998, 16-19).

An important statistical measure of hydrological flood events is their frequency. Small floods with fairly low peak water levels occur relatively often, whereas large floods are unusual events. Thus, the return periods of small floods are shorter than of large floods. The peak discharge of a flood, Q, can be classified according to the return period. A flood occurring once in five years is a Q_5-flood and a 100-year-flood is a Q_{100}-flood. Since any flood can occur any time, chances for a Q_5-flood to occur in a given year are 20% and for a Q_{100}-flood, 1%.

Hydrological flood frequencies play a crucial role in the design of flood control measures. Systems built for a Q_5-flood give no protection against large floods with long return periods. And even high flood protection levels do not guarantee absolute safety. Certain areas may be attractive to human encroachment because they are protected up to a Q_{100}-flood, however they remain vulnerable if they are in the flood outline of an extreme flood event with return periods of more than 100 years. A map with different



Source: Smith (2001, 276)

Figure 2.1: Flood-prone areas

flood risk zones illustrates that the flood outline of a rare flood event is larger than that of floods happening more frequently (see figure 2.1).

Most river floods are directly or indirectly caused by climatological events, particularly excessive rainfall. In regions with cold winters and accumulating snowfall, snowmelt and ice jams can also cause floods. Alternatively, dam failures can also cause floods or increase their severity (Smith and Ward 1998, 10-11).

Because floods result from the accumulation of upstream runoff, the understanding of flood events must be based on an understanding of the whole watershed. Characteristics of the river basin, the drainage network, and the stream channel can act as flood intensifying factors. For a given precipitation event these factors determine the magnitude of a flood. The size of a river basin, its shape, slope, and altitude are stable factors influencing a flood. The effects of climate, soil type, vegetation cover and anthropogenic influences in a river basin are variable factors affecting a flood event (Smith and Ward 1998, 10-14).

The topology of the river basin can lead to different typical flood events. In areas with mountains, locally heavy precipitation, often favored by orographic effects[1], can lead to destructive floods with very high velocities. The consequences of such precipitation events are worse if combined with snowmelt in spring. Hilly regions with narrow valleys are particularly vulnerable to locally extreme precipitation, because the size of the watershed tends to be small. Flash floods in mountains occur with short notice after heavy local precipitation. Floods in the lowlands are characterized by low velocity and large areas with inundation. Such floods in low lying flood plains are fed by a large watershed so that precipitation can be far away from the flood event, giving more time for flood warnings compared to flash floods in the mountains (WBGU (1999, 99-101) and Patt (2001, 7-8)).

[1] Orographic precipitation is precipitation generated by a forced upward movement of air upon encountering a highland.

2.2 River flood damage and flood exposure

Flood events can have enormous destructive power, leading to high damage in areas with human encroachment. Extreme floods with long return periods can be catastrophic, claiming thousands of lives, while affecting even more lives negatively and leading to high economic losses.

Before turning to the damaging impact of floods it is worth noting that floods can also bring numerous benefits to ecosystems and people. Agriculture in flood plains benefits from flood-borne silt. One example is the River Nile, one of the most fertile farming regions in the world. Floods can bring many other advantages, which are often linked to common property resources (Smith and Ward 1998, 35-38). Nevertheless, damaging floods are among the most destructive natural hazards in the world. In the period from 1980 to 2000 floods caused more than 170 000 deaths, whereas earthquakes and tropical cyclones (including hurricanes and typhoons) are associated with approximately 160 000 and 215 000 deaths, respectively (UNDP 2004, 34-42).

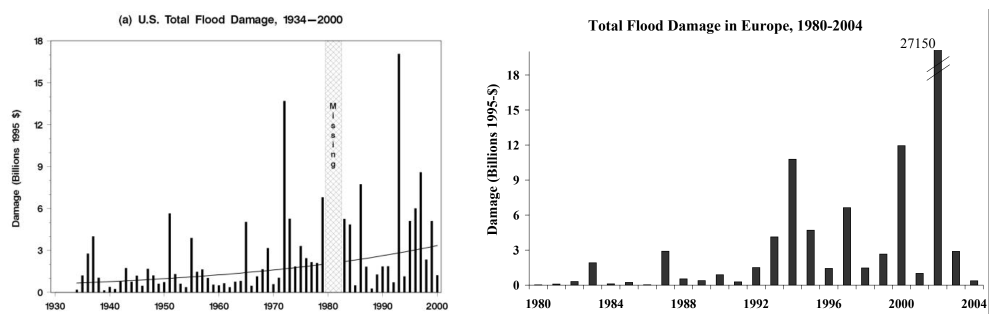
Assessment of economic flood loss is more difficult than of flood fatalities. The destructive power of a flood can cause both direct and indirect economic losses. While direct damage is the immediate consequence of water and its solids in suspension, indirect losses occur through the interruption of economic activities (Smith and Ward 1998, 34). Pielke et al. (2002, 4) specify,

"Direct costs are closely connected to a flood event and the resulting physical damage. In addition to immediate losses and repair costs they include short-term costs stemming directly from the flood event, such as flood fighting, temporary housing, and administrative assistance. By contrast, indirect costs are incurred in an extended time period following a flood. They include loss of business and personal income (including permanent loss of employment), reduction in property values, increased insurance costs, loss of tax revenue, psychological trauma, and disturbance to ecosystems."

Direct and indirect economic losses are sometimes considered as tangible losses which can be expressed in monetary values. In addition, floods can also lead to intangible losses, such as loss of life, where monetary assessment is not possible (Smith and Ward 1998, 34-57). One can note that in contrast to this classification there are numerous approaches in cost-benefit analyses to assess the values attached to a human live in monetary terms.

Economic losses from floods has increased significantly in recent decades. An accurate assessment of losses is, however, difficult. Even though the quality of damage data for the United States is better than for most other countries of the world, Pielke et al. (2002, 4) emphasize that their revised data can be best described as a "damage estimate" as opposed to precise "loss data". In the United States, the monetary value of damage is estimated and compiled soon after a flood. Flood damage estimates only comprise direct physical damage, as supposed to all direct costs of floods. There is no verification with actual costs of repair and replacement at a later stage.

Total flood damage (in inflation-adjusted US dollars) for the United States increased significantly from 1934 to 2000 (figure 2.2), although a large variation of yearly flood damage is apparent. There is also an upward trend of flood damage in Europe. Yearly flood damage is often dominated by single, high impact event, as demonstrated by the large August flood in 2002 in Central Europe. The damage of this flood is estimated to be 21.1 billion euros (Munich Re 2003, DKKV 2003). Average yearly damage for the years 1980 to 2004 was 3.3 billion US dollars. The comparable number for the United States for the years 1983 to 2000 is 4 billion US dollars. It is important to note that there is no common standard for data collection in Europe and the United States. Even within Europe there is no common standard, therefore the numbers presented are only rough estimates. Flood damages are concentrated to flood-prone areas along rivers. About 7% of the United States lies in the flood outline of a Q_{100} flood (including coastal zones). However, flood risk is also present elsewhere since 31% of insurance claims were made outside the Q_{100}-flood outline (Kusler and Larson 1993).

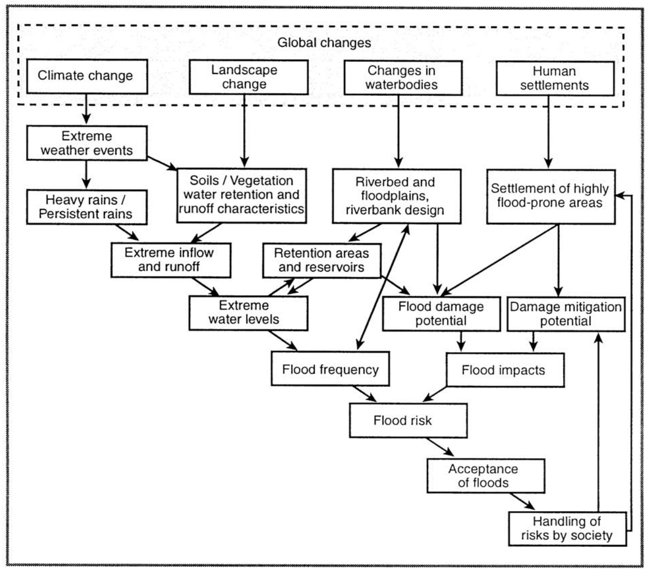


Sources: United States, Pielke et al. (2002, 55-59). Data refer to hydrological years. Europe, Munich Re (2004, 27). The numbers for Europe of the presented figure were confirmed upon e-mail request by Munich Re (23.5.2005). Data are deflated to 1995 US dollars according to the implicit price deflator for GDP as published by the Bureau of Economic Analysis (2005)

Figure 2.2: Flood damage estimate for the United States (for hydrological years) and Europe

What are the driving forces of rising flood damage? The literature discusses a number of reasons. Climate change—frequently cited in the media in cases of large, weather-related catastrophes—is one of them. Other potential causes are changes in land use and landscape, changes in waterbody systems or increasing human settlements (WBGU 1999, 101). The interplay of the various flood-inducing factors can be seen as a cascade of flood risk, as illustrated in figure 2.3. Flood risk is a joint product of the four global changes in the top line of the figure and the resulting consequences on extreme weather events, soil and vegetation conditions, riverbeds and flood plains, and human settlements on flood-prone areas. The frequency of extreme water levels and the flood impact constitute the actual flood risk of a society.

Regarding the current understanding of the quantitative relevance of flood-inducing factors, Pielke and Downton (2000) note that *"the state of knowledge is such that the relative contribution of each factor is poorly understood"*. There are, however, studies on single aspects of the flood risk cascade which demonstrate the practical relevance of



Source: (WBGU 1999 p.102)

Figure 2.3: Cascade of flood risk

some factors.

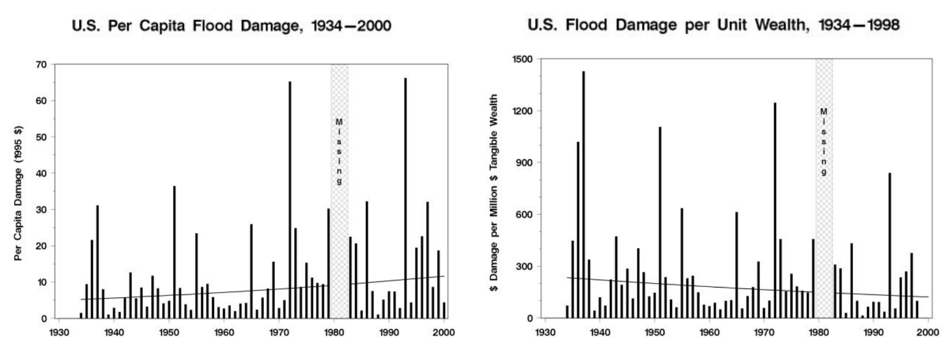
Climate change might induce an upward trend in river flood events because higher temperatures increase the water holding capacity of the atmosphere. This would intensify the hydrological cycle, making extreme weather conditions, such as extreme precipitation, more likely (WBGU 1999, 108-109). Floods resulting from extreme weather conditions might increase because the distribution function of flood events might change such that the mean value of floods (e.g. peak discharge) increases. Alternatively, or in addition, climate change might also lead to an increased variance of flood events. Both changes would make extreme flood events more likely (IPCC 2001a, 423).

In their report on the current understanding of climate change, the Intergovernmental Panel of Climate Change (IPCC) noted that the analysis of and confidence in extreme events within climate models is still emerging (IPCC 2001b, 54). Accurate predictions are not possible because floods are caused by short-duration, high-intensity, localized heavy rainfall events, which cannot be simulated sufficiently well by climate models. However, simulations by climate models suggest that extreme precipitation event will happen more frequently over many areas in the world (IPCC 2001b, 71). Parts of the insurance industry believe that more frequent extreme precipitation will translate into more extreme floods; a 100-year-flood, with a return period of 100 years, might become a flood with a return period of ten years (Munich Re 2003).

Empirical investigations of past flood events present some evidence for increased frequency of extreme floods, other studies do not confirm this result. Kundzewicz and Schnellhuber (2004) point to methodological difficulties in detecting a climate change signature in flood events. Finding such a signature in river flow data is already a complex task since human influences are typically strong (river regulation, deforestation, urbanization, dams, and reservoirs), in addition, good quality data on historical flood events are rare, especially since extreme floods are—by definition—rare events and data need to cover a long time period to allow a meaningful analysis.

Milly et al. (2002) investigate flood events exceeding a Q_{100} discharge in 23 large river basins around the world (bigger than 200 000 km^2) and find evidence for an increased frequency of flood events in the twentieth century. Muddelsee et al. (2003), on the other hand, find no evidence of increases in the number of summer or winter floods for the rivers Oder and Elbe over the last 150 years.

Even more problematic than detecting a climate change effect on flood events, is elucidating the impact of climate change on economic flood damage. There are very few studies that attempt to do this. One challenge of such studies is the separation of changes in hydrological extremes from societal factors that could lead to increased flood damage in the absence of climate change. Pielke and Downton (2000) investigate different measures of flood damage. In addition to total flood damage per year, they also look at flood damage per capita and at flood damage per unit of wealth and ask, if there is an upward trend that correlates with increasing precipitation or with a time trend. The precipitation measure is selected from ten different hydrological measures of heavy precipitation events. A time trend in a flood damage measure could capture improvements in flood policy that reduce the exposure of society to flooding.



Source: Pielke et al. (2002, 55-59). Data refer to hydrological years. Until 1997, Pielke et al. (2002) use the same data as Pielke and Downton (2000).

Figure 2.4: Flood damage estimate per capita and per million dollars of wealth for the United States

The model that tries to explain flood damage per capita finds a significant influence of precipitation but no linear trend. Figure 2.4 (left part) shows an increasing trend of damage per capita. This trend is not as clear as in total damages per year (see the left part of figure 2.2), since the population in the United States grew at a rate of 1.26% per year (for the time from 1934 to 1998). This model suggests that there might be a climate change impact on economic flood damage, since the increase of per capita damage can be explained by higher precipitation. In an alternative model specification, Pielke and Downton (2000) can explain the decreasing flood damage per unit of wealth (see figure 2.4, right part) by precipitation and a time trend that may capture a decreasing vulnerability of society towards flooding. A decline in flood vulnerability could be interpreted as a success of flood policies.

Critically one has to ask, if Pielke and Downton explain the right variables. For flood management it is of interest to know the development of per capita damages and damages per unit of wealth in flood-prone areas. However, due to shortcomings in their data, Pielke and Downton assume that the population and wealth growth in the United States are the same in and outside flood-prone areas. If, for example, the population growth in flood-prone areas is above average, per capita damages would be lower; for sufficiently large population growth in flood-prone areas, per capita damages might even fall.

It is sometimes argued that climate change mitigation is necessary to avoid higher flood risk. Pielke and Downton (2000) see this argument as one sided and emphasize that the greatest potential for reducing flood damage is to focus on flood plain management. Nevertheless they see important other reasons to mitigate climate change.

In the political debate it is a widespread phenomenon that natural disasters are associated with climate change. However, it is noteworthy that no increase in weather extremes and related losses is found in the United States for hurricanes, hail, tornadoes, wind storms, and severe thunderstorms. In fact for most of these extremes a significant downward trend was observable between 1950 and 1997. It is only for heavy rain that an significant increase in extreme events and losses is observable (Changnon 2003).[2]

Cartwright (2005) and also Pielke et al. themselves point at two shortcomings of the flood damage analysis. First, the data do not allow a sectoral disaggregation of flood damage. The comparison of two selected flood events for Minnesota (1993 and 1997) illustrates that the 1993 flood caused high damage in the agricultural sector whereas inundation affected mainly urban areas in 1997. Second, flood damage estimates do not allow regional comparisons of economic or land-use trends between areas in and outside of flood plains, because there is no single standard for delineating flood plains. Therefore the analysis of Pielke et al. hinges on the assumption that global trends in the United States and trends within flood plains are the same.

Changes in land-use patterns can be considered as a global phenomenon. The resulting (direct) impact of land-use change on river floods is, however, confined to the respective river basin. Deforestation is a land-use change, which substantially reduces the infiltration capacity of the soil, leading to reduced natural retention of water. In small basins this can aggravate flood peaks; examples of a more than fourfold increase have been monitored. For large basins the flood intensifying effect of deforestation is less direct. For the Ganges-Brahmaputra river system no effects of deforestation in the Himalayas could be found despite hydrological records of almost 100 years (Smith 2001,

[2]Note that this findings refer to a time period that does not cover recent years and the high-damage hurricanes such as 'Katrina' in 2005.

270). Similarly, a report on *"Forest and flooding"* in Asia (CIFOR and FAO 2005) found only minor relevance of deforestation for large scale flooding. This results also holds for Germany, where the vegetation is considered to have a minor impact on large scale flooding (LAWA 2000).

For a variety of reasons, substantial changes in water body systems took place in recent decades and centuries. Levees and dams were build to allow agricultural use of flood-prone areas, channel alignment eased navigation of ships on rivers, and the drainage of wetlands reduced the danger of infectious diseases. These human made changes of the water body substantially reduced the flood plain of many rivers and increased the velocity of the flood peak flowing downstream (Schmidt (2000, 15-16, 25-30) Heiland (2002, 18-20)).

The increase of human settlements in flood-prone areas is considered to be one important development leading to increased flood damage (Deutsche Forschungsgemeinschaft 2003). As mentioned above for the United States, rising flood damage can partly be attributed to a growing population. However, the specific impact of a growing population in flood-prone areas could not be analyzed due to missing data. This problems applies not only to the United States, but also to other countries. The insurance industry sees an increasing population density and the accumulation of economic values in exposed areas as the main reasons for rising damage of weather-related catastrophes (Deutsche Forschungsgemeinschaft (2003, 90), Munich Re (2002, 16) and Swiss Re (2003, 13)).

2.3 Flood defense

Despite huge progress in flood defense in modern times there is widespread agreement that flood protection measures cannot guaranty absolute safety (see for example LAWA (1995), Smith and Ward (1998), and WBGU (1999)). This view is, in part, the consequence of high damage after recent large flood events. Numerous responses to flooding are possible and this section of the chapter will describe the basic characteristics of the most important flood defense measures. Crude estimates of benefit-cost ratios of flood defense in the United States concluded that every dollar invested in flood defense prevented more than six dollars of damage (Comiskey 2005). The approach used in the estimate, however, does not take into account that flood defense measures are often also the driving force of wealth accumulation in (formerly) flood-prone areas. Therefore, prevented losses might be over-estimated.

Flood risk has a feature in common with many other human-made or naturals risks: High damage events are rare, whereas low damage events happen frequently. Societies tend to be much better equipped to cope with frequent events than with extreme events. There are many technical and non-technical measures that protect a society from frequent floods. In the case of a rare event, these measures might not protect anymore, or—even worse—might aggravate the flood, yielding a catastrophe with high damage and many fatalities (WBGU 1999, 112). It is this feature of risk that constitutes a major challenge in the design of flood defense measures.

There are two basic responses to floods. One response is to reduce the frequency (or the probability) of a damaging flood event, this will be considered as flood mitigation. Another response is the adaption to floods in order to reduce economic damage in case of flooding. The probability and the loss determine the expected damage of a flood.

2.3.1 Flood mitigation

A basic insight of hydraulic engineering is that there is a close linkage between the discharge capacity of a channel and its flow resistance, its slope, and its profile. Some conditions favor water retention and others hamper it. Water retention reduces the peak discharge downstream in the drainage system and extends the time lag to peak conditions after a precipitation event. Increasing the discharge capacity by decreasing the flow resistance of a given channel, reduces the water level of a given discharge and decreases water retention at the location where the measure is undertaken. In contrast, a reduced discharge capacity increases both the water level and the water retention (Brombach et al. 2001, 231-232). Whether or not one wishes to increase or decrease water retention in a specific portion of the drainage network depends on both the flood vulnerability of the area and that of the downstream locations.

Natural retention can occur in the catchment area or in the drainage network itself. Forest leads to a high water storage capacity of the soil and therefore favors retention. In contrast, sealed surfaces in urban areas and surfaces under intensive agricultural use, lead to a quicker runoff. Natural drainage systems with meadows have a greater storage capacity for water than developed waters. Nowadays increased retention in the drainage system itself can often only be achieved by removing existing levees and allowing natural woodland and meadows in the flood plain again (LAWA 1995).

Technical flood protection measures can increase or decrease water retention. Detention basins with retarding dams or storage dams increase water retention. It is the particular aim of detention basins to reduce the peak discharge for downstream locations. Detention basins with retarding dams are self regulating systems whose reservoirs fill as the flood exceeds a threshold level. After the flood peak is passed the reservoir empties on its own. Detention basins with storage dams can be actively regulated, which allows a more accurate control of the downstream flood peak. The location of a detention basin is important. The flood protection effect decreases as the distance to the detention basin grows (Smith and Ward 1998, 214-217). Detention basins are of limited use if the forecasting period is too short to allow an effective flood control of distant downstream locations. This problem prevails for potential detention basins on the Upper Rhine with respect to flood control for the city of Cologne on the Lower Rhine (LAWA 1995).

Some manipulations of the profile of the channel decrease water retention. Widening the profile of a channel, removing trees and brushes or other local obstacles, and increasing the slope of a channel all reduce its flow resistance, leading to reduced water levels. These measures are very effective in proximity to urban areas to reduce the risk of flooding (Smith and Ward 1998, 236-239).

Levees are constructed parallel to a river. The flood plain behind the levee is protected from floods with return periods up to the design flood. The height and the distance to the natural channel are important features determining the protection level of a levee. For floods bigger than the design flood, there is no protection behind the levee, and even for a lower flood there is no guarantee of total protection, because of potential levee failure. However, flood plains protected by levees tend to attract human encroachment. Therefore extreme floods often cause much more damage in levee protected areas than on areas without a levee. This is sometimes referred to as the *"levee effect"*. Another consequence of levees is an increase in the flow velocity of a river, potentially causing higher flooding downstream. This effect is particularly strong in the case of double embanking near the natural channel, so that the whole flood plain is protected (Smith and Ward (1998, 210-213), Tobin (1995, 361)).

2.3.2 Flood adaption

Flood adaption can take place in various ways: land-use decisions and flood-proof building influence the damage potential of a flood. Since the general flood risk is often known and since there is usually some warning time in case of flooding, behavioral responses before inundation are also often possible. Additionally, insurance of unavoidable flood losses can be seen as a flood adaption strategy (LAWA 1995).

Land-use changes where mentioned earlier as an important factor leading to increasing flood damage. These changes are often irreversible. New settlements are the typical example of land-use changes that increase the damage potential. In Germany new settlements are still planned in flood plains (Hofmeister 2006, 192). This not only increases the flood damage potential but can also prevent the establishment of new detention basins. Lacking information on the course of the natural flood outline often triggers inadequate land-use decisions. Accurate maps of the flood outline can inform the public and create awareness of flood risks.

The vulnerability of buildings to flooding can be substantially reduced by adapted construction. Homeowners can undertake many measures to reduce vulnerability. Sensitive elements of buildings are the basement, furnaces, oil tanks, and electric wiring.

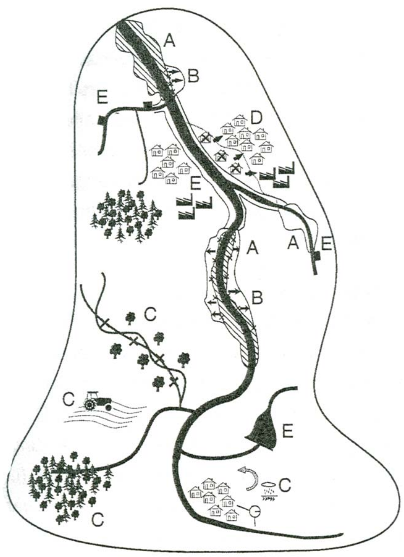
Flood forecasting is essential because it gives communities time to initiate emergency measures. Due to improved models, it has been possible to greatly extend warning times. This benefits downstream locations in large river basins, whereas streams and rivers with small watersheds react fast to precipitation, precluding long warning times.

Floods are uncertain events. Therefore the insurance of flood losses is a potential way to improve the situation of flood victims.

2.3.3 The spatial aspect of flood defense

Each flood defense measure described in the previous sections has its own spatial characteristic. Each river basin is clearly defined in space and shares some common features.

Hilly or mountainous regions tend to mark the border of a watershed. Water in the upper reaches of a river-system comes from large and small valleys, passes the middle reaches of a river and flows through the lower part of the river into the ocean (Heiland 2002, 29). One can ask what part of the watershed is suitable for what flood defense measure. A second question concerns the scope of the measure, is it local or does is also affect locations further downstream?



A Conservation of retention areas
- protection of flood plains in the natural flood outline
- protection of detention basins

B Enlargement of retention areas
- creation of new detention basins
- removal of levees and if necessary buildings
- deepening of detention basins

C Surface retention
- rainwater management
- control of surface sealing
- land use and adapted agricultural techniques
- adapted forest management
- renaturation of drainage system and adjoining meadows

D Minimization of flood damage potential
- regional development
- precautionary building
- public awareness of flood risk
- civil protection

E Technical flood protection
- levees
- walls
- detention basins
- dams

Source: Modified after Heiland (2002, 29)

Figure 2.5: Flood protection measures in a river basin

The first aspect is illustrated in figure 2.5, where the typical location of different flood defense measures within a river basin are shown. The conservation of areas near rivers preserve the possibility of water retention in the natural flood outline (type A measures). In order to reclaim the natural flood outline for flooding, levees need to be removed and land use has to be adapted to flooding (type B measures). Retention on the surface can be done most effectively near the upper reaches (type C measures). To minimize the flood damage potential, it is mainly the lower part of a river in the flat land where flood adaption measures can be undertaken (type D measures). Technical flood protection measures can be undertaken all along the river and its tributaries (type E measures).

The second aspect is the spatial range of a flood defense measure. Benefits from some measures are very local and others are regional. Upstream measures can influence the downstream flood protection level. These spillovers can be positive as well as negative. Aside from some flood defense measures—such as dams—which have also localized effects on upstream locations, spatial effects of flood defense are unidirectional spillovers. This characteristic is a general feature of water problems, because—as Hung and Shaw (2005, 85) note—*"water [...] always flow[s] to the lowest level unidirectionally"*. The unilateral character of spillovers and the resulting fundamental asymmetry between upstream and downstream riparians is also recognized in the political discourse (MKRO 2000, 515).

The extend of non-local effects of a flood defense measure depends crucially on the conditions of the particular river basin. However, some rough estimates are given in table 2.1.

The effect of flood mitigation on flood peaks of large floods through		local effect	long range effect for downstream locations
natural retention	adapted agricultural techniques	+	0
	vegetation, removal of surface sealing	0	0
	river restoration	+	0
	removal of levees	+	+
technical flood protection	levees and local flood protection	+	0 / -
	widening of channel	+	0
	detention basins (regulated and self-regulated)	+	+

Source: Modified after LAWA (2000) and IKSR (1999)

Table 2.1: Spatial flood protection effects of flood mitigation measures

Most measures listed in table 2.1 have positive local flood protection effects for large floods. The removal of surface sealing and the control of vegetation in the whole watershed have flood protection effects primarily for small floods, but not for extreme floods. Only with extreme assumptions with regard to (de-) forestation or surface sealing do these measures have a significant effect on the flood protection level (IKSR 1999, Heiland 2002). Levees and other local flood protection measures increase the flood protection level, but unlike other measures the actual flood peak is not reduced but increased. However, as long as the flood does not exceed the design flood this leads to a better flood protection level. Local flood protection effects are possible through the widening of the flood channel (LAWA 2000, IKSR 1999).

Long range effects are not present for most flood defense measures. Only increased retention due to the removal of levees and creation of detention basins are able to improve flood protection downstream. Higher levees and other technical measures of local flood protection can aggravate the flood susceptibility downstream (LAWA 2000, IKSR 1999).

Water retention depends on the condition and height of levees. In case of extreme floods that exceed the design flood, the protected areas behind levees will function as a retention area. Also if a flood does not overflow a levee, it is often technically feasible to use areas behind levees as emergency retention basins to protect high-risk areas further downstream. However, it depends crucially on the institutional framework of flood management if this form of flood defense will be used. Savanije (1995, 436) calls for a shift from pure flood protection to flood management:

"Flood management means that we take into account that extreme floods, inundations and dike failure can occur, and that we have a plan that will be followed in case of these eventualities."

Some countries follow this approach and have adapted strategies with differentiated protection levels. In Switzerland the protection level depends on the form of land use.

Housing zones and important infrastructures are protected by a high and agricultural areas with a lower protection level (IKSR 1997, 52-53).

Flood adaption reduces damage in case of flooding. These measures have primarily local effects. Only with respect to flood forecasting riparians further downstream benefit from a flood forecast upstream.

2.4 Stylized facts of flood management: an economic perspective

So far this introductory chapter has revealed a number of features of river floods that are of interest for an economic analysis. It is the task of *flood management* to consider all possible human responses to flood risk. Optimal flood management requires that marginal costs and marginal benefits of each measure are equalized. Focusing on the main characteristics of river floods, the following aspects capture the task of flood management.

2.4.1 Public goods

Many flood defense measures are public goods. Public goods are usually defined as goods whose use by one agent does not preclude the use by other agents. In addition to non-rivalry, a second feature of public goods is sometimes seen in the non-excludability from consumption (Mas-Colell et al. 1995, 359).

Flood defense can be a public good, because the benefits one person enjoys do not reduce the consumption level of other people. Although many important flood defense measures are public, private responses are also possible. A rough classification with respect to private and public is given in table 2.2. Natural and technical flood defense measures are, in most cases, public goods. Most flood defense measures, especially retention areas, need space and depend on some form of spatial planning that distributes different forms of land uses in space. Therefore spatial planning is a public task. In response to public spatial planning, private as well as some public actors make their locational decisions. Private persons might buy land and construct houses; public actors build infrastructure for transport or other uses. Since it is not always easy to distinguish between private or public responsibility in land-use decisions, Changnon (1996, 313) emphasizes that individuals and not the government must assume responsibility for their locational decisions. Adapted building construction benefits the owners of houses and is therefore a private good. Exceptions are flood-proof oil tanks that prevent oil contamination also of the neighboring properties. Public building codes can support flood adapted constructions. Flood losses can be compensated by public disaster aid. An alternative response is the private insurance of potential flood losses.

The theoretical condition for efficient provision of public goods draws on Samuelson (1954, 1955) and requires, for a quasi-linear setting, that the sum of consumer's marginal

	public good character	spatial spillovers	risk management
natural flood defense	public	some measures have spillover	mitigation
technical flood defense	public	some measures have spillover	mitigation
spatial planning: distributing land uses in space	public	some measures have spillover	mitigation and adaption
locational decisions	primary private	no spillovers	adaption
adapted building	primary private	no spillovers	adaption
civil protection	public	some measures have spillover	adaption and mitigation
flood loss	public disaster aid or private insurance	no spillovers	insurance

Table 2.2: Taxanomy of flood management measures

benefit from the public good is equal to the marginal costs of the public good. Efficient provision of public goods is not easy to achieve. Oates (1972, 31-35) develops the ideal of a *"perfect correspondence"* where jurisdictions providing a public good should include all individuals who consume the good. This ideal is not reached either if jurisdictions are too small or if jurisdictions are too large.

First, if jurisdictions are too small, free-riding problems arise when individuals outside the jurisdiction benefit from the public good because of spillovers. With positive transfrontier spillovers, free-riding can lead to an under-provision of the public good, because individuals outside the jurisdiction cannot be taxed. In case of negative spillovers, free riding can lead to an over-provision of the public good. The subsequent section will deepen the aspect of spatial unidirectional spillovers, which are present in flood defense.

Second, if jurisdictions are too large, common-pool incentive may lead to inefficient public good supply. This argument is based on political-economy considerations. In flood defense, jurisdictions may be too large because they also comprise areas outside the flood plain. A further discussion of this issue is given below.

Both, spatial spillovers as well as flood-prone areas, raise the question of the appropriate federal organization of flood management.

2.4.2 Unidirectional spatial spillovers

Flood defense can induce spatial spillovers. As analyzed above (see section 2.3.3) these spillovers are unidirectional. The spillovers can be positive as well as negative. Spillovers can lead to externalities. In economics, externalities are usually defined as direct effects of an economic agent on the well-being of other economic agents, such as consumers or the production possibilities of firms (Mas-Colell et al. 1995, 352). The effect is direct in contrast to indirect effects mediated through market prices. Therefore externalities are not only a technological phenomenon, but also the result of existing and missing markets.

As discussed earlier and indicated in table 2.2, not all flood management measures involve spatial effects. Flood adaption through adapted building and adequate land use, or financial relief such as disaster aid and insurance of flood losses do not affect the well-being of downstream riparians. Some but not all measures of flood mitigation influence the downstream flood protection level. As introduced above these measures are retention basins and levees.

Muraro (1974) discusses the economic problem of negative unidirectional externalities for the case of transfrontier pollution. The condition for optimal pollution abatement requires that marginal abatement costs equal the sum of marginal damage of the country under consideration and all downstream countries. Due to the lack of a central authority in the case of international transfrontier pollution, the key question discussed in Muraro is how to implement the optimal solution.

Because many measures of flood management are public goods and because some of these measures potentially cause spatial externalities, the federal organization of flood management becomes an issue. It is well known that many problems of river management arise because issues stretch across jurisdictional borders. Small jurisdictions may neglect spillovers and undertake too little or too much effort by neglecting effects on downstream riparians. On the other hand, big jurisdictions may neglect local differences.

2.4.3 Spatially restricted benefits of local public goods

Some public goods are national public goods, since all members of a nation benefit from the public good. Consumption of other public goods is confined to a geographical subset of an economy (Oates 1972, 34). If the subgroup is small in comparison to the whole economy, potentially corresponding to the communal level of the economy, the public good can be described as a local public good. Also for local public goods the Samuelson rule must hold for efficient provision.

Public flood defense has the characteristics of local public goods, because utility is confined to people in hazard-prone areas. People outside the flood plain do not benefit from flood defense. A political-economy perspective suggests a problem originating from such heterogeneous benefits. If decisions on public flood defense are made by majority voting, welfare enhancing projects might not be adopted if the majority does not benefit. Alternatively, projects adopted by the majority can be inefficient if the minority does not benefit (Niskanen 1998). Therefore voting decisions on public flood defense can lead to an under- or an over-provision of public goods.

In a federal state inefficient public good provision can arise if public decisions are made locally and financing is done by a central authority. Common-pool incentives can then lead to the over-provision of public goods. Alternatively, common-pool incentives arise if the special-interest groups influence the central government to their advantage (Persson and Tabellini 2000, 163-164).

Since benefits from flood defense are geographically confined to flood-prone areas, too large jurisdictions may lead to inefficient public good provision because of common-pool incentives. This can be seen as a problem of the size of the jurisdiction.

2.4.4 Risk management

Floods are uncertain events, therefore one can see flood management from the perspective of risk management. Different aspects of risk management have been treated extensively in the literature. Ehrlich and Becker (1972) discuss market insurance, self-insurance and self-protection as the basic measures of a comprehensive risk management. Risk is a phenomenon where possible states of the world as well as the probabilities of these states are known. Obviously not all uncertain events share this feature. Market insurance is the contractual arrangement that uncertain losses get compensated in return to a premium. This is a possible private response to flood risk that does not cause spillovers. Self-protection reduces the probabilities of bad states of the world that lead to losses. Above, this was referred to as risk mitigation. Flood mitigation measures are public goods and some of these measures cause spillovers. Self-insurance reduces the size of potential losses and is an adaption to the risk. This is a possible response to flood risk, which has partly public and partly private good characteristics. For most flood adaption measures there are no spillovers to downstream locations.

If there are only two states of the world (a bad state, 'damage', and a good state, 'no damage') the motivation for one of the three responses to risk is as follows: First, market insurance can improve expected utility by shifting income (or wealth) from the good to the bad state of the world. For risk-averse individuals and an actuarially fair insurance premium, a shift of income increases marginal utility in the bad state more than it decreases marginal utility in the good state. Second, self-insurance reduces the loss in the bad state of the world, but it also means less income in all states of the world, because self-insurance is not costless. Incentives for self-insurance depend on the probability of a loss. Therefore it can be expected that self-insurance is lower for rare losses than for more frequent losses, because the cost of self-insurance is not influenced by the probability of the states of the world. Third, self-protection reduces the probability of a loss at the expense of less income in both states of the world. If the reduction of the damage probability is large enough a citizen will invest in measures that make the good state more likely.

If more than one response of risk management is possible the analysis gets more complicated. If risk mitigation (self-protection) and risk adaption (self-insurance) are both available they discourage each other. The same applies for risk adaption and market insurance. It is, however, unclear how risk mitigation reacts if market insurance is also available. Potentially incentives for risk mitigation could increase as well as decrease.

The following analysis of the federal organization of flood management will not focus on a risk management perspective. Therefore a more detailed introduction to risk management is not given here. Extensions to Ehrlich and Becker are given in Briys and Schlesinger (1990). Public self-insurance and self-protection as a part of risk management is discussed by Lewis and Nickerson (1989) and Quiggin (1992). It shall be sufficient to point out (see table 2.2) that public flood defense tends to be a form of self-protection, whereas private flood adapting activities tend to be a form of self-insurance. Therefore one can think of public flood defense as activities that reduce the probability of a flood and private flood adaption as decisions that determine the flood loss potential.

Chapter 3

An institutional analysis of river flood management in Germany

> *"Einer der gravierendsten Schwachpunkte ist die unklare Zuständigkeit bei der Katastrophenvorsorge im politischen Raum"*[a]
>
> Die Vorsitzende des Deutschen Komitees für Katastrophenvorsorge (DKKV), Bundesministerin a.D. Dr. Irmgard Schwaetzer beim Gefahrentag 2004 in Mainz am 13.10.2004; http://www.dkkv.org
>
> [a] One of the most severe shortcomings is that there are unsettled responsibilities for catastrophe prevention in the political sphere.

In the last decades, large floods frequently caused substantial economic damage in Germany. Due to missing data, it is difficult to give a comprehensive overview of the exposure of people and economic values to flood risk and of flood damage. However, some data may illustrate different aspects of the problem.

Damage from the large Elbe flood in August 2002 amounted to 9.2 billion euros in Germany (Munich Re 2003, 30). It was much higher than that of any earlier flood event in Germany (see table 3.1). The August flood caused damage of 6.2 billion euros in Saxony, which was the *Bundesland*[1] affected most severely by the flood. 36% of this was damage to residential buildings, 23% damage to commercial constructions and 36% damage to governmental infrastructure (Leitstelle Wiederaufbau 2003, 2). Numbers for the whole of Germany are less precise, since unspecified losses amount to nearly 18% of the damage. The shares of residential buildings, commercial constructions, and of governmental infrastructure are estimated to be 23%, 19%, and 37%, respectively (Munich Re 2003, 27).

Despite large flood damages in the past decades, it is noteworthy that extreme floods in the last century tended to occur less frequently than extreme floods in earlier centuries. Even though measured data are only available since the middle of the 19^{th} century, reports and historical flood marks indicate the large magnitude of former floods. River management and improved flood protection are potential reasons for reduced flood risk. In addition, power plants with their cooling systems, increase the water temperature and decrease the risk of ice jam related floods (Schmidt 2000, 282-258).

[1] The German provinces are referred to as *Bundesländer*. There are 16 *Bundesländer* (the plural of one *Bundesland*) in Germany.

Month/Year	Area	economic losses [nominal values in million euros]	insured losses [nominal values in million euros]
3/1981	Germany	46	-
1981	South Germany	40	5
1983	Rhine	27	2
1984	Rhine	72	3
1988	Danube	27	4
8/1991	Danube	50	4
12/1993	Rhine	540	162
1994	Elbe	162	54
1/1995	Rhine	288	117
7/1997	Oder	324	32
1/1998	Germany	135	5
1999	Rhine	72	5
5/1999	Danube	375	63
8/2002	Elbe	9200	1740

Source: Schwarze and Wagner (2006, 225).

Table 3.1: Recent large flood events in Germany

Climate change and its potential impact on flood management will most likely increase the risk of flooding and make issues of flood management even more important in the future than they are already today. Beyond flood adaption through better flood protection, an increased flood risk may also require relocation to reduce risk exposure (IPCC 2001a, 674).

Recent high flood damages raise the question if flood defense can be improved. This question will guide the following chapters, having in mind that flood defense is expensive. As there is no comprehensive overview of expenses for flood defense in Germany, some examples will have to suffice to illustrate the cost of flood defense measures. 42% of the levees along the Elbe in Germany are in poor condition. Costs of reconstruction are estimated to be more than 450 million euros (IKSE 2001, 71). On the Rhine the flood action plan (see section 3.2.2) for the years 1998 to 2020 lists costs of 8.8 billion ECU[2] for flood defense measures (IKSR 1998).

Nowadays there are three basic strategies that are of importance for flood defense in Germany. These strategies are a combination of flood mitigating and flood adapting measures (LAWA 1995):

- Natural retention encourages the natural functions of water retention, mitigating the flood risk.
- At vulnerable locations technical flood defense measures are able to meet more ambitious protection targets than possible with natural retention. This also reduces flood risk.

[2]The 'ECU' is the precursor of the European currency 'euro'.

- Further precautionary actions ensure that people adapt themselves to the remaining flood risk.

3.1 The legal foundation of flood management

Responsibility for flood defense measures in Germany is divided among different public actors at the federal, state (*Bundesland*[3], and communal level, as well as among commercial and non-commercial private actors. Various legal acts regulate flood-related issues such as land use, building standards, levees, channel maintenance or civil protection. This dispersed responsibility results in a complicated organization of flood management.

Traditionally flood mitigation and adaption was the task of the German states and the communal level. However, the recent Flood Protection Act[4] strengthened the federal level and introduced a common standard in flood protection. In addition flood management is increasingly seen as a task of the whole river basin. The river basin approach is fundamental in the Water Framework Directive of the European Union, adopted in 2000. Table 3.2 gives a crude overview of the federal organization of the different flood management measures.

	actor		
task	federal level (Bund)	state level (Bundesländer)	communal level
retention areas	• protection of flood basins of Q_{100}-floods and designation of all flood-prone areas on maps according to the federal water act (WHG)	• designation and protection of Q_{100}-flood basins according to the federal and state water acts (WHG and others) • consideration of flood-prone areas in regional planning according to the federal regional planning act (ROG)	
technical flood protection	• maintenance of federal waterways according to the federal water act (WHG)	• maintenance of first-order water bodies • construction of levees and dams according to the federal water act (WHG), DIN-standard	• maintenance of second-order water bodies according to state water acts • obligation of discharge control according to state water acts
regional and urban land-use planning	• principles and goals of regional planning according to the federal regional planning act (ROG)	• regional plans (state regional planning acts)	• urban land-use planning: zoning restrictions according to the federal building code (BauGB)
precautionary building		• building codes	
civil protection		• civil protection acts	
insurance and public disaster aid	• flood insurance: commercial voluntary flood insurance with differentiated risk zones • disaster aid in case of large floods: no legal provision, ad hoc disaster aid at all federal levels		

Table 3.2: Competences in flood management

The Federal Water Act (*Wasserhaushaltsgesetz*, WHG) is the legal basis for water

[3]which is the singular of the German states, the *Bundesländer*

[4]The Flood Protection Act brought a number of changes to existing legal acts (*"Artikelgesetz"*), references will be given with respect to the actual legal acts.

management. The Water Framework Directive (WFD) of the European Union with its river basin management approach is now implemented in the Federal Water Act. It is the objective of river basin management to improve the ecological and chemical status of surface water and avoid any detrimental effects (WHG § 25a). Exceptions to this objectives are allowed for artificial and heavily modified surface water bodies. In this case a good ecological potential and good chemical status shall be achieved and detrimental effects shall be avoided. Flood protection measures—whose replacement by alternative measures would cause disproportional effort—can qualify water as heavily modified surface water bodies (WHG § 25b).

The federal Flood Protection Act, which was adopted in 2005, introduced major changes to flood plain protection under the Federal Water Act. The Flood Protection Act also affected the Federal Building Code (BauGB), the Federal Regional Planning Act (ROG), and other legal acts.

The Federal Water Act is the framework for flood mitigation through water retention areas as well as for technical flood protection measures. Areas in the flood outline can be protected as flood basins (WHG §§ 31b.1, 31b.2) or as flood-prone areas (WHG § 31c). *"Flood basins are areas between surface waters and dykes or high banks as well as other areas that are flooded or that flood water flows through or that are used for flood water relief or retention."* (WHG § 31b.1). WHG § 31b.2 asks the *Bundesländer* to designate flood basins located in the Q_{100}-flood-outline and to adopt provisions for flood protection. It was the original aim of the Flood Protection Act to prohibit the declaration of new housing zones in urban land-use planning, but due to political difficulties new housing zones are now permitted under rather restrictive conditions in flood basins(WHG § 31b.4). The new Flood Protection Act simplified the designation of flood basins. Designated flood basins used to be bound to stricter requirements than the location in the Q_{100}-flood-outline.

Flood-prone areas according to WHG § 31c are flooded in case of failure of flood protections measures such as levees, or they are areas in the flood outline that are not vulnerable to floods with return periods of less than a 100 years. The *Bundesländer* are required to map these areas and to take measures to avoid and abate potential impairments from floods. Flood protection plans shall achieve a protection level for floods with return periods of up to 100 years (WHG § 31d). Levees are a very common protection measure for flood-prone areas. Their construction is regulated by the norm DIN 19712[5] that not only gives guidelines on various technical issues but also on the height of the levee and the resulting flood protection level. According to the DIN-norm the flood protection level shall be determined under consideration of technical, ecological, economic as well as urban planning aspects.

The Federal Water Act contains provisions on the upkeep and development of water bodies. The upkeep of water bodies comprises the maintenance of proper conditions for water drainage (WHG § 28.1). The *Bundesländer* and their state water acts classify rivers as first-order water bodies or second-order water bodies. Some states also differentiate higher order water bodies. The *Bundesländer* hold responsibility for first-order

[5]DIN norms are defined by the German Institute for Standardization.

water bodies, whereas smaller, second or third-order water bodies are managed at the communal level. In some states single issue authorities hold responsibility for specific water related tasks, such as the maintenance of levees. Federal waterways are maintained according to the federal waterway act (*Bundewasserstraßengesetz*, WaStrG) by federal authorities. Since many large rivers are federal waterways it is important to note that responsibility for the waterways ends at the milestones on the banks. Areas that become inundated by flooding fall under the responsibility of the *Bundesländer* or the communal level (Heiland 2002, 240).

In urban areas with second-order water bodies the communal level is obliged to adjust water discharge with appropriate measures to prevent detrimental effects on riparians and ecosystems. This obligation of the state water acts serves the general public and not the interests of individuals (Fröhlich 2001, 523).

Water development measures may only be undertaken if they are in compliance with the objectives of river basin management plans. Water development has to maintain natural retention areas and avoid interferences with the natural run-off. The construction of dikes and dams is considered as a water development measure. If no agreement can be reached on water development measures extending over more than a single *Bundesland* the federal level can be asked to negotiate between the *Bundesländer* (WHG §§ 31.1-2, 31.5-6). The requirement of agreement and the possibility of mediation of the federal level is reiterated by WHG § 32. The *Bundesländer* are asked to undertake measures to maintain and reclaim natural retention areas, to allow flooding and discharge of these areas according to an optimized flood discharge concept for the whole water basin, and to restore meadows. Flood protection plans are required to guaranty protection from floods with return periods up to 100 years; they shall be developed until the year 2009.

It is the task of any kind of regional planning to regulate and distribute different land uses in space and to balance the diverse interests that are affected. Flood protection is just one interest, competing with many others at different levels of planning (Lüers 1999). Urban and regional land-use decisions have to consider the basic principles and goals of the federal Regional Planning Act (*Raumordnungsgesetz*, ROG). With respect to flood protection on rivers, a guiding principle of regional planning asks for *"protecting or restoring meadows, retention areas and areas that are in danger of being flooded"* (ROG §2.2(8)). This principle is specified by regional plans and is complemented by the sectoral planning approach of the federal and state water acts, with their binding regulations of flood basins and other issues related to the water drainage system.

Regional plans (for each state) and sub-regional plans are based on state regional planning acts. There is a growing awareness in the state ministries for regional planning that transfrontier cooperation is needed to strengthen flood protection and to prevent the development of new residential areas in flood-prone areas (Fröhlich 2001, 506-507).

Urban land-use planning at the communal level sets the legally binding framework for governmental authorities as well as for affected citizens. It is based on the Federal Building Code (*Baugesetzbuch*, BauGB) and is obliged to fit to the demands and aims of the regional planning act, regional plans, and sectoral planning. Urban land-use planning defines areas for housing and other purposes and can mark areas that are reserved for water drainage and flood protection measures, such as levees, dams, drainage channels and flood basins (BauGB §§ 5.2(7), 5.4). The recent Flood Protection Act explicitly introduced flood protection as one of the principle requirements of the Federal Building Code (BauGB § 1.6(12)). However, there is no general priority for flood protection since attention must also be paid to various other issues such as health, safety, and other socio-economic considerations. Discretion regarding flood protection in urban land-use decisions is limited when new housing zones are established, in contrast, discretion is large with respect to general preventive measures of flood protection (Fröhlich (2001, 509-512) and Lüers (1999)).

Building codes of the German states set standards with respect to specific buildings; they complement the spatial approach of urban land-use planning. One aim of building codes is hazard control, therefore building licenses can require precautionary measures such as safeguarding oil tanks (Fröhlich 2001, 514).

Civil protection in case of natural catastrophes is part of the responsibility of the *Bundesländer*. They adopted civil protection acts. In case of a catastrophe the federal level can help the *Bundesländer* with its civil defense resources. Federal authorities for civil protection take action if local resources are not large enough. Superordinate authorities can overtake responsibility in case of very large events. Civil protection authorities rely on resources from fire departments, rescue services, the German Federal Agency for Technical Relief (*Technisches Hilfswerk*, THW), and non-governmental organizations (DKKV 2003, 100-106).

3.2 Spatial spillovers

Spatial spillovers and heterogeneity of land through flood-prone areas were introduced in section 2.4 as key issues for economic efficiency in flood management. Having given overview of damaging floods and the organization of flood defense measures in Germany, this section returns to spatial spillovers to provide an in depth description of how they are considered in flood management. Flood-prone areas will be discussed in the subsequent section (see 3.3).

Efficient flood management requires the internalization of spatial externalities. As mentioned above, flood protection measures can exhibit unidirectional upstream-downstream spillovers. A detention basin in the upper reaches of a watershed can improve flood protection for downstream riparians. Levees or river channeling can have the opposite effect and aggravate the flood risk downstream.

3.2.1 The size of spatial spillovers

As it is discussed later on (see chapter 5), the magnitude of spillovers is crucial to evaluate what kind of federal organization is most efficient in providing flood defense. Large spillovers favor a centralized provision of flood protection whereas projects with small spillovers are better served by a decentralized provision.

Quantitative assessments of the spatial effects of flood defense must be based on a comprehensive understanding of hydrological and hydraulic conditions of the watershed. Recent advances in computer modeling significantly improved the understanding of flooding events. The effects of river development measures undertaken in the past can now be quantified for some rivers. Models capable of consistently simulating past flood events are becoming the basis for evaluating benefits of potential future flood protection measures. The following section outlines the importance of spatial spillover effects for large river basins in Germany.[6]

The Rhine is not only the largest river in Germany, it is is also one of the best studied watersheds in the country. Large scale water development was undertaken in the Rhine watershed during the last 200 years. In the nineteenth century, rectification of the Upper Rhine took place between Basel and Mannheim. The plan was inspired by the wish to stabilize the riverbed to prevent changes in the river course. The rectification helped to fix the borders between the state of Baden and France and also lowered the groundwater level, with positive effects on agricultural use in the flood plain (Disse and Engel 2001).

Additional measures were undertaken from 1928 to 1977 between Basel and Maxau to improve shipping by means of channels and weirs and to allow the construction of power plants. As a consequence of these measures the flood protection level increased to flood-return periods of 1000 years. However, the same measures decreased the flood protection downstream the weir Iffezheim (near Maxau) from a protection level of 200 years return period to that of a 50 to 60 year return period. At the same time the velocity of the flood peak flowing downstream increased, leading to a higher probability that flood peaks of tributaries of the Upper Rhine coincide with the main flood peak. Water development was also undertaken along the Lower Rhine, today only 15% of the natural flood outline remains available for flooding (IKSR 1997, Lammersen et al. 2002).

Heavy flooding in 1992 and 1995 boosted awareness of flood risk in the Rhine area and the consequences of earlier water development measures. The *"Guidelines for Forward-Looking Flood Protection"* reflect the current understanding of flood management in Germany. They were adopted in 1995 by the *Länder working group on water*[7] and confirmed in 2003 (LAWA 2004). A quantitative assessment of the recommendations, using hydrological models, deepened understanding of the efficiency of flood protection measures and of the magnitude of spatial effects. Simulations with such models were done extensively for the Rhine and the results are believed to carry over to other river basins in Germany (LAWA 2000).

The transformation of old flood basins into retention basins with storage dams is most efficient for flood protection further downstream. Regulated storage dams enhance flood protection significantly in comparison to the recovery of old flood basins as self

[6]Note that not all flood problems involve spatial effects, as 50% of flood damage in Southwest Germany is caused by flash floods. These floods are caused by localized, high intensity rainfalls of short duration. In contrast, floods at large rivers are the consequence of long lasting rainfalls of smaller intensity over large areas (Bronstert 1995).

[7]This group, the *Länderarbeitsgemeinschaft Wasser*, is made up of representatives from each *Bundesland*

regulated systems. A three- to fourfold increase in efficiency was found for retention basins along the Upper Rhine between Worms and Bingen. Flood protection measures display positive downstream effects only if they located at a part of the river that is also affected by the flood. Measures aiming to improve water retention in the whole watershed by the means of adapted agricultural techniques and forest management, and by control of surface sealing may be favorable for many ecological systems; the flood protection effect for large floods at large rivers is, however, not significant. Local, low-scale, technical flood protection measures have, on average, no effect on downstream riparians. A simple aggregation of upstream flood protection effects is not possible (LAWA 2000).

After pointing out the low efficiency of natural retention, it has to be added that these flood protection measures also serve other means and cannot solely be judged with respect to their flood protection effect. Cost benefit studies found high benefits from the removal of levees along the Elbe. The willingness to pay for the creation of a wetland near the Elbe was high enough to yield positive cost-benefit ratios under a set of scenarios. The ratios ranged between 2.5 and 4.2. Due to the small size of the wetland, potential benefits from better flood protection where not taken into account in this study (Dehnhardt and Meyerhoff 2002, Meyerhoff 2002).

A theoretical option for flood protection along the Rhine would be the regulation of the Lake of Constance. However, under realistic conditions lower flood peak levels on the Lower Rhine (Cologne, Düsseldorf) cannot be reached by this measure. This is mainly because the distance is so large that regulation would have to start before the flood-generating rainfall. Currently there are no models available that would allow such long warning times, nor can they be expected to be available in the future. In the 1970s there was a discussion if regulation of the Lake of Constance could improve flood protection along the Upper Rhine. Strong local resistance against these plans arose among the riparians of the Lake of Constance. The Swiss canton Thurgau even held a referendum demanding the government of the Canton to oppose such regulation. The German *Bundesland* Baden-Wurttemberg also opposed regulation because it would not be in accordance with environmental objectives in the region of the Lake of Constance (IKSR 1997, 15-17).

Far reaching flood-protection effects (potential externalities) are also present along the Elbe. The Elbe basin has a high density of reservoirs and storage lakes, higher than in any other large river basin in Europe. A lot of these reservoirs have storage capacities for flood water. Many reservoirs were constructed between 1950 and 1980, increasing flood water storage capacity from 74 to almost 500 million m^3, of which roughly half is located in Germany and the other half in the Czech Republic. Large reservoirs in the Czech Republic have significant flood-reducing effects, reaching far into the Middle Elbe in Germany. Simulation analysis found a flood peak reduction of 30 cm in Dresden as well as flood reducing effects in Magdeburg, which is even further downstream. On the Saale, one of the large tributaries of the Elbe, a peak reduction of up top 50 cm was found for Halle from reservoirs 190 km upstream. But these results need further analysis to provide reliable benchmarks that give a picture of the extent of spatial spillovers

(IKSE 2001, 28-35).[8] Non-stationary data, caused by human impacts and long term climatological variability, constitute the major problem in flood data analysis.

Detrimental effects from flood protection on downstream riparians due to the upstream construction of levees and the resulting destruction of natural flood basins are also present along the Elbe. Nowadays most areas along the Elbe are protected by levees. In the area of Lutherstadt Wittenberg the Q_{100}-flood peak rose approximately 10 cm and further downstream in the area of Wittenberge it rose 50 cm (IKSE 2001, 16).

Efficient flood protection measures do not always have to be undertaken upstream. In urban areas local flood defense is crucial. In Dresden—the city most affected by the 2002 flood—there are two flood channels constructed to release the main Elbe channel if water rises above a certain level. A water level reduction of up to 30 cm can thereby be achieved in the city of Dresden (IKSE 2001, 35). In 2002 the water level in Dresden was the highest ever measured; with 940 cm the gage was considerably higher than the highest gage of 877 cm, measured in 1845. However, in contrast to early speculations, the flood was not a millennium flood. After a number of calculations of the peak discharge, the return period of the flood is now estimated to range between 150 and 200 years. Reasons for extreme water levels were obstacles in one of the flood channels (*Ostraflutrinne*) and natural aggradations near to the Elbe bridges in the city. Responsibility for these problems is shared between the city of Dresden, which maintains the flood channels and the federal ministry of environment, which supported natural conditions on the federal water way Elbe and prevailed against the federal ministry of transport (DKKV 2003, 31).

One can conclude that spatial spillovers play an important role in current flood management. Nowadays flood defense measures discussed for the future mainly exhibit positive spillovers. Retention basins and river restoration are two important examples. However, in the past large scale water development in combination with new or higher levees caused predominantly negative spillovers.

3.2.2 Spatial spillovers and the federal organization of flood management

Federal, state, or communal responsibility?

Spatial spillovers lead to the question: What is the appropriate federal organization? It is the aim of the federal organization to promote efficient provision of public goods. As noted in section 2.4.1, efficiency requires that benefits and costs of public goods are equalized at the margin. For local public goods, the efficiency condition can be fulfilled within a local jurisdiction. Local governments can consider the utility of all its citizen and provide an efficient quantity of the public good. The economic literature stresses that local governments are able to take into account local preferences, which promotes

[8] Helms et al. (2002) work in this direction and emphasize that up to now no (international) agreement could be reached on the flood statistics of the Elbe.

efficient public good allocation (Oates 1972).

However, decentralized decisions can be inefficient if spillovers also affect citizens beyond the borders of the respective jurisdiction. Local governments neglect those externalities, since it is generally assumed that the interests of citizens outside the jurisdiction are not considered. Centralization is the traditional answer to this problem, because a central government of a large jurisdiction can consider benefits of all affected individuals. The classical literature on fiscal federalism argues that this advantage of centralization is not costless, since local differences in tastes cannot be taken into account in large jurisdictions. Oates (1972), for example, specifies that centralization requires inefficient uniformity in public good provision.

After giving an overview on the legal basis of flood management and after looking at the spatial effects of flood defense measures, the question arises if the federal organization of flood management is efficient in taking into account spatial spillovers. Flood management is a complex task. The introductory chapter (see table 2.2) distinguished between flood mitigation, which can have spillovers, and flood adaption, which predominantly has no spillovers. Here the responsibilities for flood mitigation in the federal system will be analyzed first, followed by a brief description of flood adaption measures.

Flood mitigation can be achieved by natural or technical flood defense. Some of these measures exhibit upstream-downstream effects that range further than the local level of the federal system and also further than a *Bundesland* and may, in some cases, even affect other countries. The Federal Water Act is only a framework legislation of water policy and leaves it to the *Bundesländer* to decide on specific policies. The *Bundesländer* differentiate in their water acts between large, first-order water bodies and smaller, second and third-order water bodies. Therefore flood protection for large water bodies falls under the responsibility of the *Bundesländer*, while that for small water bodies falls under the responsibility of the communal level. This division allows a separation of responsibilities in approximation with the size of the spatial interdependencies of streams and rivers.

As mentioned above, flood protection effects on large rivers often extend further than one *Bundesland*. The two large rivers Rhine and Elbe flow through five and seven *Bundesländer* and their watersheds extend over eight and ten *Bundesländer*, respectively. In addition, both rivers cross international borders. Large-scale water development measures undertaken in the past decades, and in some cases even centuries, led to increased flood risk on some downstream locations (such as Cologne). The economic approach on federalism suggests that those spillovers were not taken into account by upstream decision making bodies.

Nowadays, after a number of floods with high economic losses, priorities in flood protection have changed. There is a growing awareness of the spatial effects of flood protection measures. Levees are now seen in a much more critical light than in the past and flood retention basins, with positive downstream effects, are considered to be very effective. Recent changes, through the Flood Protection Act have strengthened the central (federal) level in flood management. The German government argued that a common federal standard in flood protection is necessary to reach a fair balance of interests between upstream and downstream riparians (Deutscher Bundestag 2004). There is now (1) a common minimum standard in the flood protection level that shall be reached (flood protection up to Q_{100}-floods) and (2) a common standard in the declaration of flood plains (Q_{100}-flood outline).

From an economic perspective, it is well known that common standards do not necessarily fully internalize externalities. Whereas complete internalization of externalities leads to efficiency, common standards usually involve inefficiencies (Baumol and Oates 1988). Therefore it worth asking to what extent common standards lead to an internalization of spillovers.

To (1): A common flood protection level can be reached by two different flood defense measures: Increased water retention measures or higher levees. In principle the two measures can be combined. Today, however, the flood plains of most large rivers are already protected by levees, which reduces flexibility in these combination of both measures. Human encroachment in flood plains often leaves little room for larger retention areas. A large scale removal of levees to give more room to the rivers is often not possible. The remaining option are higher levees.

As described before, higher levees have, in most cases, a negative impact on downstream flood protection. If higher levees were the only option for better flood protection, a higher flood protection level upstream would also require higher levees downstream to maintain the original flood protection level. If a common minimum standard aims to increase the flood protection level, downstream levees need an additional increase. A uniform, minimum flood protection standard upstream and downstream in the presence of negative spillovers can have counterproductive effects and aggravate, rather than improve, efficiency in flood defense.

In contrast to levees, water retention measures can have significant positive spillovers, particularly when regulated retention basins are used. Retention basins can be constructed behind existing levees in the natural flood outline. This possibility prevails in many situations, even if the general population density in the natural flood plain is high. The key challenge for the establishment of new retention areas is to find appropriate locations and financing for these projects.

Traditionally, financing of flood defense is done by the federal level that is responsible for planning and conducting these measures. The *Bundesländer* finance flood protection on first-order rivers and on federal waterways. Flood protection along second and higher order water bodies is financed on the communal level. In practice, however, assistance from the *Bundesländer* is available as co-financing for flood protection projects. In addition, most water acts of the *Bundesländer* allow the communal level to share costs among riparians who benefit from a specific flood protection measure. Funding from the federal level is also available under the joint task *"Verbesserung der Agrarstruktur und des Küstenschutzes"* (improvement of agricultural structure and coastal protection, GAK), which provides co-financing of up to 70% of costs. Further co-financing opportunities are also given from the European Union; an example is the completed INTERREG II

C program[9] (Heiland 2002, 240-251). As mentioned already earlier, it is not possible to give a comprehensive overview of the financing of flood protection measures undertaken in Germany in recent years.

The new flood protection plans (WHG § 31d) strengthen the need for cooperation within water basins. However, the Flood Protection Act does not introduce transfer mechanisms to finance new retention areas. One has to conclude, therefore, that a common minimum standard in the flood protection level does little to internalize positive spillovers from retention basins. The problem of how to establish new retention basins is not solved by a common flood protection level alone.

One can note that the situation would be different if the flood plains were still in their natural conditions today. Under such conditions levees are probably a very efficient means of flood defense. A common standard of flood protection would then help to achieve flood protection without comprising the flood safety further downstream. However, this is not the starting point today, since the flood plains of all major rivers in Germany are already protected by levees.

To (2): The second common standard is the declaration of the Q_{100}-flood outline as legally protected flood basins. Areas behind levees in the natural flood plain do not fall under this provision. Many settlements were constructed in the Q_{100}-flood outline in the past, which built up pressure to protect these areas with new levees. The legal protection of the flood plain might help to stop this cycles, which favored negative spillovers. However, the new Flood Protection Act still allows exceptions for new housing zones in the high risk Q_{100}-flood outline.

Like the common flood protection standard, the legal protection of the Q_{100}-flood outline does not foster the establishment of retention basins for downstream flood protection. Potential locations for these basins are in many cases behind existing levees and thus do not fall under the provisions of the new Flood Protection Act.

This assessment of standards is tentative as long as there is no closer description and analysis of decentralized and centralized decision making. Such an analysis is provided in chapters 5, 6, and 7.

Flood adaption aims to reduce the damaging impact of floods and has, in most cases, no spillover effects (see the summarizing table 2.2). From an economic perspective, public flood adapting activities are best provided by decentralized jurisdictions.

Flood adaption is possible by land-use decisions, precautionary building, and civil

[9] The INTERREG II C program of the European Union (1997-1999) was a transnational co-operation on regional and spatial planning that also funded flood mitigation projects. The INTERREG program on Rhine-Meuse Activities (IRMA) was funded with more than 130 million ECU. Since member states had to co-finance the projects the total costs amounted to approximately 430 euro. Interestingly, more than 70% of EU funding went to the Netherlands, which certainly can be considered as a downstream riparian of the Rhine. This is in contrast to the requirements of the flood action plan for the whole Rhine (see the following section on cooperation), where the suggested measures in the Netherlands amount to not more than 20% of the total costs along the Rhine (Heiland 2002, 248-251).

protection. Even though the federal government and the *Bundesländer* have some influence on land-use decisions, it is the communal level, with its land-use planning, that has most influence on the flood loss potential. This division of responsibilities seems justified with respect to spillovers, since, in most cases, the loss potential has no impact on flood risk further downstream.

Building codes and civil protection fall under the responsibility of the *Bundesländer*. Spatial effects of most of these flood adapting measures are not present for downstream riparians. One important exception is the flood proof installation of oil tanks, since oil contamination through upstream leakages significantly increases the flood damage to a house. After the 2002 Elbe flood, 44% of the damaged houses were affected by oil contamination, whereas only 13% of households had unprotected oil tanks (DKKV 2003, 50).

Substantial wealth accumulation in the protected parts of the flood plains raises the question: Is the communal level able to promote efficient locational decisions of individuals. Since this important concern is not primarily based on inadequate considerations of spillovers, it will be discussed in section 3.3, which concentrates on the particularities of flood-prone areas.

Civil protection could potentially cause spillover effects. During the Elbe flood in 2002 more than 131 levees were breeched in Saxonia alone (DKKV 2003, 81, 103). It is recognized that failure of levees or low levees reduced flood peaks downstream during major flood events in the past years. However, publications outlining the general principals of future flood protection in Germany (LAWA 2000, IKSR 1999) do not discuss these "flood protection measures", neglecting the fact that higher levees built according to modern technical standards reduce these accidental flood protection effects.

The current understanding of civil protection in the case of flooding does not promote the idea that areas behind levees can be intentionally flooded to protect other, more valuable areas further downstream. For example, no guidelines were given with respect to this issue in the recent recommendations of the *Länder working group on water* (LAWA 2004). This issue has gained importance since the new Flood Protection Act introduced a common flood protection level for all flood plains and substantial rebuilding of levees is currently being undertaken nowadays along many rivers to reach this goal.

Cooperation

The hierarchically organized federal structure of governmental authorities in charge of flood defense is complemented by numerous approaches to cooperation within river basins. Cooperation is seen here as the collaboration of jurisdictions beyond the hierarchical structure of the formalized federal system. Cooperation increased parallel to a growing understanding of the inter-regional effects of flood protection and river development. Cooperation at the international level increased as did cooperation within countries. The Rhine is an early example of this development.

Due to a changed flood risk, France and Germany agreed, in 1982, to implement retention measures along the Upper Rhine between Basel and Worms. The agreement was a response to the substantial river development along the Upper Rhine, which was completed in 1977. It was the objective of the agreement to implement retention measures in the volume of 290 million m^3. By 1997 a volume of 80 million m^3 retention capacity was available. Simulation analyses show that these measures were able to improve flood protection downstream (along the Lower Rhine), but were not able to reach the flood protection level of 1955. For the Upper Rhine, whose protection is the main objective of the agreed protection measures, the flood protection level increased from a 50 – 60 year to a 80 – 100 year protection level (Lammersen et al. 2002, IKSR 1997).

Financing of the retention measures of the international agreement is shared between the federal government of Germany (40%), and the *Bundesländer* Rhineland-Palatinate (40%) and Hesse (20%). The cost-sharing agreement of the flood defense measures is unique for the Rhine watershed and evolved from the particular historical situation between France and Germany after World War I (Heiland 2002, 255-257).

A further step was taken in 1998 when an *"action plan of floods"* was adopted under the umbrella of the *International Commission for the Protection of the Rhine* (IKSR). The IKSR works on the basis of an international agreement of the riparian states of the Rhine (Übereinkommen zum Schutz des Rheins) with the aims to promote sustainable development of the ecosystem Rhine (§ 3.1) and to undertake a holistic approach to flood protection under considerations of ecological needs (§ 3.4). The aggregated effects of a bundle of measures on the Upper Rhine are quantified as an 80 cm reduction of the flood peak at the Upper Rhine and 45 cm reduction at Cologne for an extreme flood with a Q_{200}-discharge. Additional measures at the end of the Upper Rhine and along the Lower Rhine would be able to achieve a further reduction of 50 cm for Cologne. A reduction of the peak water level from 13 m to 12 m in Cologne reduces a flood from a Q_{1000}- to a Q_{280}-flood (IKSR 1999, 7-8). Costs of the action plan exceed 12 billion euro for the years 1998 to 2020 (IKSR 1998). They are financed by the country (and *Bundesland*) responsible for implementing the flood defense measure (Heiland 2002, 181).

Implementation of the action plan is making progress. Important objectives for the year 2000 could be reached; examples are the reduction of the flood peak and longer flood warning times. However, a reduction of the flood loss potential in flood-prone areas could not be reached (see the following section 3.3). In order to reach the future goals of the action plan, increased effort is needed in the future (IKSR 2001b, 27). Heiland (2002, 177-181) points to fundamental difficulties in implementing the action plan of floods. Unlike water quality problems, which were the starting point of cooperation within the IKSR, flood defense is not solely part of water management, but also requires the integration of spatial planning. Whereas costs of measures to improve water quality were shared among upstream and downstream riparians, no such cost sharing agreement could be reached for the flood action plan. Costs are carried by the party who is undertaking the action, regardless of who reaps the benefits.

One extreme example is the *Bundesland* Hesse that refused to establish regulated retention basins, even though it can be expected that they lead to a substantial reduction of flood risk on the Middle and the Lower Rhine. North-Rhine Westphalia even offered funding for these measures, but Hesse refused because of local resistance. Instead, Hesse chose to build higher levees as a response to increased flood risk after the water development on the Upper Rhine (Heiland 2002, 258-261). Local resistance against retention areas, particularly from the agricultural sector, is a common phenomenon at many potential flood basins (Holtmeier and Kolf 1999).

After analyzing various other approaches of cooperation in the field of water management and regional planning, Heiland (2002, 270) comes to the conclusion that economic linkages between upstream and downstream riparians taking account of cost and benefits from flood defense measures are presently non-existent in Germany. The only exception—which has to be seen in a special historical context—are the above-mentioned flood defense measures along the Upper Rhine that aim to reach the flood protection level of 1995.

Spillovers and the river basin approach

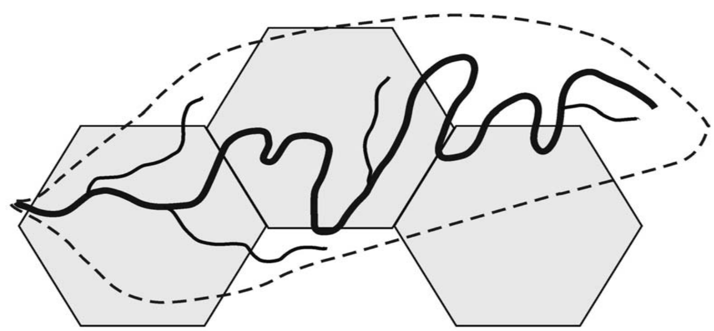
Unidirectional spillovers are not only present in flood defense but also in many other water related issues. It is therefore useful to link the discussion of flood management to the broader policy field of water management. In order to take spillovers into account, the river basin management approach became popular in recent decades. As many river basins comprise more than one country, river basin management is often a transnational task.

Common characteristics of river systems that imply the necessity of public action are (1) economies of scale for large dams (2) upstream-downstream interdependencies and (3) non-rivalry and non-exclusiveness of almost all water uses. A simple normative economic analysis would suggest that a central river basin authority would be suitable to incorporate all relevant externalities (Wandschneider 1984). An ambitious proposal for such river basin authorities is made by Spulber and Sabbaghi (1998, ch. 10) for the United States. They suggest that a wide array of water quality and quantity issues should be addressed by a central authority. This authority should be provided with competence over quality standards, taxes and user fees. However, after analyzing a number of river management experiences, Wandschneider (1984, 1066) comes to the conclusion that *"no general recommendations for decentralized or centralized river basin management structures are justified"*. Maass (1962, 597) is skeptical of river basin authorities for very large rivers and asks, *"what degree of segmentation is desirable"*? Some authors even see *"the promise of decentralization"*, since decentralization can lead to improved efficiency in water use, greater equity in water allocation and the preservation of ecosystems (Mody 2004, 29)

Analyzing problems of existing river basin authorities, Barrow (1998) finds that such authorities often lack the control over the whole basin. They are not able to *'tax'* certain activities upstream in order to allow more efficient development in other parts of the basin. River basin authorities are often too centralized and inflexible. They suffer from over ambition and do not work well together with local authorities and non-governmental organizations. Barrow suggests that river basin authorities focus on coordination and oversight: River basins should be managed by more than one authority, *"to reduce bias and improve scrutiny of development activities."* (Barrow 1998, 180).

Despite the controversy on the best degree of (de-) centralization within river basins, consensus emerged in recent decades that *"water resources management [...] should be carried out at the level of the catchment basin or sub-basin."* (United Nations 1992, Agenda 21 § 18.9). Water policy of the European Union follows the river basin approach. Its Water Framework Directive (WFD) of 2000 asks for "*river basin management plans*" (WFD § 13) and *"programs of measures"* (WFD § 11) to achieve the environmental goals of the directive. Countries of the European Union shall coordinate activities required by the directive. Upon request the European Commission will support coordination activities (WFD § 3).

Beside the fact that most river basins in Germany are shared with other countries, river basins usually comprise several *Bundesländer*. This constitutes a major challenge for the implementation of the Water Framework Directive, since numerous *"problems of fit"* arise through externalities between jurisdictions (Moss 2003, 33-36). Figure 3.1 illustrates that jurisdictions in charge of water management can be too small, since they do not comprise the whole water basin. But they can be also too large when they stretch over more than one water basin.



Source: Moss (2003, 34)

Figure 3.1: Problems of fit. Hexagons represent jurisdictions. Dotted outline shows the river basin.

The Water Framework Directive leaves it to the member states to find institutional arrangements to implement the river basin approach. Two options were discussed in Germany: Either to create new river basin authorities (*"ländergrenzenüberschreitende Planungsverbände"*) with fiscal autonomy or to develop coordination groups between the *Bundesländer* that share a river basin (*"Koordinierungsverbund zwischen den Ländern"*). The advantage of river basin authorities was seen in efficient decision making. However, due to constitutional constraints, closer coordination within existing structures was chosen and river basin authorities were not established (LAWA without year). Even though it is recognized that closer coordination is required, there is a tendency to decrease the administrative capacities of the *Bundesländer* (SRU 2004, 331-332).

As mentioned above, the Flood Protection Act follows the river basin approach of the Water Framework Directive. Therefore institutional arrangements found for the Water Framework Directive will also be of high relevance for flood management.

3.2.3 Summary on spatial spillovers

One key requirement of efficiency in flood management is the internalization of spatial spillovers. The institutional analysis of flood management in Germany leads to the following conclusions.

- ▷ Spatial spillovers play an important role in flood management. However, a lot of flood defense measures have no spatial spillovers and are primarily *local public goods* or in some cases also private goods. Flood adaption activities, in particular, have no spatial spillovers. Local public flood defense along small rivers and streams lies primarily in the responsibility of the communal level, which is responsible for second and higher order water bodies. On first-order water bodies and on federal water ways the *Bundesländer* are responsible for flood defense, reflecting the fact that spillovers can range further then communal borders.
- ▷ Some spillovers extend beyond *Bundesländer*-borders causing *unidirectional externalities*. In the past, large scale water development measures caused positive as well as negative spillovers. Whereas human-made reservoirs usually decreased flooding further downstream, the construction of levees and the straightening of rivers increased flood risk downstream. Efficient flood defense measures are presently (regulated) retention basins. In addition, higher levees are also, in many cases, the answer to the present flood risk.
- ▷ In response to spillovers in flood defense, a number of *cooperation approaches* emerged in the past. Cooperation was successful in some cases in improving communication among riparians of a river. However, cooperation was not able to establish economic linkages between upstream and downstream riparians taking account of costs and benefits from flood defense.
- ▷ The new Flood Protection Act introduced a *common standard* with respect to the flood protection level as well as with respect to legally defined flood basins. Flood protection shall be designed for floods with a return period up to 100 years. The second standard specifies that all areas in the flood outline of a Q_{100}-flood are legally protected flood basins. A common standard does not solve the problem how to remove levees and/or increase water retention capacities for the benefit of downstream riparians. The new Flood Protection Act does not introduce any transfer mechanisms to finance new flood protection measures. Weaknesses in existing cooperation approaches are therefore not eased.
- ▷ Unidirectional spillovers are a common feature of many water management issues. The *river basin approach* is often seen as the institutional answer to water related problems. However, it was found that this approach does not solve the question of centralization or decentralization in water management. The Water Framework

Directive of the European Union follows a river basin approach, but leaves it to the member states to find institutional arrangements how to reach the ambitious environmental goals of the directive. In Germany, no fundamental reorganization of water responsibilities will take place in response to the Water Framework directive.

▷ One reason that a centralized river basin authority might not be the best answer in flood management is that *flood-prone areas* are unevenly distributed. Centralization is often seen as the answer to spillovers. However, larger jurisdictions usually also incorporate many areas without flood risk and therefore do not solve the problems of fit. Large jurisdictions increase heterogeneity of benefits within the jurisdiction. It will be the focus of the following section to discuss how the interests of flood-prone areas are reflected in the federal system. Since only few areas of the country are actually exposed to river flood risk, the problem might be that jurisdictions are rather too large than too small as suggested by the externality problem. This issue is emphasized by Pielke (1999, 432) who states that *"Calls for changes in federal flood policy are seemingly paradoxical because they identify a need to be simultaneously more comprehensive and more localized [...]"*.[10]

3.3 Flood-prone areas

River flood risk is not evenly distributed in Germany. It is restricted to flood-prone areas near rivers. Therefore flood management has a distinct spatial aspect. Most areas of Germany are not exposed to flood risk, but a substantial part is. Flood protection and other measures of flood management benefit individuals who reside in flood-prone areas. Beneficiaries of flood protection are not concentrated in any specific region, but are found in the whole of Germany, since numerous large rivers and a tight drainage system is typical for Middle Europe.

Land use in flood-prone areas has an important influence on the flood loss potential. Whereas the property value of a square meter under agricultural use or forestry is not more than nine euros in Germany, human settlements and transport areas have property values between 144 and 345 euros. Property values translate into flood damage values of not more than one euro for agricultural areas and forestry. For human settlements and transport areas, damage functions are needed to estimate flood damage. In housing areas flood losses can exceed 50 euros per square meter (IKSR 2001a). Since different alternatives of land use influence the flood loss potential significantly, it will be of interest in this section to investigate whether or not the flood risk is taken into account in land-use decisions in flood-prone areas.

The discussion of land use in flood-prone areas also seems worthwhile, because rising flood damage is often attributed to increases in wealth in hazard-prone areas (see section 2.2). The *Raumordnungsbericht* ("regional planning report") for Germany (BBR 2000, 163-164) states that there is little awareness of flood risk behind levees. Flood defense often does not take into account changes in population density in flood-prone areas.

[10] The quote also refers to the findings of Kusler and Larson (1993).

Land use in flood-prone areas is certainly also the result of public decisions. However, as table 2.2 summarized, there are also a number of private decisions that influence the value at risk in flood-prone areas.

The discussion of flood-prone areas will first focus on land-use trends in flood-prone areas (section 3.3.1). Section 3.3.2 then describes private responses to flood risk, which finally leads to the role of the public sector for land use in flood-prone areas (section 3.3.3). Since benefits from flood defense are geographically confined to flood-prone areas, the question arises: How does the federal organization of flood management responds to this spatial heterogeneity?

3.3.1 Land use in flood-prone areas

Approximately 15% of the buildings in Germany are located in the Q_{200} flood outline, and 3% of the buildings are exposed to floods with return periods of 50 years or shorter (GDV 2004). In the densely populated flood outline of the Rhine, 10.7 million people live in the flood outline of an extreme flood, that is 18% of the total population of the watershed. Most people that are exposed to flood risk along the Rhine (8.6 million people) live in the Nethertlands. The German share of the watershed constitutes 54% of the land area and 64% of to the population. Accumulated potential flood losses for the entire flood outline of the Rhine from the Lake of Constance to the border to the Netherlands are estimated to amount to 33 billion euros (IKSR 2001a, Koordinierungskomitee Rhein 2005).[11]

In the whole of Germany, some long-term land-use trends can be observed in flood plains: since 1900 human settlements and transport areas increased fourfold. The land use share was 3% in 1900 and is 12% today. After 1950 the share of human settlements and transport areas doubled. To this day this trend continues. There are no precise numbers on how land-use is developing in German flood plains. 16% of the flood plain of the Rhine between the Lake of Constance and the border to the Netherlands is occupied by human settlements and transport areas (IKSR 2001a, LAWA 1995). This number is representative for all flood-prone areas in Germany. 16.5% of areas not more than three kilometers away from large rivers are used for human settlements and transport infrastructure. The share of the total area of Germany used for human settlements and transport areas is about 7.7%. If areas near rivers (within three kilometers) serve as a proxy for the flood outline, one can observe a special dynamic of urbanization in flood-prone areas.

In the nineteen nineties 0.56% of flood-prone areas were transformed into human settlements and transport areas. For the whole of Germany the respective number was 0.48%. The difference might not seem large, but it demonstrates that, despite a high degree of urbanization in flood-prone areas (16.5% compared to 7.7%), a saturation point has not yet been reached.[12] At the same time as human settlements and transport

[11] The flood outline of this part of the Rhine includes areas in Germany, France and Switzerland.

[12] The numbers reported here rely on CORINE (2004) and the analyzes of the CORINE database by my former colleague Friderike Hofmeister. See also Hofmeister (2006, ch. 11.2). Unfortunately the

infrastructure was increasing, flood protection constructions were built along the rivers. Nowadays 80% of the natural flood outline of the two main rivers Rhine and Elbe is protected by levees or other flood protection measures (LAWA 1995).

Even though the following discussion of land use will focus on the accumulation of wealth through human settlements and transport areas in flood-prone areas, other land-use forms in flood plains are also of high value for society. Flood plains help to maintain high water quality and sustain groundwater supplies. Productive wetlands are found in flood plains, home of many endangered species. In addition, flood plains are often beautiful landscapes offering recreational opportunities (Kusler and Larson 1993).

Exposure to flood risk is in many cases not public information. Even though water authorities keep records of flood events and know the areas flooded by a design flood (usually a Q_{100}-flood) and also of other return periods, the public often has no access to this data. It is only recently that public information became available for some rivers. In 2001 the International Commission for the Protection of the Rhine published the *"Rhine Atlas"*, which contains information on flood-risk areas of the Rhine between the Lake of Constance and the Rhine delta in the Netherlands. Flood-risk zones also include areas that are protected by levees. Flood-prone areas of tributaries of the Rhine are not included in the atlas.

The Flood Protection Act will improve transparency with respect to flood-prone areas. The *Bundesländer* are required to publish this information. The new law not only requires the publication of legal flood basins (according to WHG § 31b), but also the release of maps showing flood-prone areas that are protected by levees or that are only threatened by extreme floods (WHG § 31c). Flood-prone areas have to be marked in urban land-use plans according to the Federal Building Code (BauGB § 5.4). These new requirements aim to improve flood awareness on the communal level. In the past flood-risk awareness was sometimes low or even entirely absent. An example is the recently established industrial area *"An der Flutrinne"* ("by the flood channel") in Dresden. Even after the flood in 2002, an extension of the industrial area was approved by the city of Dresden (DKKV 2003, 41-44).

3.3.2 Private responses to flooding

There are several possible private responses to flood risk. The available information and the institutional framework influence individuals to undertake measures to reduce potential flood damage. Flood risk may influence locational choices and adapted building or promote the insurance of flood losses.

Locational choices are a very important private decisions that determine the flood loss potential. As the preceding numbers showed, there is a changing land-use pattern

CORINE database does no allow a precise definition of flood-prone areas. Instead, areas not further away than three kilometers from large rivers serve as a proxy. The definition of large rivers is also somewhat random, since some parts of rivers are recognized as *"flowing waterbodies"* in the CORINE database and other parts are not. Large rivers tend to be classified as waterbodies and small rivers are not differentiated from their surrounding.

in flood-prone areas in recent decades. An increasing urbanization of flood-prone areas is accompanied by a very low willingness to move out of flood-prone areas after flood events. Less than 5% of households that suffered damage from the Elbe flood in 2002 considered moving out of flood-prone areas (DKKV 2003, 52-53).

There is a higher willingness to undertake measures that reduce the vulnerability of flood-exposed buildings. This willingness usually increases after flood events. Building licenses can require basic flood protection measures for new houses, but for existing buildings most measures are voluntary (DKKV (2003, 46-53) and Lüers (1999)).

Another private response to flood risk is the insurance against flood losses. Since not all flood-prone areas are equally exposed, flood-risk zones are essential for the insurance industry in establishing risk-differentiated premiums. In 2001 a zoning system for flooding, backwater in rivers, and torrential rain (*Zonierungssystem für Überschwemmung, Rückstau und Starkregen*, ZÜRS) was introduced. It was developed by the German Insurance Association (GDV). The information on risk zones of ZÜRS is not public but only accessible to insurance companies. In 2004 ZÜRS was extended to four risk zones comprising now the high risk zone IV (return periods of shorter than 10 years), zone III (return periods longer than 10 years and shorter than 50 years), zone II (return periods longer than 50 years and shorter than 200 years) and zone I with low flood risk (return periods longer than 200 years). Differentiation between risk zones I and II was introduced after the Elbe flood in 2002, when failure of levees increased damage significantly. Risk zone II now also comprises flood-prone areas behind levees. A natural hazard insurance is possible in zones I, II, and III for a risk-differentiated premium, whereas no insurance is available in the high risk zone IV (GDV 2004, DKKV 2003). However, in zones II and III insurance companies might also decide, on a case-by-case basis, that insurance is not possible, so that the share of uninsurable areas in Germany (which had been 10%) is expected to increase significantly (Schwarze and Wagner 2003).

Individuals can insure their property against natural hazards; this insurance includes flood damage. Since the insurance is voluntary, market penetration is low. Household insurance has two separate branches. At the time of the Elbe flood in 2002, approximately 10% of household contents insurance (*Hausratversicherung*) comprised natural hazards, whereas only 4% of the residential buildings themselves were insured (*Wohngebäudeversicherung*) (DKKV 2003, 62). Up to the year 2005, insurance of residential buildings increased to approximately 5.5%, whereas household contents insurance remained constant (GDV 2005). There are significant regional differences in market penetration of natural hazard insurance. The *Bundesland* Baden-Wurttemberg had a compulsory insurance offered by a regional monopoly insurance until the year 1992. Due to requirements of the European Union, natural hazard insurance became voluntary and market penetration declined to 80 – 90%. For historical reasons, household contents insurance is above average in Eastern Germany (DKKV 2003, 62). Insured flood losses for large floods in Germany were given in table 3.1.

Public disaster aid might be a reason for low market penetration of private insurance of flood losses. Public compensation of flood losses has been significant in some past flood events. A systematic analysis of public flood aid is not available in the literature.

The Elbe flood illustrates, however, that most flood damage was compensated by the government. Economic losses were estimated to be 9.2 billion euros, of which 1.8 billion were covered by the insurance industry. Disaster aid accumulated to 9.2 billion euros, raising questions as to the actual contribution of public aid to cover total economic losses (Munich Re 2003). Independent from questions of data consistency, public disaster aid usually does not only cover economic losses, but rather the financial needs for reconstruction. This is in accordance with the estimation method that is usually based on reconstruction costs and not on a rigorous economic cost assessment. The federal government spent 5 billion euros on disaster aid and reconstruction, the *Bundesländer* and the communal level together spent 3.6 billion euros, and the European Union 0.6 billion euros (only for Germany) (Munich Re 2003, 30). This accumulates to the 9.2 billion euros mentioned above.

Public disaster aid for flood losses is in most cases voluntary. Even though flood protection is a public task, there is no general liability of the government for flood damage. Floods are natural disasters and are considered to be an individual and not a public risk. In some cases shortcomings in flood defense can lead to public compensation for flood damage. However, legal requirements are usually high since liability depends on causation and fault (Reinhardt 2004).

Reasons for voluntary public disaster aid are not only seen in altruistic motives, but also in the political system and in considerations of reelection of politicians (Schwarze and Wagner 2006). An empirical analysis of this hypothesis by Garrett and Sobel (2003) finds that, in the United States, presidential disaster declarations and congressional influence on allocation of disaster aid is partly driven by political motives. States that are politically important have higher shares of disaster declarations, and states that are represented in the oversight committee of FEMA[13]—the agency actually allocating disaster aid—receive a disproportionally large amount of disaster aid. Garret and Sobel find that nearly half of disaster aid is driven by political motives and not by altruism.[14]

In response to high disaster relief after the flood in 2002 and in response to a low market penetration of private insurance for flood damage, a compulsory natural hazard insurance was considered by the *Bundesländer*. There were a number of suggestions from the scientific community as well as wide support from politicians. Schwarze and Wagner (2003) suggested a compulsory natural hazard insurance that is in line with a competitive market. The basic objective of this model was to reduce the need of public support and to foster incentives for flood defense. However, due to a number of difficulties, attempts to introduce a compulsory insurance terminated in early 2004.

[13] FEMA, the Federal Emergency Management Agency, is responsible for disaster aid after severe flooding, hurricanes, earthquakes, tornadoes and fires.

[14] Linnerooth-Bayer and Amendola (2003) find cross-country differences in public flood aid. Some countries pay hardly any disaster relief after floods (e.g. United Kingdom), whereas in other countries disaster relief is common and also expected by the population, because the state failed to protect flood victims (e.g. Hungary). Cross-country differences are also present in flood insurance (Schwarze and Wagner 2006). Whereas in some European countries there is an almost perfect market penetration of flood (or natural disaster) insurance, in others countries—like Germany—only a small fraction of potential flood losses is insured.

Also the new Flood Protection Act of 2005 does not include any provision on private insurance of flood losses (Schwarze and Wagner 2006).

People exposed to flood risk might organize themselves in the political process. Even though public disaster aid was substantial for past flood events, there are no examples of lobbying activities for public compensation of flood losses. There are, however, a number of examples of lobbying activities in favor of better flood defense measures. The *"Hochwassernotgemeinschaft Rhein e.V."* is a registered private law association (*eingetragener Verein*) with membership of municipalities, rural districts and non-governmental organizations in flood-prone areas along the lower section of the Upper Rhine, the Middle and the Lower Rhine. As mentioned above, this section of the Rhine experienced increased flood risk after the completion of river development along the Upper Rhine in 1977. The association aims to improve flood protection for its members. The *Hochwassernotgemeinschaft* supports the flood protection plan of the IKSR, it is, however, not authorized to conduct flood defense measures or negotiate further flood protection plans. Because it offers a platform to exchange experiences in flood management, the association is considered to be useful by most members (Heiland 2002, 184-185).

3.3.3 Flood-prone areas and the federal organization of flood management

The discussion of land use in flood-prone areas revealed that private incentives are biased for several reasons. Risk zone mapping is just evolving, market penetration of private insurance is low at the same time as substantial public disaster aid is paid. All these issues are certainly important and influential for land-use decisions in flood-prone areas. However, the following analyzes will primarily focus on public flood defense and land use in flood-prone areas.

The previous chapter characterized flood defense as a local public good whose benefits are restricted to flood-prone areas. From a political-economy perspective this leads to the question, if jurisdictions are too large and do not efficiently provide flood defense. Depending on their exposure to flood risk, political powerful groups of the population may either provide too much or too little flood defense. From this perspective, an uneven spatial distribution of public good benefits can lead to inefficient public flood defense.

One way to avoid such inefficiencies is to tailor jurisdictions to flood-prone areas. Problems originating from too large or too small jurisdictions can be avoided. Looking at boundaries in existing federal systems, Oates (1999, 1131) remarks that many jurisdictions *"are quite poorly designated to deal with the provision of certain important public goods, notably environmental resources."* Rivers, for example, often mark borders between jurisdictions. An effective management of public goods would avoid such shared resource use. Oates is convinced that a rational system would be very different than the historically grown federal organizations. He speculates that on a rational map fairly sizable jurisdictions would extend over watersheds containing smaller jurisdictions of metropolitan and local areas. However, a complete re-organization of the existing federal system according to flood risk zones is unlikely to achieve efficiency gains, since flood defense is only one of many public tasks. Other public goods are likely to have completely different spatial characteristics than flood defense.

An interesting idea for a new federalism was suggested by Frey (1997). He developed the concept of *"functional, overlapping, competing, jurisdictions"*. Such jurisdictions aim to fulfill a specific task, and jurisdictions for different tasks can be geographically overlapping. Mobility between jurisdiction in the sense of Tiebout (1956) (voting with the feet) introduces an element of competition in public good provision. Such a new federalism would force governments to consider the actual preferences of citizens more closely. Borders of jurisdictions would be based on the actual geographical needs and would not be merely the result of history or just chance.

Since flood risk is geographically confined to flood-prone areas, it seems worthwhile to investigate if this spatial peculiarity is reflected in the actual federal organization of flood management. Both flood risk zones and the areas suitable for most flood defense measures are located in flood-prone areas. An exception is water retention in the whole watershed (e.g. soil water retention). However, this measure is not very efficient to protect against extreme floods (LAWA 2000). Thus, risk zones as well as areas for flood defense are both located in flood-prone areas, which would make it possible to tailor jurisdictions to flood-prone areas.

There is another reason to investigate the linkage of flood-prone areas and the federal organization. As the preceding sections showed, some long term land-use changes can be observed in flood-prone areas. During the last decades, there was a steady increase of human encroachment on flood plains. Numerous contributions to the literature argue that this development is influenced by public flood defense. Without a special focus on Germany, Smith (2001, 273-274) describes a *"circular link"* between flood control works and flood plain encroachment. First, better flood defense is more likely to be justified on cost-benefit grounds if existing flood plain development is great. Second, better flood defense makes flood plain invasion more likely. Third, individual locational decisions are often biased, since the cost of public flood defense measures is often not borne by the parties directly involved, but by the central government.

A similar view is expressed by Tobin (1995, 365), who describes the *"levee effect"*:

"Once [... a levee] has been constructed, however, the structure may generate a false sense of security [... which] can also lead to greater development in the so-called safe areas, thus adding to the property placed at risk [...] when the levee does fail, the increase in development can actually raise losses even higher than if no levee system had been constructed in the first place."

The dilemma of improving flood protection without raising human encroachment on flood plains has been increasingly recognized in recent years. One of the goals of the flood action plan of the Rhine (adopted in 1998) is a 25% reduction of the damage potential by 2020. This goal shall be reached through regional and urban planning (IKSR 1998). In its first progress report in 2000, the *International Commission for the Protection of the Rhine* (IKSR 2001b, 4, 25-26) found that all member countries legally implemented provisions that allow a better protection of flood plains. However, the report finds that a reduction of potential damage could not be achieved. Despite the legal progress and the fact that it is very difficult to quantify (additional) wealth accumulation in flood-prone areas, the report suspects that an increase and not a decrease took place in recent years.

The influence of public flood protection on private land-use decisions does not necessarily imply that public flood protection is always inefficient. It stresses, however, that inefficiencies in flood defense may have far reaching consequences with respect to land-use patterns in flood-prone areas. This brings the federal organization of flood management into the center of attention. Over- or under-provision of public flood defense is not only an issue of upstream-downstream spillovers, but also an issue of locational decisions in flood-prone areas.

Single issue authorities in flood and water management

Single issue authorities responsible for flood defense would be one way to take account of the spatial characteristics of the flood problem. There are no examples of such jurisdictions that fulfill a broad range of flood defense tasks. There are, however, examples of jurisdictions that focus on a specific aspect of flood defense. The examples are primarily related to water management issues.

There are different legal acts that allow for single issue authorities. The term *single issue authority* is used here as a general term for different legal institutions. A single issue authority is a jurisdiction in addition to the regular hierarchical federal system that provides a public good with a certain degree of financial autonomy. Two possibilities are of relevance with respect to flood management:

- ▷ water and soil associations, according to the Water Association Act,
- ▷ special purpose associations.

Water and soil associations are based on the Federal Water Association act (*Gesetz über Wasser- und Bodenverbände*, WVG), which gives guidelines for the establishment of water and soil associations (*Wasser- und Bodenverbände*). All *Bundesländer* allow such associations, which can be responsible for various, primarily water-related issues. Such issues can also be the maintenance of water courses and dikes. More than half of the *Bundesländer* established water and soil associations in charge of watercourse maintenance for second and third-order water bodies. Five *Bundesländer* have associations in charge of dike maintenance (Monsees 2004; 2005). One example is North-Rhine Westphalia, where § 108.2 of the State Water Act (*Landeswassergesetz*, LWG) declares that the party who constructed a levee is responsible for maintenance and reconstruction.

A fundamental characteristic of water and soil associations is that membership is generally linked to property and not to persons. Private landowners as well as bodies under public law can be members of an association (WVG § 4). Membership is primarily voluntary, but WHG § 9 also allows compulsory membership, notably if the purpose of a water and soil association requires a contiguous territory. A contiguous territory is essential for the building and maintenance of levees or for water maintenance. The establishment of a water and soil association requires a unanimous approval of all participant, a majority of votes of (potential) participants, or the decision of a public authority (WHG § 7). The regulation of water drainage and the protection from floods (WHG § 10) are specially mentioned as objectives for water and soil associations established by a public authority (Monsees 2004).

Water and soil associations are self-governed jurisdictions. Resolutions are usually made by majority voting. The number of votes is based on the expected advantage of a participant; in case of a disadvantage, the weight of the vote is based on the size of the disadvantage (WVG § 13). Financing of the work of water and soil associations is primarily done by members, but can also be subsidized by the general public, as is often done in the case of flood-defense measures. Members pay contributions to an association according to the received benefits (WVG § 28). For watercourse maintenance, the size of the land usually serves as a benchmark for contributions, and in the case of flood-defense measures, flood-prone areas (polder areas) contribute more than others (Monsees 2004).

Special purpose associations (*Zweckverbände*) are a form of cooperation on the communal level that can also be interpreted as single issue authorities. In some *Bundesländer* some special purpose authorities are responsible for watercourse maintenance (Monsees 2005). They can be established either voluntarily (*Freiverband*) or by a higher ranking public authority (*Pflichtverband*). Enforced special purpose associations are only allowed for public goods that legally have to be provided on the communal level (*Pflichtaufgaben*). North-Rhine Westphalia is the only *Bundesland* in which a special purpose association can be enforced for the provision of public goods that the communal level is not legally required to provide. However, the creation of such an enforced special purpose association requires a legal act of the parliament of North-Rhine Westphalia (GkG NW § 22). Water development and maintenance and urban land-use planning are tasks that have to be provided by municipalities and rural districts. It is determined by law that the communal level has to provide these goods, but not how it has to do it (*Pflichtaufgaben ohne Weisung*). Members of special purpose associations are usually municipalities or rural districts, but in some cases also other legal bodies such as private persons. Special purpose associations have fiscal autonomy and their budget is financed according to the benefits of members (Gern 2003, ch. 7 and pp. 595-601).

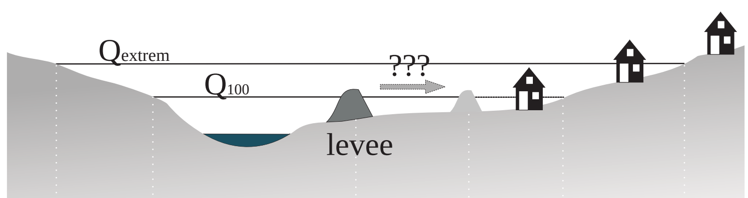
One example of a single issue authority with far reaching water management competence is the *"Emschergenossenschaft"*, which is responsible for the second-order water body Emscher. The legal authority *Emschergenossenschaft* was founded by a special law of North-Rhine Westphalia in 1990 (the *Emschergenossenschaftsgesetz*, EmscherGG) but has its roots already at the time of the industrialization of the Ruhr area. The *Emschergenossenschaft* is responsible for water supply, sewage treatment and flood protection in a densely populated watershed with 2.4 million people (2800 per km^2). Cities and other communal jurisdictions as well as local companies are members of the *Emschergenossenschaft*. In 2005 the *Emschergenossenschaft* adopted a flood action plan (Emschergenossenschaft 2005) that does not propose fundamental changes in flood defense, since the flood protection level is already above a Q_{100} design flood in most cases.

There are other institutions that could be interpreted as single issue authorities. However, they either have no financial autonomy or are of no relevance for flood management. An overview of the legal aspects of cooperation on the communal level is given by Gern (2003, ch. 20).

One can summarize that the federal system in Germany allows for single issue authorities in charge of public flood defense measures. In some *Bundesländer* there are examples of single issue authorities. It is, however, apparent that these jurisdictions are established on small rivers and streams. On first-order water bodies the *Bundesländer* are generally responsible for flood defense. They finance flood-protection measures through their general budget and not according to benefits.

Regional and urban land-use planning in flood-prone areas

Traditionally, flood defense was seen as a task of water management in Germany. In response to large floods in 1988 in Southern Germany, it was increasingly recognized that flooding has to be taken into account of in regional and urban land-use planning. This development led to recommended actions of the *"Ministerkonferenz für Raumordnung"* (Ministerial Conference on Regional Planning) of the *Bundesländer* in 2000. Regional planning now not only aims to support the sectoral planning approach in water management, but also to control the flood loss potential in areas that do not belong to the legal flood basin (Heiland (2002, 32-33) and MKRO (2000)). A stylized illustration of responsibilities for water management and regional planning is given in figure 3.2.



flood prone area: maximum possible flood outline			
regional and urban land use planning			
flood plain		potential flood plain	
Vorbehalt	Vorrang		Vorbehalt
water management according to water laws			
flood hazard zone	protected flood basin	potential retention area	flood hazard zone
risk maps and analysis of potential flood losses			

Source: Modified version of Heiland (2002, 87) and MKRO (2000, 523)

Figure 3.2: Stylized illustration of the different flood-prone areas. The figures shows a typical situation where water retention could be improved by the removal of a levee.

Regional planning can designate areas for flood defense in two categories. The first are priority areas for flood defense (*"Vorranggebiete"*) according to ROG § 7.4(1). In these areas the main spatial function is flood defense and all other land uses are of minor importance. Such priority areas are protected flood basins according to the water acts, as well as high risk zones behind levees. The new Flood Protection Act made the water laws stricter with respect to land-use possibilities in protected flood basins, since new housing zones are now only allowed as an exception.

The second category is used for areas where flood defense has high importance (*"Vorbehaltgebiete"*) according to ROG § 7.4(2). In these areas land-use regulation decisions need to give flood defense high importance, but can also consider other forms of land use. Flood-prone areas where inundation is possible only in cases of extreme flooding are such *Vorbehaltgebiete*. The regulations of the Regional Planning Act were particularly important for protected areas behind levees, since the water law, before changes through the Flood Protection Act, did not contain any provision for these areas (MKRO 2000).

A study on regional planning in Germany finds varying importance of the different flood-defense measures. Heiland (2002, 90-134) investigated 39 regional plans in Germany, covering the watersheds of the Rhine, Elbe and Danube. He finds that most regional plans give clear goals and principles for the protection and extension of retention areas. In contrast, the reduction or control of the flood damage potential is only the goal of six regional plans. Only three of these plans entail detailed provisions on land-use forms and adapted building.

The lack of regulation of the flood damage potential can be seen as a weakness of regional planning as well as of flood management in general. Heiland (2002, 82) notes that a different argument is possible. A society that recognizes that absolute flood safety is not possible can leave it to individuals to decide how to respond to the remaining risk. Strict regional planning of the flood damage potential would then be a form of over-regulation. Heiland himself does not support this view. However, such a view is in line with the argument made by Changnon (1996, 313) with respect to flood management in the United States: He states that individuals and not the government must resume responsibility for their locational decisions (see also Pielke (1999) and section 2.4.1).

Even if one opposes a strong role of regional planning, it has to be recognized that the current organization of flood management in Germany is far from being first best. In the past the lack of access to information on flood risk zones and the high public disaster aid systematically undermined the ability of individuals to make socially optimal decisions. The risk zoning system, ZÜRS, of the insurance industry, introduced a few years ago, and publicly accessible flood risk maps, which are promoted through the new Flood Protection Act, are first steps to strengthen private responsibility within flood management.

3.4 Future developments in flood and water management

In response to a number of large flood events throughout Europe, the European Union initiated an action program of flood risk management that led to the proposal of a directive *"On the assessment and management of floods"* (Commission 2006). This directive requires the member states to develop flood risk maps and flood risk management plans for river basins (§§ 7, 9). The management plans shall be developed in close coordination with the river basin management plans of the European Water Framework Directive. Since the recent Flood Protection Act in Germany adopted stricter flood protection goals with more ambitious deadlines, the adoption of the current proposal from the European Union will not bring major additional changes to German flood management.

The most important future issue in water management will be the implementation of the Water Framework Directive. The legal implementation into national law is now completed, but this is only the first step with many more to follow. An important future step is the adoption of a program of measures (§ 11) and of river management plans (§ 13) that shall help to reach the ambitious water quality goals of the directive by 2015. With the decision in favor of close coordination between existing water authorities in Germany (see section 3.2 on *länderübegreifende Planungsverbände*) an important institutional decision has been made already. However, it can be expected that this issue will stay on the agenda in the future. According to the German Advisory Council on the Environment, federal competence for legislation as well as implementation needs to be strengthened to ensure a watershed-oriented implementation of the Water Framework Directive (SRU 2004, 329-335). The advisory council sees serious difficulties in the current approach, since good examples of cooperation are missing and water authorities from the different *Bundesländer* each have their own way of implementing the framework directive.

These difficulties are also likely to arise with respect to the implementation of the new Flood Protection Act. This act is also watershed-oriented and requires long term management plans. In addition, the Flood Protection Act also asks for strong cross-sectoral cooperation with spatial planning to control the wealth accumulation in flood-prone areas.

Flood management in Germany is affected by the reform of the federal system that was adopted on June 30$^{\text{th}}$ 2006 by the German parliament. The reform of the federal system affects a large number of legal acts, among others it also changed basic elements in environmental law. Instead of its competence for framework legislation, the federal level has now the right to adopt detailed provisions on many environmental issues (*konkurrierende Gesetzgebung*). Depending on the subject, this right is bound on the condition that the federal government can fullfil a certain task better than the *Bundesländer* (*Erforderlichkeitsklausel*). However, in addition the reform introduced the possibility that a *Bundesland* can deviate from the federal law (*Abweichungsbefugnisse*). Since there are very few areas in environmental law that are exempted from the right of deviation, the reform of the federal system in Germany does not consolidate existing environmental law in a unified framework, but rather complicates the responsibilities (SRU 2006, 3-8). This general critic also applies in the field of water and flood management. The reform of the federal system gives the *Bundesländer* the principle right to deviate from federal law and it is a open question at this point if the *Bundesländer* will use this right in the future. In water management the European Water Framework Directive is still binding to the *Bundesländer*, limiting the possibility of deviation. As long as there is no European flood directive, the *Bundesländer* are not restricted from the European level.

As one can only speculate about these future developments, the Flood Protection Act will be considered as the relevant legal provision in flood management in subsequent discussions.

3.5 River flood management: In search of an efficient organization

The forgoing study of the institutional organization of river flood management in Germany leads to a number of conclusions that can serve as the starting point for a formal economic analysis of some key problems. The study focused on two characteristics of flood defense. First, some flood defense measures have unidirectional, spatial spillovers. Second, benefits from flood defense are geographical confined to flood-prone areas.

- ▷ A number of responses to flood risk are possible. Measures of flood management can be the provision of public as well as of private goods. The previous analysis focused primarily on *public* flood management. However, it was recognized that public flood defense has important impacts on private locational decisions and on the insurance of flood risks.
- ▷ Benefits of public flood defense measures have different geographical characteristics. Some measures are clearly local public goods and others have inter-regional spatial effects. Water always flows downwards, this gives the spatial effects of flood defense a fundamental structure since spillovers are *unidirectional*. Upstream riparians can influence downstream locations. Neglecting a few special cases, the opposite is not possible.
- ▷ Due to different spatial characteristics of public flood management, the question of an efficient *federal organization* arises naturally. Spatial spillovers raise the question if decentralization or centralization is the more efficient federal organization. Responsibilities in flood management are distributed among all federal levels in Germany. Public goods with large spatial effects tend to be provided by the *Bundesländer* whereas purely local public goods are provided on the communal level.

  Since benefits from certain flood defense measures range further than a *Bundesland*, there are externalities that were not considered in the past. The strengthening of the federal level through the Flood Protection Act might reduce externalities, but it appears unlikely that the new regulations will solve this problem completely. Given high public disaster aid, one can speculate that the introduced common standard to legally protect the Q_{100}-flood outline rather aims to control potential damage than spatial spillovers. However, so far no convincing arguments were found that the control of wealth accumulation is a public good so that a central standard is justified.

- ▷ Economic theory suggests that *bargaining* between jurisdictions can promote efficient public good provision, even when spillovers between jurisdiction are present. The analyses of different cooperation approaches revealed that transfers between jurisdictions are not common in flood management. As long as successful bargaining does not take place, the federal structure is crucial for taking spillovers into account.
- ▷ Some flood defense measures are highly political because local resistance is large. Traditional approaches of fiscal federalism assume that decisions within a jurisdiction are made from a welfare perspective. This assumption appears somewhat unrealistic and a *political-economy approach to federalism* seems promising for the analysis of public good provision when interests are diverse because of heterogeneous benefits and unidirectional spillovers.
- ▷ A political-economy approach, focusing on the distribution of power within a jurisdiction, seems promising for the analysis of local public goods with unilateral spillovers. Investigations of *water policy issues* come to inconclusive results with regard to an efficient federal organization. Both centralization as well as decentralization are recommended for river basin management.
- ▷ Flood risk is distributed very unevenly in Germany. It is confined to flood-prone areas. It was therefore analyzed how flood management incorporates this *spatial heterogeneity*. Different approaches were found on small and large rivers. On small rivers, heterogeneity can be taken into account by single issue authorities. In practice such jurisdictions are responsible for water maintenance and sometimes also for levees. On large rivers (first-order water bodies), single issue authorities are not found, except for very few cases.
- ▷ There is an ongoing *accumulation of wealth* in flood-prone areas. High flood damages in the past clearly indicate this trend. Large public disaster aid occurred at the same time as market penetration of natural hazard insurance is low. This all leads to a situation where awareness of flood risk and incentives to adapt to flood risks are low. Aside from obvious reasons, it is also the federal organization that leads to this unsatisfying situation. The federal government and the *Bundesländer* play an important role in financing disaster aid, whereas it is mainly the communal level and private decisions that crucially determine the potential damage.

Chapter 4

Local public goods and fiscal federalism: Related literature and the economic problem

"We should also know over which matters several local tribunals are to have jurisdiction, and which authority should be centralized"

Aristotle, Politics 4.15

The preceding chapters introduced flood management as a problem of public good provision in a federal system with mobile households. With this focus, it is primarily the literature on fiscal federalism that is relevant for the subsequent analysis. Fiscal federalism emerges from the theory of public finance and has its focus on fiscal issues of federal countries. It is *"[...] drawing on the theory of public goods, taxation and public debt incidence, public choice theories of the political process and various aspects of locational theory."* (Groenewegen 1987). This chapter gives an overview of the different aspects of fiscal federalism and is the starting point for the subsequent formal analysis of flood defense. The overview starts with the early literature on fiscal federalism and the special problems arising from unidirectional spillovers. This is followed by a survey on political-economy approaches to local public goods under different federal structures. Then the literature that relates to migration in a federal state is presented. The chapter closes with the formulation of the economic problems of flood defense that emerge from the analysis of actual flood management in Germany and the review of the related economic literature.

4.1 The early literature on fiscal federalism

The role of the public sector in the economy is the subject of numerous contributions in the economic literature. In his influential contribution, Musgrave (1959) distinguished between the three basic functions of the public sector that contribute to the overall welfare of the economy. One function is the efficient allocation of resources, another an equitable income distribution, and the third the stabilization of the output level of an economy. With this classification it is apparent that public flood defense requires primarily an efficient supply of public goods, which is an issue of resource allocation. Disastrous floods and mobile households may, however, also raise distributional issues.

Public goods are defined as goods whose use by one agent does not preclude the use by other agents. In addition to non-rivalry, a second feature of public goods is sometimes seen in the non-excludability from consumption (Mas-Colell et al. 1995, 359). Externalities are defined as the direct effects of an agent of an economy on the well-being of a consumer or the production possibilities of a firm (Mas-Colell et al. 1995, 352). The term "direct effect" stresses that the effect is not mediated by prices or coordination between different jurisdictions. There is a close interrelation between externalities and public goods. The private provision of public goods causes spillovers so that other individuals, who do not provide the public good, can enjoy the benefits. In this case spillovers are externalities. As introduced already in section 2.4, the Pareto-optimal supply of public goods requires that the aggregated marginal benefits equal the marginal costs of public goods (Samuelson 1954; 1955).

Since public goods and externalities generally result in inefficient market allocation (the first welfare theorem does not apply (Mas-Colell et al. 1995, ch. 16.C)), it is the goal of the public sector to ensure an efficient allocation of resources. In a federal state with a number of regions and different levels of government, the question arises (Oates 1972): What assignment of responsibilities promises the greatest success in fulfilling the (three) functions of the public sector? The spatial distribution of benefits can vary for different public goods. Ideally there is a perfect correspondence of a jurisdiction that provides a public good and the citizens who consume the public good. However, a perfect correspondence is not always possible, so that jurisdictions can be either too small (there are individuals outside the jurisdiction who benefit from the public good) or to too large (a subset of citizens of a jurisdiction have no benefits from the public good). For a given organization of a federal state the question arises, if the provision of public goods should be decentralized or centralized. The literature discusses numerous arguments in favor of each solution. If not stated otherwise the following arguments go back to Oates (1972, ch. 1 and 2).

- Strong spillovers favor centralization. Benevolent local governments balance marginal cost of public good supply and marginal benefits to their constituents. Consequently the public good is under-supplied because benefits outside the jurisdiction are neglected. For nation-wide public goods this implies that a centralized provision is more efficient than decentralized supply. A decentralized government contemplating an additional unit of a public good has to carry the full cost, which it will weigh against the benefits within the jurisdiction.
- Local variations in the tastes of individuals favor decentralized public good provision, since a central government tends—by the assumption of Oates—to provide the public good in uniform quantity. Decentralized public good provision allows differentiated levels of public good supply that follow local preferences.
- Collective decision making on public goods is costly and connected to fixed costs. Economizing on the number of governmental levels and the number of jurisdictions

favors fewer federal levels and fewer jurisdictions if such costs are high.

- Mobility of individuals can be an argument in favor of or against decentralization. In a decentralized setting, mobile individuals can choose the community with the most preferred public good supply. With a uniform centralized supply such a choice does not exist. In addition, decentralization introduces an element of competition between jurisdictions that is not present under centralization. This argument, which inspired a whole strand of literature (see section 4.4), goes back to Tiebout (1956). However, migration can also cause distortions in a decentralized public sector. One example is congestion, where public good utility depends on the number of individuals who consume the good. With such impure public goods, migration is likely to promote inefficient results, because an immigrant only considers the average level of congestion of a jurisdiction and not the marginal congestion he imposes on all other citizens.
- Apart from migration, the literature on inter-jurisdictional competition considers other mobile economic untis, particularly capital. It is often feared that decentralized taxes and public good provision will be distorted, because local governments seek to attract mobile capital or try to shift the tax burden outside the jurisdiction. As Oates (1999) points out, it is very difficult to find theoretical or empirical evidence for distorted allocations in a decentralized public sector. In contrast, theoretical models show that decentralization can be efficiency enhancing. However, since the following chapters adopt a highly stylized model without capital, this chapter refrains from giving a broader overview of that branch of the literature.
- The afore-mentioned public sector functions, redistribution and stabilization, are unlikely to be fulfilled by local governments. Potential migration poses a serious restriction on decentralized redistribution. Low level jurisdictions are like small open economies. Thus they are neither very effective in fiscal nor in monetary policy, so that stabilization can not be efficiently achieved by decentralized jurisdictions.

In his decentralization theorem, Oates (1972, 35) assumes equal costs and no inter-regional spillovers and concludes that local public goods are best provided by decentralized jurisdictions, since they can consider local preferences. Large, centralized jurisdictions are not superior to smaller, decentralized units, because they are—by assumption—bound to provide the public good in uniform quantity. With its strict assumptions, the decentralization theorem basically compares a first-best decentralized with an imperfect centralized setting. With inter-regional spillovers the assumptions of the decentralization theorem are violated and neither decentralized nor centralized supply will reach the first-best outcome. Depending on spillovers, the best federal organization is either decentralized jurisdictions that neglect spillovers or a centralized jurisdiction that is bound to uniform supply. According to Oates, centralization is favorable if inter-jurisdictional spillovers are strong in comparison to regional differences in taste.

An environmental economic example that entails the basic trade-off between decentralized and centralized settings is given by List and Mason (2001), who analyze a transboundary stock pollutant in a two region setting. Even though pollution is in essence a global issue, the economic problem is allowed to be very asymmetric since abatement costs and environmental damage are region specific. List and Mason compare two second-best settings, where the first scenario captures decentralized optimization of benevolent local governments and the second scenario represents a centralized approach with a uniform emission standard. Strong asymmetries between regions favor a decentralized emission control approach. Even if centralized emission control maximizes aggregated payoffs, it does not necessarily imply an improvement for both regions.

Issues of federal structure are not the only potential solution to the problem of internalizing spillovers. Intergovernmental grants can complement the federal structure and aim to achieve Pareto-optimal public good provision. Grants can be paid between jurisdictions on the same hierarchical level, or from a central to a subcentral government. There are unconditional and conditional grants, where the latter are bound to a special purpose of spending. A common conditional grant is a matching grant, where the spending is financed by a specified formula by the grantor and the recipient government. Oates (1972, ch. 3) argues that a matching grant, and not a conditional lump-sum grant or an unconditional grant, is best suitable to internalize spillover effects. A comprehensive analysis of the effects of grants is given by King (1984).

Empirical studies on the federal structure of a country try to explain the the federal structure either in terms of the degree of centralization or with respect to the consequences of the federal structure on economic growth. In an international, cross-country comparison, Panizza (1999) finds that the size and the income of countries have a negative effect on the degree of centralization in terms of central government revenues or expenditures. Depending on the elimination of outliers, Panizza also found a negative effect of ethnic fragmentation and a democracy proxy on the degree of fiscal centralization. Analyzing growth in industrialized countries, Thießen (2003) finds support for the hypothesis that a medium level of fiscal decentralization leads to more growth than either very high or very low degrees of fiscal centralization.

4.2 Unidirectional spillover

Unidirectional spillovers, as they are present in flood defense and other water economic issues, create an asymmetry between upstream and downstream riparians along a river. Whereas upstream activities affect downstream parties, the opposite does not hold.[1] If the upstream party independently decides on pollution abatement, it equates marginal

[1]Note that unidirectional spillovers are only one class of inter-jurisdictional spillovers. Oates (2001) points to reciprocal spillovers that also may be present in water economics, when different jurisdictions share a lake or bay by occupying parts of the same shoreline. The focus on (unidirectional) spillovers and issues of fiscal federalism in the present context is not intended to imply that water economics can be reduced to these aspects. Water economics involves resource economics, since water is a renewable resource, which is available in different quantities and qualities at different places of the world. It is used by different major user groups and its use often requires infrastructure that exhibits economies of scale. Survey articles on water economics are Becker et al. (2000) and Ziberman and Lipper (1999). An in-depth introduction to water economics is given by Spulber and Sabbaghi (1998).

abatement costs and its own marginal pollution damage. Since downstream damage is not taken into account spillovers are too high. If the downstream party has the right to an unpolluted river and if it is also able to enforce this right, the upstream party may be hindered in engaging in beneficial but polluting activities. Muraro (1974) derives the optimal level of abatement activities in the case of negative, unidirectional externalities along rivers. In a utilitarian framework, optimal pollution abatement requires that marginal abatement costs equal the sum of marginal damages in the country under consideration and all downstream countries. This insight holds for different countries and can be generalized to all riparians along a river. In the case of positive spillovers from upstream economic activities, optimality requires that the marginal cost of that activity equal the marginal benefits of all riparians along the river.

The implementation of the optimal solution has proved to be difficult for many upstream-downstream problems. This seems somewhat surprising since the set up of the problem seems suited to be solved by bargaining. In his seminal contribution on *"The Problem of Social Cost"*, Coase (1960) analyzes economic activities that involve harmful effects to others. He argues that the socially optimal outcome can be achieved independently from the initial distribution of rights. With well defined rights, bargaining can lead to this optimal outcome. However, high transaction costs or ill-defined property rights can impair an optimal bargaining outcome.

Muraro (1974) and also Mueller and Oates (1996) argue that often there is no clear commitment to the distribution of property rights (particularly on the international level); this leads to inefficient outcomes because the victims of an externality favors to appeal to standards of social justice instead of settling with the polluter. Difficulties in committing to a distribution of property rights arise because of equity or distributional implications. Even if the optimal level of spillovers is realized, the question remains how the benefits and costs are shared. For the case of one upstream and one downstream region an overview of possible property right distributions and the resulting incidence of abatement costs and environmental damage is given by Smets (1974). Three basic principle are:

- With the *victim pays principle*, all pollution rights are given to the upstream region. The optimal solution can be reached if the downstream region pays for upstream abatement. This principle favors the upstream region, because all abatement and pollution costs are borne by the downstream region.
- The *civil liability principle* guaranties that no spillovers affect the downstream region without permission. The upstream region must compensate downstream damages and its own abatement costs. This principle, which allows an optimal allocation, favors the downstream region.
- The *polluters pay principle* holds the polluters responsible for undertaking pollution abatement activities. The remaining downstream damage is borne by the downstream region. This principle is suggested by the Organization of Economic Co-operation and Development (OECD).

The literature on international transfrontier pollution often assumes that there is an important difference to the situation within a country. Smets (1974), for example, argues that national pollution issues are easier to settle because polluters and polluted groups are part of the same decision-making mechanism. This makes for a relatively smoother debate because there is a central authority which is absent on the international level (Muraro (1974) and Baumol and Oates (1988, ch. 16)). This statement could be justified because a) either the federal system or b) bargaining between decentralized jurisdictions internalizes spillovers.

To a): According to the traditional understanding of fiscal federalism, whether the public task of internalization should be fulfilled centralized or decentralized depends on the spatial dimension of the spillovers. It is a common assumption that governments aim to maximize the welfare of their constituents. However, in the spirit of Oates (1972, ch. 2), a centralized jurisdiction that takes all spillovers into account is bound to provide the public good in a uniform quantity within the jurisdiction. For water pollution, this may be implemented by an emission standard or a water quality requirement. However, even with complete spillovers both standards are unlikely to lead to the socially optimal spillover level, since optimality compares marginal damages and marginal abatement costs and says little on the absolute level of pollution or the water quality. Thus, the choices for a federal setting, as discussed by Oates, provide only very imperfect solutions to the problem of inter-regional spillovers. Oates (2002) sees unidirectional spillovers as a special case and states that *"[...] this is both a common case in practice and a complicated one in principle for environmental federalism."* Political-economy approaches (see next section) relax the uniformity restriction, making it even more questionable whether the federal structure can internalize spillovers.

To b): Bargaining may internalize inter-jurisdictional spillovers within a country. The analysis of flood defense in Germany does not support this optimism, since successful inter-jurisdictional bargaining does not seem to be taking place (see section 3.2.2). Pessimism with regard to the possibilities of inter-jurisdictional bargaining is widespread in the literature on fiscal federalism. Mueller and Oates (1996) argue, with regard to water pollution in Chesapeake Bay, that bargaining between the different user groups is likely to involve high transaction costs. On a more general level, Inman and Rubinfeld (1997b) give a wide range of reasons that inter-jurisdictional bargaining is unlikely to be efficient. The reasons range from different concepts of fairness and poor information to strategic behavior of the involved parties. This basically covers all the same problems that arise on the internationally level, implying that it is the federal organization that plays a crucial role for internalizing unidirectional spillovers within a federal state.

There are few empirical studies on unidirectional spillovers in rivers. Sigman (2002) investigates water quality in international rivers and finds support for a free-rider hypothesis. Water pollution at measuring stations upstream of an international border is 42% higher than at other comparable stations. This effect is not present within the European Union, since stations upstream of a border have similar pollution levels as other stations. This can be seen as an indication that the European Union is able to prevent free-riding. In another study, Sigman (2005) investigates water quality around the United States with respect of the consequences of local or centralized (federal) responsibilities in water policy. The federal Clean Water Act allows the transfer of implementation and enforcement responsibilities from the federal to the state level, while leaving it only to the federal level to specify the effluent levels and water quality standards. Responsibilities were gradually transfered after 1973, leaving seven states 'unauthorized' by 1995. The gradual transfer of responsibilities allows the assessment of free-riding in water policy and its institutional determinants. Sigman finds that authorization of an upstream state reduces the water quality index of a bordering downstream state by 4%. This result indicates that decentralized responsibilities give rise to free-riding even when there are federal standards. However, in trying to quantify the economic costs of free-riding Sigman comes to the rather modest figure of $17 million per year.

4.3 The political-economy of local public goods

The discussion of unilateral spillovers and the federal organization neglected an important strand of the literature: the public choice mechanism. As it is widely recognized, the assumption of a benevolent social planner or government is not a very satisfying approximation of real-world decision making since some form of voting frequently takes place. Recent contributions capture different political-economy aspects of local public good supply in a federal state.

Lockwood (2002) considers the multi-regions case in a political-economy setting with majority voting. There are discrete public projects with spillovers to other regions. Under decentralization, only local benefits determine the supply decisions. In contrast, under centralization voting decisions are mainly driven by externalities, since elected representative have to form a winning coalition. To ensure a single Condorcet winner, Lockwood imposes restrictions on internal benefits and externalities. A crucial assumption ensures that all receiving regions agree on the sign of the externality from any region. Furthermore, he assumes that the last pairwise vote involves the status quo without the implementation of any projects. Given the assumptions, the political equilibrium outcome is agenda-independent. If there is a majority of projects with positive net-spillovers, all these projects get implemented by the winning coalition, regardless of the internal benefits of projects. In the case of negative net-spillovers, those projects get implemented that have the least impairing effect on other regions. The comparison of federal organizations is analogous to Oates's arguments, because decentralization is sensitive to local preferences, whereas centralization responds to spillovers. With some qualification this leads to the result that centralization is superior to decentralization if spillovers are positive and sufficiently large.

Besley and Coate (2003) follow a political-economy approach that is complementary to Lockwood. In assuming heterogeneous preferences within regions, voters have the possibility for strategic delegation in the election of representatives. In a two regions setting there are symmetrically positive spillovers from perfectly divisible public goods. Public goods are financed by equal tax shares of all individuals of a jurisdiction. The model is a citizen-candidate approach, where elected representatives follow their own policy when in office. Under decentralization there is no strategic delegation and the resulting Nash equilibrium is inefficient because spillovers are neglected. With an uncooperative central legislature, voters prefer a representative of their own kind who decides randomly, with equal probability, on both public goods. Centralization is superior to decentralization if spillovers exceed a critical level. Taking the standard approach in the spirit of Oates as a benchmark, Besley and Coate show that the political-economy approach implies a weaker case for centralization. Given the same preference structure in both regions, the standard approach suggests centralization as soon as there are positive spillovers. In contrast, the political-economy approach suggests centralization only for sufficiently positive spillovers. This is also true for different median preferences in the two regions. The different results are driven by different assumptions with respect to centralization. Whereas the standard approach assumes a uniform quantity of public good provision, the political-economy approaches of Lockwood, and Besley and Coate allow differentiated levels of the public good across regions.

Besley and Coate (2003) also investigate a cooperative central legislature. The conjecture that cooperation makes centralization generally superior to decentralization cannot be confirmed. Instead strategic delegation hampers the performance of centralization. With symmetrical regions, voters delegate to public good lovers who over-provide the public good. The over-provision is strongest for small spillover levels and vanishes if spillovers are complete. Thus the comparison between decentralization and centralization comes to a similar result as with an uncooperative central legislature.

As an extension to Besley and Coate (2003), Dur and Roelfsema (2005) introduce non-sharable local costs that are solely borne by the region where the public good is provided. They argue that non-sharable costs are important in environmental policy but also in other policy fields. With such costs the problem of strategic delegation is somewhat altered. With small local per capita costs, the incentive to delegate to public good lovers is similar as in Besley and Coate. If a large part of the costs is non-sharable, voters try to delegate to conservatives[2] in the hope that they will provide a small amount of the public good in the voters' own region. In addition voters hope for large spillovers from the other region. This introduces a similar free-riding behavior as under decentralization. For the extreme case that all costs are local, centralization does not deviate from the social optimum either when spillovers are absent or if spillovers are complete. The problem of strategic delegation is therefore particularly high for intermediate spillover levels. As an extension of their model, Dur and Roelfsema find that appropriate region-specific taxes or subsidies can prevent strategic delegation in the election of representatives. This allows the socially optimal supply of public goods in a cooperative central legislature.

However, if the tax scheme is not given but endogenous, the outcome can be very inefficient. For the case of an uncooperative central legislature Besley and Coate (2003) find that voting on region-specific taxes and on public good provision not only leads to redistribution but also triggers very inefficient public good supply. A representative in the central legislature has to consider the full cost of public good provision, since there

[2] 'Conservatives' favor less public goods than the median voter. They are the opposite of 'public good lovers', who want more than the median voter.

is no given cost-sharing rule. Therefore, the public good supply is the same as under decentralization in the home region of the representative and lower in the other region, as long as spillovers are not complete. This implies, for all spillover levels, that the aggregated surplus of centralization never exceeds that of decentralization, even with quasi-linear utility.[3] Therefore a given (uniform) tax scheme may be needed to allow a meaningful comparison of centralization with decentralization.

Crémer and Palfrey (2003) consider the implications of a federal standard for decentralized provision of public goods. The starting point of the analysis is the conjecture that a federal standard may avoid the under-supply that occurs under decentralization when positive spillovers are present. Spillovers from other regions enter the utility function of a citizen in a non-additive way, which does not lead to dominant voting strategies. With a binding federal standard, which requires a minimum amount of the public goods in each district, voting preferences may not be single peaked, which may lead to voting cycles. However, local equilibria are always possible. For such an equilibrium a federal standard increases the total spending on public goods, but this increase results from more public good provision in low demand districts, whereas high demand districts provide less. This pattern is exactly the opposite of what would be optimal.

Political-economy contributions to fiscal federalism do not only analyze voting on public goods within a given federal structure, but also consider voting on the federal organization itself. Lorz and Willmann (2005) use a similar setting as Besley and Coate (2003) and extend the analysis to the endogenous formation of centralization. The model is set up as a three stage game. Public good provision is made at the third stage by local and central governments that maximize welfare of their constituents. There is a continuum of public goods that range from purely local to global public goods. Centralized decision making has the disadvantage that the supply of public goods causes some fixed costs. At the second stage, elected representatives bargain on the degree of centralization and on inter-regional transfers. As the result of bargaining there is a critical level of spillovers and public goods with stronger spillovers are provided centrally while those with weaker spillovers are decentralized. The critical level of spillovers is negatively influenced by the public good preferences of the representatives, which implies a high degree of centralization for representatives with a high preference for public goods. At the first stage, there is decentralized voting on the representatives. It turns out that there is inefficient strategic delegation so that public good preference of the elected representative is lower than that of the median voter. This implies that the resulting degree of centralization will be too small.

Another approach on endogenous decisions on centralization is Redoano and Scharf (2004) who consider a two region setting. There are two types of preferences for public goods and one region is a high-preference region (with a majority of high-type voters) and the other region is a low-preference region. At the last stage of the game, the federal organization (decentralization or centralization) is given and representatives decide on public goods. Under centralization, which is restricted to a uniform supply of public goods, this decision is influenced by symmetrical inter-regional spillovers. Prior to the

[3] For this argument, see also the discussion paper of Besley and Coate (2000).

last stage, two different possibilities of voting to centralize the supply of public goods are considered. Either there is a direct referendum or elected representatives decide unanimously on centralization. Under the representative democracy scenario, the elected representatives also decide on the public goods at the last stage of the game. Due to the different preferences of the majorities, centralization is not necessarily favored by both regions. It turns out that, depending on the spillovers, centralization is more likely to be instituted with representative democracy than with a direct referendum on the federal setting. This result is driven by the possibility of strategic delegation in the representative democracy scenario; the high-preference region can credibly commit to a low-preference representative, which increases the chance that also the low-preference region favors centralization.

Political-economy approaches on local public goods often see the key problem in common pool incentives in the central legislature that trigger the over-provision of local public goods (Persson and Tabellini 2000, Inman and Rubinfeld 1997a). This problem—which was also inherent in the contributions mentioned above—was subject to a number of empirical investigations. DelRossi and Inman (1999) investigate the funding of water projects in the United States. The Water Resources Development Act of 1986 introduced higher local cost shares for water projects such as flood control and navigation measures and shoreline protection. In response to the changed sharing rules, Congress members could re-negotiate their local projects that had been already approved but not yet implemented. The adjustments allow the estimation of price elasticities of demand that range between -0.81 for flood projects and -2.55 for large, deep-draft navigation projects. DelRossi and Inman also estimate the effect of upstream and downstream users on flood protection projects. These user groups could potentially have an influence on flood projects because legislators can build a coalition and internalize externalities. However, the number of upstream as well as downstream users (within 50 miles of county borders) has no significant impact on the size of flood protection projects, indicating, according to DelRossi and Inman, that these projects are fundamentally designed to meet local constituents preferences.

In another study on common pool incentives, Knight (2004) investigates voting by US Congress representatives on transportation projects. He finds that legislators respond to common pool incentives and are more likely to approve projects when they are provided in their own district. In addition, project approval is negatively influenced by tax costs from overall spending. The empirical model estimates several parameters that yield insight into the welfare implications of the voting outcome. Whereas there is under-provision in some districts, there is over-provision in a majority of districts. The actual spending is $7.5 billion, whereas the estimated efficient level is $5 billion. Knight concludes that his study raises serious doubt on the assumption that a benevolent social planner maximizes national welfare.

There is some empirical evidence on the normative issue of whether direct democracy has a positive impact on the supply of public goods. Frey and Stutzler (2004) summarize the literature, which finds a negative correlation between the possibility of direct referendums, and public spending and revenues on sub-central governmental levels in

Switzerland and the United States. Other studies find that efficiency in public good provision is positively influenced by the possibility of direct democratic involvement. An example is Pommerehne (1983) who showed for Switzerland that the costs of waste collection is substantially lower in cities with direct democratic participation rights than in cities with representative democracy only.

In earlier chapters it was argued that the geography of flood defense restricts benefits from public flood protection to areas near rivers. Spatial aspects of public goods have hardly been researched in the context of fiscal federalism. The spatial distribution of public benefits is the starting point for the literature on the formation of nations (Alesina and Spolaore 2003), where the size of a state influences the cost of preference heterogeneity and the advantage of cost-sharing of public goods. This literature considers a linear representation of space. If there is voting on jurisdictional boundaries, it turns out that the resulting number of nations is too large, which can be interpreted as an inefficiently high degree of decentralization. Other approaches recognize that public goods have different spatial characteristics and suggest that a flexible system of overlapping jurisdictions can efficiently provide different bundles of public goods within a nation (Frey 1997). This approach does not take jurisdictional boundaries as given, but asks what *"functional, overlapping, competing jurisdictions (FOCJ)"* can best fulfill a particular task. An example that is well suited for a flexible federal setting is water management at Chesapeake Bay in the United States. Mueller and Oates (1996) discuss the creation of a new jurisdiction that can better address the interests of different user groups than the existing federal structure, since the current structure is not well suited to incorporate the different bilateral and unilateral externalities.

The issue of flood defense certainly does not raise such principle issues as the formation of nations, but it does raise the issue of whether jurisdictions should be tailored to flood-prone areas. This can be done through single issue authorities that complement an existing federal structure. Such considerations seem important in a political-economy context, where the benefits from public goods drive voting preferences. In assuming that voting preferences of the median and the average voter are the same, the current literature says little about the conditions under which single issue authorities are well suited to provide public goods such as flood defense. Another issue that has received little attention in the literature is that of unidirectional spillovers. In a political-economy setting, such spillovers are likely to influence the outcome under centralized supply. However, unidirectional and also asymmetrical spillovers are neglected in much of the political-economy literature.

4.4 Migration in a federal state

The literature on local public goods and migration traditionally focused on decentralized jurisdictional settings and asked if they are able to achieve an efficient outcome. Often the implicit, and sometimes also explicit, assumption of these studies is that the central government can achieve the efficient outcome, see for example Wellisch (1993, 675). With this focus, the literature says little on the classical question of fiscal federalism:

What is the appropriate federal level that should provide a public good? Nechyba (1997) remarks that the literature on issues of fiscal federalism is separated from that on issues of local public goods and migration that followed Tiebout (1956). The following section will first focus on the latter strand of literature that was inspired by Tiebout before turning to the literature that also captures aspects of fiscal federalism.

Public goods have a spatial pattern of benefits and costs that may be a cause for migration. Utility differences induce migration if relocation improves utility. With free and costless migration, individuals are highly responsive to changes in public good provision. The opposite is the case if there are high migration costs or preferences that attach individuals to regions. A migration equilibrium is reached if nobody can improve his utility by relocation. This equilibrium concept allows unilateral action but not the coordinated relocation of a subgroup (Scotchmer 2002, 2004).

In considering the possibility of migration, Tiebout (1956) came to his seminal hypothesis that "voting-with-the-feet" can ensure Pareto-optimal public good provision. This hypothesis is in contrast to the rather skeptical conclusion of Samuelson (1954), who offered a rule for Pareto-optimal provision but could not propose any decision procedure for implementing the optimal solution. Therefore it is well established in the literature that, while markets can ensure an efficient allocation of private goods, there is no such mechanism for public goods, since individuals are reluctant to reveal their true preferences. Tiebout's hypothesis is based on a number of assumptions. The economy comprises enough communities so that all desired public good bundles are available. Citizens are fully mobile and well informed on the characteristics of the communities. Their income opportunities are the same in all communities. Each desired public good bundle is available at minimum average cost, which implies that each community has its optimal size. There are no spillovers between communities. Public goods are not provided by a central government, but by local communities that are run by "city managers". Given the assumptions, Tiebout postulates that citizens can choose a community with a public good supply that best suites their preferences. Since citizens can choose between communities, there is a market-like framework that promotes Pareto-efficiency.

Tiebout stimulated a whole strand of literature that formalized different aspects of local public goods and migration; for surveys see Wildasin (1987) or Scotchmer (2002). One of the main purposes of spatial models of local public goods is the analysis of the population distribution across space. There are different forces at work that either a) favor the concentration of individuals at one location or b) scatter the population to a rather even spatial distribution. These forces can be explained by referring to Boadway and Flatters (1982), who consider two regions, purely local public goods, and local governments that maximize welfare of their citizens. Beside public goods, there is a private good, which is produced with labor, and a region-specific factor (which is typically interpreted as land). Governments are myopic in the sense that they assume that public goods do not induce migration. Approximating the population size of region i with the continuous variable n_i, this optimization problem leads to the indirect utility function, $v^i(n_i)$, that is the indirect utility of a representative citizens in region i.

To a): A large population size, n_i, comes together with a low individual cost-share that finances public goods. This has a positive effect on the indirect utility, since pure public goods allow the same quantity of consumption independent of the consumption of other individuals. Since public good provision needs the input of scarce resources, it is always more efficient to share these costs within a larger population. This argument is weakened if there are crowding effects in public good consumption (congestion), so that additional consumers have a negative impact on other consumers.

To b): A large population size, n_i, leads to a low indirect utility because per capita output of the private good is low. With a concave production function, the per capita level of the private good always decreases in the population size (work force) of a region even when the marginal output of labor is positive.

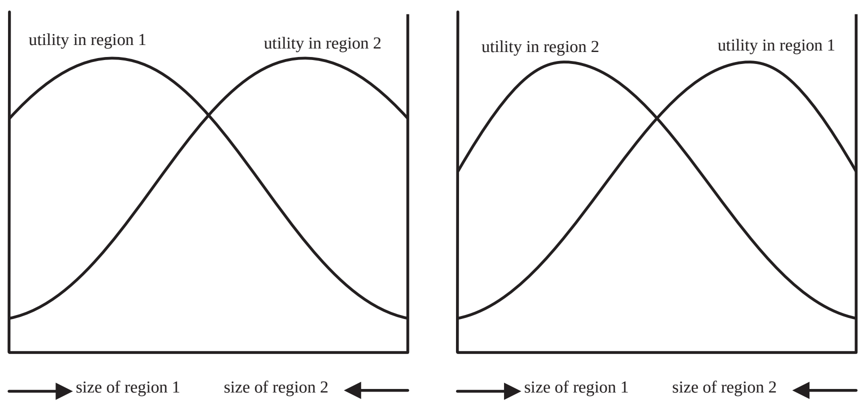


Figure 4.1: Migration equilibria in a two region local economy. Left: The crossing point indicates a migration equilibrium. Right: At the crossing point the necessary but not the sufficient conditions for a migration equilibrium are met.

Depending on the magnitude of these two effects, an additional citizen can increase or decrease the utility of residents in a community. With respect to the partial derivative $\frac{\partial v^i}{\partial n_i}$, it is often assumed that the cost-sharing effect dominates for a small population, whereas the decreasing per-capita level of the private good dominates for a large population. This effect of an additional citizen is of course a local property and can vary in the population size. For the two region case, an illustration of the two effects is given in figure 4.1 for two scenarios.[4] In both scenarios, indirect utility is first increasing and then decreasing in the population size of the region, implying that there is a population size that yields to a maximal utility level. This size is sometimes referred to as the optimal population size of a jurisdiction.

There are several migration equilibria in figure 4.1. As introduced above, a migration equilibrium requires that nobody has an incentive for relocation. Following the lead

[4] The consequences of migration depend on the assumptions of the model. Figure 4.1 shows a situation where governments immediately re-optimize the public good in response to migration. Graphs of similar shape would be reached if the level of public goods is held fixed and the public goods are financed by the final residents of a region. The following chapters will offer more detail on this point.

of the literature (Stiglitz 1977, Wildasin 1987), Boadway and Flatters (1982) assume identical preferences and equal treatment of individuals within a community. With respect to land rents Boadway and Flatters assume that they are distributed to the final residents of a region. With these assumptions the crossing points of the two graphs in figure 4.1 indicate the natural candidates for a migration equilibrium, since utility is the same in both regions. However, whereas the left crossing point is a migration equilibrium, the right one is not. The crossing point on the left part of figure 4.1 depicts a situation where nobody can improve his utility by migration and therefore a migration equilibrium prevails. In contrast, the right crossing point indicates a situation where migration can still improve the utility level of the immigrant, which is sometimes referred to as an unstable migration equilibrium. In the right part of the illustration, migration results in the complete concentration of all individuals in one of the two regions. In the left part of figure 4.1 there are no migration equilibria with complete concentration. Additional possible migration equilibria are illustrated in Stiglitz (1977). For the two region case of Boadway and Flatters (1982), the sufficient condition for a migration equilibrium requires $\frac{\partial v^i - v^j}{\partial n_i} < 0$, which they refer to as an over-populated federation.

From a normative perspective migration equilibria are often not optimal. Normative judgments crucially depend on the underlying welfare function. With a utilitarian welfare function, migration equilibria are not generally optimal, because optimality may require that equal individuals be treated unequally, because this leads to the highest social welfare (Mirrlees 1972, Stiglitz 1977). Optimality in the utilitarian sense requires a direct control of locational choices of individuals. If a direct control is not possible, one naturally chooses a Rawlsian welfare function, because it is compatible with the free migration restriction. Such a welfare approach concentrates on the Pareto-optimal allocation that is compatible with free migration (Wellisch 1993).

With a Rawlsian welfare function, a migration equilibrium can be inefficient for two reasons. Firstly, inefficiency arises when public goods are not provided according to the Samuelson rule. Secondly, the migration equilibrium can be locationally inefficient. Locational efficiency requires that the social net-benefits of an immigrant to a region must be equalized. The net-benefit is the additional output (the marginal labor productivity) minus the private good consumption of an immigrant. Without public goods, an efficient locational pattern of individuals is given if the marginal labor productivity is the same in all regions, because this maximizes the total output of the economy. With concave production functions and competitive labor markets it is only a question of rent-distribution how to achieve such an outcome. With (pure) public goods, the equilibrium consumption of the public goods can be different across regions. For a locationally efficient migration equilibrium, two conditions must hold. First, to ensure a migration equilibrium, utility differentials stemming from public good consumption need to be compensated by the private good so that utility is equalized across regions and the conditions for a migration equilibrium are given. In addition, to ensure locational efficiency of the migration equilibrium, a region favored by high public good consumption (and a low consumption of the private good) must have a relatively low labor productivity. Thus, locational efficiency requires that the social marginal net-benefit of an immigrant to a region is the same for all regions (Wildasin 1987).

A migration equilibrium is locationally inefficient if the net-benefit of an immigrant to a region deviates across regions. A Pareto-improvement is possible through migration to the region with the higher net-benefit. However, due to institutional shortcomings there might be no incentive for migration. The literature investigates different tax and income distribution schemes with regard to locational efficiency. Boadway and Flatters (1982) find that competitive labor markets and rent distribution to residents lead to locational inefficiency, if public goods are financed by head taxes. Their model, as well as many others, assumes a concave production function and no public good spillovers between regions. Locational efficiency is possible if transfers between regions are introduced. Also, without inter-regional transfers, a locationally efficient migration equilibrium can be reached if land rents do not accrue to residents as assumed above, but are distributed to land owners. Boadway (1982) shows that with equal property shares of all citizens the resulting migration equilibrium is locationally efficient. This result holds regardless of whether local governments, which provide purely local public goods, are aware of the free migration restriction or not.

Wildasin (1987) summarizes the literature and states, in a model that also allows for congestion in public good consumption, that a combination of head and land-rent taxes can yield locational efficiency of the migration equilibrium. This result is achieved when head taxes equal the marginal crowding effects of an immigrant and taxes on land rents assure that the budget constraint for public good provision is met.

The literature makes different assumptions with respect to the awareness of migration. The above approach of Boadway and Flatters (1982) considers myopic local governments. Other approaches assume non-myopic behavior, so that local governments consider the linkage between public goods and locational choices. In a contribution of Boadway (1982), for example, differences between myopic and non-myopic behavior arise, when public goods are financed by property taxes that are also collected from non-residents. Whereas with myopic decisions this leads to an over-provision with public goods, with non-myopic behavior that correctly anticipates the (potential) migration responses, the public good is provided according to the Samuelson rule.

The approaches presented so far followed Tiebout in neglecting inter-regional spillovers. Such spillovers are crucial in the context of flood defense. One local economy approach that considers spillovers and mobile households is Wellisch (1993; 1994). In a two region model he comes to the result that regional governments that maximize the welfare of their residents provide the public good according to the Samuelson rule and promote locational efficiency. This result relies on the assumption that regional governments have the appropriate tax and transfer instruments to implement the first-best allocation under the restriction of free migration. Furthermore, regional governments are aware of potential migration responses when deciding on public good provision and take the action of the other regional government as given. Thus, the resulting socially optimal allocation is a Nash-equilibrium. Wellisch argues that the optimal outcome is reached, because local governments have essentially the same objective as a social planner: both aim to maximize utility of a representative household. The resulting allocations coincide, since both face the equal utility constraint, and local governments are aware of migration and can use the appropriate tax instruments.

The analysis of migration equilibria becomes more complicated if the total number of jurisdictions is not given but endogenous. Such a setting is the starting point for the analysis of clubs. Clubs also offer (impure) public goods, but, unlike jurisdictions, they are usually not defined over geographic space. In the theory on club formation different equilibrium concepts are used. One of them is the free mobility equilibrium that was introduced above. Other equilibrium concepts in club theory, for example the core, allow coordinated actions of more than one individual and not just unilateral actions. With these concepts it is often difficult to find an equilibrium of the economy (Scotchmer 2002). Since flood defense is a public good where benefits are closely linked to space, a free migration equilibrium for public goods provided in jurisdictions seems to be the adequate equilibrium concept for the present problem. Therefore a broader overview of club theory is not given here.

Voting has been introduced to the literature on local public goods and migration. With the focus on decentralized voting and a one-dimensional voting problem, voting cycles are usually avoided (Scotchmer 2002). Stiglitz (1977) adapts simple majority voting in a setting akin to Boadway and Flatters (1982) and comes to similar results. With non-myopic voters and equal property shares of all voters, the resulting migration equilibrium is Pareto optimal; a result similar to that found by Boadway (1982). Westhoff (1977) relaxes the assumption of identical voters and considers differences in preferences. With a proportional wealth tax that finances local public goods, he finds that a stable migration equilibrium exists if a continuous ordering of consumers preferences is possible. However, Konishi (1996) notes that the assumptions of no scarcity of land and pure public goods are a serious shortcoming of the model, because consumers could concentrate in one community and enjoy a much higher public good supply. Thus, the relevance of the migration equilibrium found by Westhoff is not clear. Konishi (1996) gives a general existence theorem for a migration equilibrium in a multi region setting with inter-regional spillovers. Public goods are financed by local income taxes that avoid the problem of non-convexities that was present in similar earlier models.

With the focus on decentralized settings, the literature on local public goods and migration by and large omits the classical issue of fiscal federalism, which questiones whether a public good should be provided by decentralized or centralized decision making. Some contributions consider such complex settings that normative issues are neglected all together. However, there are some contributions concerned with issues related to the federal structure of an economy. Nechyba (1997) combines the analysis of local public goods with an additional national public good, so that there is a hierarchical governmental structure. There is majority voting on the local and on the national public goods, which are financed by property and income taxes, respectively. A voting and migration equilibrium is shown to exist under certain assumptions. But, even though local public goods with inter-jurisdictional spillovers are allowed, variations of the federal setting that provides the public goods are not considered.

Empirical studies have tried to confirm links between public goods and mobile economics units, particularly capital and labor. A number of studies assess the impact of public environmental regulation on investment decisions. Levinson (2003) summarizes studies that find evidence for a negative impact of regulation stringency on investment in polluting industries in the United States. However, a transfer of regulation responsibility from the federal to the State level in the early nineteen-eighties was not accompanied by degradation of air quality, so that there is no confirmation for a race to the bottom. Levinson notes that the efficiency of inter-jurisdictional competition cannot be judged by the absolute air quality alone, but also depends on the responsiveness of individual states to regulatory stringency in neighboring states. Levinson presents his own evidence and that of other studies showing that neighboring states have a positive impact on the environmental regulation in a state. A result that he interprets as a case against decentralized responsibilities.

In a textbook context, Mueller (2003, 199-202) summarizes the empirical evidence with regard to migration and public expenditure. There are several examples that show that emigration from a jurisdiction positively correlates with high tax levels. Welfare payments of a state correlate negatively with the number of poor people in neighboring states. As a consequence of voting-with-the-feet, Tiebout (1956) predicted a preference-driven sorting of individuals into communities. Sorting according to income could be observed for different urban areas in the United States, as Mueller reports.

4.5 The economic problem of flood defense

The review of the literature shows that numerous theoretical and empirical contributions are of relevance for flood management and its federal organization. The discussion of the relevant economic theory complements the institutional analysis of flood management in German (chapter 3) and helps to define the economic question that will be the focus of this dissertation. The literature is the starting point for the formal analysis of public flood defense as a local public good with unidirectional spillovers and a distinct spatial distribution of benefits.

- ▷ Public flood protection measures cause spillovers that are unidirectional. Recent contributions to fiscal federalism emphasized political-economy aspects, whose relevance was also suggested by empirical studies. However, these contributions mostly focus on symmetrical, inter-regional spillovers and do not discuss the consequences of unidirectional spillovers. So it is an open question, under what conditions centralization or decentralization is the better federal organization if unidirectional spillovers are present. This is not only a question for the case of positive spillovers, but also when spillovers are negative. The latter case is hardly discussed in the literature. Therefore one can conclude that unidirectional spillovers—which Oates referred to as a relevant as well as complicated issue in fiscal federalism—are a fruitful field for an analysis in a political-economy context.
- ▷ Heterogeneous benefits from public goods may lead to a deviation of the median and the average voting preference of a region. With the geography of flood defense, it is possible to create a single issue authority that increases the homogeneity of

voting preferences within a jurisdiction. The political-economy of this issue is hardly researched.

- Since unidirectional spillovers and heterogeneous benefits are both present in flood defense, it is interesting to to investigate the linkages between these issues.
- The possibility of relocation creates a more complex setting for public flood defense. Whereas there is a substantial literature on the linkage between public goods and migration, there is little insight into what kind of federal setting is recommended for public goods with unidirectional spillovers. The answer to this question is likely to depend on the voting behavior, which can be either myopic or non-myopic with respect to potential migration.

Chapter 5

The political-economy of local public goods

This chapter gives a formal analysis of local public good provision with unidirectional spillovers and spatially heterogeneous public good benefits, where the amount of public goods are determined by voting. Unidirectional spillovers and heterogeneous benefits were found to be crucial in flood management and are not well covered in the literature.

The recent political-economy approach of Besley and Coate (2003) to the issue of the optimal vertical federal structure is the starting point of the analysis. In a two region setting, this approach allows the comparison of decentralized and centralized public good provision. As an extension of Besley and Coate, spillovers are allowed to be asymmetric, covering the extreme case of unidirectional spillovers, which is present in flood management and also in other water related issues. Spillovers are allowed to be positive as well as negative. Thus, in the two region economy it is possible to consider positive and negative unidirectional spillovers between an upstream and a downstream community along a river.

In addition, the model allows for public goods with unevenly distributed benefits. Benefits are high in some parts of a region and low in other parts. For the case of flood defense there are high-benefit individuals that live in flood-prone areas, where benefits from public goods are high. Low-benefit individuals live outside these areas. The location determines the voting preference of citizens.

The uneven distribution of the benefits from public goods allows the spatial separation of citizens into high and low-benefit groups. Such a separation might be a promising possibility, since public good provision is determined by voting. Through separation, high-benefit individuals can establish their own jurisdiction, a *single issue authority*, which only comprises individuals of the same voting preference. Since there is the possibility of spillovers between the high-benefit groups in different regions, the single issue authority can be established with a decentralized or centralized structure. Single issue authorities are viewed as some kind of new jurisdictions, which are new in comparison to the status quo—or *classical*—jurisdictions.

Using majority voting as a decision rule is a simple way to capture the fundamental conflict of interests between upstream and downstream and high and low benefits citizens within a political-economy framework. As the last chapter showed (see section 4.3), political-economy approaches are not only used in theoretical approaches on fiscal federalism, but they are also found to be of empirical relevance.

With spillovers and heterogeneous benefits, the two region political-economy can be organized into four different federal organizations: classical decentralization or centralization and decentralized or centralized single issue authorities. In focusing on different federal structures and simple majority voting, this approach does not contain the delegation problem which arises in the framework of Besley and Coate (2003) and also other political-economy contributions (Lorz and Willmann 2005, Dur and Roelfsema 2005). A more sophisticated modeling of the political process usually involves the election of representatives, who then decide on public goods.

A formal analysis of single issue authorities seems promising because the institutional analysis of flood management in Germany (see section 3.3.3) showed their practical relevance for many water related issues. Unlike many other public goods, for many water related issues it is possible to clearly identify (sub-) regions where benefits are concentrated. In addition, single issue authorities draw on contributions to a new federalism (see also section 4.3), such as Frey (1997) who promotes 'functional, overlapping, competing jurisdictions'. Single issue authorities are of high relevance in water issues, since the literature speculates that in a rational federal system, fairly sizable jurisdictions would extend over watersheds containing smaller jurisdictions of metropolitan and local areas (Oates 1999). However, crucial aspects of such 'watershed' jurisdictions are unidirectional spillovers and unevenly distributed benefits.

As is common in the fiscal federalism literature, there is no federal setting that always reaches the first-best outcome. All federal settings have their own imperfections and which setting is best depends on the context. In focusing on second-best settings, the economy under consideration has an imperfect constitution that can be interpreted as the result of an incomplete social contract. The literature on social contracts usually assumes that "behind a veil of ignorance" everybody could agree on a social contract that yields efficient outcomes. However, as such a contract cannot foresee all future contingencies, it has to remain incomplete. Because a deviation from an incomplete social contract can be beneficial from an ex-post point of view, the question arises under what social decision rule to decide on such a deviation. The literature on social contracts finds that some kind of majority voting and not unanimity is optimal if compensating transfers within a society are costly (Aghion and Bolton 2003). This general setting can be applied to the case of flood defense, if a constitution cannot differentiate taxes because the exposition to flood risk is not ex-post verifiable. If, however, flood risk zones are observable at the constitutional stage, it is possible to assign the responsibility of flood defense to single issue authorities or other jurisdictions. Thus, one could see the following analysis as reflecting the situation at the time a social contract is made. After the constitutional phase, majority voting—instead of unanimity—allows greater flexibility to change the status quo in flood defense. However, it can be asked which federal organization avoids very inefficient supply patterns in flood defense through the tyranny of the majority. As the following analysis concentrates on majority voting, it does not consider or allow purely redistributive policies. Instead, it focuses on public good provision in a federal economy.

The four federal organizations will be compared with respect to their aggregated public surplus. To shed light on the different forces that drive the results, the analysis will proceed step by step and considers three voting scenarios. After establishing the benchmark case of socially optimal public good provision, the first voting scenario considers the general case of asymmetrical spillovers, which captures—as an extreme case—unidirectional spillovers. However, it is assumed that the whole population enjoys the same public good benefits. In a second scenario the population has heterogeneous benefits but spillovers are symmetrical. The last scenario captures heterogeneous benefits as well as unidirectional spillovers. As extensions, central standards and partial centralization are investigated as potential ways to improve the outcome under centralization.

The three scenarios consider aggregated surplus as a welfare measure to compare different federal organizations. As one of the important results of this chapter it will turn out that—with unidirectional spillovers—centralized federal organizations are never surplus superior to decentralized ones if regions have the same population size. With centralized voting there is either an extreme over- or under-provision of the downstream public good, which makes central jurisdictions inferior to a decentralized federal organizations. Centralized jurisdictions that are bound to provide the same consumption level of the public good upstream and downstream or that only provide the upstream public good can improve on the performance of unrestricted centralized public good provision.

The chapter is organized as follows. First the model is introduced. Then section 5.2 compares aggregated surplus of jurisdictional organizations for different specifications of the model. Section 5.3 considers extensions of the model with variations in centralized public good supply. The last section of the chapter summarizes the results and concludes.

5.1 The model

There is a two region economy with public goods. The collective decision on public good supply is based on individual preferences, physical characteristics of the public and private goods, and income restrictions.

Two regions (or communities) $i \in \{1,2\}$ are considered. The size of the population in region i is n_i, which, for simplicity, is unity for most of the chapter. A public good can be provided in both regions. The quantity of the public good in region i is g_i, with $g_i \in \mathbb{R}_+$. Beside the public goods there is a private good and the endowment of the private good is the same for all individuals. The public good can be produced by using the private good. Expressing the cost of the public good in units of the private good, the cost function of the public good is given by $\frac{g_i^2}{2}$. It is assumed that the private good is available in sufficient quantity to finance the public good.

Preferences are assumed to be the same for all citizens. However, public good benefits are unevenly distributed across a region so that voting preferences are not necessarily the same for all citizens. Within a region it is possible to differentiate between a high-benefit area—which represents the flood-prone area—and a low-benefit area. For simplicity it is assumed that benefits in a low-benefit area are zero. Marginal public good benefits are the same throughout the high-benefit area of a region. They are captured by the parameter λ_i, with $\lambda_i \gg 0$. Therefore no index for individuals is used and λ_i is the benefit parameter of a representative citizen living in the high-benefit sub-region of region i. For the case of flood protection, λ_i can be seen as a parameter that closely relates to the expected flood loss in region i. A large expected flood loss translates into a large λ_i because benefits from public flood defense are high.

α denotes the share of the high-benefit individuals of the population, therefore $\alpha \in [0,1]$. It is assumed that high and no-benefit individuals can be geographically separated.

Utility is assumed to be linear in the private as well as in the public goods. λ is therefore the constant marginal utility in public goods. For a representative high-benefit individual of region i, utility can be expressed by

$$y_i + \lambda_i(g_i + \kappa_i g_j), \tag{5.1}$$

where y_i denotes consumption of the private good. The consumption of the public goods is the sum of the public good provided in the home region and that provided in the foreign region. The foreign public good is weighted by a spillover parameter. Public good consumption is weighted by the benefit parameter. With linear utility the model assumes risk neutral agents. Hence, problems related to risk management that arise when risk-averse agents are exposed to flood risk are not captured by the model.

With increasing marginal costs of supplying public goods, the utility function captures a basic trade-off in flood defense: Without flood defense, the utility of citizens in flood-prone areas is low, because flood damages can be expected. With flood defense, utility is higher because of lower expected flood losses. However, at the same time public flood defense must be financed by taxes, which decreases the consumption of the private good. To keep the model simple there is no explicit variable for the flood loss without flood defense.

κ_i captures spillovers from the public good provided in region j to region i. It indicates how the public good provided in region j translates into public good consumption in region i. It is assumed that $\kappa_i \in [-1,1]$. Without spillovers ($\kappa_i = 0$), g_j is a purely local public good with all benefits accruing in region j and no physical impacts on region i. $\kappa_i = 1$ is the case of a complete positive spillover, representing the case that the public good provided in region j is a national public good. With unidirectional spillovers it will be assumed that the spillover goes from region 1 to region 2, therefore $\kappa_1 = 0$, and $\kappa_2 \in [-1,1]$. For the example of flood prevention, the upstream community is region 1 and the downstream community is region 2.

Individuals outside of flood-prone areas do not benefit from public good supply. However, depending on the federal organization, they may be obliged to pay taxes. It is assumed that public goods are financed by head taxes on all citizens of the jurisdiction that provides the public good. This assumption is common in much of the political-economy literature on federalism.[1]

[1]Lockwood (2002) allows for regionally differentiated taxes. However, it is important that the tax

Public good provision is determined by simple majority voting of the residents of a jurisdiction. With two regions under consideration, there can be decentralization or centralization. This is the classical situation in fiscal federalism, where the best federal organization is determined by the size of the spillover. However, benefits within regions can be heterogeneous and the separation of individuals into jurisdictions with high benefits and without benefits is possible. Such a separation is assumed to be feasible and costless. Thus, a high-benefit jurisdiction can provide the public good at the same cost as a large jurisdiction with heterogeneous benefits. Possible jurisdictional organizations are therefore:

- Classical decentralization. Each community is an independent jurisdiction. There is decentralized voting on public good supply in each of the two jurisdictions. All citizens participate in voting. With a population size of unity in each community, cost shares for public good provision in region i are given by $\frac{g_i^2}{2}$.
- Classical centralization. Both communities are unified in one jurisdiction and all citizens vote centralized on public good supply. Individual cost-shares for public good provision are given by $\frac{g_i^2+g_j^2}{4}$.
- Decentralized single issue authorities. In each region high-benefit individuals are separated from individuals without benefits from the public good. The high-benefit groups form two separate jurisdictions and the public good supply is determined by decentralized voting. Citizens without benefits from the public goods are not part of the voting decisions. Cost shares for public good provision in region i are given by $\frac{g_i^2}{2\,\alpha}$.
- A centralized single issue authority. Areas with citizens who benefit from the public good constitute one jurisdiction. Therefore this jurisdiction comprises the high-benefit individuals from both regions. Citizens without public good benefits are not part of the voting decisions. Cost shares for public good provision are given by $\frac{g_i^2+g_j^2}{4\,\alpha}$.

Classical decentralization and centralization are seen as 'natural' federal organizations, since they cover the whole territory of the economy. One can imagine a more complex setting where the classical decentralized and centralized jurisdictions provide additional public goods. However, the present approach focuses on unevenly distributed benefits of a particular public good and the possibility of the spatial separation of individuals into high-benefit jurisdictions. These jurisdictions serve a single purpose and are therefore referred to as single issue authorities.

Public good supply is determined by simple majority voting. The analysis will focus on voting outcomes that are preferred by a majority over any other outcomes. Thus, the voting outcomes under consideration are Condorcet winners, where such a winner is defined as an outcome that beats any other feasible outcome in a pair-wise vote (see for

scheme is given and not endogenously determined if excessive redistribution in non-cooperative central legislatures shall be avoided. As Besley and Coate (2003; 2000) note, a (uniform) tax scheme may be needed to allow a meaningful comparison of different federal settings. To keep the model simple, this leads to the above assumption of uniform head taxes within jurisdictions.

example Persson and Tabellini (2000, ch. 2)).

Given the assumptions, preferences on public goods are single peaked in the case of a single voting issue. Therefore the median voter theorem holds and the median voter determines the level of the public good provision. A single voting decision is made in decentralized jurisdictions. However, in a centralized jurisdiction there are two variables to be determined, upstream and downstream public good provision; therefore the decision problem is two-dimensional. Mueller (2003, ch. 5) discusses ways to avoid voting cycles and to ensure a voting equilibrium. One possibility is sequential decision making, where decisions are made on one dimension at a time. This approach is followed here. Due to the special form of the utility function, the sequence of decision making is not crucial.

With the given benefit structure of public goods, voting preferences of the population are quite basic, so that the set of most preferred allocations is restricted to few cases and not to a continuum of values. Therefore the group sizes of individuals with different benefits play a crucial role for the voting outcome.

5.2 Public good provision under different federal organizations

5.2.1 The socially optimal outcome

To compare different jurisdictional settings in a political-economy framework, the welfare-optimal provision of public goods is determined as a benchmark. Concentrating on the public goods and their opportunity costs in units of the private good, aggregated public good surplus, S, is taken as a welfare measure, which implies a purely utilitarian framework.[2]

The objective function of a benevolent social planer is given by

$$S(g_i, g_j) = \alpha\lambda_i(g_i + \kappa_i g_j) + \alpha\lambda_j(g_j + \kappa_j g_i) - \tfrac{g_i^2 + g_j^2}{2} \ . \tag{5.2}$$

$S(g_i, g_j)$ is strictly concave for non-negative values of g_i and g_j. For interior solutions, one can easily check that the second-order conditions for a maximum are met, and the first-order conditions indicate a unique absolute maximum. The socially optimal level of public good supply in region i, denoted by g_i^*, for interior solutions is given by

$$g_i^* = \alpha\lambda_i + \alpha\kappa_j\lambda_j \quad \text{for} \quad \lambda_i + \kappa_j\lambda_j \geq 0 \quad \text{for } i, j = 1, 2; \quad i \neq j \, . \tag{5.3}$$

The level of public good supply in region i depends positively on the marginal benefits in region i and the share of the high-benefit population in the providing region. In

[2] Similar benchmarks are used, for example, by Oates (1972), Besley and Coate (2003) and Lockwood (2002).

addition, benefits in the foreign region have to be taken into account. Positive spillovers have a positive effect on public good supply and negative spillovers reduce the optimal level. With large marginal utility in public goods and large negative spillovers in the foreign region, the optimal level of the public good may become zero. For unilateral spillovers with $\kappa_1 = 0$ the public good in region 2 only depends on the benefits of region 2, $g_2^* = \alpha\lambda_2$.

Aggregated public good surplus for inner solutions ($g_i^* > 0$) is given by

$$S(g_i^*, g_j^*) = \alpha^2\lambda_i^2(1+\kappa_i^2)\frac{1}{2} + \alpha^2\lambda_j^2(1+\kappa_j^2)\frac{1}{2} + \alpha^2\lambda_i\lambda_j(\kappa_i+\kappa_j) \ . \tag{5.4}$$

In the following sections it will be investigated how public goods are provided under majority voting. Different jurisdictional settings will be investigated and different assumptions apply with respect to the share of high-benefit individuals and the spillovers (bilateral, unilateral).

5.2.2 Asymmetric spillovers and homogeneous regions

Following a political-economy approach, there is simple majority voting on public good provision. Assuming—as a first case—a homogeneous population of high-benefit individuals, $\alpha = 1$, there are two possible jurisdictional organizations: classical decentralization and centralization.

The political-economy literature on fiscal federalism focuses mainly on the case of bilateral, symmetrical spillovers. Symmetrical spillovers imply that $\kappa_1 = \kappa_2$.[3] However, the case of flood defense shows that there are also relevant cases of unidirectional spillovers. Since the model is set up to analyze flood defense, it allows the general case of asymmetrical spillovers, covering the extreme cases of either symmetrical or unidirectional spillovers. With unidirectional spillovers it will be assumed that $\kappa_1 = 0$, implying that the spillover goes from the upstream region 1 to the downstream region 2.

Classical decentralization

Under classical decentralization there are two jurisdictions, each deciding independently on public good supply. Public good costs are divided equally among individuals of the providing region. Since public good supply is determined by majority voting, the optimization problem is that of the median voter in each jurisdiction. Let λ_{mi} denote the public good benefit parameter of the median voter in region i. The median voter takes the public good in the other jurisdiction as given. The first-order condition determines the reaction functions. The Nash equilibrium is the solution of the problem. Omitting consumption of the private good, the optimization problem of the median voter under decentralization in region i is given by

[3] Besley and Coate (2003) consider symmetrical spillovers and give roads or parks as examples of such public goods.

$$g_i^d = \arg\max_{g_i \in \mathbb{R}_+} \quad \lambda_{mi}(g_i + \kappa_i g_j) - \frac{g_i^2}{2} \quad \text{for } i,j = 1,2; \quad i \neq j \,. \tag{5.5}$$

The superscript 'd' denotes outcomes under decentralization. The utility of the median voter in region i with decentralized public good provision is given by

- the utility from the provision of public goods in the home region. This term depends on the benefit parameter of the median voter. Given the assumption of a homogeneous high-benefit population the median voter is also a high-benefit citizen and the benefit from public good provision is positive. If the median voter would have no benefits from public goods, utility from public good provision is zero.
- utility from public good provision in the foreign region. With a high-benefit median voter, this term can be positive or negative depending on spillovers.
- the cost-share of the median voter for the given level of public good provision. The cost-share reduces the possibility for private good consumption and has therefore a negative sign. For decentralized public good provision costs are shared among the population of the whole region. Other federal organizations are associated with other cost-shares. Citizens without benefits from public goods are only affected by the different cost-shares of the federal organizations.

Since citizens within a region have the same benefits from the public good, the median voter is easily identified as a high-benefit type, $\lambda_{mi} = \lambda_i$ since $\lambda_{mi} \in \{\lambda_i\}$. Given the linear utility function, the solution of the problems are dominant strategies with reaction functions independent of the public good provision of the foreign region. Hence, the timing of decentralized voting it irrelevant for the voting outcome. With concave utility of region i in g_i, the second-order sufficient conditions are met for the optimal public good choices and the Nash-equilibrium is given by

$$(g_1^d, g_2^d) = \quad (\lambda_{m1}, \quad \lambda_{m2}) \quad = (\lambda_1, \quad \lambda_2)\,. \tag{5.6}$$

Since the high-benefit median voters neglect positive (or negative) spillovers to the other region, decentralized public good supply is either too small (or too large) in both jurisdictions compared to the social optimum.

Besley and Coate (2003) as well as Dur and Roelfsema (2005) find a similar result by allowing a continuum of public good preferences within a region. In their approach, where elected representatives decide on public good provision, there can be another reason for inefficient public good provision. Depending on the utility function, (positive) spillovers induce strategic delegation, which creates an additional free riding problem. Citizens vote for a representative with a low public good preference which aggravates the under-supply of the public goods. However, both contributions focus primarily on utility functions that do not induce strategic delegation under decentralization.

Classical centralization

Under classical centralization there is only one jurisdiction in which voters decide on public good supply. As mentioned above, there is sequential voting on the two public goods (g_i and g_j). The order of the decisions can be either g_1 at the first stage and g_2 at the second stage, or the other way around. In principle, the second decision takes the outcome of the first stage into account, by responding according to the reaction function. This reaction at the second stage can be anticipated at the first stage. At each stage the median preference determines the outcome. Given the linear utility function, the sequence of decision making does not influence the outcome, since dominant strategies are present. Therefore there are two independent voting decisions that are voted on sequentially. The median voter from region i or j, with the public good benefit parameter λ_m and $\lambda_m \in \{\lambda_i, \lambda_j\}$, faces the following optimization problem for public good provision in region i:

$$g_i^c = \arg\max_{g_i \in \mathbb{R}_+} \begin{cases} \lambda_m(g_i + \kappa_i\, g_j) - \frac{g_i^2+g_j^2}{4} & \text{median voter region } i \\ \lambda_m(g_j + \kappa_j\, g_i) - \frac{g_i^2+g_j^2}{4} & \text{median voter region } j \end{cases} \quad \text{for } i,j = 1,2; \quad i \neq j\,. \tag{5.7}$$

The superscript 'c' denotes the outcome under classical centralization. It is important to note that, due to sequential decision making, there are two votes on public good supply and not just one simultaneous vote. With the given voting preferences this rules out the possibility of voting cycles and ensures the existence of a Condorcet winner in each voting decision. This aspect becomes important if there are more than two preference groups involved in centralized decision making. With the size of both regions being unity, the question arises: which region is decisive for the voting decision? To answer this question the following tie-braking rule is used:

Assumption 5.1 *There is an infinitesimal difference in the population size of the two regions. The larger region will be denoted by i, the smaller region by j. For matters of convenience the population size will be approximated as being unity.*

With infinitesimal differences in size, voting on public good provision leads to clear-cut results, since the median voter resides in the larger region. The assumption implies that size does matter and therefore guarantees that the outcome of voting is not random, as in Besley and Coate (2003). If the residence region of the median voter would be random in each voting decision, then both public goods could be determined by non-resident voters. With small differences in the population size and homogeneous benefits, voters from one region determine the public good in the majority as well as in the minority region. The implications of explicitly accounting for differences in the population size will be analyzed for homogeneous regions latter on.

Denoting the marginal utility in public good consumption of the median voter with $\lambda_m = \lambda_i$, and using the superscript c for centralization, the outcome is given by

$$(g_i^c, g_j^c) = \begin{cases} (2\,\lambda_i, \quad \kappa_i\, 2\,\lambda_i) & \text{for } \kappa_i \geq 0 \\ (2\,\lambda_i, \quad 0) & \text{for } \kappa_i < 0 \end{cases} . \tag{5.8}$$

With positive spillovers there is an interior solution that is a global maximum, since strict concavity of the utility in public goods is given. With negative spillovers, a corner solution occurs with respect to the foreign public good. With this public good supply, it is clear that centralization is not generally socially optimal. With positive spillovers, the public good tends to be over-provided in the majority region and under-provided in the minority region. The median voter from the majority region considers only his own public good benefit, but relies on the tax base of the whole population of both regions. Faced with the common pool incentive, he favors his own region and neglects benefits to the minority region in his public good decisions.

The median voter is in a situation similar to that of the decisive representative under centralization in the contribution of Besley and Coate (2003). Uncooperative representatives would determine the same public good allocation as above, if the randomly picked decisive representative would come from the majority region.

For a unidirectional spillover and an upstream majority (region 1) this implies that no public good is provided downstream (region 2), $g_2^c < g_2^* \Leftrightarrow 0 < \lambda_2$. An inefficiently large level is supplied upstream since $g_1^c > g_1^* \Leftrightarrow 2\,\lambda_1 > \lambda_1 + \kappa_2\lambda_2$, which holds as long as spillovers and benefit differences between regions are not too large. With a downstream majority (region 2) the public good is provided in both regions, however the supply is inefficiently large in the downstream region with $g_2^c > g_2^* \Leftrightarrow 2\lambda_2 > \lambda_2$. The upstream good tends to be under-supplied as long as benefits and spillovers are not too large since $g_1^c < g_1^* \Leftrightarrow 2\,\kappa_2\,\lambda_2 < \lambda_1 + \kappa_2\lambda_2$.

For positive spillovers, it is apparent that centralization leads to a partial internalization of spillovers. Only the spillover received by the majority region is taken into account, whereas the spillover received by the minority region is irrelevant for public good provision.

Comparison of classical decentralization and centralization

With the majority region i, the comparison of decentralization and centralization yields a critical level of spillover, where both federal organizations have the same aggregated surplus. This critical level of spillovers is determined by equating $S^d(g_i^d, g_j^d) = S^c(g_i^c, g_j^c)$. If the majority region receives a positive spillover, the critical spillover level can be derived from $(\lambda_i^2 + \lambda_j^2)\frac{1}{2} + \lambda_i\,\lambda_j\,(\kappa_i + \kappa_j) = 2\,\lambda_i\,\lambda_j\,(\kappa_i + \kappa_j)$. As it is evident, the surplus under centralization is not influenced by the location of the majority, as a region j majority would lead to the same surplus. With a negative κ_i, the critical level is determined from $(\lambda_i^2 + \lambda_j^2)\frac{1}{2} + \lambda_i\,\lambda_j\,(\kappa_i + \kappa_j) = 2\,\lambda_i\,\lambda_j\,\kappa_j$.

Normalization of the benefits leads to a marginal public good utility in region i of

$\frac{\lambda_i}{\lambda_i} = 1$ and in region j of $\frac{\lambda_j}{\lambda_i} \equiv \lambda$. λ is the marginal benefit in region j, in relation to the marginal benefits in region i. With region i as the majority region, a large λ indicates that the marginal public good benefit in the minority region is high in comparison to the majority region. It turns out that the critical value of spillovers does not depend on the absolute benefit parameters in both regions, but only on the relative benefits λ:

$$\kappa_i^{crit1} = \begin{cases} \frac{1+\lambda^2}{2\,\lambda} - \kappa_j & \text{for } \kappa_i \geq 0 \\ -\frac{1+\lambda^2}{2\,\lambda} + \kappa_j & \text{for } \kappa_i < 0 \end{cases} \tag{5.9}$$

The critical spillover level not only depends on the relative marginal benefits of the minority region λ, but also on the spillover that is received by the minority region. For positive spillovers received by the majority region, the critical spillover level decreases in the spillover received in the minority region. The opposite holds for negative, majority-region spillovers. This leads to the next proposition.

Proposition 5.1 *Simple majority voting and assumption 5.1 imply the following result, if all citizens have an identical high-benefit parameter and spillovers are asymmetrical:*

There is a critical level of the spillover received by the majority region, $\kappa_i^{crit1}(\kappa_j)$, for $\kappa_j \geq 0$. If the absolute value of κ_i is below this level, decentralization is surplus superior; if it is above this level, centralization is superior. For $\kappa_j < 0$ decentralization is always superior.

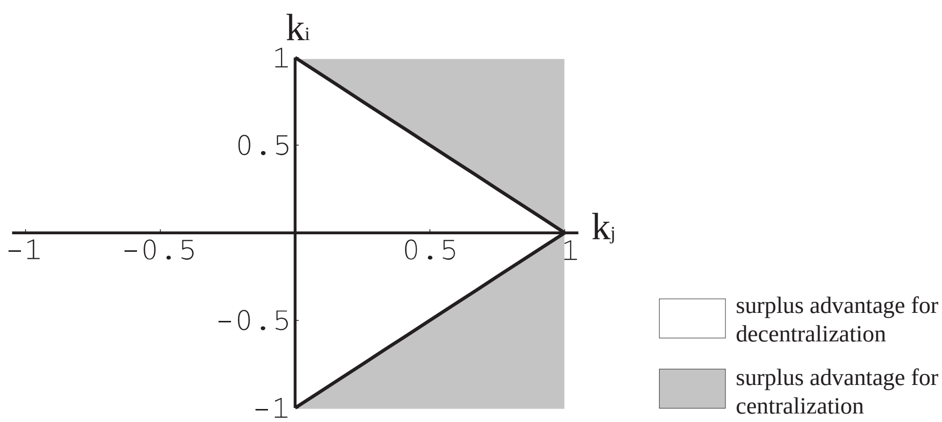


Figure 5.1: Surplus optimal federal organizations with asymmetrical spillovers and identical marginal benefits

Proposition 5.1 is illustrated in figure 5.1, which is based on κ_i^{crit1} as calculated in equation 5.9. For positive spillovers in both regions, the sum of spillovers must be large enough to justify centralization. With $\lambda = 1$ and regions of the same population size, both spillovers are perfect substitutes and a change of the majority region has no impact on public good surplus, even for very asymmetric spillovers. For the comparison of centralization and decentralization, it does not matter if the majority region receives a large or a small spillover.

If the majority receives a negative and the minority region a positive spillover (the lower right quadrant in figure 5.1), centralization is again superior, if the sum of the absolute values of the spillovers is large enough. Centralization is superior to decentralization, because the majority does not provide the public good in the minority region and therefore avoids negative spillovers that would be present under decentralization. At the same time there is still a positive spillover received in the minority region.

If the minority region receives negative spillovers (the left half of figure 5.1), decentralization is always superior to centralization. Under centralization the majority region pays no attention to the negative spillover to the minority region and at the same time over-provides the public good in the home region. Both effects impair the surplus under centralization, so that decentralization is always the better federal organization.

This leads to the conclusion that the surplus resulting from centralized voting depends on political-economy factors if one spillover is negative. If one public good causes negative spillovers, whether or not centralization is superior to decentralization depends on the majority constellation. The surplus is higher if the majority and not the minority region receives the negative spillover.

The case of unidirectional spillovers is found on either of the two axes in figure 5.1. With a unidirectional spillover received in the minority region, the horizontal κ_j-axes illustrates the possible range of spillovers. If the majority region receives the spillover, the vertical κ_i-axes shows the relevant values of spillovers. As it is evident in figure 5.1, neither of the two axes includes spillovers where centralization is superior to decentralization. This allows the statement that unidirectional spillovers favor decentralization.

The disadvantage of centralization can be explained with respect to an upstream and a downstream majority in flood defense. With unidirectional spillovers, an upstream majority over-provides flood defense in the upstream region and does not protect the downstream region (see above). This pattern extremely favors upstream voters, because the downstream region pays for the over-provided flood defense upstream without getting much (or anything) back. In case of negative spillovers, it is even harmed by upstream flood defense. One can summarize: An upstream majority always fails to provide flood defense downstream (which has purely local benefits), and it is insensitive to spillovers from upstream flood defense. This supply pattern is very inefficient for negative spillovers, and it is also not better than decentralized provision when positive spillovers are very large.

A downstream majority causes a significant over-provision of downstream flood defense. Since the upstream majority does not receive any benefit from downstream flood defense, this over-provision does not allow a high aggregated surplus. In addition, the downstream majority under-provides flood defense upstream unless positive spillovers are complete.

Figure 5.1 also contains the case of symmetrical spillovers, which is considered by

Besley and Coate (2003). The case of $\kappa_1 = \kappa_2$ is given at the curve with the slope unity that traverses the point of origin. The critical level of spillovers, where decentralization and centralization yield the same surplus, is given by $\kappa_1 = \kappa_2 = \frac{1}{2}$.

Variations in the population size and marginal public good benefits

Proposition 5.1 assumed, firstly, that regions have the same population size, and, secondly, that the public good benefit parameter is the same in both regions. If these assumptions are relaxed, the case for centralization can become stronger or weaker. This can be discussed with respect to unidirectional spillovers. Let n denote the relative size of the minority region j in relation to the majority region i, which implies $n \equiv \frac{n_j}{n_i} \in (0,1)$. With $\lambda = \frac{\lambda_j}{\lambda_i}$ this leads to the critical spillover level where decentralization and centralization yield the same surplus ($S^d = S^c$):

$$\kappa_2^{crit} = \begin{cases} \frac{1+\lambda^2}{2\,\lambda} & \text{for an upstream majority} \\ \frac{-n^2\,\lambda+\sqrt{n^2(1+\lambda^2)-n^4}}{1-n} & \text{for } \kappa_2 \geq 0 \text{ and a downstream majority} \\ -n\frac{1+\lambda^2}{2\,\lambda} & \text{for } \kappa_2 < 0 \text{ and a downstream majority}\,. \end{cases} \tag{5.10}$$

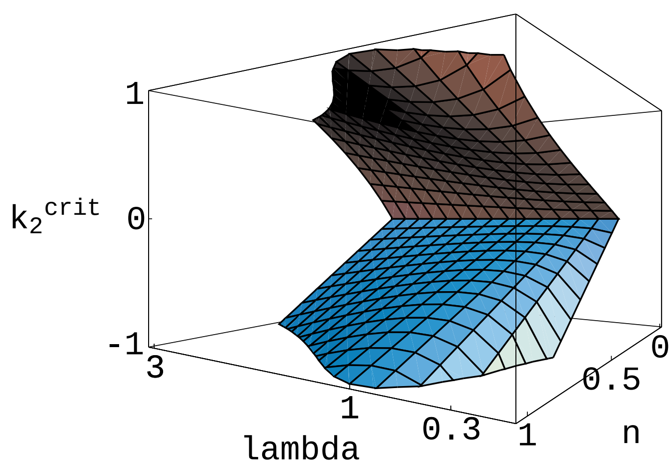


Figure 5.2: Critical unidirectional spillover, κ_2^{crit}, with a downstream majority for $n \in (0,1)$ and $\lambda \in (\frac{1}{3}, 3)$. n is the relative population size of the upstream region in comparison to the majority region downstream. Similarly, λ stands for the relative level of the public good benefit parameter in the minority region.

There can be an upstream or a downstream majority. For an upstream majority, the upstream region does not receive any spillovers and public good supply is given by $g_1 = \lambda_1(n_1 + n_2)$ and $g_2 = 0$. Equating surplus from decentralization and centralization, and using relative size and marginal public good utility, yields the critical value of the unidirectional spillover $\kappa_2^{crit} = \frac{1+\lambda^2}{2\,\lambda}$. This expression, which is independent of size of the regions, has its minimum at $\lambda = 1$.[4] Therefore there is no $\kappa_2 \in [-1, 1]$ where centralization with an upstream majority is superior. The example of flood defense can illustrate the poor performance of centralization with an upstream majority. Independent of the size of the spillover there is no downstream and a very high level of upstream flood defense. If negative spillovers are present, it is evident that this supply pattern is very inefficient. Also with positive spillovers this supply pattern is far from being efficient, since there is no downstream flood defense. A relatively large upstream population implies a relatively small minority region downstream, which is exploited by the majority. However, such size differences do not make centralization better than decentralization.

Figure 5.2 shows the critical level of the unidirectional spillover for a downstream majority. With a downstream majority public good supply is given by $g_1 = \kappa_2\lambda_2(n_1+n_2)$ and $g_2 = \lambda_2(n_1 + n_2)$ for positive spillovers, and $g_1 = 0$ and $g_2 = \lambda_2(n_1 + n_2)$ for negative spillovers. The critical spillover level depends on the relative size of the minority (upstream) region n and on the relative size of the public good preference parameter λ. If the minority region is small in relation to the majority region, n takes small values. $\lambda > (<)\, 1$ represents the case that the minority region has larger (smaller) marginal public good benefits than the majority region. Figure 5.2, firstly, illustrates proposition 5.1. For the same marginal public good benefits and the same population size in both regions ($n = 1$ and $\lambda = 1$), centralization is never superior to decentralization, since the critical spillover level is either a complete positive spillover or a negative spillover of minus 1. Secondly, figure 5.2 shows that a small population in the upstream region—a small minority region, $n \ll 1$—comes together with a smaller (larger) level of the critical spillover when spillovers are positive (negative). Thirdly, differences in the marginal public goods benefits ($\lambda \neq 1$) make the critical spillover levels more extreme. Thus, centralization is only the favorable federal setting if spillover levels are higher or lower compared to the case of identical marginal public good benefits.

The logic of figure 5.2 and a downstream majority can be discussed with respect to flood defense. For flood defense measures with positive spillovers, such a retention basins, centralization is not recommended if the upstream and downstream region are of similar size and $\kappa_2 < 1$. However, if the downstream region is much larger, centralization may be the better federal setting. A large downstream region has the advantage that the over-provision of the downstream public good is not quite as extreme as with regions of the same size. In addition, with positive spillovers there is also flood defense upstream, what is the crucial difference to a upstream majority, which only provide flood defense in one region. With negative spillovers there is no upstream flood defense. Centralized provision with this supply pattern is desirable when negative spillovers, for example from levees, are very strong and the downstream region is large in comparison to the upstream region.

One can conclude that, with unidirectional spillovers, the population size of both regions and the marginal public good benefits influence if decentralization or centralization is superior. In addition, it depends on the location of the majority, which federal setting is superior. With an upstream majority decentralization is always superior to central-

[4] The minimum is calculated by $\frac{\partial \kappa^{crit}}{\partial \lambda} = \frac{1}{2} - \frac{1}{2\lambda^2} = 0$. $\frac{\partial \kappa^{crit}}{\partial \lambda} = 0$ is given for $\lambda = 1$.

ization. With a downstream majority differences in size improve the performance of centralization and may make it better than decentralization. Differences in the marginal public good benefits improve the performance of decentralization.

5.2.3 Heterogeneous benefits within regions, no spillovers

In many situations public good benefits are not evenly distributed within a region. Some individuals may have high and others low marginal benefits. In recent political-economy contributions to federalism, voting preferences are usually not assumed to be the same for all individuals. However, the literature does not consider the case that the average and the median voter differ.[5] Such a deviation is not unrealistic. In this model a deviation of the mean and the average voter arises, if the share of individuals with high benefits is smaller than one, $0 < \alpha < 1$. Since heterogeneous benefits within regions can be the consequence of the geography of a region, the separation of a region into high and low-benefit citizens is possible. Flood defense is a good example of heterogeneous benefits, since the benefits are concentrated on flood-prone areas, whereas people outside the flood plain do not benefit. This leads to the question if voters should be separated into different jurisdiction according to the distribution of benefits.

To answer this question it is worthwhile to start by neglecting spillovers ($\kappa_i = 0$ for $i = 1, 2$) and to focus on the role of α in public good provision. Under decentralization the role of the high-benefit share is not continuous but discrete. Assuming a population size of one, the optimization problem is given by

$$g_i^{ds} = \arg\max_{g_i \in \mathbb{R}_+} \quad \lambda_{mi}\, g_i - \frac{g_i^2}{2} \quad \text{for } i, j = 1, 2; \quad i \neq j\,. \tag{5.11}$$

The preference of the median voter is given by $\lambda_{mi} \in \{0, \lambda_i\}$. The public good will be provided in quantity $g_i = \lambda_i$, as long as $\alpha \in (0.5, 1]$, since the median benefit parameter is given by λ_i. When $\alpha \in [0, 0.5]$, the group of high-benefit individuals is a minority and the median voter will vote for $g_i = 0$. In comparison to the socially optimal level of the public good, $g_i^* = \alpha\lambda_i$, there is an over-provision of the public good as long as the median voter has high-benefits, and an under-provision when the median voter has no benefits from the public good. Over-provision of the public good is accompanied by a cost-sharing spillover, which reduces the utility of individuals with no benefits from the public good.

With decentralized single issue authorities the population size of a jurisdiction that provides the public good is α. If there are no spillovers, the optimization problem in a decentralized single issue authority, which is denoted by the superscript 'ds', is given by

$$g_i^{ds} = \arg\max_{g_i \in \mathbb{R}_+} \quad \lambda_{mi}\, g_i - \frac{g_i^2}{2\,\alpha} \quad \text{for } i, j = 1, 2; \quad i \neq j\,. \tag{5.12}$$

[5] An exception is Redoano and Scharf (2004). However, since high and low preferences are not tied to the geography of a region, they do not analyze the implications of different federal organizations beyond the comparison of decentralization and centralization.

Since all voters within a jurisdiction have the same voting preference, the median preference is $\lambda_{mi} \in \{\lambda_i\}$ and the resulting amount of public good is given by

$$(g_1^{ds}, g_2^{ds}) = \quad (\alpha\lambda_1, \quad \alpha\lambda_2)\,. \tag{5.13}$$

It is evident that this supply pattern is socially efficient since there are no spillovers. For heterogeneous benefits within a region, $\alpha \in (0,1)$, the supply pattern is not efficient under decentralization. The next proposition follows directly from this.

Proposition 5.2 *Simple majority voting and $\alpha \in (0,1)$ implies that decentralized single issue authorities are the best federal organization if no inter-regional spillovers are present.*

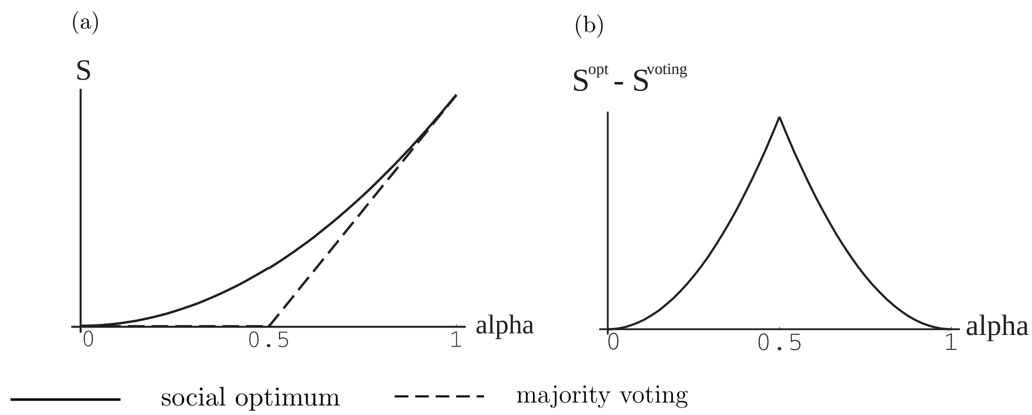


Figure 5.3: Majority decision depending on the high-benefit share, α. (a) socially optimal surplus and surplus under majority decision, (b) surplus losses due to majority decision.

The impact of the high-benefit share on the public good surplus is demonstrated in figure 5.3a. It depicts socially optimal surplus (the upper curve) and the surplus resulting from majority voting (the lower curve). The socially optimal surplus—which is the same than surplus resulting from single issue authorities—gradually increases in α. Under majority voting the amount of the public good is zero as long as $\alpha \leq \frac{1}{2}$. Therefore the surplus is also zero. With $\alpha > \frac{1}{2}$ the public good is provided in quantity $g_i = \lambda_i$, and the surplus gradually increases in α. For $\alpha = 1$, majority voting leads to the socially optimal surplus. For a high-benefit share close to $\frac{1}{2}$ the welfare loss due to majority voting is the largest. The closer α is to 1 or 0, the smaller the difference between the mean and the average voter, and the smaller the surplus-loss due to majority voting (figure 5.3b). It is a special feature of the utility function used here that there is a symmetry of the welfare-loss due to an over- and under-provision of the public good. Thus, a high-benefit majority leads to the same surplus than a no-benefit majority if the the size of the majority population is the same.

One can conclude: if there is a deviation of the median and the mean voter due to spatially heterogeneous benefits within a region, the separation of a region into different jurisdictions is surplus improving. In the current setting and the example of flood defense, a separation can be achieved by the establishment of single issue authorities in flood-prone areas. In the absence of spillovers such a separation is clearly surplus enhancing, if there are no costs of separation. As the next section shows, the argument is less clear when spillovers are present.

5.2.4 Unidirectional spillovers and heterogeneous regions

In a two region economy with unidirectional spillovers and heterogeneous benefits within regions, it is not only the question of classical decentralization and centralization, but also, if regions should be sub-divided. This leads to the additional federal organizations of decentralized or centralized single issue authorities. As discussed in the previous chapters, unidirectional spillovers and heterogeneous benefits within regions are typical for flood defense. This section analyzes how the different federal organizations provide upstream and downstream flood defense. The unidirectional spillover originates in the upstream region 1 and is received by the downstream region 2, hence, $\kappa_1 = 0$ and $\kappa_2 \in [-1, 1]$. To focus on heterogeneous benefits within regions, the following assumption will be made.

Assumption 5.2 *The public good benefit parameter is the same in both regions, thus* $\lambda_i = \lambda_j$.

Public good supply

Under classical decentralization the objective function of the median voter is similar to the case of asymmetrical spillovers, see equation 5.5. With heterogeneous benefits, there can be a majority or minority of high-benefit voters within each region. With the median voting preference of $\lambda_{mi} \in \{0, \lambda_i\}$, the supply pattern of public goods is given by

$$(g_1^d, g_2^d) = (\lambda_{m1}, \lambda_{m2}) = \begin{cases} (\lambda_1, \quad \lambda_2) & \text{for } \alpha > \frac{1}{2} \\ (0, \quad 0) & \text{for } 1 - \alpha \geq \frac{1}{2}\,. \end{cases} \tag{5.14}$$

If the majority of voters lives in the flood plain, the flood protection level is high, and if the majority of voters lives outside the flood plain there is no flood defense.

For classical centralization the optimization problems for high-benefit voters is given by equation 5.7. However, there is an additional potential median benefit parameter, hence $\lambda_m \in \{0, \lambda_i, \lambda_j\}$. With heterogeneous benefits within regions, there are now three group of voters with different interests. There are the high-benefit groups in the upstream and the downstream region. In addition, there is a third group—living outside the flood plain—without benefits from public goods. Each group of voters has its own ideal allocation. With the assumption of sequential majority voting, the public good specific median preference determines the amount of the public good and voting cycles are avoided. With the same population size in both regions and assumption 5.2, this yields the following supply pattern

$$(g_1^c, g_2^c) = \begin{cases} (\kappa_2\, 2\, \lambda_2, & 0) \quad \text{for } \alpha > \frac{1}{2} \text{ and } \kappa \in (0,1] \geq 0 \\ (0, & 0) \quad \text{for } \alpha > \frac{1}{2} \text{ and } \kappa \in [-1,0] \\ (0, & 0) \quad \text{for } 1-\alpha \geq \frac{1}{2} \text{ and } \kappa \in [-1,1]\,. \end{cases} \tag{5.15}$$

With the respective optimization problems, the second-order sufficient conditions are met and the given solutions lead to the unique absolute maxima. There may be a positive level of upstream public good provision depending on the majorities. Independent of the majorities, there is no upstream supply when spillovers are negative, because only the group of upstream voters with high benefits have an interest in it. However, since both regions have the same population size, this group of voters has no majority on its own. There is no public good provision downstream, because neither the no-benefit group nor the upstream high-benefit group has an interest in it.

If the assumptions of the same population size and the same high-benefit parameter in both regions were relaxed, there could be additional patterns of public good supply. Differences in the population size of the regions make it possible that a high-benefit majority from one region determines public good supply in both regions. If the high-benefit parameter is not the same in both regions and there is no single group majority, the median voter in both votes may come from the same region, if spillovers are large enough. However, to keep the model from becoming too complex these cases are omitted.

The optimization problem of voters in a decentralized high-benefit single issue authority yield:

$$g_i^{ds} = \arg\max_{g_i \in \mathbb{R}_+} \quad \lambda_{mi}(g_i + \kappa_j g_j) - \frac{g_i^2}{2\alpha} \quad i,j = 1,2; \quad i \neq j\,. \tag{5.16}$$

With $\lambda_{mi} \in \{\lambda_i\}$, the solution is

$$(g_1^{ds}, g_2^{ds}) = (\alpha\, \lambda_{m1}, \alpha\, \lambda_{m2}) = (\alpha\, \lambda_1, \alpha\, \lambda_2)\,. \tag{5.17}$$

It is evident that decentralized single issue authorities do not take spillovers to other regions into account, since their optimization problems are similar to decentralized jurisdictions with homogeneous benefits.

A centralized single issue authority is very similar to a centralized jurisdiction with homogeneous benefits within regions. With $\alpha = 1$ it would be the same in fact. Denoting the allocation resulting from a centralized single issue authority with the superscript '*cs*', the optimal public good provision from the point of view of the median voter is given by

$$g_i^{cs} = \arg\max_{g_i \in \mathbb{R}_+} \begin{cases} \lambda_m(g_i + \kappa_i\, g_j) - \frac{g_i^2+g_j^2}{4\,\alpha} & \text{median voter region } i \\ \lambda_m(g_j + \kappa_j\, g_i) - \frac{g_i^2+g_j^2}{4\,\alpha} & \text{median voter region } j \end{cases} \tag{5.18}$$
$$\text{for } i, j = 1, 2; \quad i \neq j\,.$$

Depending on the majority, the median public good benefit parameter is given by $\lambda_m \in \{\lambda_i, \lambda_j\}$. With very small size differences between regions (assumption 5.1) and unidirectional spillovers, public good supply is

$$(g_1^{cs}, g_2^{cs}) = \begin{cases} (2\,\alpha\lambda_1, & 0) & \text{upstream majority} \\ (\kappa_2 2\,\alpha\lambda_2, & 2\,\alpha\,\lambda_2) & \text{downstream majority and } \kappa_2 > 0 \\ (0, & 2\,\alpha\,\lambda_2) & \text{downstream majority and } \kappa_2 \leq 0\,. \end{cases} \tag{5.19}$$

A centralized single issue authority comprises two groups, the high-benefit citizens of the upstream and downstream regions. With an upstream majority there is no public good provision downstream. With a downstream majority the upstream public good is provided if spillovers are positive.

Comparison of federal settings

Inserting the public good allocations into aggregated public good surplus allows the comparison of the different federal organizations. Aggregated surplus for each federal organization and the critical values of spillovers are derived in the appendix to this chapter. In addition, the appendix specifies the parameter constellations where one federal organization is superior to all other federal organizations. The comparison of the federal settings yields the next proposition.

Proposition 5.3 *Assume simple majority voting, unidirectional spillovers and heterogeneous populations. Assumptions 5.1 and 5.2 hold.*

For $\alpha \in (0, 1)$ neither classical centralization nor a centralized single issue authority is ever surplus superior to decentralized jurisdictions. For a positive spillover received by region 2, there is a critical value of the spillover which depends on the high-benefit share, $\kappa^{crit2}(\alpha) = \frac{1-\alpha}{\alpha}$. For large high-benefit shares and a large spillover, classical decentralization is superior to decentralized single issue authorities. For all other parameter constellations the opposite holds. If the spillover is complete and the high-benefit share is one, all jurisdictional organizations produce the same surplus.

Figure 5.4 illustrates proposition 5.3. It is apparent that any form of centralization is inferior to decentralized jurisdictions. A centralized single issue authority is not superior to decentralized single issue authorities for the same reasons as stated in proposition 5.1. Unidirectional spillover and centralized decision making is very inefficient with an

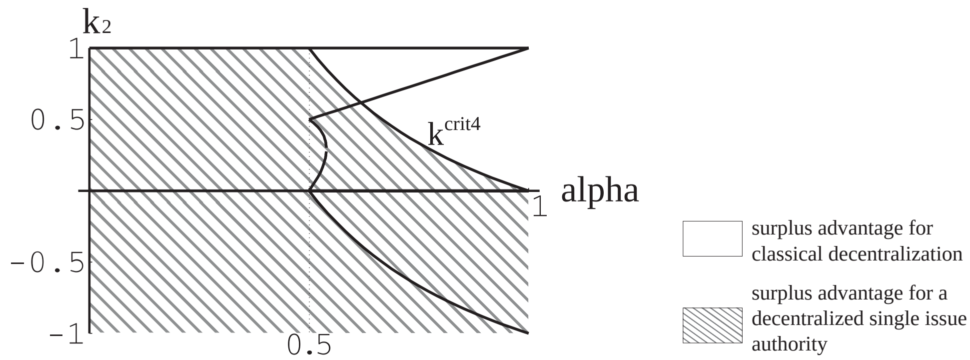


Figure 5.4: Federal organizations with unidirectional spillovers and heterogeneous benefits within regions

upstream majority, since there is no flood defense downstream. With a downstream majority, there is an extreme over-provision downstream, which makes a centralized single issue jurisdiction inferior to decentralized ones.

The comparison between classical centralization and decentralization is less clear. With a positive spillover, classical centralization can be superior to decentralization, but only for a high-benefit share that barely exceeds $\frac{1}{2}$. Even though the no-benefit minority is exploited under classical centralization, public good provision is not excessively large because it depends on the (unidirectional) spillover. If this spillover is not too large, there is a moderate level of upstream flood defense and no flood defense downstream. For larger high-benefit shares and a large spillover, classical centralization is not superior to classical decentralization because the former provides flood defense only in the upstream region.

Complete decentralization is superior to all other jurisdictional organizations, if there is only a minority of voters living in the flood plain (a minority of high-benefit voters) or if the spillover is negative. For positive spillovers and a majority of individuals living in the flood plain, classical decentralization can be superior to decentralized single issue authorities. The reason is that under decentralization the cost-sharing spillover drives the amount of flood defense up. Therefore classical decentralization is efficient because it exploits the no-benefit minority outside the flood plain and not because it internalizes the inter-regional spillovers. The co-financing of flood defense by citizens outside the flood plain only has a positive surplus effect when spillovers are positive. Hence, with negative spillovers, heterogeneous benefits within a jurisdiction are undesirable and decentralized single issue authorities are superior to classical decentralization.

5.3 Extensions: central standards and partial centralization

The preceding analyses showed for unidirectional spillovers that centralized jurisdictions may not lead to better results than decentralized jurisdictions. This result was found for homogeneous benefits within regions, but also for heterogeneous benefits with the option of single issue authorities. Of course, one could now consider the implications of different population sizes of regions and also of region-specific high-benefit shares or region-specific marginal benefits. As seen in the preceding sections, such asymmetries can strengthen the case for centralization. One example were differences in the population size of regions. However, it is evident that unidirectional spillovers can challenge the federal organization. This raises the question if there are better organizations of regions into jurisdictions or if other mechanisms can foster better outcomes.

The following analyses will concentrate on two potential ways to improve public good provision under centralization. The first one is a uniformity restriction on centralized supply of public goods. Such a restriction is seen by Oates (1972) as crucial for centralization. With a uniformity restriction, a benevolent central government is not able to provide the public good efficiently because it cannot differentiate the public good level according to local preferences. An example of a uniformity restriction—which are common in many policy fields—is a common ambient air quality standard in a country. Besley and Coate (2003) find the uniformity restriction not very plausible for a welfare maximizing central government and follow a political-economy approach where region specific levels of public good provision is allowed. However, voting on public good provision does not exclude a uniformity restriction, so that it is worthwhile to consider the consequences of such an approach for unidirectional spillovers. A formal analysis uniformity restrictions is given below.

A second potential way to improve the outcome of a central jurisdiction is the partial centralization of public good provision. It would be possible to provide the upstream public good in a centralized jurisdiction and the downstream public good decentralized. Partial centralization, through a single issue authority, leads to a central jurisdiction which is a single issue authority in the true sense of the word, since it is responsible for a single public good only. Also for partial centralization, a formal analysis is given below.

Central standards

A uniformity restriction can be seen as a central standard with regard to public good provision. Since spillovers are present, such a standard can refer to public good supply or to the consumption of the public good. With regard to flood protection it seems natural to interpret a common standard as a certain level of flood protection, which is a uniform consumption quantity of the public good. However, it is also possible to require a certain spending on flood protection that might result in different flood protection levels upstream and downstream. The recent flood protection act in Germany introduced a federal flood protection level for the whole of Germany (see section 3.1). This can be seen as uniform consumption requirement for flood protection. In addition, the Flood Protection Act also has an element of uniform supply, since the Q_{100}-flood-outline is now legally protected as a flood basin along the whole river. The protection of the Q_{100}-flood-outline provides room for water retention.[6]

For the following analyses both forms of standards are sequentially considered, which leads to new comparisons of the four federal organizations.

Standards regulate centralized decision making. With a uniform upstream and downstream public good supply, public good levels must be the same, $g_1 = g_2 = g$ in both regions. The same consumption level implies that the optimization problems of the median voter is restricted by $g_1 = g_2 + \kappa_2 g_1$. In the following analyses assumptions 5.1 and 5.2 apply: marginal public good benefits are the same upstream, and downstream and regions are of similar size.

For classical centralization, the optimization problems with the two uniformity restrictions are given below, where the superscript 'c, us' and 'c, uc' refer to centralization with uniform public good supply and with uniform public good consumption, respectively. With a uniform restriction, the optimization problems reduce to a one-dimensional voting problem.[7]

$$\begin{aligned} g^{c,us} &= \arg\max_{g \in \mathbb{R}_+} \begin{cases} \lambda_m\, g - \frac{2\,g^2}{4} & \text{up. median voter} \\ \lambda_m (g + \kappa_2\, g) - \frac{2\,g^2}{4} & \text{do. median voter} \end{cases} \\ g_2^{c,uc} &= \arg\max_{g_2 \in \mathbb{R}_+} \begin{cases} \lambda_m \frac{g_2}{1-\kappa_2} - \frac{(\frac{g_2}{1-\kappa_2})^2 + g_2^2}{4} & \text{up. median} \\ \lambda_m (g_2 + \kappa_2 \frac{g_2}{1-\kappa_2}) - \frac{(\frac{g_2}{1-\kappa_2})^2 + g_2^2}{4} & \text{do. median.} \end{cases} \end{aligned} \tag{5.20}$$

For interior solutions the optimization problems lead to unique absolute maxima, since the second-order sufficient conditions are met and utility is concave in public goods. Corner solutions do not occur for spillovers that are restricted to the interval $\kappa_2 \in (-1, 1)$. With $\lambda_m \in \{0, \lambda_i, \lambda_j\}$ and depending on the majority constellation the optimization problems lead to:

$$\begin{aligned} (g_1^{c,us}, g_2^{c,us}) &= \begin{cases} (\lambda_1, \quad \lambda_1) & \text{for } \alpha > \frac{1}{2} \text{ and } \kappa_2 \geq 0 \\ (\lambda_2(1+\kappa_2), \quad \lambda_2(1+\kappa_2)) & \text{for } \alpha > \frac{1}{2} \text{ and } \kappa_2 < 0 \\ (0, \quad 0) & \text{for } 1-\alpha \geq \frac{1}{2} \end{cases} \\ (g_1^{c,uc}, g_2^{c,uc}) &= \begin{cases} (\lambda_i \frac{2}{2-(2-\kappa_2)\kappa_2}, \quad \lambda_i \frac{2(1-\kappa_2)}{2-(2-\kappa_2)\kappa_2}) & \text{for } \alpha > \frac{1}{2} \text{ and} \\ & \lambda_i = min\{\lambda_1, \lambda_2\} \\ (0, \quad 0) & \text{for } 1-\alpha \geq \frac{1}{2}\,. \end{cases} \end{aligned} \tag{5.21}$$

[6] Note, however, that the central standards of the Flood Protection Act do not represent a total regime change to centralization in flood defense, since the financing is still left to decentral jurisdictions. The concluding chapter 8 will discuss the implications of this arrangement.

[7] With uniform consumption $g_1 = g_2 + \kappa_2 g_1$ implies $g_1 = \frac{g_2}{1-\kappa_2}$.

If spillovers are positive and the uniform supply restriction holds, there is no difference between centralized or decentralized public good provision. For negative spillovers, the median voting preference is the downstream preference and negative spillovers are taken into account. With uniform consumption, the most preferred allocation is the same for upstream and downstream high-benefit citizens. This is the case despite the fact that the objective functions of upstream and downstream citizens are different.

In a centralized single issue authority, the optimization problems of the median voter from the majority region i, for uniform supply and uniform public good consumption, are as follows:

$$\begin{aligned} g^{cs,us} &= \arg\max_{g\in\mathbb{R}_+} \begin{cases} \lambda_m\, g - \frac{2\,g^2}{4\,\alpha} & \text{up. median voter} \\ \lambda_m (g + \kappa_2\, g) - \frac{2\,g^2}{4\,\alpha} & \text{do. median voter} \end{cases} \\ g_2^{cs,uc} &= \arg\max_{g_2\in\mathbb{R}_+} \begin{cases} \lambda_m\, \frac{g_2}{1-\kappa_2} - \frac{(\frac{g_2}{1-\kappa_2})^2 + g_2^2}{4\,\alpha} & \text{up. median.} \\ \lambda_m (g_2 + \kappa_2\, \frac{g_2}{1-\kappa_2}) - \frac{(\frac{g_2}{1-\kappa_2})^2 + g_2^2}{4\,\alpha} & \text{do. median.} \end{cases} \end{aligned} \tag{5.22}$$

For interior solutions the optimization problems lead to unique absolute maxima, since the second-order sufficient conditions are met and utility is concave in public goods. Corner solutions do not occur for spillovers that are restricted to the interval $\kappa_2 \in (-1, 1)$. With $\lambda_m \in \{\lambda_i, \lambda_j\}$ the optimal levels of public good supply are

$$\begin{aligned} (g_1^{cs,us}, g_2^{cs,us}) &= \begin{cases} (\alpha\lambda_1, \quad \alpha\lambda_1) & \text{up. majority} \\ (\alpha\,\lambda_2(1+\kappa_2), \quad \alpha\,\lambda_2(1+\kappa_2)) & \text{do. majority} \end{cases} \\ (g_1^{cs,uc}, g_2^{cs,uc}) &= \begin{cases} (\lambda_i \frac{2\,\alpha}{2-(2-\kappa_2)\kappa_2}, \quad \lambda_i \frac{2\,\alpha\,(1-\kappa_2)}{2-(2-\kappa_2)\kappa_2}) & \text{region } i \text{ majority.} \end{cases} \end{aligned} \tag{5.23}$$

A centralized single issue authority always provides a positive level of public goods, unless there is a complete negative spillover. With a uniform supply, public good provision depends on the majority region. An upstream majority provides the same quantity as decentralized single issue authorities. A downstream majority provides more if spillovers are positive, and less if they are negative. With a uniform consumption restriction, public good provision does not depend on the location of the majority, as both high-benefit groups prefer the same allocation, given the assumption that they have the same benefit parameter.

Proposition 5.4 *Assume simple majority voting, unidirectional spillovers and heterogeneous populations. Assumptions 5.1 and 5.2 hold. If centralized public good provision is restricted to uniform supply or uniform consumption of the public good, the best federal organization is either a centralized single issue authority with uniform public good consumption or classical decentralization.*

A centralized single issue authority with uniform public good consumption leads to the same surplus as classical decentralization for $\alpha^{crit} = \frac{1}{4}(4+\kappa_2^3+\kappa_2(-2\pm\sqrt{\kappa_2(8-4\kappa_2+\kappa_2^3)-4}))$.

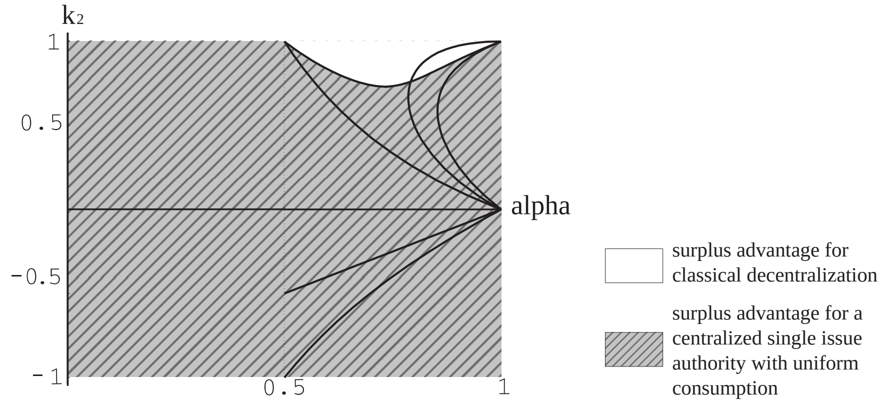


Figure 5.5: Surplus optimal federal organizations with unidirectional spillovers, heterogeneous benefits within regions, and uniformity restrictions

Figure 5.5 illustrates proposition 5.4. All critical parameter constellations where two different federal organizations yield the same public good surplus are given in the appendix to this chapter. In addition, the appendix specifies the parameter constellations where one federal organization is superior to all other federal organizations. With the same level of public good consumption in both regions, a centralized single issue authority is superior for almost all high-benefit shares and spillover levels. Only for very large spillovers and a high-benefit majority, classical decentralization yields a higher surplus. The comparison of the different possible federal organizations is a bit tedious and the details are left to the appendix to this chapter. However, it is illuminating to compare public good provision under the different federal settings in order to see the sources of inefficiencies. This is done in figure 5.6, which also shows the optimal supply levels of public goods.

Figure 5.6 shows public good provision in centralized jurisdictions for an upstream and a downstream majority and a high-benefit majority, $\alpha > \frac{1}{2}$. For each form of centralization it shows public good provision without any uniformity restrictions and with uniform public good supply and uniform consumption.

Figure 5.6 shows how inefficient public good supply tends to be without any uniformity restrictions (the bold dotted lines). Under classical centralization there is no public good provision downstream and also no provision upstream if spillovers are negative. For positive spillovers there is an over-provision if the spillover is large. A centralized single issue authority either over-provides the upstream public good and under-provides the downstream public good (with an upstream majority) or vice versa (with a downstream majority).

With uniform supply of the public good, an upstream majority provides the public good independently of spillovers. A centralized single issue authority is efficient for downstream public good supply, but inefficient for the upstream public good, since spillovers are not taken into account. The opposite holds with a downstream majority, since it provides the public good efficiently upstream, but over- or under-provides the

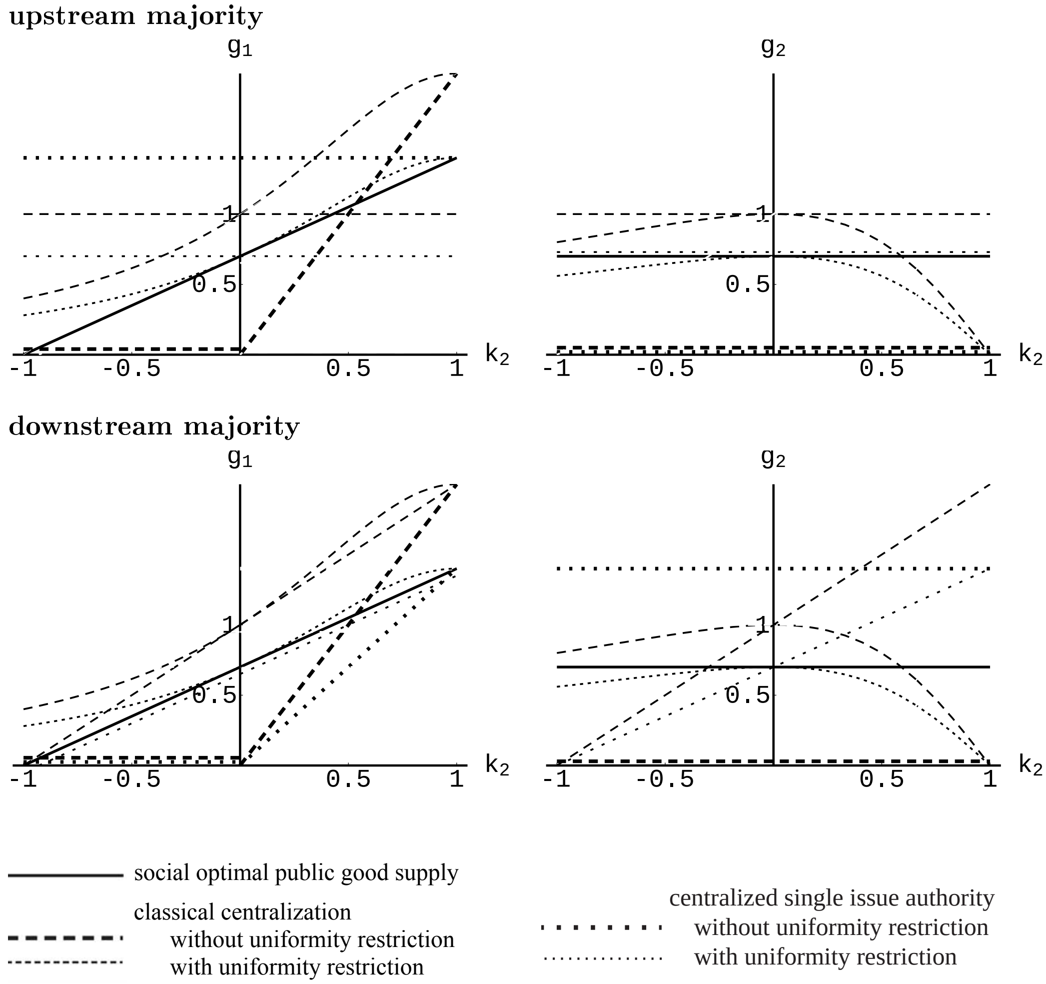


Figure 5.6: Centralized public good provision with and without uniformity restrictions for $\alpha = 0.7$ and $\lambda_1 = \lambda_2 = 1$. The non-linear curves result from the uniform public good consumption restriction.

downstream public good.

With uniform public good consumption (represented by the non-linear curves) this dilemma can be avoided. With this restriction, upstream and downstream high-benefit citizens want the same pattern of public good supply, which is also fairly efficient as long as spillovers are not too large. A centralized single issue authority tends to provide the public goods more efficiently than classical centralization, because it avoids the problem of over-provision due to heterogeneous benefits within regions. Uniform consumption of the public goods becomes inefficient if the spillover is very positive.

With large positive spillovers, the socially optimal public good supply is large upstream and at a constant level downstream. Uniform consumption requires a low downstream public good supply when spillovers are high. However, such a low level of the downstream public good is inefficient. This is why proposition 5.4 suggests classical decentralization, instead of a centralized single issue authority, as the superior federal organization when there are large positive spillovers.

Partial centralization

Figure 5.6 shows that part of the problem of centralized decision making stems from inefficient downstream public good provision. Downstream public good provision is, however, a purely local public good and therefore the second strategy to improve the performance of centralization is to decentralize downstream public good provision and to centralize the upstream supply.

With classical centralization this reduces the centralized voting problem to one issue. Voting on upstream public good provision takes place in the same way as above. Downstream public good provision is determined decentrally, which yields the following public good supply for partial centralization, denoted with the superscript 'c,p':

$$(g_1^{c,p}, g_2^{c,p}) = \begin{cases} (\kappa_2\, 2\, \lambda_2, & \lambda_2) \quad \text{for } \alpha > \frac{1}{2} \text{ and } \kappa_2 \geq 0 \\ (0, & \lambda_2) \quad \text{for } \alpha > \frac{1}{2} \text{ and } \kappa_2 < 0 \\ (0, & \lambda_2) \quad \text{for } 1-\alpha \geq \frac{1}{2}\,. \end{cases} \tag{5.24}$$

In a similar way, the outcome of partial centralization with a central single issue authority is given by

$$(g_1^{cs,p}, g_2^{cs,p}) = \begin{cases} (2\,\alpha\lambda_1, & \alpha\lambda_2) \quad \text{for an upstream majority} \\ (\kappa_2 2\,\alpha\lambda_2, & \alpha\,\lambda_2) \quad \text{for a down. majority and } \kappa_2 \geq 0 \\ (0, & \alpha\,\lambda_2) \quad \text{for a down. majority and } \kappa_2 < 0\,. \end{cases} \tag{5.25}$$

With this public good provision the comparison of the four possible federal organizations yields the following proposition.

Proposition 5.5 *Assume simple majority voting, unidirectional spillovers and regions with heterogeneous benefits. Assumptions 5.1 and 5.2 hold. The comparison of the four federal organizations—classical decentralization, decentralized single issue authorities, partial centralization (centralized voting on g_1 and decentralized voting on g_2), and partial centralization through a single issue authority—leads to the following results:*

With positive spillovers there is a critical level of spillovers, $\kappa_2^{crit} = \frac{1}{2}$. Below this level, decentralized and above this level, partially centralized voting leads to the highest surplus. Single issue authorities yield the highest surplus unless the high-benefit share is large. For a partially centralized single issue authority to be superior, it must hold that $\alpha < \alpha^{crit}(\kappa_2) = \frac{1+\kappa_2^2}{1+\kappa_2}$. For decentralized single issue authorities to be superior, it must hold that $\alpha < \alpha^{crit}(\kappa_2) = \frac{1}{1+\kappa}$.

With negative spillovers, decentralized single issue authorities are superior with an upstream majority. With a downstream majority there is a critical level of spillovers, $\kappa_2^{crit} = -\frac{1}{2}$. For larger spillovers, decentralized single issue authorities are superior, and for lower spillovers a partial centralized single issue authority is the best federal organization.

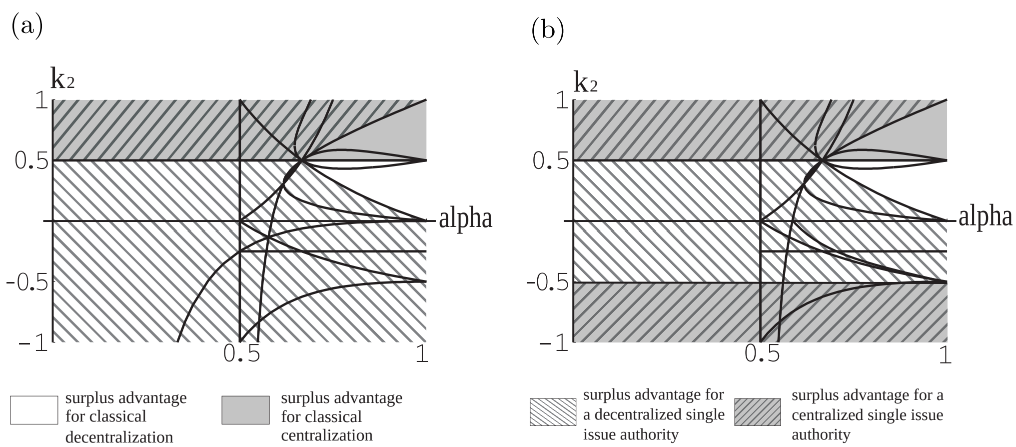


Figure 5.7: Surplus optimal federal organizations with partial centralized voting and unidirectional spillovers and heterogeneous benefits within regions. (a) upstream majority, (b) downstream majority.

All critical parameter constellations for which two different federal organizations yield the same public good surplus are given in the appendix to this chapter. In addition, the appendix specifies the parameter constellations where one federal organization is superior to all other federal organizations. Figure 5.7 illustrates proposition 5.5. Public good provision through partial centralization improves the outcome of centralized voting and can be the best option for public good provision if spillovers are large enough (positive or negative). This is in contrast to proposition 5.3, which stated that centralized voting on public good provision is never superior to decentralized voting. Single issue authorities are the best federal organization unless the high-benefit share is large and the no-benefit minority is fairly small. With this constellation in combination with positive spillovers, classical federal organizations yield a higher surplus than single issue authorities. The exploitation of the minority brings the supply of public goods closer to the social optimum than voting in single issue authorities.

Proposition 5.5 also states that with negative spillovers it depends on the political majority constellations if centralized or decentralized voting is superior. A downstream majority votes for no upstream public good, which is good if spillovers are very negative. A upstream majority favors a high upstream public good level, which is very inefficient.

As in the previous propositions that assumed unidirectional spillovers, heterogeneous benefits within a jurisdiction have no positive effect when spillovers are negative. A minority without public good benefits has no positive effect, since it increases public good provision. Heterogeneous benefits in decentralized jurisdictions increase public good provision, which makes classical decentralization inefficient when spillovers are negative. With a high-benefit minority and negative spillovers, there is no public good provision in a decentralized or partially centralized jurisdiction. However, there are single issue authorities that provide the public good and lead to a positive surplus compared to a zero surplus without public good provision.

5.4 Conclusions

This chapter analyzed different jurisdictional organizations of public good provision. In search of a good federal organization for flood defense, the first aim was to understand the difficulties arising from unidirectional spillovers and spatially heterogeneous public good benefits. A political-economy approach, with voting on public good provision, was found suitable to analyze the fundamental conflict of interests between upstream and downstream riparians as well as the spatial heterogeneity of benefits.

In contrast to a common view in the literature on upstream-downstream water issues, it was found that not only the international level but also a federal system within a country may be seriously challenged by unidirectional spillovers. As on the international level, decentralized jurisdictions neglect transfrontier spillovers and over- or under-provide the public goods. Centralized jurisdictions suffer from the dominance of the majority. Unlike the first conjecture, it is not so much the upstream public good that is flawed with centralized voting, but primarily the downstream public good that causes large inefficiencies. The downstream public good is either extremely over- or under-provided.

Inefficiencies resulting from an uneven distribution of benefits may call for single issue authorities. Inefficiencies in classical jurisdictions are particularly large when the majority and the minority group of a population are of similar size. But also a small minority causes inefficiencies when spillovers are absent. If spillovers are present, single issue authorities are not the general recommendation. The first case where jurisdictions with heterogeneous benefits are good is a small minority without benefits from public good provision and large positive spillovers. The no-benefit minority drives public good provision up, which is good, given the positive spillovers. The second case where heterogeneous benefits are good is a negative spillover and a high-benefit minority. With this constellation there is no public good provision, which is particularly good if there are large negative spillovers.

It was a second aim of this chapter to identify jurisdictional organizations that avoid the shortcomings of the four basic federal settings. Central standards that require a uniform supply or a uniform consumption level of public goods where found to have very different consequences. Whereas uniform public good supply does not make centralized voting superior to decentralized voting, given unidirectional spillovers, a uniform consumption requirement can make centralized jurisdictions superior to decentralized ones.

Instead of relying on an exogenous uniformity restriction for centralized voting, centralization can be improved by focusing on the public good with spillovers. Since the downstream public good is purely local, partial centralization through centralized voting on upstream public good provision only makes central jurisdictions superior to decentralized jurisdictions if spillovers are large enough. However, with negative spillovers partially centralized voting is favorable, whether or not depends crucially on which region has the majority. This is because an upstream majority prefers an inefficiently high level of public good provision, whereas a downstream majority favors no supply, which is more efficient.

The analyses assumed linear utility in public goods. This was an easy way to consider positive as well as negative spillovers. With non-linear utility in public goods, the analysis becomes more complex, as the reaction functions in a decentralized setting may no longer imply dominant strategies. Crémer and Palfrey (2003) analyze such a decentralized setting with concave utility and positive spillovers and find that voting preferences depend on spillovers and that they may not be single peaked if a central standard is introduced.

In analyzing different federal organizations, this chapter focused on the aggregated public good surplus of the economy. As it became apparent, voting on public good provision determines not only the allocation of resources, but also has distributional implications. Since the median voter belonging to the majority (or median preference) group always maximizes his own utility, this may lead to very unevenly distributed benefits across regions. With such differences the preceding analysis may not be very accurate since individuals may have the option of relocation. This possibility will be considered in the next chapter.

5.5 Appendix

To proposition 5.3

Assumptions 5.1, 5.2, $\kappa_1 = 0$, and $\kappa_2 \in [-1, 1]$ hold in proposition 5.3. To distinguish between the different majority constellations, n_i denotes the population size of region i. Surplus for decentralized single issue authorities

$$S^{ds} = \alpha^2 \lambda_1^2 \tfrac{1}{2} + \alpha^2 \lambda_2^2 \tfrac{1}{2} + \alpha^2 \kappa_2 \lambda_1 \lambda_2 \,. \tag{5.26}$$

Surplus for decentralization

$$S^d = \begin{cases} (2\alpha - 1)\lambda_1^2 \frac{1}{2} + (2\alpha - 1)\lambda_2^2 \frac{1}{2} + \alpha\kappa_2\lambda_1\lambda_2 & \text{for } \alpha > \frac{1}{2} \\ 0 & \text{for } \alpha \leq \frac{1}{2} \,. \end{cases} \tag{5.27}$$

Surplus for centralization

$$S^c = \begin{cases} 2\,\lambda_2^2 \kappa_2^2\,(\alpha - 1) + 2\alpha\,\lambda_1\,\lambda_2\,\kappa_2 & \text{for } \kappa_2 > 0 \\ 0 & \text{for } \kappa_2 \leq 0 \text{ or } \alpha \leq \frac{1}{2} \,. \end{cases} \tag{5.28}$$

Surplus for a centralized single issue authority and median-voters from region 1 ($n_1 > n_2$) or region 2 ($n_1 < n_2$)

$$S^{cs} = \begin{cases} 2\kappa_2\,\alpha^2 \lambda_2\,\lambda_1 & \text{for } n_1 > n_2 \\ 2\kappa_2\,\alpha^2 \lambda_2\,\lambda_1 & \text{for } n_1 < n_2 \,\wedge\, \kappa_2 \geq 0 \\ 0 & \text{for } n_1 < n_2 \,\wedge\, \kappa_2 < 0 \,. \end{cases} \tag{5.29}$$

Comparing the public good surplus of the different federal organizations for the parameter range $\kappa_2 \in [-1,1]$ and $\alpha \in (0,1)$ leads to

$$\begin{array}{lllll}
S^{ds} = S^{d} & \Leftrightarrow & \kappa_2^{crit21} = & \kappa_2^{crit2} = \frac{1-\alpha}{\alpha} & \alpha > \frac{1}{2} \\
 & & \kappa_2^{crit22} = & -1 & \alpha \leq \frac{1}{2} \\
S^{ds} = S^{c} & \Leftrightarrow & \text{not possible} & & \kappa_2 \geq 0 \\
 & & \kappa_2^{crit22} & & \kappa_2 < 0 \\
S^{ds} = S^{cs} & \Leftrightarrow & \kappa_2^{crit23} = & 1 & \kappa_2 \geq 0 \\
 & & \kappa_2^{crit22} & & n_1 < n_2 \wedge \kappa_2 < 0 \\
 & & \text{not possible} & & n_1 > n_2 \wedge \kappa_2 < 0 \\
S^{d} = S^{c} & \Leftrightarrow & \kappa_2^{crit24} = & \frac{\alpha \pm \sqrt{8-24\alpha+17\alpha^2}}{4(1-\alpha)} & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit25} = & \frac{1-2\alpha}{\alpha} & \alpha > \frac{1}{2} \wedge \kappa_2 < 0 \\
 & & \forall \kappa_2 & & \alpha \leq \frac{1}{2} \\
S^{d} = S^{cs} & \Leftrightarrow & \kappa_2^{crit26} = & \frac{1}{\alpha} & \alpha > \frac{1}{2} \wedge n_1 > n_2 \\
 & & \kappa_2^{crit26} & & \alpha > \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit25} & & \alpha > \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 < 0 \\
 & & \kappa_2^{crit27} = & 0 & \alpha \leq \frac{1}{2} \wedge n_1 > n_2 \\
 & & \kappa_2^{crit27} & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 \geq 0 \\
 & & \forall \kappa_2 & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 < 0 \\
S^{c} = S^{cs} & \Leftrightarrow & \kappa_2^{crit28} = & \alpha & \alpha > \frac{1}{2} \wedge \kappa_2 > 0 \\
 & & \forall \kappa_2 & & \alpha > \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 \leq 0 \\
 & & \kappa_2^{crit27} & & \alpha > \frac{1}{2} \wedge n_1 > n_2 \wedge \kappa_2 \leq 0 \\
 & & \kappa_2^{crit27} & & \alpha \leq \frac{1}{2} \wedge n_1 > n_2 \\
 & & \kappa_2^{crit27} & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 \geq 0 \\
 & & \forall \kappa_2 & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2 \wedge \kappa_2 < 0\,.
\end{array} \tag{5.30}$$

S^{ds} is superior to S^d, S^c and S^{cs} if

$$\alpha > \tfrac{1}{2} \quad \wedge \quad \kappa_2(\alpha) < \kappa_2^{crit21}(\alpha)\,. \tag{5.31}$$

S^d is superior to S^{ds}, S^c and S^{cs} if

$$\alpha > \tfrac{1}{2} \quad \wedge \quad \kappa_2(\alpha) > \kappa_2^{crit21}(\alpha)\,. \tag{5.32}$$

To proposition 5.4

Assumptions 5.1, 5.2, and $\kappa_2 \in [-1,1]$ hold in proposition 5.4. Public good surplusses for decentralized jurisdictions are the same as for proposition 5.3. Denoting the identical high benefits of both regions with λ_α, public good surplus for centralization with uniform public good supply and uniform public good consumption is given by

Surplus for centralization:

$$S^{c,us} = \begin{cases} \lambda_\alpha^2 (2\,\alpha - 1 + \alpha\,\kappa_2) & \text{with } \alpha > \frac{1}{2} \text{ and } \kappa_2 \geq 0 \\ \lambda_\alpha^2 (1+\kappa_2)(2\,\alpha - 1 - (1-\alpha)\,\kappa_2) & \text{with } \alpha > \frac{1}{2} \text{ and } \kappa_2 < 0 \\ 0 & \text{with } \alpha \leq \frac{1}{2}. \end{cases} \tag{5.33}$$

$$S^{c,uc} = \begin{cases} \frac{2\,(2\,\alpha-1)\lambda_\alpha^2}{2-(2-\kappa_2)\kappa_2} & \text{with } \alpha > \frac{1}{2} \\ 0 & \text{with } \alpha \leq \frac{1}{2}. \end{cases} \tag{5.34}$$

Surplus for a centralized single issue authority:

$$S^{cs,us} = \alpha^2 \lambda_\alpha^2 (1+\kappa_2) \tag{5.35}$$

$$S^{cs,uc} = \frac{2\,\alpha^2\lambda_\alpha^2}{2-(2-\kappa_2)\kappa_2}. \tag{5.36}$$

Comparing the public good surplus of the different federal organizations for the parameter range $\kappa_2 \in [-1,1]$ and $\alpha \in (0,1)$ leads to

$$\begin{array}{llll}
S^{ds} = S^{d} & \Leftrightarrow \; \alpha^{crit31} = & \frac{1}{1+\kappa_2} & \alpha > \frac{1}{2} \\
 & \quad \text{not possible} & & \alpha \leq \frac{1}{2} \wedge -1 < \kappa_2 \leq 1 \\
 & \quad \forall\,\alpha & & \alpha \leq \frac{1}{2} \wedge \kappa_2 = -1 \\
S^{ds} = S^{c,us} & \Leftrightarrow \; \alpha^{crit32} = & \frac{1}{1+\kappa_2} & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & \quad \alpha^{crit33} = & 1+\kappa_2 & \alpha > \frac{1}{2} \wedge \kappa_2 < 0 \\
 & \quad \text{not possible} & & \alpha \leq \frac{1}{2} \\
S^{ds} = S^{c,uc} & \Leftrightarrow \; \alpha^{crit34} = & \frac{1}{1\pm\sqrt{\frac{\kappa_2^2-\kappa_2^3}{2}}} & \alpha > \frac{1}{2} \\
 & \quad \text{not possible} & & \alpha \leq \frac{1}{2} \\
S^{ds} = S^{cs,us} & \Leftrightarrow \; \forall\,(\kappa_2,\,\alpha) & & \\
S^{ds} = S^{cs,uc} & \Leftrightarrow \; \text{not possible} & & -1\leq\kappa_2<0 \vee 0<\kappa_2<1 \\
 & \quad \forall\,\alpha & & \kappa_2 = 0 \vee \kappa_2 = 1 \\
S^{d} = S^{c,us} & \Leftrightarrow \; \forall\,(\kappa_2,\alpha) & & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & \quad \text{not possible} & & \alpha > \frac{1}{2} \wedge \kappa_2 < 0 \\
 & \quad \forall\,(\kappa_2,\alpha) & & \alpha \leq \frac{1}{2} \\
S^{d} = S^{c,uc} & \Leftrightarrow \; \alpha^{crit35} = & \frac{2-\kappa_2}{2-\kappa_2^2} & \alpha > \frac{1}{2} \wedge \kappa_2 > 0 \\
 & \quad \forall\,\alpha & & \alpha > \frac{1}{2} \wedge \kappa_2 = 0 \\
 & \quad \forall\,(\kappa_2,\alpha) & & \alpha \leq \frac{1}{2} \\
S^{d} = S^{cs,us} & \Leftrightarrow \; S^{d} = S^{ds} & & \\
S^{d} = S^{cs,uc} & \Leftrightarrow \; \alpha^{crit36} = & \frac{1}{4}(4+\kappa_2^3+\kappa_2(-2\pm\sqrt{\kappa_2(8-4\kappa_2+\kappa_2^3)-4})) & \alpha > \frac{1}{2} \\
 & \quad \text{not possible} & & \alpha \leq \frac{1}{2} \\
S^{c,us} = S^{cs,us} & \Leftrightarrow \; S^{c,us} = S^{ds} & & \\
S^{c,uc} = S^{cs,us} & \Leftrightarrow \; S^{c,uc} = S^{ds} & & \\
S^{c,uc} = S^{cs,uc} & \Leftrightarrow \; \text{not possible.} & &
\end{array} \tag{5.37}$$

S^{ds} is superior to S^{d}, $S^{c,us}$, $S^{c,uc}$, $S^{cs,us}$ and $S^{cs,uc}$ if

$$\kappa_2 \in [-1,1] \quad \wedge \quad \alpha(\kappa_2) < \alpha^{crit36-}(\kappa_2) \quad \vee \quad \alpha(\kappa_2) > \alpha^{crit36+}(\kappa_2). \tag{5.38}$$

$S^{cs,uc}$ is superior to S^{ds}, S^{d}, $S^{c,us}$, $S^{c,uc}$, and $S^{cs,us}$ if

$$\kappa_2 \in [-1,1] \quad \wedge \quad \alpha^{crit56-}(\kappa_2) < \alpha(\kappa_2) < \alpha^{crit56+}(\kappa_2), \tag{5.39}$$

where $\alpha^{crit36+}(\kappa_2)$ denotes the branch with the positive square root of $\alpha^{crit36}(\kappa_2)$.

With the critical parameter values of α and κ_2 derived above, S^{d}, $S^{c,us}$, $S^{c,uc}$, and $S^{cs,us}$ never lead to the highest public good surplus in comparison to the other federal organizations.

To proposition 5.5

Assumptions 5.1, 5.2, and $\kappa_2 \in [-1,1]$ hold in the proposition. Public good surplus for decentralized jurisdictions are the same as for proposition 5.3. Denoting the identical high benefits of both regions with λ_α, the outcome for partially centralized jurisdictions is given by

Surplus for partial centralization:

$$S^{c,p} = \begin{cases} \frac{1}{2}\lambda_\alpha^2(2\,\alpha - 1 + 4\kappa_2(\alpha - (1-\alpha)\kappa_2)) & \text{with } \kappa_2 \geq 0 \text{ and } \alpha > \frac{1}{2} \\ \frac{1}{2}(2\,\alpha - 1)\lambda_\alpha^2 & \text{with } \kappa_2 < 0 \text{ and } \alpha > \frac{1}{2} \\ 0 & \text{with } \alpha \leq \frac{1}{2}. \end{cases} \tag{5.40}$$

Surplus for a partially centralized single issue authority and the median-voter from region 1 ($n_1 > n_2$) or region 2 ($n_1 < n_2$):

$$S^{cs,p} = \begin{cases} \frac{1}{2}\,\alpha^2\lambda_\alpha^2(1 + 4\,\kappa_2) & n_1 > n_2 \\ \frac{1}{2}\,\alpha^2\lambda_\alpha^2(1 + 4\,\kappa_2) & n_1 < n_2 \wedge \kappa_2 \geq 0 \\ \frac{\alpha^2\lambda_\alpha^2}{2} & n_1 < n_2 \wedge \kappa_2 < 0. \end{cases} \tag{5.41}$$

Comparing the public good surplus of the different federal organizations for the parameter range $\kappa_2 \in [-1,1]$ and $\alpha \in (0,1)$ leads to

$$
\begin{array}{lllll}
S^{ds} = S^{d} & \Leftrightarrow & \kappa_2^{crit41} = & \frac{1-\alpha}{\alpha} & \alpha > \frac{1}{2} \\
 & & \kappa_2^{crit42} = & -1 & \alpha \leq \frac{1}{2} \\
S^{ds} = S^{c,p} & \Leftrightarrow & \kappa_2^{crit43} = & \frac{\alpha(2-\alpha)}{4(1-\alpha)} \pm \frac{\sqrt{-4+\alpha(12-\alpha(2-\alpha)(6+\alpha))}}{4(1-\alpha)} & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit44} = & \frac{2\,\alpha-2\,\alpha^2-1}{2\,\alpha^2} & \alpha > \frac{1}{2} \wedge \kappa_2 < 0 \\
 & & \kappa_2 = & \kappa_2^{crit42} & \alpha \leq \frac{1}{2} \\
S^{ds} = S^{cs,p} & \Leftrightarrow & \kappa_2^{crit45} = & \frac{1}{2} & \kappa_2 \geq 0 \\
 & & \kappa_2^{crit46} = & -\frac{1}{2} & n_1 < n_2 \wedge \kappa_2 < 0 \\
 & & \text{not possible} & & n_1 > n_2 \wedge \kappa_2 < 0 \\
S^{d} = S^{c,p} & \Leftrightarrow & \kappa_2^{crit47;48} = & \frac{1}{2-2\alpha} - 1 \text{ and } \frac{1}{2} & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit49} = & \frac{1}{2\,\alpha} - 1 & \alpha > \frac{1}{2} \wedge \kappa_2 < 0 \\
 & & \forall \kappa_2 & & \alpha \leq \frac{1}{2} \\
S^{d} = S^{cs,p} & \Leftrightarrow & \kappa_2^{crit410} = & \frac{2-4\alpha+\alpha^2}{2\,\alpha-4\,\alpha^2} & \alpha > \frac{1}{2} \wedge n_1 > n_2 \\
 & & \kappa_2 = & \kappa_2^{crit410} & \alpha > \frac{1}{2} \wedge \\
 & & & & n_1 < n_2 \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit411} = & \frac{2-4\alpha+\alpha^2}{2\,\alpha} & \alpha > \frac{1}{2} \wedge \\
 & & & & n_1 < n_2 \wedge \kappa_2 < 0 \\
 & & \kappa_2^{crit412} = & -\frac{1}{4} & \alpha \leq \frac{1}{2} \wedge n_1 > n_2 \\
 & & \text{not possible} & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2 \\
S^{c,p} = S^{cs,p} & \Leftrightarrow & \kappa_2^{crit413} = & \frac{\alpha \pm \sqrt{\alpha^2+\alpha-1}}{2} & \alpha > \frac{1}{2} \wedge \kappa_2 \geq 0 \\
 & & \kappa_2^{crit414} = & -\frac{(1-\alpha)^2}{4\,\alpha^2} & \alpha > \frac{1}{2} \wedge \\
 & & & & n_1 > n_2 \wedge \kappa_2 \leq 0 \\
 & & \text{not possible} & & \alpha > \frac{1}{2} \wedge \\
 & & & & n_1 < n_2 \wedge \kappa_2 \leq 0 \\
 & & \kappa_2 = & \kappa_2^{crit412} & \alpha \leq \frac{1}{2} \wedge n_1 > n_2 \\
 & & \text{not possible} & & \alpha \leq \frac{1}{2} \wedge n_1 < n_2\,.
\end{array}
\tag{5.42}
$$

With regard to proposition 5.5 it holds that $\alpha^{crit} = \frac{1}{1+\kappa_2} \Leftrightarrow \kappa_2^{crit41} = \frac{1-\alpha}{\alpha}$ and $\alpha^{crit} = \frac{1+\kappa_2^2}{1+\kappa_2} \Leftrightarrow \kappa_2^{crit413} = \frac{\alpha \pm \sqrt{\alpha^2+\alpha-1}}{2}$.

S^{ds} is superior to S^{d}, $S^{c,p}$ and $S^{cs,p}$ if

$$
\begin{array}{lllll}
\alpha \in (0,1) & \wedge & \kappa_2(\alpha) < \min\{\kappa_2^{crit41}(\alpha), \kappa_2^{crit45}\} & \wedge & n_1 > n_2 \quad \vee \\
\alpha \in (0,1) & \wedge & \kappa_2^{crit46} < \kappa_2 < \min\{\kappa_2^{crit41}(\alpha), \kappa_2^{crit45}\} & \wedge & n_1 < n_2\,.
\end{array}
\tag{5.43}
$$

S^{d} is superior to S^{ds}, $S^{c,p}$, and $S^{cs,p}$ if

$$
\alpha > \tfrac{1}{2} \quad \wedge \quad \kappa_2^{crit41}(\alpha) < \kappa_2(\alpha) < \kappa_2^{crit42}(\alpha)\,. \tag{5.44}
$$

$S^{c,p}$ is superior to S^{ds}, S^{d}, and $S^{cs,p}$ if

$$
\alpha > \tfrac{1}{2} \quad \wedge \quad \kappa_2^{crit42}(\alpha) < \kappa_2(\alpha) < \kappa_2^{crit413+}(\alpha), \tag{5.45}
$$

where $\kappa_2^{crit413+}(\alpha)$ denotes the branch with the positive square root of $\kappa_2^{crit413}(\alpha)$.

$S^{cs,p}$ is superior to S^{ds}, S^{d}, and $S^{c,p}$ if

$$
\begin{array}{lll}
\alpha \in (0,1) & \wedge & \kappa_2(\alpha) > \max\{\kappa_2^{crit413+}(\alpha), \kappa_2^{crit45}(\alpha)\} \vee \\
\alpha \in (0,1) & \wedge & \kappa_2 < \kappa_2^{crit46} \wedge n_1 < n_2.
\end{array}
\tag{5.46}
$$

Chapter 6

Migration and myopic voting

In the previous chapter the population size of the regions was assumed to be given. It is obvious that this assumption does not always hold since individuals can move from one region to another. Some authors even see the possibility of migration as the crucial difference between the theory of public goods and the theory of local public goods (Stiglitz 1977, 274). With free migration the locational choices of individuals do not only depend on the income opportunities but also on the benefits from local public goods in different regions. Flood defense is a good example of this. A flood-prone area with a high level of public flood protection favors human encroachment much more than unprotected areas. Smith (2001) critically sees this interdependency as a circular link where locational choices are biased by central government involvement (see section 3.3.3). Wellisch (1994) gives the example of water pollution, where upstream sewage treatment has a positive effect on downstream cities. Public schooling is another example of a public good that can trigger locational choices. In order to develop a model that captures the basic characteristics of these interdependencies, the possibility of free migration will be introduced in the following two chapters.

This approach to local public goods and free migration builds on Boadway (1982), Boadway and Flatters (1982), Wellisch (1994; 1993) and others. The widespread approach in the literature is a two regions model with a private and a public good. Public good provision is made by a social planner who considers the welfare of its jurisdiction. Production is tied to the region through a region-specific factor (usually land) and needs labor as an additional input. Whereas Boadway (1982) and Boadway and Flatters (1982) do not incorporate spillovers, more recent contributions of Wellisch (1994; 1993) do consider inter-regional spillovers from public goods. It is a common approach in the literature to focus on decentralized solutions and consider mechanisms by which the social optimum can be reached under free migration. If inter-regional transfers are possible the first-best is usually attainable. In focusing on first-best outcomes, issues of fiscal federalism are hardly discussed in the literature. Another strand of literature rather focuses on equilibria and their existence in more general local public economies that also allow for voting on public goods. For an overview see Konishi (1996). Due to fundamental existence problems in these models, the federal structure is kept simple. A need to also consider the classical issue of fiscal federalism—decentralization or centralization—is pointed out by Besley and Coate (2003, 2614). One contribution with free migration and with local as well as federal jurisdictions is Nechyba (1997). However, he also does not address the issue of the appropriate vertical federal structure.

The following chapters consider a local public good economy with free migration in a second-best setting. This leads again to the question if public flood defense should be provided decentralized or centralized. In addition the question arises if single issue authorities should provide flood defense. To focus on the fundamental arguments, both questions will be analyzed independently from each other. As in the last chapter the modeling approach is the basic political-economy setting with simple majority voting on public goods. Public good provision and migration decisions are seen as a two stage game, with voting on public goods at the first stage and locational choices at the second stage. This chapter focuses on the case where voters are unaware of migration and therefore vote myopically. The following chapter (chapter 7) relaxes this assumption by considering non-myopic voters.

6.1 The model

The set up of the economy is similar to the basic model in chapter 5. For reasons of notational convenience the formulation is slightly more general. Two regions (or communities) $i \in \{1, 2\}$ are considered. A public good can be provided in both regions. The quantity of the public good in region i is g_i, with $g_i \in \mathbb{R}_+$. Beside the public goods there is a private good that is produced within the economy. The public good can be produced by using the private good. Using the private good as a numéraire, the convex cost function of the public good in region i can be expressed by $c_i(g_i)$, with $c_i'(g_i) > 0$ and $c_i''(g_i) > 0$.

As it is common in the literature on migration, preferences are assumed to be the same for all citizens. However, public good benefits may be different depending on the region of residency. To focus on the fundamental role of spillovers it will be assumed that utility is linear in private as well as public good consumption. Utility of a representative individual of region i depends on the private and the public goods: $y_i + u^i(g_i, g_j)$. y_i is the amount of private good that is consumed in region i.

The public good of the foreign region enters the utility function in case of spillovers. Spillovers can be positive, $u^i_{gj} > 0$, or negative, $u^i_{gj} < 0$. The second order derivatives are zero, $u_{gigi} = 0$. Spillovers are seen as spatial spillovers and it is assumed that they are unidirectional, so that the public good of one region affects utility of the other region but not the other way around. This allows the interpretation that the location of one region is upstream (denoted as region 1) and the other region is downstream (denoted as region 2), thus, u^1_{g2} is always zero. Due to the linearity assumption the cross derivatives in public good consumptions are zero, $u^i_{gigj} = 0$.

The total population of the economy is given by $\bar{n}$. Individuals can migrate between regions and mobility is assumed to be costless. The following concept for a migration equilibrium will be considered.

Definition 6.1 *A migration equilibrium is reached if nobody has an incentive to move* *to another region.*[1]

With the later assumptions on income distribution and taxation, a necessary condition for an interior migration equilibrium is equal utility in both regions, $y_i + u^i(g_i, g_j) = y_j + u^j(g_j, g_i)$. Hence, free migration imposes a strong restriction on the economy, as it exclude any utility differentials between regions in the equilibrium allocation. As soon as utility in one region is higher than in the other region, citizens face the incentive to live in the region with higher utility.

What prevents individuals from all moving to the same region? With free and costless migration in the model of chapter 5, all individuals would want to live in the same region. With complete concentration individuals have the highest utility since cost from public goods can be shared within the entire population. Therefore a force is needed that favors a population distribution without complete concentration.

This approach follows the main strand of the literature on local public goods and migration in assuming that there is a spatially fixed factor of production. This factor will be interpreted as land. A spatially fixed factor is only productive at a specific location, which is the crucial characteristic of land. If other factors of production, such as labor, exhibit decreasing returns to scale—which is usually assumed—it is efficient to produce at different locations.[2] Each region produces a private good with the production function $f^i(n_i, \bar{x})$. There are two inputs to production, labor and the fixed factor land. The corresponding quantities are denoted by n_i and $\bar{x}$, respectively. The production function is concave in both factors, therefore f^i_n, $f^i_{\bar{x}} > 0$ and f^i_{nn}, $f^i_{\bar{x}\bar{x}} < 0$, where partial derivatives are denoted by subscripts. As is common in much of the literature on local public economies, labor supply is assumed to be fixed and normalized to one unit of labor per worker. Therefore n_i also represents the population size of region i. For reasons of convenience the population size is approximated as a continues variable, thus $n_i \in \mathbb{R}_+$. To concentrate on spillovers, symmetry assumptions hold with respect to the production function and the land endowment, thus $\bar{x} = \bar{x}_i = \bar{x}_j$ and $f^i(n_i, \bar{x}) = f^j(n_j, \bar{x})$ for $n_i = n_j$. Note that the chapters on migration assume homogeneous benefits from public goods within each region. With respect to the previous chapters this implies that the high-benefit share of the population is one, $\alpha = 1$.

[1] Thus, this equilibrium concept considers the incentives for unilateral actions. For other equilibrium concepts in local public economies and also in club economies see Scotchmer (2002). Alternative equilibrium concepts also allow coordinated deviation, but they are usually not well suited for the analysis of a spatial context with migration between jurisdictions.

[2] Other assumptions that avoid the concentration of the population in one region are (1) congestion and (2) preferences that attach individuals to a region. To (1): Many public goods are impure so that there are crowding effects. Additional individuals consuming a public good reduce the utility of other individuals who consume the same public good. Boadway and Flatters (1982), for example, assume a utility function of the form $u^i(\frac{g_i}{n_i^\delta})$. With $\delta = 0$ the public good is a pure public good. With $\delta < 1$ public good utility depends on the number of individuals who consume the public good. $\delta = 1$ represents the case of complete rivalry which is characteristic for pure private goods. To (2): The preference to live in a specific region or state can be based on cultural factors such as languages or social attachment (Wellisch 1994). With a preference to live in a certain region there must be a utility differential across regions to create migration incentives.

6.2 Social optimum

6.2.1 Two regions with unidirectional spillovers

The analysis of different federal organizations needs to be based on a welfare function that allows the comparison of different federal settings. Furthermore it is desirable to know the first-best allocation of that welfare function as a benchmark. It is well known that different welfare functions may yield different optimal allocations. Since the following analysis allows free and costless migration, it is desirable that also the social optimum is compatible with free migration. The only welfare function compatible with free and costless migration is a Rawlsian welfare function.[3] The maximum of a Rawlsian welfare function yields a Pareto-efficient allocation that is compatible with free mobility. Other welfare functions may find other optimal allocations, however, these allocations will generally involve different utility levels of individuals, which contradicts the free migration restriction. A Rawlsian welfare function gives the appropriate benchmark if it is assumed that a social planner cannot directly control locational choices.

With a Rawlsian welfare function and the feasibility constraints of the economy, the optimization problem of the social planner is given by

$$\begin{aligned}
\max_{g_i,g_j,y_i,y_j,n_i,n_j\in\mathbb{R}_+} \quad & y_i + u^i(g_i,g_j) \\
\text{s.t.} \quad & y_i + u^i(g_i,g_j) = y_j + u^j(g_i,g_j) \\
& f^i(n_i,\bar{x}) + f^j(n_j,\bar{x}) - n_i y_i - n_j y_j \\
& -c_i(g_i) - c_j(g_j) = 0 \\
& \bar{n} - n_i - n_j = 0.
\end{aligned} \tag{6.1}$$

The first-order conditions for interior solutions are as follows

$$\begin{aligned}
& n_i u^i_{gi} + n_j u^j_{gi} - c'_i(g_i) = 0 \qquad \text{for} \quad i,j = 1,2; \quad i \neq j \\
& (f^i_n - y_i) - (f^j_n - y_j) = 0.
\end{aligned} \tag{6.2}$$

The first condition states that the socially optimal supply with public goods follows the Samuelson rule. The sum of the marginal benefits of all individuals has to equal the marginal cost of public good provision. The second condition defines the optimal location of individuals in the economy. Locational efficiency does not imply equalization of marginal labor productivity across regions. It requires that the marginal productivity minus private consumption of an immigrant has to be the same for both regions. This term can be seen as the social net-benefit of an additional individual to a region. Without locational efficiency, welfare and individual utility can be increased by migration.

[3] See Stiglitz (1977), Wellisch (1993), and Quaas (2005) for similar approaches.

The second-order sufficient conditions for a local maximum as an interior solution require the bordered Hessian matrix to be negative definite.With the three first-order conditions, the free migration restriction, and the feasibility constraints the critical condition is

$$|\bar{H}_5| = \frac{1}{\bar{n}}[c_1''(u_{g2}^2)^2 + c_2''(c_1''(f_{nn}^1 + f_{nn}^2) + (u_{g1}^1 - u_{g1}^2)^2)] < 0 \ . \tag{6.3}$$

For high marginal benefits from public goods this condition may be violated. The marginal benefit from the domestic public good, u_{gi}^i, is positive and constant. In the downstream region, the marginal public good benefit from the upstream public good, u_{g1}^2, has the same sign as the spillover. The second-order derivatives of the concave production function, f_{nn}, are negative. Increasing marginal costs of public goods are reflected in a positive c_i''. Spillovers—which can vary in a range of negative to positive values— affect the size of some of these partial derivatives. This is obvious for u_{g1}^2, whose magnitude is proportional to the size of the spillover. In addition spillovers may influence the population distribution, which affects the second-order derivatives of the production and cost functions. Assuming that the later two impacts are not too strong, positive spillovers make it easier for the second-order sufficient conditions to be met and small or negative spillovers make it harder. The other bordered principal minors of the bordered Hessian are given in the appendix to this chapter.

Assumption 6.1 *The analysis is restricted to production, costs and utility functions that satisfy the condition of equation 6.3.*

Assuming that the first-order conditions determine the single optimal solution, the comparative static analysis reveals the impact of spillovers on the amount of public good provision and the population distribution across regions. The unilateral spillover from the upstream region 1 to the downstream region 2 can be positive or negative and it is denoted by κ_2. The allocation of the socially optimal migration equilibrium depends on spillovers as follows

$$\begin{aligned}
\frac{dg_1}{d\kappa_2} &= \frac{c_2''u_{\kappa 2}^2(u_{g1}^1 - u_{g1}^2) + n_2 u_{g1\kappa 2}^2[(u_{g2}^2)^2 + c_2''(f_{nn}^1 + f_{nn}^2)]}{\bar{n}\,|\bar{H}_5|} \\
\frac{dg_2}{d\kappa_2} &= u_{g2}^2 \frac{n_2 u_{g1\kappa 2}^2(u_{g1}^1 - u_{g1}^2) - c_1'' u_{\kappa 2}^2}{\bar{n}\,|\bar{H}_5|} \\
\frac{dn_1}{d\kappa_2} &= -c_2'' \frac{n_2 u_{g1\kappa 2}^2(u_{g1}^1 - u_{g1}^2) - c_1'' u_{\kappa 2}^2}{\bar{n}\,|\bar{H}_5|} \ .
\end{aligned} \tag{6.4}$$

With assumption 6.1, the second-order conditions are met and the denominator of the three equations is negative. Beside the partial derivatives in $|\bar{H}_5|$ there are two additional derivatives. An increase in spillovers increases the downstream utility. This direct effect holds for positive as well as negative spillovers, which implies $u_{\kappa 2}^2 > 0$. A marginal change in spillovers affects the marginal benefit from the upstream public good in the downstream region, $u_{g1\kappa 2}^2$. This effect is positive and does not depend on the level of spillovers.

Since the comparative statics are generally ambiguous, it is helpful to understand how the different derivatives depend on spillovers. Downstream, the marginal benefit from the upstream public good, u^2_{g1}, is proportional to the spillover. In the comparative statics the derivative is part of the term $u^1_{g1} - u^2_{g1}$. This term decreases in spillovers but remains positive unless spillovers are strongly positive or the marginal benefit from the downstream public good is sufficiently large compared to the marginal benefit upstream. Another partial derivative that is influenced by spillovers is the marginal increase of downstream utility in spillovers, $u^2_{\kappa 2}$. It depends on the level of the upstream public good and is large for a high supply with the public good. In addition, spillovers may influence the population distribution, which affects the second-order derivatives of the production and cost functions. Assuming—as before— that the two last impacts are not too strong, one can state the following:

- The impact of spillovers on the optimal amount of the upstream public good tends to be positive. For sufficiently small marginal benefits from public goods, $f^1_{nn} + f^2_{nn}$ dominates the other terms of the enumerator. If this is the case the impact of spillovers on the upstream public good is positive since both the enumerator and the denominator are negative. In the enumerator both partial derivatives that strongly depend on spillovers are multiplied, $u^2_{\kappa 2}(u^1_{g1} - u^2_{g1})$. This product is zero either when spillovers are so negative that there is no upstream public good provision, $u^2_{\kappa_2} = 0$, or if spillovers are so large that the marginal effects on the utility in both regions cancel out, $u^1_{g1} - u^2_{g1} = 0$. For intermediate values of spillovers, the product is positive, which reduces the impact of spillovers on the upstream public good. The absolute value of the denominator tends to be small for very negative spillovers and large for very positive spillovers. Thus, for strongly positive spillovers a small absolute value of the enumerator coincides with a large value of the denominator, which implies a large impact of spillovers on the optimal amount of the upstream public good. As long as the upstream public good increases in spillovers, the downstream utility change in response to spillovers, $u^2_{\kappa 2}$, depends positively on the spillover level.
- The impact of spillovers on the optimal supply of the downstream public good is qualitatively the opposite of that on the upstream population size. This is not surprising since the first-order conditions state that the downstream public good is proportional to the population size downstream. As long as spillovers have a positive impact on the upstream public good, $u^2_{\kappa 2}$ grows in spillovers. $u^1_{g1} - u^2_{g1}$ decreases in spillovers. Thus, for sufficiently low spillovers the downstream public good decreases because $u^1_{g1} - u^2_{g1}$ dominates. As spillovers grow $u^2_{\kappa 2}$ becomes dominant and the amount of the downstream public good depends positively on spillovers.
- The optimal upstream population size may increase or decrease in spillovers, depending if the positive impact of $u^1_{g1} - u^2_{g1}$ or the negative impact of $-u^2_{\kappa 2}$ dominates. Having in mind the above discussion on the role of the spillover level, there is migration to the upstream region in response to a marginal increase in spillovers if spillovers are sufficiently small and there is migration to the downstream region if

spillovers are sufficiently large. This implies a U-shape of the downstream population size in spillovers, unless one of the two terms of the enumerator dominates for all spillover levels.

The impact of spillovers on socially optimal welfare (the equilibrium utility level) is given by

$$\frac{du^i}{d\kappa_2} = \frac{n_2 u_{k2}}{\bar{n}} > 0\,, \tag{6.5}$$

which is positive for all levels of spillovers. The change is large for big amounts of the upstream public good and for a large downstream population size. Both tend to be the case for large positive spillovers.

The impact of spillovers on welfare and the utility level helps to understand the U-shaped downstream population size in spillovers. A locationally efficient migration equilibrium implies that marginal labor productivity and public good utility are equalized across regions: $f_n^1 + u^1(g_1) = f_n^2 + u^2(g_1, g_2)$. Since a marginal change in the unidirectional spillovers causes asymmetric utility changes in the upstream and downstream region, a relocation of some individuals is required. If a marginal increase of spillovers favors the downstream region—which tends to be the case for positive spillovers—individuals need to migrate to the downstream region, which reduces the marginal labor productivity and neutralizes utility differentials. The opposite holds if higher spillovers overproportionally increase upstream public good utility. This can be equalized by migration to the upstream region, which decreases upstream and increases downstream labor productivity. Migration to the upstream region tends to be the optimal response to higher spillovers for negative (or small positive) spillovers.

6.2.2 An illustrative example of the social optimum

An example with a functional specification can illustrate the socially optimal allocation. Similar to chapter 5, the utility of a representative individual of region i is given by $y_i + \lambda(g_i + \kappa_i g_j)$. Marginal benefits from public good consumption are given by the parameter λ, which is assumed to be the same in both regions. Consumption of the public good stems from the domestic and, if spillovers are present, from the foreign public good. Spillovers are unilateral from the upstream to the downstream region, they are restricted to the interval $\kappa_2 \in [-1, 1]$.

To generate explicit solutions the private good is produced with a quadratic production function with input labor and the spatially fixed factor land. The respective quantities are denoted n_i and $\bar{x}$. The production function of region i is assumed to take the quadratic form $f^i(n_i, \bar{x}) = n_i - \frac{n_i^2}{2\bar{x}}$.[4] Due to the specific form of the production function there may be negative marginal output in labor for large levels of labor input. To

[4]Quadratic functions are frequently used in economics. List and Mason (2001), for example, use a quadratic payoff function in a transboundary pollution setting.

facilitate a straightforward economic interpretation and to avoid degenerated outcomes, the following analysis will focus on the increasing part of f^i. Thus, also in the case of complete concentration of individuals in one region, there is a positive marginal output of labor, $\bar{n} < \bar{x}$. For the case without benefits from public goods this implies that utility in the migration equilibrium is positive. The cost function of the public good is assumed to be the same in both regions and it is given by $c(g_i) = \frac{g_i^2}{2}$.

In the following it will be analyzed how the migration equilibrium is influenced by spillovers and marginal benefits from the public goods. Given linear utility it is not surprising that corner solutions may occur for some parameter values of κ_2 and λ. Large spillovers or high marginal public good benefits favor corner solutions. Conditions for corner solutions can be different for the socially optimal allocation and the federal organizations discussed below. The following corner solutions may occur:

- $g_i = 0$. If negative spillovers are sufficiently large the first-order conditions for interior solutions require negative upstream public good provision. The non-negativity constraint then holds. High marginal benefits from public goods favor this situation. A corner solution with no downstream public good provision is possible when the whole population lives upstream.
- $y_i = 0$. Marginal benefits from public goods may be so large that consumption of the private good would become negative without the non-negativity constraint.
- $n_i = 0$. If marginal public good benefits are high, complete concentration may result. Also large spillover may lead to the complete depopulation of an entire region.

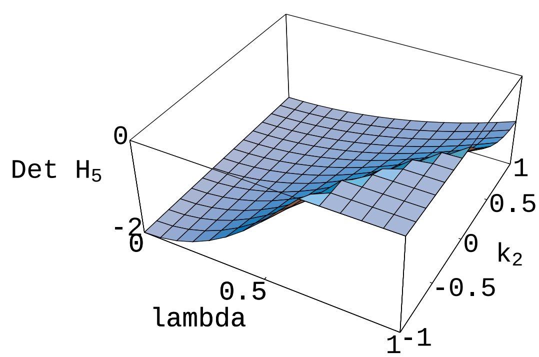


Figure 6.1: $|\bar{H}_5|$ of the social optimum for $\bar{n} = 1$ and $\bar{x} = 1$

The explicit interior solutions for the adopted functional forms are given in in the appendix to this chapter. These solutions are only optimal if the second-order conditions are met. This is not always the case, particularly when the marginal benefit of the public goods is large. Figure 6.1 shows that negative spillovers make it harder for the second-order conditions to be met. For the illustration the range of marginal benefits is chosen in a way that the second-order conditions are met if no spillovers are present. For negative spillovers and large marginal public good benefits the second-order conditions are violated if $|\bar{H}_5| = \frac{\lambda^2 - \frac{2}{\bar{x}} + \lambda^2(1-\kappa_2)^2}{\bar{n}} > 0$. For positive spillovers the marginal benefits could be higher than the illustrated range.

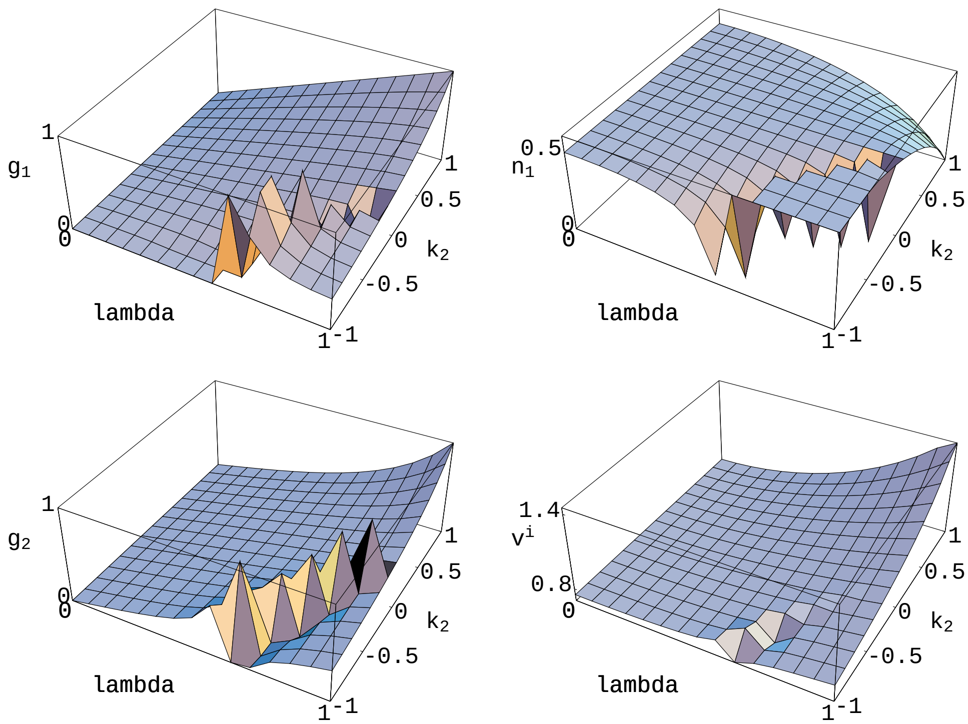


Figure 6.2: Social optimal equilibrium allocation for $\bar{n} = 1$ and $\bar{x} = 1$

Figure 6.2 illustrates the socially optimal allocation for interior solutions. Not all illustrated allocations are optimal because either the second-order sufficient conditions are violated (see above) or because corner solutions occur when non-negativity restrictions are binding. If non-negativity restrictions are binding, the corresponding allocations are not feasible. As apparent in figure 6.2, non-feasible allocations are possible for large marginal public good benefits in combination with negative spillovers. Some allocations in the very front right corner of the four diagrams do not violate the non-negativity constraints. However, they are not optimal since the second-order sufficient conditions are not met. Thus, the non-negativity restrictions as well as the second-order conditions are violated for similar parameter values.

As figure 6.2 shows, efficient upstream public good provision increases in spillovers. The amount of the downstream public good is U-shaped in spillovers. For sufficiently large marginal benefits from public goods the U-shape is not present due to corner solutions in case of negative spillovers. The amount of the downstream public good increases as spillovers become stronger. This reflects the changing size of the regions. Due to the strong symmetry assumptions, the upstream and downstream region have the same population size when spillovers are absent. The upstream regions depopulates as spillovers become more extreme, regardless of whether they are positive or negative.

Corner solutions are possible if spillovers or marginal benefits from public goods are sufficiently strong.

Figure 6.2 shows that utility increases monotonically in spillovers. Utility increases at the same time as upstream public good provision increases and the efficient population size in the downstream region is U-shaped in spillovers. The impact of spillovers is bigger for positive than for negative spillovers. With positive unidirectional spillovers, a marginal increase in spillover has a large impact on the utility level since the optimal quantity of the upstream public good is large. With negative spillovers the optimal amount of the upstream supply is low and therefore marginal changes in spillovers have a moderate influence on the overall utility level.

6.3 Sequence of the game and the federal organization

With voting decisions on the supply of public goods and locational decisions of individuals, the sequence of events is assumed to be as follows:

- ▷ There is an initial population distribution. This distribution is denoted by $\tilde{n}_i$. All individuals live either in region i or j.
- ▷ There is a given scheme of land ownership.
- ▷ In a given federal setting, all citizens vote on the supply of public goods. With decentralized jurisdictions the voting decision is simultaneous, whereas in a centralized jurisdiction there is sequential voting.
- ▷ After voting citizens can migrate.
- ▷ There is production of the private good at the final location of citizens.
- ▷ Wages are paid to workers and rents to land owners or residents.
- ▷ Voters pay taxes and public goods are provided according to the previous voting decisions.
- ▷ Consumption of the public and the private good.

This sequence of events is based on the following considerations. There is a status quo with an initial location of citizens and given land ownership. Given their location, citizens vote on the supply of public goods within a given federal setting. Under centralization there is only one jurisdiction, where citizens vote sequentially on the supply with public goods. Public goods are financed by head taxes and the individual cost-share is given by $\frac{c_i(g_i)+c_j(g_j)}{\bar{n}}$. Under decentralization two jurisdictions decide simultaneously and independently on public good provision. Each jurisdiction comprises the citizens that live in that region. Voting takes place by a simple majority rule and the action of the other region is taken as given. Public goods are financed by head taxes on residents of the jurisdiction. With decentralized jurisdictions the cost-share of a resident is given by $\frac{c_i(g_i)}{n_i}$.

After voting citizens decide on their location. This decision anticipates the outcome of the remaining events. Migration is assumed to be free and costless. The following analysis considers migration equilibria according to definition 6.1. Hence, if nobody has an incentive to live in another region, a migration equilibrium is reached.

At the final location, citizens inelastically offer their labor on perfectly competitive labor markets. This leads to a wage income of f_n^i since the labor supply per person is normalized to one unit. In addition individuals receive a rent income. The total rent of region i is given by $r_i = f^i - n_i f_n^i$. Rents accrue to the fixed factor of production. Thus the distribution of rent income within the economy depends on land ownership and the way land rents are distributed. Two common assumptions are used in the literature:

- Rents are distributed to the final residents of a region. For a region with the population size n_i this leads to an income before taxes of $\frac{f^i(n_i,\bar{x})}{n_i} = f_n^i + \frac{r_i}{n_i}$. Examples for this rent distribution scheme are Stiglitz (1977) and Wellisch (1994). This rent distribution scheme is plausible if land is owned by the regional government. Alternatively if a regional government is able to collect all land rents by rent taxes, land rents can be shifted from non-residents to residents. See also Quaas (2004, 224) or Wellisch (1994, 174).
- Rents are distributed to land owners and land is owned by all citizens by equal property shares. With this assumption each citizen receives rents from both regions and gross income (income before taxes) is given by $f_n^i + \frac{r_i+r_j}{\bar{n}} = f_n^i + \frac{f^i(n_i,\bar{x})-n_i f_n^i+f^j(n_j,\bar{x})-n_j f_n^j}{\bar{n}}$. Equal property shares are assumed by Boadway (1982), Wellisch (1993; 2000) and others.

Since the two rents distribution schemes are used in the literature, they are both considered in the following analysis. After production and income distribution, citizen pay head taxes and the public good is provided according to the previous voting decisions. Alternatively one could assume that voters pay taxes at their initial location and that public goods are also provided before migration. Given the timing of events, this alternative would be only feasible if citizens are not credit restricted, because production takes place at the final location. The example of flood defense shows that there are plausible reasons why the public good can be provided before or after migration.

- Many measures for flood protection involve large fix costs, these costs have to be carried as soon as the measures are undertaken. With this assumption public good costs do no influence the later migration decision.
- Flood defense is provided after production and migration. With this alternative locational choices are not only influenced by public good benefits, but also by its costs. Also if flood defense would be provided earlier, a substantial part of flood defense costs arise through the maintenance of infrastructure or because long-lived projects are financed by credits, which shifts the costs to the final residents of a region.

Both alternatives only lead to different results under decentralization, since migration has no influences on taxes under centralization. Following the lead of the literature the following analysis assumes that taxes are paid by the final residents of a jurisdiction.

The sequence of events and the discussion lead to the following structure of the game:

- At stage one all citizens vote on the supply of public goods at their initial location.
- At stage two individuals decide on their location with the given supply of public goods from the first stage.

6.4 Unidirectional spillovers

6.4.1 Decentralization

At the first stage of the game, citizens vote on public goods at their initial location. Migration responses to public good provision at the second stage of the game are not taken into account, which implies that voters take the initial population size as given with $\tilde{n}_1$ and $\tilde{n}_2$. In voting on public goods the level of the foreign public good is taken as given. With the two rent sharing alternatives the optimization problem of the median voter in region i is given by

$$\max_{g_i \in \mathbb{R}_+} \; y_i + u^i(g_i, g_j) \qquad \text{s.t. } y_i \geq 0 \quad \text{for} \quad i,j = 1,2; \quad i \neq j$$
$$\text{with } y_i = \begin{cases} \frac{f^i(\tilde{n}_i, \bar{x}) - c_i(g_i)}{\tilde{n}_i} & \text{with rents to residents} \\ f^i_n + \frac{r_i + r_j}{\bar{n}} - \frac{c_i(g_i)}{\tilde{n}_i} & \text{with equal property shares.} \end{cases} \tag{6.6}$$

Since all voters of a region have the same marginal benefits from public goods, the optimization problem of the median voters of both jurisdictions lead to the first-order conditions for the upstream and downstream public good:

$$\tilde{n}_i u^i_{gi} - c_i'(g_i) \leq 0 \quad g_i \geq 0 \text{ and } g_i \frac{\partial(y_i + u^i)}{\partial g_i} = 0 \qquad \text{for } i,j = 1,2;\ i \neq j\,. \tag{6.7}$$

Given the linear utility functions and myopic voting, optimal choices for the provision of public goods are dominant strategies, with reaction functions independent of the foreign public good. Thus the Nash-equilibrium can be easily determined. Public good provision is independent of spillovers, but is sensitive to the initial population distribution. Regarding the initial population distribution there is an under-supply of the upstream public good compared to the Samuelson rule when spillovers are positive. With negative spillovers there is an over-supply. Downstream public good provision is efficient for the given initial population distribution.

The Hessian determinants indicate if the second-order sufficient conditions for a local maximum as an interior solution are met. The determinants, which are independent of spillovers, are always met since marginal costs of public goods are increasing. The second-order conditions for a maximum require the Hessian determinants for public good supply in region i, $|H_1^i|$, to be negative:

$$|H_1^i| = -\frac{c_i''}{\tilde{n}_i} < 0 \qquad \text{for} \qquad i = 1, 2\,. \tag{6.8}$$

After voting on public goods individuals can migrate at the second stage of the game. They will do so if they can improve their utility. Let $g_i^d = g_i^d(\tilde{n}_i)$ denote the supply of public goods from the first stage. Inserting g_i^d and g_j^d into the utility function yields the indirect utility function that depends on the population distribution. With the assumption that taxes for the public goods are paid by the final residents of a jurisdiction, the indirect utility function is given by

$$v^i(n_i) = \begin{cases} \frac{f^i(n_i,\bar{x})-c_i(g_i^d)}{n_i} + u^i(g_i^d, g_j^d) & \text{with rents to residents} \\ f_n^i + \frac{r_i+r_j}{\bar{n}} - \frac{c_i(g_i^d)}{n_i} + u^i(g_i^d, g_j^d) & \text{with equal property shares.} \end{cases} \tag{6.9}$$

Whereas the supply of public goods depends solely on the initial population distribution, the indirect utility also depends on the population distribution resulting from the migration decisions of individuals. For the initial population distribution and after voting on public goods, individuals in the upstream region face one of the following migration incentives

- Utility in the upstream region is the same as in the downstream region. Despite equal utility—a necessary condition for a migration equilibrium—an individual from the upstream region may improve his utility by moving to the downstream region. With such migration incentives, there is no migration equilibrium despite equal utility. The sufficient conditions for a migration equilibrium are given below.
- Utility in the upstream region is higher than in the downstream region. This utility differential creates migration incentives to the upstream region.
- Utility in the upstream region is lower than in the downstream region, what creates an incentive to migrate to the downstream region.

With two regions under consideration, the migration incentives in the downstream region are the opposite than in the upstream region. As mentioned above, equal utility in both regions is not a sufficient condition for a migration equilibrium. The necessary condition 'equal utility' indicates a migration equilibrium, if nobody can improves his utility by migration, thus $\frac{\partial(v^i-v^j)}{\partial n_i}$ must be negative:

$$\frac{\partial(v^i-v^j)}{\partial n_i} = \begin{cases} \frac{c_i(\tilde{n}_i)}{n_i^2} + \frac{c_j(\tilde{n}_j)}{n_j^2} + \frac{f_n^i - \frac{f^i}{n_i}}{n_i} + \frac{f_n^j - \frac{f^j}{n_j}}{n_j} < 0 & \text{with rents to residents} \\ \frac{c_i(\tilde{n}_i)}{n_i^2} + \frac{c_j(\tilde{n}_j)}{n_j^2} + f_{nn}^i + f_{nn}^j < 0 & \text{with equal prop. shares.} \end{cases} \tag{6.10}$$

If an immigrant to region i is worse off after migration, the marginal change in the utility difference is negative and a migration equilibrium is given, if the utility difference is zero. If the utility difference increases, a migrant can improve his utility and there is no migration equilibrium. Without a migration equilibrium, the utility difference is typically not zero and the utility difference between regions can increase or decrease in response to migration.

Looking at changes of the utility level of a single region in response to an immigrant is the first step in describing how the utility differential changes in response to migration. An individual moving to a region has a positive as well as a negative effect on the utility in that region. The effects are given by

$$\frac{\partial v^i}{\partial n_i} = \begin{cases} \frac{c_i(\tilde{n}_i)}{n_i^2} + \frac{f_n^i - \frac{f^i}{n_i}}{n_i} & \text{with rents to residents} \\ \frac{c_i(\tilde{n}_i)}{n_i^2} + \frac{n_j}{\bar{n}}(f_{nn}^i + f_{nn}^j) & \text{with equal property shares.} \end{cases} \tag{6.11}$$

An immigrant to a region increases utility because the cost-share (first term) becomes smaller. An immigrant decreases utility, because the gross income (second term) falls. With rents going to residents, an immigrant increases the output of a region since the marginal output is positive. At the same time output per capita decreases since the production function is concave. In combination, the marginal output minus the average output is clearly negative, $f_n^i - \frac{f_i}{n_i} < 0$. Thus, the change in gross income in response to an immigrant to a region is negative, $\frac{f_n^i - \frac{f^i}{n_i}}{n_i} < 0$. With the equal endowment assumption, higher output through an additional individual increases the total rent in the immigrant region and decreases the rent of the emigrant region. The effect on wages is contrary, they fall in the immigrant region and rise in the emigrant region. The wage effect is stronger than the rent effect so that the gross income of the immigrant region falls.[5] With equal property shares, gross income depends on output of both regions, whereas with residency-based rent distribution, it depends on the regional output only.

If cost-shares for public goods are not too large, utility in region i will fall in response to an immigrant, $\frac{\partial v^i}{\partial n_i} < 0$. Large cost-shares can be the consequence of high marginal benefits from public goods that induce high levels of public good supply at the first stage (see equation 6.7). With large cost-shares an immigrant can increase the utility in the immigration region. The literature usually assumes that an interior migration equilibrium exists and refers to this case as an over-populated federation. See, for example, Stiglitz (1977), Boadway and Flatters (1982) or Wellisch (1993).[6] In an over-populated federation it holds that $\frac{\partial(v^i - v^j)}{\partial n_i} < 0$. A similar assumption is also made here.

[5] With gross income of region i of $f_n^i + \frac{f^i(\tilde{n}_i,\bar{x}) - n_i f_n^i + f^j(\tilde{n}_j,\bar{x}) - n_j f_n^j}{\bar{n}}$, it is apparent that for concave production functions, a marginal increase of the population has a negative effect on gross income since the derivative given by $\frac{\partial(\bullet)}{\partial n_i} = \frac{n_j}{\bar{n}}(f_{nn}^i + f_{nn}^j)$, which is negative.

[6] The literature sometimes characterizes a migration equilibrium as stable. Instability arises if equal utility coincides with migration incentives, $\frac{\partial(v^i - v^j)}{\partial n_i} > 0$. To avoid confusion, the terms stable and unstable migration equilibria are not used here.

In the subsequent analysis a slightly different assumption is made by focusing on sufficiently small marginal benefits from public goods so that each region is over-populated in the sense that $\frac{\partial v^i}{\partial n_i} < 0$. With this assumption the migration equilibrium exists.

Assumption 6.2 *In the economy under consideration a migration equilibrium exists that is characterized by* $\frac{\partial v^i}{\partial n_i} < 0$.

With a utility differential between regions, citizens will migrate to the high-utility region. In extreme cases this can lead to the concentration of the whole population in one region.[7] Assuming over-populated regions and neglecting cases where one region has higher utility for all population distributions, utility differentials between regions are eliminated by migration and an interior migration equilibrium is reached. With residency-based rent distribution, this process depends on global characteristics of the production function, since the average output is part of $\frac{\partial v^i}{\partial n_i}$. With equal property shares, changes of the regional utility level in response to migration are only caused by local properties of both production functions. Thus the two rent distribution schemes can lead to different equilibrium distributions of the population.

Specifying a functional form for the production and cost functions illustrates the role of spillovers for the equilibrium allocation. To focus on the role of spillovers, symmetry assumptions are made with respect to public good benefits, cost functions, the initial population distribution, and the endowment with the fixed factor land. As for the social optimum, the production function is $f^i(n_i, \bar{x}) = n_i + \frac{n_i^2}{2\bar{x}}$ and the cost function for the public goods are $c_i(g_i) = \frac{g_i^2}{2}$. Figure 6.3 shows the indirect utility function of both regions for a positive and a negative spillover. Assuming that rents are distributed to residents, the indirect utility is given by

$$\begin{aligned} v^1(n_1) = &\ 1 + \tilde{n}_1\lambda^2 - \tfrac{\tilde{n}_1\lambda^2}{2n_1} - \tfrac{n_1}{2\bar{x}} \\ v^2(n_1) = &\ 1 + \kappa_2\tilde{n}_1\lambda^2 + \tilde{n}_2\lambda^2(1 - \tfrac{\tilde{n}_2}{2(\bar{n}-n_1)}) - \tfrac{\bar{n}-n_1}{2\bar{x}}\ . \end{aligned} \tag{6.12}$$

Indirect utility has a peak in the regional population as figure 6.3 confirms. For a given supply with public goods the cost-share is very large if the population is small. In extreme cases this would lead to negative utility, because citizens have to pay more for public goods than they earn, which is not feasible. As the population grows, the cost-share falls and the decreasing productivity of a region becomes dominant. For over-populated regions, marginal public good benefits must be sufficiently small, so that the cost sharing argument is dominated by the decreasing productivity in that region. Figure 6.3 shows a positive and a negative spillover ($\kappa_2 = -\frac{1}{2}, \frac{1}{2}$). Spillovers only affect

[7] With full concentration the model is inconsistent, because nobody pays for the public good in the unpopulated region. Another inconsistency can arise if emigration leads to high cost-shares of individuals that violate the budget constraints of the remaining citizens. However, these extreme cases are omitted in the subsequent analysis by neglecting strong asymmetries of land endowment and the initial distribution of the population.

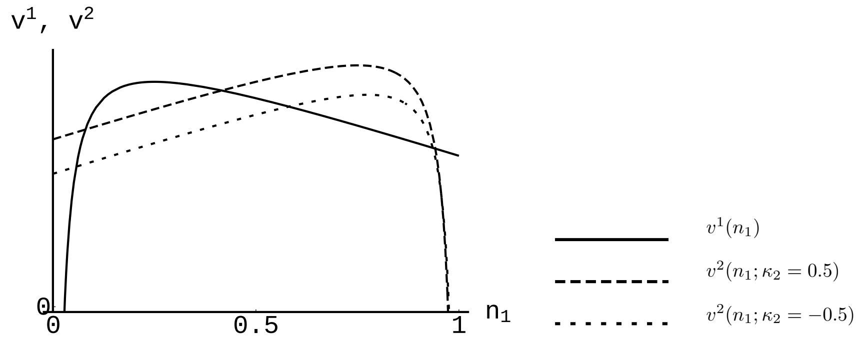


Figure 6.3: Indirect utility from decentralization for a positive and a negative spillover for $\tilde{n}_1 = 0.5$, $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$

the downstream region and the utility level is higher for the positive than for the negative spillover. The positive spillover leads to a smaller equilibrium upstream population than the negative spillover. The migration equilibrium is represented by the middle crossing point of the indirect utility functions, where $\frac{\partial(v^1 - v^2)}{\partial n_1} < 0$ holds (the slope of v^1 is smaller than of v^2). With the symmetric initial population distribution there will be migration to the downstream region in case of the positive spillover and migration to the upstream region given the negative spillover.

For general production and cost functions the impact of spillovers on the equilibrium population distribution is derived by total differentiation of the free migration restriction.

$$\frac{dn_1}{d\kappa_2} = \frac{u^2_{\kappa 2}}{\frac{A_1}{n_1} + \frac{A_2}{n_2}}$$
$$\text{with } A_i = \begin{cases} f^i_n - \frac{f^i - c_i(\tilde{n}_i)}{n_i} & \text{with rents to residents} \\ \frac{c_i(\tilde{n}_i)}{n_i} + \frac{n_i n_j (f^i_{nn} + f^j_{nn})}{\bar{n}} & \text{with equal property shares.} \end{cases} \tag{6.13}$$

For over-populated regions (assumption 6.2) the denominator is negative. This holds for both rent-sharing schemes because $\frac{\partial v^i}{\partial n_i} < 0$ implies $\frac{A_i}{n_i} = \frac{\partial v^i}{\partial n_i} < 0$. The enumerator consists only of the marginal change in downstream utility in response to spillover changes. This change is positive. Thus, the impact of spillovers on the upstream population size is always negative. This is in contrast to the social optimum, where there are additional effects so that the upstream population size may also increase in spillovers. This difference is particularly relevant for negative spillover levels. The socially efficient allocation implies a small amount of the upstream public good with negative spillovers. This favors a large downstream population. In contrast, with decentralized public good provision, spillovers are neglected and downstream citizens try to avoid the negative spillovers by migrating to the upstream region. Another difference is the magnitude of $u^2_{\kappa 2}$. Since the supply of the upstream public good does not depend on spillovers, an increase in spillovers always has the same effect on downstream utility, no matter if the initial spillover level is small or large.

With myopic voters and decentralized responsibilities, there are no comparative static effects of spillovers on public goods. It is only the initial population distribution that determines the the supply level of public goods.

With respect to the social optimum, the concept of locational efficiency was discussed above. Locational efficiency requires that the social net-benefits of an immigrant to a region are equalized, $f_n^i - y_i = f_n^j - y_j$. With decentralized voting it is fortuitous if the resulting migration equilibrium is locationally efficient since there is no mechanism that ensures that the social net-benefits of an immigrant are equalized across regions. The two rent-sharing assumptions have different implications regarding locational efficiency. In the special case of an economy without public goods, the migration equilibrium is locationally efficient with equal property shares ($v^1 = v^2 \Leftrightarrow f_n^1 = f_n^2$), whereas this is not generally the case with rent distribution to residents ($v^1 = v^2 \Leftrightarrow \frac{f^1}{n_1} = \frac{f^2}{n_2} \neq f_n^1 = f_n^2$). Thus, in a local public good economy with fairly small marginal public good benefits, the resulting migration equilibrium is almost locationally efficient, if the equal property share condition holds. With rent distribution to residents this is not necessarily the case, especially when regions are asymmetric. However, independent of the rent-sharing scheme, the migration equilibrium is inefficient with respect to public goods.

With migration flows at the second stage, public good supply will not reflect the voting preferences of the final residents in the migration equilibrium. With migration to the upstream region, the supply of public goods will be lower than favored by the final residents of the region. The opposite holds for the downstream region, where public good provision is too large. Thus, if there would be another vote on public flood defense, the outcome would be different and new migration flows would be induced. Therefore the outcome depends decisively on the initial population distribution.

One can ask if a deviation of the initial and the final locational pattern of individuals has a negative impact on the equilibrium utility level? Using the free migration restriction and the first-order conditions for public goods, the impact of the initial upstream population size on the final utility is given by

$$\frac{\partial v^i}{\partial \tilde{n}_1} = \frac{(n_1 - \tilde{n}_1)[\frac{A_1 (u_{g2}^2)^2}{c_2''} + \frac{A_2 (u_{g1}^1)^2}{c_1''}] + \frac{n_2 A_1 u_{g1}^1 u_{g1}^2}{c_1''}}{A_1 n_2 + A_2 n_1} . \tag{6.14}$$

Without spillovers the question can be answered by yes, since utility is increasing in $\tilde{n}_1$ as long as the initial upstream population size is smaller than the final population size, thus $\frac{\partial v^i}{\partial \tilde{n}_1}$ is positive. The opposite holds for $\tilde{n}_1 > n_1$. Thus, the equilibrium utility level has a peak in the initial population size and the peak is at $\tilde{n}_1 = n_1$ if spillovers are absent. With positive spillovers the highest utility is reached when the initial upstream population is larger than final population size. With negative spillovers the initial upstream population must be smaller than the final population.

6.4.2 Centralization

Public goods are provided at the first stage of the game. In a centralized jurisdiction two public goods need to be determined by voting. As in chapter 5 it is assumed that there are sequential votes on the supply of the upstream and the downstream public good. Citizens vote at their initial location and the sizes of the regions are given by $\tilde{n}_i$. With myopic voting, migration responses at the second stage of the game are not taken into account and the initial population distribution is perceived as final. The median voter from region m, which can be either the upstream or downstream region, $m \in \{1,2\}$, has the utility function $y_m + u^m(g_i, g_j)$ and faces the following optimization problem in voting on the supply of the public good in region i:

$$\begin{aligned}
&\max_{g_i \in \mathbb{R}_+} \; y_m + u^m(g_i, g_j) \;\text{ s.t. }\; y_i, y_j \geq 0 \;\text{ for }\quad i,j,m \in \{1,2\};\, i \neq j \\
&y_m = \begin{cases} \frac{f^m(\tilde{n}_m, \bar{x})}{\tilde{n}_m} - \frac{c_i(g_i)+c_j(g_j)}{\bar{n}} & \text{with rents to residents} \\ f_n^m + \frac{r_i+r_j}{\bar{n}} - \frac{c_i(g_i)+c_j(g_j)}{\bar{n}} & \text{with equal property shares.} \end{cases}
\end{aligned} \tag{6.15}$$

This leads to the first-order conditions for the supply of the upstream and downstream public good

$$\begin{aligned}
&\bar{n} u^m_{gi} - c_i'(g_i) \leq 0 \quad g_i \geq 0 \text{ and } g_i \frac{\partial(y_m + u^m)}{\partial g_i} = 0 \\
&\text{for } \; i,j,m \in \{1,2\}; \quad i \neq j.
\end{aligned} \tag{6.16}$$

Due to the linear form of the utility function, the preferred amounts of the public goods are dominant strategies, and the sequence of voting has no influence on the voting outcome[8]. With two regions under consideration, the median voter is a representative individual from the majority region. To avoid ambiguity, the further analysis neglects equally populated regions ($\tilde{n}_i = \tilde{n}_j$) as the initial population distribution. With a centralized jurisdiction there can be either an upstream or a downstream majority. For an upstream majority the median voter lives upstream and there will only be public good provision upstream. For a median voter from the downstream region there is an interior solution for positive spillovers with positive quantities of the upstream as well as the downstream public good. For negative spillovers only the downstream public good is supplied because the median voter has no interest in the upstream public good. Since the cost-shares are the same in both regions, public good provision does not depend on the initial population distribution as long as the majority constellations do not change.

The second-order sufficient conditions for a local maximum as an interior solution are always met. For an upstream and a downstream majority they are given by the Hessian determinants for public good supply in region i, $|\mathrm{H}_1^i|$: [9]

[8] In a setting where the sequence of voting is important it would be necessary to approach the model as a three stage game with voting at the first two stages and migration at the third stage.

[9] The term interior solution is not quite accurate, since the equilibrium majority can vote for no public good provision without a non-negativity constraint being binding.

$$
\begin{array}{llll}
|H_1^1| = -\frac{c_1''}{\tilde{n}} < 0 & & \text{for } \tilde{n}_1 > \tilde{n}_2 & \\
|H_1^1| = -\frac{c_1''}{\tilde{n}} < 0 & |H_1^2| = -\frac{c_2''}{\tilde{n}} < 0 & \text{for } \tilde{n}_1 < \tilde{n}_2, \text{ and } \kappa_2 \geq 0 & \\
|H_1^2| = -\frac{c_2''}{\tilde{n}} < 0 & & \text{for } \tilde{n}_1 < \tilde{n}_2, \text{ and } \kappa_2 < 0. &
\end{array}
\tag{6.17}
$$

After voting at the first stage, individuals can migrate at the second stage. Let $g_i^c = g_i(\tilde{n}_i)$ denote the supply of public goods from the first stage. Inserting g_i^c and g_j^c into the utility function yields the indirect utility function that depends on the population distribution:

$$
v^i(n_i) = \begin{cases} \frac{f^i(n_i,\bar{x})}{n_i} - \frac{c_i(g_i^c)+c_i(g_j^c)}{\tilde{n}} + u^i(g_i^c, g_j^c) & \text{rents to residents} \\ f_n^i + \frac{r_i+r_j}{\tilde{n}} - \frac{c_i(g_i^c)+c_i(g_j^c)}{\tilde{n}} + u^i(g_i^c, g_j^c) & \text{with eq. prop. shares.} \end{cases}
\tag{6.18}
$$

As under decentralization, citizens will migrate to the region with the higher utility. An inner migration equilibrium is reached when utility is the same in both regions, $v^i(n_i) = v^j(n_j)$ and if the utility difference of a migrant is negative, $\frac{\partial(v^i - v^j)}{\partial n_i} < 0$. For centralization this leads to

$$
\frac{\partial(v^i - v^j)}{\partial n_i} = \begin{cases} \frac{f_n^i - \frac{f^i}{n_i}}{n_i} + \frac{f_n^j - \frac{f^j}{n_j}}{n_j} < 0 & \text{with rents to residents} \\ f_{nn}^i + f_{nn}^j < 0 & \text{with equal property shares.} \end{cases}
\tag{6.19}
$$

With concave production functions, there is always a migration equilibrium for both rent distribution schemes. Unlike under decentralization, the existence of the equilibrium does not depend on the cost-shares of the public good.

The consequences of migration can be also considered with respect to the utility level in a region. The effects of an immigrant to a region is given by

$$
\frac{\partial v^i}{\partial n_i} = \begin{cases} \frac{f_n^i - \frac{f^i}{n_i}}{n_i} & \text{with rents to residents} \\ \frac{n_j}{\tilde{n}}(f_{nn}^i + f_{nn}^j) & \text{with equal property shares.} \end{cases}
\tag{6.20}
$$

An immigrant to a region decreases utility because the gross income falls. Since the public goods are financed through the general budget, citizens cannot avoid taxes by migrating to the other region. To ensure over-populated regions it is sufficient to assume concave production functions, since benefits from public goods are irrelevant.

Total differentiation of the first-order conditions and of the free migration restriction leads to changes of the the equilibrium population distribution in response to marginal changes in spillovers. For an upstream majority the unilateral spillover κ_2 influences the optimal supply of the upstream and downstream public good as follows:

$$\begin{aligned}
&\tfrac{dg_1}{d\kappa_2} = 0\\
&\tfrac{dg_2}{d\kappa_2} = 0\\
&\tfrac{dn_1}{d\kappa_2} = \tfrac{u^2_{\kappa 2}}{\frac{A_1}{n_1}+\frac{A_2}{n_2}} < 0\\
&\text{with } A_i = \begin{cases} f^i_n - \frac{f_n}{n_i} & \text{with rents to residents}\\ \frac{n_i n_j (f^i_{nn}+f^j_{nn})}{\bar{n}} & \text{with equal property shares.}\end{cases}
\end{aligned} \tag{6.21}$$

With an upstream majority, public goods do not depend on spillovers. Despite a constant level of public good provision the population distribution is influenced by spillovers. With concave production functions the denominator is negative for both rent sharing schemes. Thus, increasing spillovers make the downstream region more attractive which induces migration to the downstream region.

For a downstream majority a positive unidirectional spillover influences the upstream and downstream public good as follows:

$$\begin{aligned}
&\tfrac{dg_1}{d\kappa_2} = \tfrac{\bar{n}u^2_{g1\kappa 2}}{c''_1} > 0 && \text{for } \kappa_2 \geq 0\\
&\tfrac{dg_2}{d\kappa_2} = 0 && \text{for } \kappa_2 \geq 0\\
&\tfrac{dn_1}{d\kappa_2} = \tfrac{u^2_{\kappa 2}}{\frac{A_1}{n_1}+\frac{A_2}{n_2}} - \tfrac{\bar{n}(u^1_{g1}-u^2_{g1})u^2_{g1\kappa 2}}{(\frac{A_1}{n_1}+\frac{A_2}{n_2})c''_1} && \text{for } \kappa_2 \geq 0\,.
\end{aligned} \tag{6.22}$$

The upstream public good increases in positive spillovers, whereas the downstream public good remains constant. There are both direct and indirects effects of spillovers on the downstream population. Higher spillovers increase downstream utility directly ($u^2_{\kappa 2} > 0$), inducing migration to the downstream region. In addition there is an indirect effect since upstream public good provision increases in spillovers ($u^2_{g1} > 0$ for $\kappa_2 > 0$). Assuming that the impact of other indirect effects of spillovers on the partial derivatives are sufficiently small, one finds an opposing impact of $u^2_{\kappa 2}$ and u^2_{g1}. As the direct effect depends on the amount of the upstream public good, the effect is very small for small spillovers. Thus, the second term may dominate and the upstream population grows (the denominators are negative). The partial derivative u^2_{g1} grows in spillovers, and for sufficiently large spillovers, the first term dominates so that the upstream population decreases in spillovers. For a downstream majority and negative spillovers, there is no upstream public good provision. Therefore a marginal change in spillovers has no influence on the upstream or the downstream public good and the population distribution does not change.

The comparative static results and the consequences of majority voting can be illustrated by specifying a functional form for the production and cost functions. The same functional specification is used as for decentralized jurisdictions. With rents distributed to residents, the indirect utility functions, which depend on the population size of the regions, are given by

$$
v^1(n_1) = \begin{cases} 1 + \frac{\bar{n}\lambda^2}{2} - \frac{n_1}{2\bar{x}} & \text{with } \tilde{n}_1 > \tilde{n}_2 \\ 1 - \frac{\bar{n}\lambda^2(1-\kappa_2)^2}{2} - \frac{n_1}{2\bar{x}} & \text{with } \tilde{n}_1 < \tilde{n}_2 \text{ and } \kappa_2 \geq 0 \\ 1 - \frac{\bar{n}\lambda^2}{2} - \frac{n_1}{2\bar{x}} & \text{with } \tilde{n}_1 < \tilde{n}_2 \text{ and } \kappa_2 < 0 \end{cases}
$$
$$
v^2(n_1) = \begin{cases} 1 - \frac{\bar{n}\lambda^2(1-2\kappa_2)}{2} - \frac{\bar{n}-n_1}{2\bar{x}} & \text{with } \tilde{n}_1 > \tilde{n}_2 \\ 1 + \frac{\bar{n}\lambda^2(1+\kappa_2^2)}{2} - \frac{\bar{n}-n_1}{2\bar{x}} & \text{with } \tilde{n}_1 < \tilde{n}_2 \text{ and } \kappa_2 \geq 0 \\ 1 + \frac{\bar{n}\lambda^2}{2} - \frac{\bar{n}-n_1}{2\bar{x}} & \text{with } \tilde{n}_1 < \tilde{n}_2 \text{ and } \kappa_2 < 0\,. \end{cases} \tag{6.23}
$$

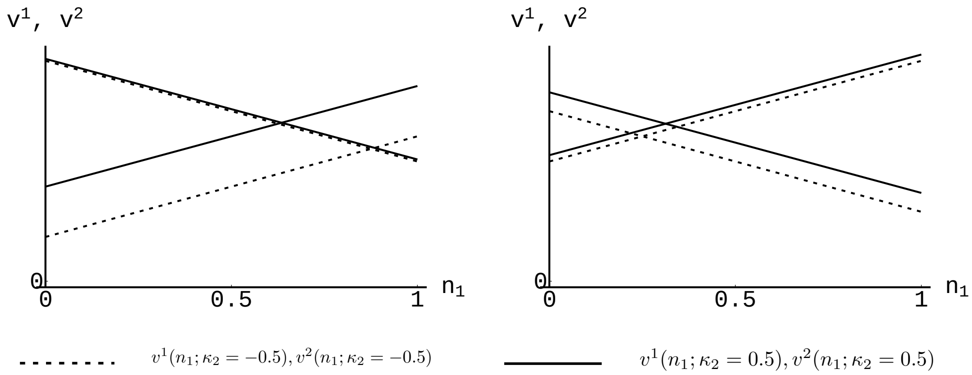


Figure 6.4: Indirect utility from centralization with an upstream majority (left) and a downstream majority (right) for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$. v^1 is increasing and v^2 is decreasing in n_1.

Figure 6.4 shows the utility levels in the upstream and downstream region that may result from migration decisions at the second stage of the game. In both regions utility decreases in the population size. An upstream majority (left part of figure 6.4) favors the upstream region and neglects the downstream region in public good provision. Since migration does not depend on taxation under centralization (the tax share is the same in both regions), it is only the supply of public goods and the income opportunities that determine the population distribution. With a large supply of the upstream public good and no downstream public good, the population distribution is distorted in favor of a large upstream population size. As the comparative statics showed, the equilibrium upstream population size decreases monotonically in spillovers. A negative and a positive spillover level is illustrated in figure 6.4. A migration equilibrium is given where both indirect utility functions cross. Migration flows on the second stage may change the majorities compared to the initial population distribution. A change of majorities is more likely for positive than for negative spillovers. However, this does not influence public good provision since a sequential timing of events is assumed in the game.

A downstream majority (right part of figure 6.4) over-supplies the downstream public good and under-supplies the upstream public good. Again two spillover levels are illustrated. Positive spillovers lead to higher utility in both regions compared to the case of negative spillovers. Because both regions benefit it is not generally clear how the equilibrium population distribution is affected by spillovers. This was also the results found in the comparative static analysis. In figure 6.4 the positive spillover level leads to a clearly larger upstream population than the negative spillover. Thus, depending on the political majorities, positive spillovers can lead to a smaller or larger upstream population size compared to negative spillovers.

Migration at the second stage leads to a population distribution that is characterized by $v^1 = v^2$. With equal property shares the migration equilibrium is generally locationally efficient since $f_n^1 - y_1 = f_n^2 - y_2 \Leftrightarrow f_n^1 - (f_n^1 + \frac{r_1+r_2}{\bar{n}} - \frac{c_1+c_2}{\bar{n}}) = f_n^2 - (f_n^2 + \frac{r_1+r_2}{\bar{n}} - \frac{c_1+c_2}{\bar{n}}) \Leftrightarrow f_n^1 = f_n^2$. This tends not to be the case for residency-based rent distribution, since it does not generally hold that $f_n^1 - (\frac{f^1}{n_1} - \frac{c_1+c_2}{\bar{n}}) = f_n^2 - (\frac{f^2}{n_2} - \frac{c_1+c_2}{\bar{n}})$.

With centralized voting one finds that the initial population distribution has less significance for the migration equilibrium than it has for decentralized jurisdictions. With centralized voting it is only the majority constellation that has an impact on the outcome, whereas with decentralized voting there is a different outcome for each possible initial locational pattern. The following section gives a more detailed comparison of both federal organizations.

6.4.3 Decentralization or centralization?

Neither decentralization nor centralization lead to a socially efficient allocation when spillovers are present and voters are not aware of migration. This raises the classical question of fiscal federalism: Which is the best federal organization? A comparison of the two federal settings cannot only rely on the first-order conditions and the comparative static properties of the different migration equilibria, but it must also consider the absolute utility level reached in the migration equilibrium. This is possible with a functional specification of the model. The same assumptions are made as for the social optimum (see section 6.2.2), and the utility is given by $y_i + \lambda(g_i + \kappa_i g_j)$, the regional production function by $n_i - \frac{n_i^2}{2\bar{x}}$, and the cost functions of the public goods by $\frac{g_i^2}{2}$. As apparent, symmetry assumptions are made with respect to marginal public good benefits and costs, and the endowment with the fixed factor land.

The previous sections showed that the initial population distribution has an important impact on the final migration equilibrium. Since this impact also influences the federal comparison, a special initial locational patterns will be assumed.

Assumption 6.3 *The initial population is the same under both federal settings. Under decentralization it holds that the initial population distribution is the same as in the final migration equilibrium, thus* $\tilde{n}_i = n_i^d$.

With this assumption, nobody has an incentive for migration after voting if public goods are provided decentralized. Under centralization there is generally migration at the second stage. Assumption 6.3 ensures that a hypothetical vote of the final residents of a region would lead to the same supply pattern of public goods than the actual vote. Under decentralization and interior solutions, there is only one initial population distribution where a hypothetical vote of the final residents leads to the same outcome. This is different under centralization, since the voting outcome depends only on the location of the majority population but not on the exact size of the majority.

The previous analysis showed that the supply of public goods is not influenced by the rent sharing scheme. With the focus on the interdependency between spillovers and public goods, the following discussion focuses on rent distribution to residents. The explicit solutions of the migration equilibrium for decentralization and centralization are given in the appendix of this chapter. The appendix also contains graphical illustrations of the allocations that not only show the impact of spillovers but also the influence of the marginal benefits from public goods. The appendix also shows the parameter values for which corner solutions are relevant.

Conditions for the existence of interior migration equilibria were given in the preceding sections. It was argued that over-populated regions ensure the existence of an interior migration equilibrium. A region is over-populated if $\frac{\partial v^i}{\partial n_i} < 0$. With the adopted functional form, the conditions can be specified for decentralized migration equilibria:

$$\frac{\partial v^i}{\partial n_i} = \frac{\tilde{n}_i^2 \lambda^2}{2n_i^2} - \frac{1}{2\bar{x}} < 0 \quad \text{for } i = 1, 2\,. \tag{6.24}$$

For both regions those conditions do not depend on spillovers. Since the provision of public goods is not changed through migration, the marginal change of utility in response to an immigrant is not influenced by the spillover level. With assumption 6.3, the initial population distribution is the same as in the migration equilibrium (under decentralization) and, since regions are over-populated, an interior migration equilibrium requires $\bar{x}\lambda^2 < 1$. High marginal benefits from public goods or a large land endowment can imply that there is no migration equilibrium under decentralization. Assuming, for the following analysis, that the total land endowment of each region is $\bar{x} = 1$, the relevant range of marginal public good benefits is $\lambda \in (0, 1)$. For centralized public good provision there is no such restriction on the marginal benefits from public goods, since concavity of the production functions is sufficient for the existence of an interior migration equilibrium.

With the specified functional forms, the migration equilibria are illustrated with respect to public goods, the population distribution, and the resulting utility levels.

Upstream public good provision is inefficient for both federal settings for most spillover levels. With decentralized supply the amount of the upstream public good decreases in spillovers. This reflects the negative impact of spillovers on the upstream population size (see figure 6.6). Under centralization, public goods depend on the voting majority. It follows from assumption 6.3 that there is an upstream majority for negative spillovers and a downstream majority for positive spillovers. An upstream majority disregards spillovers and votes for a high level of the public good upstream (the upper curve of centralized provision of g_1 in figure 6.5). Since a downstream majority only considers spillovers, the upstream public good is proportional to positive spillovers (the lower curve of centralized provision of g_1 in figure 6.5). With the parameter values assumed in figure

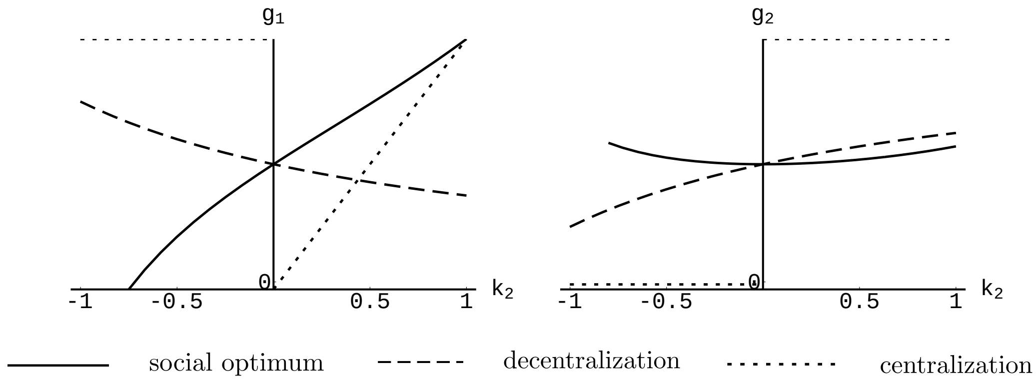


Figure 6.5: Comparison of public good provision with myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$.

6.5, the social optimum has corner solutions for very negative spillovers. In this case it is efficient to have no upstream public good provision. Decentralized provision of the downstream public good is fairly close to the social optimum unless spillovers are very negative. This is much in contrast to centralized provision, which is much too low or much too high, depending on an upstream or downstream majority.

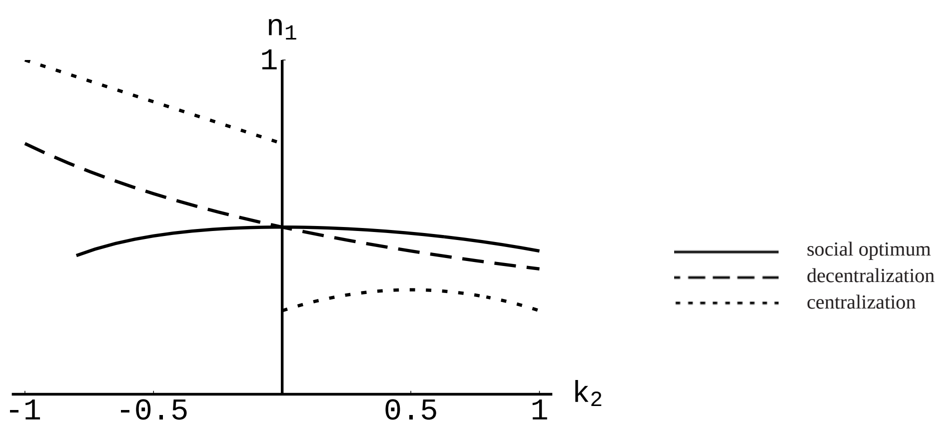


Figure 6.6: Comparison of the population distribution with myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$. There are two curves for centralized supply since two voting majorities are possible.

The population distributions correspond to the inefficiencies in public good supply. A high level of public good consumption attracts a large population with detrimental effects on regional wages and rents. The combination of these effects can still lead to equal utility as required by an interior migration equilibrium. Decentralized jurisdictions neglect spillovers, which results in an over-provision upstream when spillovers are negative. This induces migration to the upstream region because downstream citizens want to avoid the negative spillovers. This mechanism is in sharp contrast to the social optimum, where there is only a low level of the upstream public good and a large share of the population lives downstream. With positive spillovers there is an under-provision of the upstream public good. This is detrimental for both regions so that there is no clear bias of locational choices. Even though spillovers are disregarded, the downstream population grows in spillovers with decentralization as well as with the socially efficient provision of public goods. Under centralization the population distribution is influenced by spillovers as well by the political-economy, since the majority regions attract a large population share. Therefore, for a given level of spillovers the final upstream population is relatively large with an initial upstream majority and it is small with an initial downstream majority. The population of the upstream region is either larger or smaller than in the social optimum or under decentralization. In principle there is no mechanism that ensures that the location of the initial majority is the same as the final majority constellation. However, with the current assumptions on spillovers and public good benefits, there is no switch in the majority after migration as figures 6.12 and 6.13 in the appendix show. Note that a switching majority has no effect on the equilibrium outcome, since voting only takes place at the first stage and not later on.

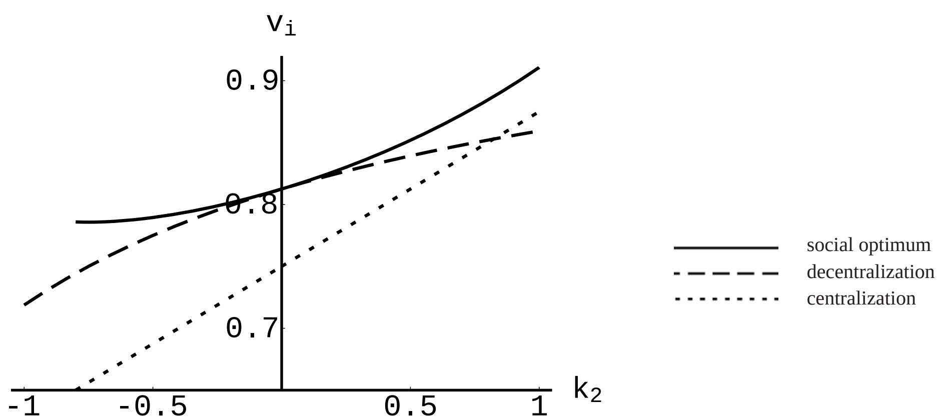


Figure 6.7: Comparison of utility with myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$. There are two curves for centralized supply and negative spillovers since two voting majorities are possible.

The utility levels of the federal organizations are influenced by inefficiencies in public good provision and locational choices. Free and costless migration leads to the same utility level of all citizens. The equilibrium utility levels are shown in figure 6.7. They strictly increase in spillovers for decentralization and centralization. The comparison of decentralization and centralization leads to a critical spillover level where both federal organizations produce the same utility. Equating $v^1(g_1^d, n_1^d) = v^1(g_1^c, g_2^c, n_1^c)$ can be solved for κ_2:[10]

$$\kappa_2^{crit} = \frac{1}{2} + \frac{\sqrt{1+4\,\bar{x}\lambda^2(1-\bar{x}\lambda^2)}-1}{4\,\bar{x}\lambda^2} \quad \text{for } \kappa_2 \geq 0 \tag{6.25}$$

This leads to the following proposition.

Proposition 6.1 *Assume simple majority voting with myopic voters that receive land rents based on their region of residency. Assume, in addition, interior solutions, and equal marginal public good benefits, equal regional production functions and land endowments, and that assumptions 6.2 and 6.3 hold.*

By equation 6.25 there is a critical level of positive spillovers, κ_2^{crit}. Below this level decentralization and above this level centralization lead to higher equilibrium utility levels. For negative spillovers centralization is never superior to decentralization.

Given the assumptions, there is no mechanism that ensures locational efficiency in the migration equilibrium.

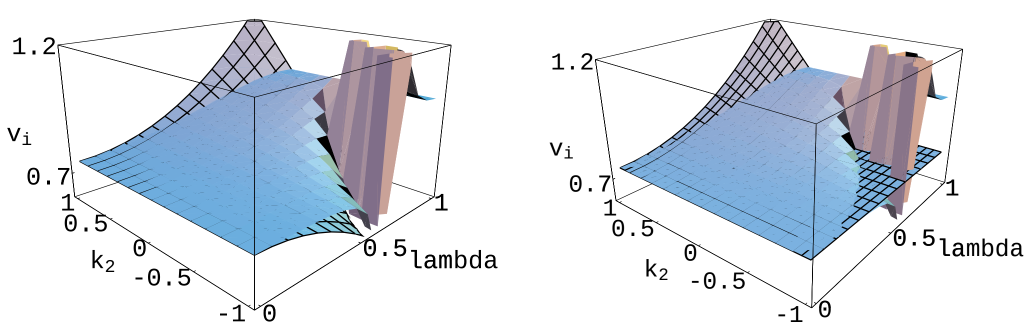


Figure 6.8: Utility depending on spillovers and on public good benefits with myopic voting for $\bar{n} = 1$, and $\bar{x} = 1$. Without mesh: decentralization, with mesh: centralization. Left: assumption 6.3 applies. Right: downstream majority under centralization, same initial and final location under decentralization.

Without spillovers decentralization leads to the socially optimal utility. In contrast centralization clearly results in a lower utility because it suffers from the dominance of the voting majority. Utility from centralization increases in positive spillovers at a higher rate than utility from decentralization and if spillovers are large enough centralization is superior to decentralization. With negative spillovers there is a upstream majority under centralization and decentralization is always superior to centralization.

The critical level of spillovers, where decentralization and centralization produce the same utility, depends on the size of the marginal benefits from public goods. This influence, together with the impact of spillovers, is illustrated on the left part of figure

[10] The critical values are derived by using the explicit solutions given in the appendix. The solution with the negative square root of solving $v^1 = v^1$ for κ_2 does not yield relevant critical spillover levels in $\kappa_2 \in (1, 0)$ for $\lambda^2\bar{x} < 1$ (condition from equation 6.24).

6.8, which confirms proposition 6.1. Note that for large negative spillovers in combination with high marginal public good benefits, the plotted utility for decentralization is not economically feasible since the non-negativity restriction for public goods is violated (see also figure 6.11 in the appendix of this chapter). With sufficiently positive spillovers, centralization is superior. The spillover range where centralization is superior to decentralization growths in the marginal benefit from public goods. For negative spillovers and an upstream majority, decentralization is superior to centralization for interior solutions.

The last part of proposition 6.1 states what was found already above (see the sections on decentralization and centralization). With rent distribution to residents, there is no mechanism that ensures locational efficiency in the migration equilibrium.

The above comparison of federal organizations relies crucially on the assumption that the initial location is the same under both federal settings and that there is no real migration under decentralization (assumption 6.3). This assumption can be relaxed.

First, if all possible initial locations are allowed under centralization but not under decentralization, some of the above results remain valid. Under centralization, the migration equilibrium is only sensitive toward the location of the voting majority, but not to the exact size of the initial population in each region. Therefore, as long as the location of the initial majority does not change, the above results remain valid. If there is, however, a downstream (upstream) majority for negative (positive) spillovers, the outcome is different. A different voting majority leads to a different supply of public goods and to different locational patterns (see figures 6.12 and 6.13 in the appendix). Interestingly, the resulting equilibrium utility is the same when spillovers are positive (see equation 6.33 in the appendix). Hence, even though the supply of public goods follows the myopic interests of the majority region, the resulting utility level is the same for both majorities and positive spillovers. In contrast, a downstream majority and negative spillovers lead to a different utility level than an upstream majority. With negative and also without any spillovers, a downstream majority does not provide the upstream public good. The downstream supply is at a constant high level independent of spillovers. The utility level with a downstream majority is the same with negative and without spillovers. Thus, a downstream majority leads to better outcomes than a upstream majority when spillovers are negative. This yields the result that centralization is better than decentralization for sufficiently negative spillovers (see the right part of figure 6.8).

Second, if deviations between the initial and the final population distributions are allowed under decentralization, proposition 6.1 does not hold any longer. For small deviations of the initial and the final population distribution, equation 6.14 holds, which states that the performance of decentralization can improve under certain conditions. This would strengthens the case of decentralization. Large deviations, however, are likely to decrease the equilibrium utility level under decentralization, which strengthens the case for centralization.

Third, if there are no restrictions on the initial population, proposition 6.1 does not hold. The comparison of both federal settings will than depend on the location of the majority region and on the deviation of the initial and the final locations under decentralizations. Qualitatively, the same basic considerations apply which were discussed in the above two paragraphs.

The discussion on the federal settings focused on rent distribution to residents. With the alternative assumption of equal property shares the above discussion is qualitatively the same.

6.5 Flood-prone areas

The two region model is not only suitable for the analysis of upstream-downstream spillovers, but also for the analysis of flood-prone areas and the question if single issue authorities shall be responsible for public flood defense. Instead of an upstream and a downstream region, the model now studies the relation between a flood-prone community and an adjacent community not exposed to flood risk. The alternative to a single issue authority is a large jurisdiction that comprises both communities, creating heterogeneous voting preferences within this jurisdiction. The analogy of a single issue authority and the above decentralized jurisdictions is evident. The same applies to a large jurisdiction and centralization. Assuming that region 2 is the region not exposed to flood risk, it follows that u^2_{g2} as well as u^2_{g1} are zero. With this modification the formal analysis of two regions can be easily adapted to the issue of flood defense and its implications on human encroachment on flood-prone areas.

The issue of the best federal organization is likely to be influenced by the benefit level of public goods. The two alternative federal setting are a single issue authority (denoted by 'sia') and a large—or status quo—jurisdiction with heterogeneous public good benefits (denoted by 'lj'). Assuming that the first-order condition for the supply of public goods in region 1 determines the optimal solution, the impact of the marginal public good benefit can be determined by a comparative static analysis. The marginal public good benefits in region 1 influence the equilibrium allocation as follows

$$\left.\frac{dv^i}{d\lambda_1}\right|_{sia} = \frac{A_2 n_1 c_1'' u^1_{\lambda 1} + A_2(n_1 - \tilde{n}_1)\tilde{n}_1 u^1_{g1} u^1_{g1\lambda 1}}{(A_1 n_2 + A_2 n_1)c_1''}$$
$$\text{with } A_i = \begin{cases} f^i_n - \frac{f^i - c_i(\tilde{n}_i)}{n_i} & \text{with rents to residents} \\ \frac{c_i(\tilde{n}_i)}{n_i} + \frac{n_i n_j (f^i_{nn} + f^j_{nn})}{\bar{n}} & \text{with equal property shares.} \end{cases} \tag{6.26}$$

$$\left.\frac{dv^i}{d\lambda_1}\right|_{lj} = \begin{cases} \frac{A_2 n_1 c_1'' u^1_{\lambda 1} - A_1 n_2 \bar{n}\, u^1_{g1} u^1_{g1\lambda 1}}{(A_1 n_2 + A_2 n_1)c_1''} & \text{with region 1 majority} \\ 0 & \text{with region 2 majority} \end{cases}$$
$$\text{with } A_i = \begin{cases} f^i_n - \frac{f_n}{n_i} & \text{with rents to residents} \\ \frac{n_i n_j (f^i_{nn} + f^j_{nn})}{\bar{n}} & \text{with equal property shares.} \end{cases} \tag{6.27}$$

The partial derivatives $u^1_{\lambda 1}$ and $u^1_{g1\lambda 1}$ are both positive. $u^1_{\lambda 1}$ indicates the increase in utility when the marginal public good benefits grow. This partial derivative depends on the level of flood defense. An increase in the marginal public good benefits can be interpreted as a better flood defense technology, since a given level of spending translates into a higher utility level and higher marginal benefits. $u^1_{g1\lambda 1}$ is constant, given the linear utility in public goods.

If, in a single issue authority, the initial location is the same as in the migration equilibrium, higher marginal benefits clearly increase utility. This also holds as long as the initial population in the high-benefit region is not too large. Without a single issue authority, the marginal benefits have no impact on the utility when a majority of voters live outside flood-prone areas, because no flood defense is provided. With a majority of voters in flood-prone areas, the marginal benefits can increase or decrease the equilibrium utility level. With the functional specification used previously (see chapter 6.2.2) and rent distribution to residents, the impact is zero for symmetric regions, since $\frac{dv^i}{d\lambda_1} = \frac{\bar{n}\lambda_1(\bar{x}_1 - \bar{x}_2)}{\bar{x}_1 + \bar{x}_2} = 0$ if $\bar{x}_1 = \bar{x}_2$. Thus, whereas a single issue authority promotes a higher utility level in response to higher marginal benefits under a fairly wide range of conditions, this is not the case in a large jurisdiction. With heterogeneous benefits, majority voting leads to extreme supply levels of the public good and may lead to a utility level that is the same with and without the public good (when $\frac{dv^i}{d\lambda_1} = 0$). As already became clear in the earlier discussion, extreme supply levels of public goods correspond to extreme locational patterns, since the majority region attracts a large population share. Thus, flood defense in a heterogeneous benefit jurisdiction may foster human encroachment on flood-prone areas without a positive effect on the overall utility level.

Explicit solutions of the migration equilibrium are given in the appendix to this chapter. Given the same functional specification as used before, a single issue authority yields the socially optimal outcome if the initial and the final location of citizens is the same. A large jurisdiction fails to achieve the social optimum.

It is a typical question in flood management, if a flood plain should be protected by public flood defense. As figure 6.9 shows, the answer to this question depends on the federal setting, the scarcity of land outside the flood plain, and the marginal benefit from flood defense. The left illustrations of figure 6.9 show the allocation (location and utility) of a single issue authority under the assumption that the initial and the final location of individuals is the same. The right two illustrations show a large jurisdiction with an initial majority of voters living in the flood plain.

Both federal settings lead to the same outcome, if flood defense is not beneficial, $\lambda = 0$. For this special case the amount of land outside the flood plain, $\bar{x}_2$, has a positive influence on welfare and a negative impact on human encroachment on flood-prone areas. If flood defense is beneficial, $\lambda > 0$, the outcome of both federal settings is not the same. The case $\lambda = 0$ can be interpreted as the status quo without flood defense. The equilibrium allocations can be compared to the status quo, yielding insight into the question of how much flood defense influences the equilibrium population sizes of regions and the equilibrium utility level.

If flood defense is provided by a single issue authority, both the level of the marginal public good benefit and the scarcity of land outside the flood plain have a positive

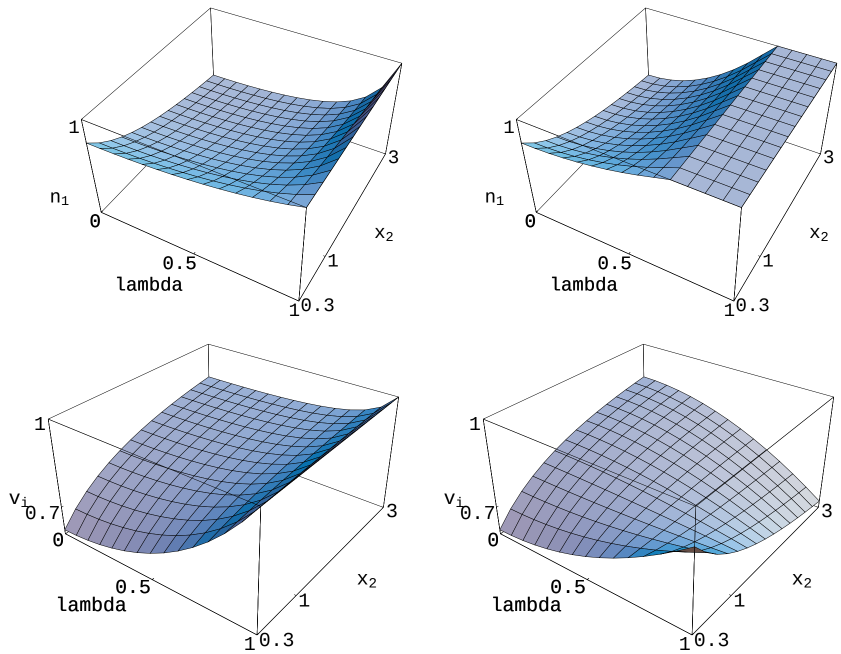


Figure 6.9: Utility depending on land outside the flood plain with myopic voting for $\bar{n} = 1$, $\bar{x}_1 = 1$, and residency based rent distribution. Left: Single issue authority. Right: Large jurisdiction.

effect on utility (see the lower left part of figure 6.9). Human encroachment on flood-prone areas is increasing in the level of the marginal benefits of flood defense. A large quantity of land outside the flood plain coincides with little human encroachment of flood-prone areas. For sufficiently large marginal public good benefits, the final location of all citizens is in the flood plain. The case of complete concentration arises because the force that favors the complete concentration (the public good benefits) dominates the force that scatters citizens over both regions (land scarcity). For the case $\lambda_1 = 1$, the quantity of land has no impact on the equilibrium utility level and the population distribution. It can be summarized: In situations of extreme land scarcity outside the flood plain, flood defense has a large positive impact on welfare and a small impact on human encroachment on flood-prone areas, compared to the status quo without flood defense. With abundant land outside the flood plain, the impact of flood defense on welfare is positive but small and the impact on human encroachment on flood-prone areas is large. Since the allocations are the same for the adopted functional forms, this result does not only hold for single issue authorities but also for the social optimum.

Flood defense provided by a large jurisdiction can decrease or increase utility (see the lower right part of figure 6.9). Flood defense is only provided if the initial majority of the population is living in the flood plain. With a large quantity of land outside the flood plain, flood defense decreases utility. The higher the marginal benefits from flood defense, the larger the negative effect on the equilibrium utility. If land outside the flood plain is scarce (small values of $\bar{x}_2$), flood defense increases utility. With the same land endowment in and outside the flood plain ($\bar{x}_1 = \bar{x}_2 = 1$), public flood defense does not change utility. This is the above case of $\frac{dv^i}{d\lambda_1} = 0$. Human encroachment on flood-prone areas is increasing in the level of the marginal benefits of flood defense. For sufficiently large marginal benefits, all citizens will live in the flood plain in the migration equilibrium. As figure 6.9 shows, the full concentration of the population is reached for a marginal public good benefit that is independent of the land endowment outside the flood plain. With a large jurisdiction the complete regional concentration of citizens is reached for lower marginal public good benefits than with a single issue authority. Together with the arguments made with respect to the case of $\lambda_1 = 0$, one can state, for a large jurisdiction and an initial majority of citizens living in the flood plain: In situations of extreme land scarcity outside the flood plain, flood defense has a positive impact on welfare and a small impact on human encroachment on flood-prone areas, compared to the status quo without flood defense. With abundant land outside the flood plain, the impact of flood defense on welfare is negative and the impact on human encroachment on flood-prone areas is large.

One can conclude that flood defense tends to have a large impact on the population distribution when the potential welfare gains are low. The larger the marginal public good benefits, the less important the influence of land size outside the flood plain on the equilibrium utility level. Given the assumption regarding the initial location of voters and the functional specification, a single issue authority leads to higher welfare than a large jurisdiction, since it reaches the social optimum.

6.6 Concluding remarks

This chapter introduced migration as a possible response of citizens to the supply of public goods. Symmetry assumptions with respect to the preference and production side of the economy were made in order to concentrate on unidirectional spillovers and their impact on the migration equilibrium under different federal organizations. As voters were assumed to be myopic with respect to migration, the provision of public goods followed the established pattern of the last chapter. With the assumption that the initial population distribution is the same as the equilibrium population distribution, a comparison of decentralized and centralized supply showed that decentralization is superior for most spillover levels, since centralization suffers from an inefficient, majority preferred, supply pattern of public goods. Political-economy conditions and the federal organization also drive the spatial distribution of the population. With decentralized supply that neglects spillovers, the population size of the upstream region decreases in spillovers. This pattern also holds for centralization with an upstream majority, but is not a general property for a downstream majority. Under centralization the majority regions attract a large population share, which tends to be a stronger influence on the locational pattern than spillovers.

With the set up of the game the initial population distribution has a large impact on the final migration equilibrium. Under decentralization this impact is gradual, whereas under centralization it is only the location of the majority that depends on the initial locational pattern.

With the two region model it was possible to investigate single issue authorities as a federal organization that avoids heterogeneous benefits within a jurisdiction. This interpretation of the model allows to analyze human encroachment of flood-prone areas. With the adopted functional form and symmetry assumptions it turned out that single issue authorities are the superior federal organization, because they have a positive welfare effect compared to a status quo without flood defense. Negative welfare effects can arise when flood defense is provided by a large jurisdiction that comprises areas with and without public good benefits. This leads to the conclusion that flood defense provided by jurisdictions with heterogeneous benefits may just change the locational pattern without having positive welfare effects.

The allocation in the migration equilibrium is sensitive toward the tax scheme. The preceding analysis focused on head taxes. Possible alternatives are income or rent taxes. However, relying on other than head taxes does not entirely change the pattern of public good supply, since upstream voters still neglect spillovers and over-provision still occurs if non-beneficiaries can be taxed.

The above specification of the model assumed myopic voters that were unaware of potential migration at the second stage of the game. It is this assumption that will be relaxed in the following chapter.

6.7 Appendix

Social optimum

The second-order sufficient conditions for a local maximum require alternating signs of the bordered principal minors of the bordered Hessian. This leads to the following conditions that are always met for $|\bar{H}_2|$, $|\bar{H}_3|$, and $|\bar{H}_4|$. The case of $|\bar{H}_5|$ was already discussed earlier in chapter 6.

$$\begin{aligned}
&|\bar{H}_2| = \bar{n}^2(u^1_{g1})^2(u^2_{g2})^2 > 0\\
&|\bar{H}_3| = -\bar{n}(c''_1(u^2_{g2})^2 + c''_2(u^2_{g1})^2) < 0\\
&|\bar{H}_4| = c''_1 c''_2 > 0\\
&|\bar{H}_5| = \tfrac{1}{\bar{n}}[c''_1(u^2_{g2})^2 + c''_2(c''_1(f^1_{nn} + f^2_{nn}) + (u^1_{g1} - u^2_{g1})^2)] < 0
\end{aligned} \tag{6.28}$$

Total differentiation of the first-order conditions yields

$$\begin{pmatrix} -c''_1 & 0 & 0 & 0 & u^1_{g1} - u^2_{g1} \\ 0 & -c''_2 & 0 & 0 & -u^2_{g2} \\ 0 & 0 & -1 & 1 & f^1_{nn} + f^2_{nn} \\ u^1_{g1} - u^2_{g1} & -u^2_{g2} & 1 & -1 & 0 \\ -n_1 u^1_{g1} - n_2 u^2_{g1} & -n_2 u^2_{g2} & -n_1 & -n_2 & 0 \end{pmatrix} \begin{pmatrix} dg_1 \\ dg_2 \\ dy_1 \\ dy_2 \\ dn_1 \end{pmatrix} = \begin{pmatrix} n_2 u^2_{g1k2} & d\kappa_2 \\ 0 & \\ 0 & \\ -u^2_{k2} & d\kappa_2 \\ 0 & \end{pmatrix} . \tag{6.29}$$

Solving the first-order conditions for the specified functional form yields the explicit solutions for public good provision as well as the population size of the regions. The efficient allocation for an interior solution is given by

$$\begin{aligned}
&g^*_1 = \tfrac{\bar{n}\lambda(1-\lambda^2\bar{x}-\kappa_2)}{2-\lambda^2\bar{x}B}\\
&g^*_2 = \tfrac{\bar{n}\lambda(1-\lambda^2\bar{x}(1-\kappa_2))}{2-\lambda^2\bar{x}B}\\
&y^*_1 = 1 - \tfrac{\bar{n}(1-\lambda^2\bar{x}(\lambda^2\bar{x}-\kappa_2(2-\kappa_2)))}{2\bar{x}(2-\lambda^2\bar{x}B)}\\
&y^*_2 = 1 - \tfrac{\bar{n}(1-\lambda^2\bar{x}(\lambda^2\bar{x}-\kappa_2(2+\kappa_2)))}{2\bar{x}(2-\lambda^2\bar{x}B)}\\
&n^*_1 = \tfrac{\bar{n}(1-\lambda^2\bar{x}(1-(1-\kappa_2)\kappa_2)}{2-\lambda^2\bar{x}B}\\
&\text{with } B \equiv 2 - (2-\kappa_2)\kappa_2 \,.
\end{aligned} \tag{6.30}$$

B is non-negative for all relevant spillovers ($B > 0 \,\forall\, \kappa \in [-1, 1]$). This yields the indirect utility function

$$v^*_1 = v^*_2 = y^*_1 + \lambda g^*_1 = y^*_2 + \lambda(g^*_2 + \kappa_2 g^*_1) = 1 - \tfrac{\bar{n}(1+\lambda^2\bar{x}(\lambda^2\bar{x}-(2+\kappa_2^2)))}{2\bar{x}(2-\lambda^2\bar{x}B)} \,. \tag{6.31}$$

The plots of public goods, the population distribution and the utility level were given in the main part of this chapter. Consumption of the private goods is illustrated in figure 6.10.

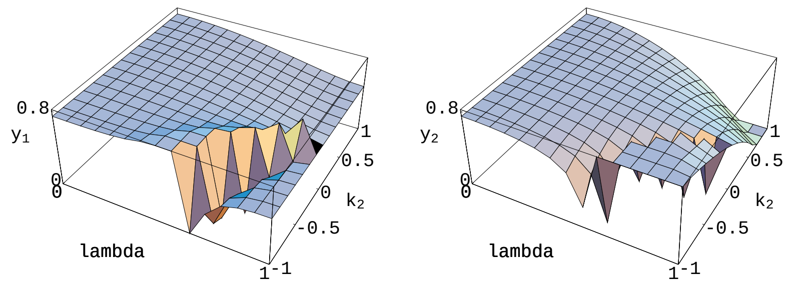


Figure 6.10: Social optimal consumption of the private goods for $\bar{n} = 1$ and $\bar{x} = 1$

Decentralization and unidirectional spillovers

The equilibrium allocation for the adopted functional form and residency-based rent distribution is given by

$$\begin{aligned} g_1^d &= \tfrac{\bar{n}\lambda(\lambda^2\bar{x}-1)}{2(\lambda^2\bar{x}(1-\kappa_2)-1)} \\ g_2^d &= \tfrac{\bar{n}\lambda(\lambda^2\bar{x}(1-2\kappa_2)-1)}{2(\lambda^2\bar{x}(1-\kappa_2)-1)} \\ y_1^d &= 1 - \tfrac{\bar{n}(\lambda^4\bar{x}^2-1)}{4\,\bar{x}(\lambda^2\bar{x}(1-\kappa_2)-1)} \\ y_2^d &= 1 - \tfrac{\bar{n}(\lambda^2\bar{x}+1)(\lambda^2\bar{x}(1-2\kappa_2)-1)}{4\,\bar{x}(\lambda^2\bar{x}(1-\kappa_2)-1)} \\ n_1^d &= \tfrac{\bar{n}(\lambda^2\bar{x}-1)}{2(\lambda^2\bar{x}(1-\kappa_2)-1)} \\ v_i^d &= 1 + \tfrac{\bar{n}(\lambda^2\bar{x}-1)^2}{4\,\bar{x}(\lambda^2\bar{x}(1-\kappa_2)-1)}\ . \end{aligned} \tag{6.32}$$

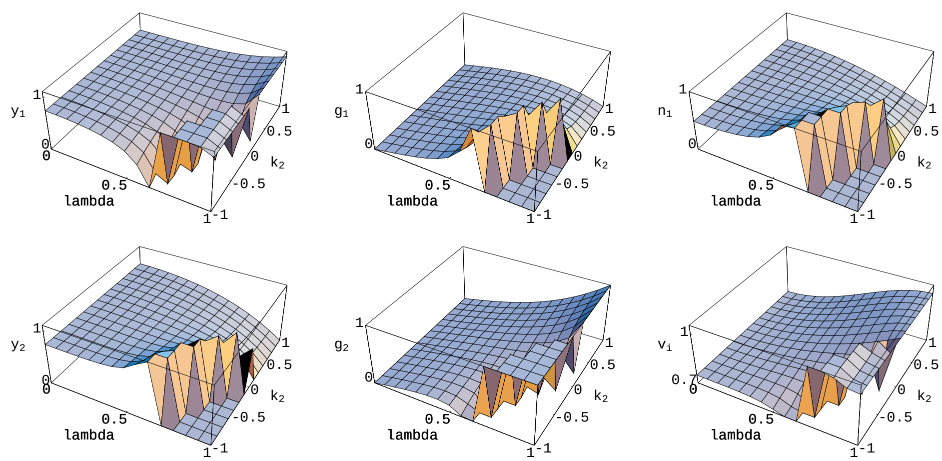


Figure 6.11: Decentralized equilibrium allocation with myopic voting for $\bar{n} = 1$ and $\bar{x} = 1$

A corner solution of the population or one of the public or private goods implies that all corresponding combinations of spillovers and marginal benefits lead to allocations that are either not feasible or not optimal. For the graphical illustrations, corner solutions occur for high marginal benefits and negative spillovers (front corners of the allocation). However, the second-order sufficient conditions for a local maximum are met for all parameter values since they neither depend on marginal benefits from public goods nor on spillovers. A migration equilibrium exists for $\lambda < 1$.

Centralization and unidirectional spillovers

The equilibrium allocation for the adopted functional form and residency-based rent distribution is given by

$$\begin{array}{lll} & \text{region 1 majority} & \text{region 2 majority, } \kappa_2 \geq 0 \\ g_1^c = & \bar{n}\lambda & \bar{n}\lambda\kappa_2 \\ g_2^c = & 0 & \bar{n}\lambda \\ y_1^c = & 1 - \frac{\bar{n}(1+2\,\lambda^2\bar{x}(2-\kappa_2))}{4\bar{x}} & 1 - \frac{\bar{n}(1+2\,\lambda^2\bar{x}\,\kappa_2)}{4\bar{x}} \\ y_2^c = & 1 - \frac{\bar{n}(1+2\,\lambda^2\bar{x}\,\kappa_2)}{4\bar{x}} & 1 - \frac{\bar{n}(1+2\,\lambda^2\bar{x}(2-\kappa_2+2\kappa_2^2))}{4\bar{x}} \\ n_1^c = & \frac{\bar{n}(1+2\lambda^2\bar{x}(1-\kappa_2))}{2} & \frac{\bar{n}(1-2\lambda^2\bar{x}(1-\kappa_2+\kappa_2^2))}{2} \\ v_i^c = & 1 - \frac{\bar{n}(1-2\,\lambda^2\bar{x}\,\kappa_2)}{4\bar{x}} & 1 - \frac{\bar{n}(1-2\,\lambda^2\bar{x}\,\kappa_2)}{4\bar{x}}\,. \end{array} \tag{6.33}$$

The allocation for a downstream majority with negative spillovers can be derived by setting $\kappa_2 = 0$ in the allocation of a downstream majority and positive spillovers.

A corner solution of the population or one of the public or private goods implies that all corresponding combinations of spillovers and marginal benefits lead to allocations that are either not feasible or not optimal. For the graphical illustrations, corner solutions occur for high marginal benefits and negative spillovers (front corners of the allocation). However, the second-order sufficient conditions for a local maximum are met for all parameter values since they neither depend on marginal benefits from public goods nor on spillovers.

Flood-prone areas

The equilibrium allocation for the functional form used before, the same initial and final location of voters in a single issue authority, and residency-based rent distribution is given by

$$\begin{array}{lll} & \text{social optimum and} & \text{large jurisdiction, } \tilde{n}_1 > \frac{\bar{n}}{2} \\ & \text{single issue authority} & \\ g_1 = & \frac{\bar{n}\lambda_1\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} & \bar{n}\lambda_1 \\ n_1 = & \frac{\bar{n}\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} & \bar{n}\,\bar{x}_1\frac{1+2\lambda_1^2\bar{x}_2}{\bar{x}_1+\bar{x}_2} \\ v_i = & 1-\bar{n}\frac{1-\lambda_1^2\bar{x}_1}{2(\bar{x}_1+\bar{x}_2)-2\lambda_1^2\bar{x}_1\bar{x}_2} & 1+\bar{n}\frac{\lambda_1^2(\bar{x}_1-\bar{x}_2)}{2(\bar{x}_1+\bar{x}_2)}\,. \end{array} \tag{6.34}$$

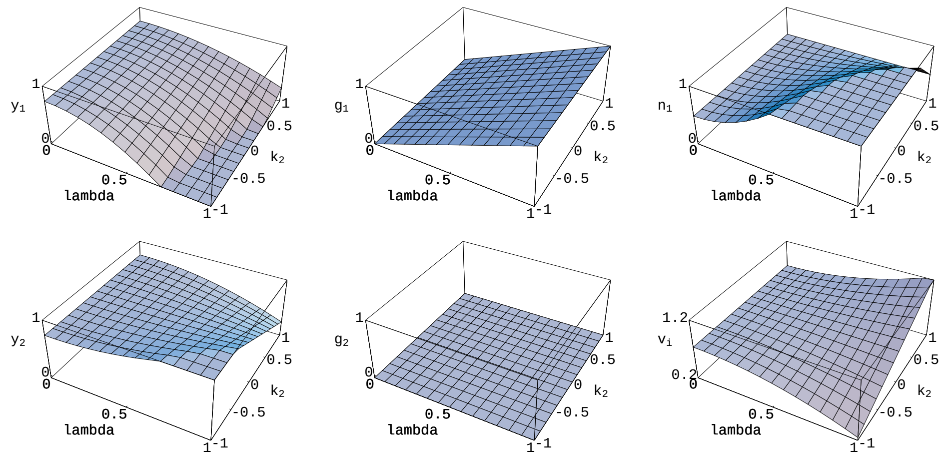


Figure 6.12: Centralized equilibrium allocation with myopic voting and an upstream majority for $\bar{n} = 1$ and $\bar{x} = 1$

For a region 2-majority in a large jurisdiction, the allocation is the same as with a region 1-majority, only that λ_1 must be set to zero.

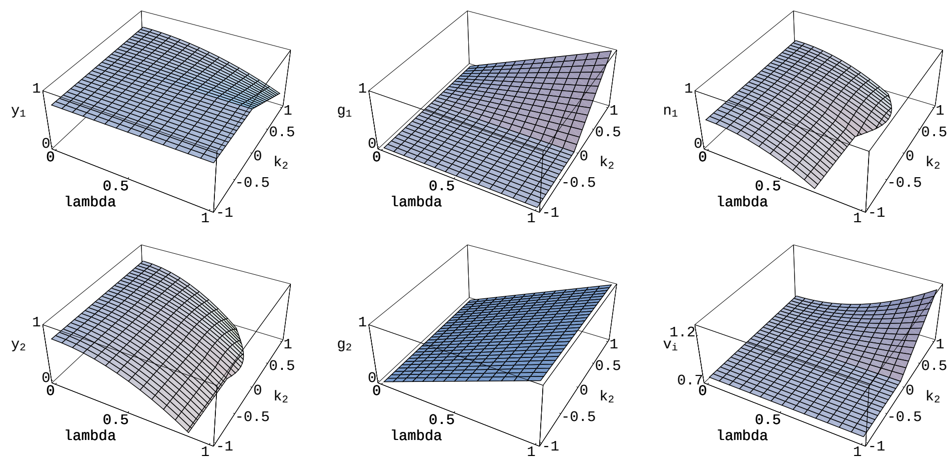


Figure 6.13: Centralized equilibrium allocation with myopic voting and a downstream majority for $\bar{n} = 1$ and $\bar{x} = 1$

Chapter 7

Migration and non-myopic voting

The previous chapter showed how public goods influence migration decisions. By assumption, voters neglected this influence, since they took the initial population distribution as the final population distribution. This assumption may not be very realistic, since in most cases migration flows lead to a different equilibrium utility level than the one aimed at in the voting decision. If, for example, the voting majority under centralization realizes that it is not able to achieve a high utility level through high public good supply because this induces immigration, it may choose a different supply pattern with public goods to achieve a better population distribution with a higher utility. Such considerations seem not unrealistic in the case of flood defense. The majority may realize that no public goods downstream will have an effect on the locational choices of downstream citizens. The awareness of interdependent utility levels may be particularly pronounced when spillovers are present.

In this chapter, non-myopic voters who take potential migration at the second stage of the game into account are assumed. Even though much of the literature assumes myopic voters, it is well established that migration responses can be taken into account. Examples are Stiglitz (1977), Boadway (1982), and Wellisch (1993; 1994). With non-myopic voters the supply of public goods can be expected to be different, which leads to the question whether non-myopic voting produces better results than myopic voting and how this influences the comparison between decentralized and centralized decision making.

This chapter uses the same model as introduced in the previous chapter. Also the set up of the game is the same as described in section 6.3. Now it is only assumed that potential migration at the second stage of the game is anticipated at the first stage when citizens vote on public goods. The implications of this assumption will be described in detail for decentralized and centralized voting.

7.1 Unidirectional spillovers

7.1.1 Decentralization

Under decentralization, each region decides independently on public goods at the first stage. The cost of public good provision is shared within the jurisdiction. At the second stage individuals decide on migration. Solving the game by backward induction yields the equilibrium allocation.

At the second stage individuals choose their location. As before, a migration equilibrium requires that nobody has an incentive for relocation. Given the set up of the economy, an equilibrium distribution of individuals, without complete concentration of the population in one region, requires that all individuals have the same utility, no matter where they reside. As before, the free migration restriction is therefore $y_i + u^i(g_i, g_j) = y_j + u^j(g_i, g_j)$. With taxes paid at the second stage of the game, the consumption of the private good in region i differs for the two rent distribution schemes

$$y_i = \begin{cases} \frac{f^i(n_i,\bar{x})-c_i(g_i)}{n_i} & \text{with rents to residents} \\ f_n^i + \frac{r_i+r_j}{\bar{n}} - \frac{c_i(g_i)}{n_i} & \text{with equal property shares.} \end{cases} \tag{7.1}$$

Changes in public good provision induce migration. Total differentiation of the free migration restriction yields migration response functions, denoted by $n_i = n_i(g_i, g_j)$, that capture changes in the population size of a region in response to changes in public good provision. Migration responses are not only relevant for an optimal supply of public goods, but also for any migration equilibrium without complete concentration. Thus, the population size of a region can be seen as a function of public goods. By the implicit function theorem, the derivatives of the migration response function of the upstream population size are given by

$$\begin{aligned} \frac{dn_1}{dg_1} &= \frac{\frac{c_1'}{n_1} - u_{g1}^1 + u_{g1}^2}{\frac{A_1}{n_1} + \frac{A_2}{n_2}} \\ \frac{dn_1}{dg_2} &= -\frac{\frac{c_2'}{n_2} - u_{g2}^2}{\frac{A_1}{n_1} + \frac{A_2}{n_2}} \\ \text{with } A_i &= \begin{cases} f_n^i - y_i & \text{with rents to residents} \\ \frac{c_i(g_i)}{n_i} + \frac{n_i n_j (f_{nn}^i + f_{nn}^j)}{\bar{n}} & \text{with equal property shares.} \end{cases} \end{aligned} \tag{7.2}$$

With the whole economy comprising two regions, the downstream population responds in the opposite way than indicated by the upstream migration responses. What are the signs of the migration responses to changes in the supply of public goods? The denominators of the migration responses are the sum of marginal changes of utility in response to an immigrant to a region. If regions are over-populated so that assumption 6.2 of the last chapter holds ($\frac{\partial v^i}{\partial n_i} < 0$ for both regions), this sum is negative and the denominators have a negative sign.

The sign of the enumerators depend on the level of public good provision. The easier case is the enumerator of the downstream public good. It can be positive or negative. With a small amount of the downstream public good, a marginal expansion of supply increases the downstream utility because the marginal utility is higher than the marginal cost. This leads to a negative enumerator and a negative sign of the total expression. Thus, a marginal increase of the public good downstream increases downstream utility and induces migration to the downstream region, which reduces the upstream population size, $\frac{dn_1}{dg_2} < 0$. Migration takes the opposite direction for high supply levels of the downstream public good, because utility decreases in the amount of g_2.

For the upstream public good there is an additional effect through spillovers. A marginal increase of the upstream public good increases the downstream utility when spillovers are positive. For negative spillovers it decreases utility downstream. This effect may be dominant if the marginal upstream benefits and costs have a similar size. Therefore negative spillovers in combination with a low level of the upstream public good favor an increase of the upstream population because a higher upstream public good does not only increase upstream utility, but also decreases the downstream utility due to the negative spillovers. Positive spillovers, in combination with a high level of the upstream public good, favor a negative migration response toward a marginal increase of the upstream public good, because this induces migration to the downstream region.

At the first stage there is voting on public goods. Individuals vote at their initial location. Since voters are aware of migration they consider potential migration flows as determined by the migration response functions $n_i(g_i, g_j)$. It is assumed that voters anticipate the correct migration responses as determined by equation 7.2.[1] Voters take public good provision of the other region as given. The optimization problem of the median voter in region i is therefore given by

$$\begin{aligned} &\max_{g_i \in \mathbb{R}_+} \; y_i + u^i(g_i, g_j) \\ &\text{with } n_i = n_i(g_i, g_j); \quad y_i, y_j \geq 0; \quad i, j = 1, 2; \;\; i \neq j. \end{aligned} \tag{7.3}$$

This leads to the first-order conditions for public good provision

$$-\frac{c_i'(g_i)}{n_i} + u^i_{gi} + \frac{A_i}{n_i}\frac{dn_i}{dg_i} \leq 0 \quad g_i \geq 0 \text{ and } g_i \frac{\partial(y_i + u^i)}{\partial g_i} = 0; \quad i, j = 1, 2; \, i \neq j\,. \tag{7.4}$$

In his decision on the public good, the median voter in each region considers his cost and benefit. Public good costs are shared only among individuals living in that region, even if spillovers to other regions prevail. In addition to his cost and benefit, the median voter also considers potential migration responses. He is aware that his public good decision has an impact on the locational decisions of other individuals. Therefore it is not the initial population distribution that is relevant for the voting decision, but the anticipated final population distribution. In taking the migration responses into account, the median voter may favor more or less public good provision than by just considering his own cost and benefit for the given initial population size. After inserting the migration responses and by concentrating on interior solutions, the first-order conditions reduce to the following equations

$$n_i u^i_{gi} + \frac{A_i}{A_j} n_j u^j_{gi} = c_i'(g_i) \qquad \text{for} \quad i, j = 1, 2; \quad i \neq j\,. \tag{7.5}$$

[1] A similar assumption is made with respect to the social planer in a decentralized setting by Wellisch (1993) and others.

By considering migration responses, upstream voters take spillovers into account. For an (anticipated) population distribution of n_i and n_j, the upstream public good is expanded in comparison to myopic voting for positive and reduced for negative spillovers. Despite this consideration the amount of the upstream public good is not generally efficient. Only if the fraction $\frac{A_1}{A_2}$ is unity or if spillovers are absent, the upstream good is provided according to the Samuelson rule. Downstream voters provide the public good efficiently since their first-order condition is not affected by spillovers.

Second-order sufficient conditions for a local maximum require the Hessian matrix to be negative definite. The optimization problems of the representative voters in the two jurisdictions yield two Hessian determinants. For residency-based rent distribution this restricts the Hessian determinants for public good supply in region i, $|H_1^i|$ to

$$\begin{aligned} |H_1^1| &= -c_1'' + \frac{n_2 u_{g1}^2 [2A_2^2 u_{g1}^1 + u_{g1}^2 (n_2(A_2 f_{nn}^1 + A_1 f_{nn}^2) - 2A_1 A_2)]}{A_2^3} < 0 \\ |H_1^2| &= -c_2'' < 0. \end{aligned} \tag{7.6}$$

For equal property shares the Hessian determinants are restricted to

$$\begin{aligned} |H_1^1| &= -c_1'' + \frac{n_2 u_{g1}^2 [(1+n_1) A_2^2 u_{g1}^1 + u_{g1}^2 (n_2(\frac{\partial A_1}{\partial n_1} A_2 + \frac{\partial A_2}{\partial n_1} A_1) - (1-n_2) A_1 A_2)]}{A_2^3} < 0 \\ |H_1^2| &= -c_2'' < 0 \\ \text{with } \frac{\partial A_i}{\partial n_i} &= -\frac{c_i}{n_i^2} + \frac{(\bar{n} - 2n_i)(f_{nn}^i + f_{nn}^j)}{\bar{n}} + \frac{n_i n_j (f_{nnn}^i - f_{nnn}^j)}{\bar{n}} . \end{aligned} \tag{7.7}$$

Without spillovers, the second-order sufficient conditions are always met since the Hessian determinants only depend on the cost functions. With spillovers, marginal benefits from public goods must be sufficiently small for the second-order sufficient conditions to hold. The influence of spillovers on the Hessian determinants is not straight forward. The Hessians are not only influenced by spillovers, but also by the production function and the resulting (in-) efficient population distribution.

Unlike the case with myopic voting, voters have no dominant strategy for the provision of public goods with non-myopic voting. In focusing on the Nash-equilibrium in pure strategies, it is assumed that voters of one region take the action of voters of the other region as given. Since all voters have identical preferences and the budget restrictions are the same within both regions, it is again possible to consider representative voters of region i and j. The slopes of the reaction functions, $g_i = R_i(g_j)$, are given by

$$\begin{aligned} \frac{\partial R_1}{\partial g_2} &= \frac{A_1 n_2 u_{g1}^2 u_{g2}^2}{|H_1^1| A_2^2} \\ \frac{\partial R_2}{\partial g_1} &= -\frac{n_2 u_{g1}^2 u_{g2}^2}{|H_1^2| A_2} . \end{aligned} \tag{7.8}$$

Depending on the sign of the spillover the slope is either positive or negative. If the second-order conditions are met and regions are over-populated (assumption 6.2 holds), positive spillovers imply that public good provision in the upstream and the downstream region are strategic complements since $\frac{\partial^2 (y_i + u^i)}{\partial g_i \partial g_j} > 0$. With negative spillovers, public goods are strategic substitutes, $\frac{\partial^2(y_i+u^i)}{\partial g_i \partial g_j} < 0$. Remember that with non-myopic behavior the net-income y_i depends in both cases on the migration response functions $n_i(g_i, g_j)$ so that it generally holds that $\frac{\partial^2(y_i+u^i)}{\partial g_i \partial g_j} \neq 0$. The Nash-equilibrium is characterized by $g_1^d = R_1(g_2^d)$ and $g_2^d = R_2(g_1^d)$.

After voting on the supply of public goods, citizens can migrate at the second stage of the game. Since the supply of public goods at the first stage is optimized with respect to the anticipated final population distribution, migration takes place if the final population distribution deviates from the initial population size of the regions. With the assumption of over-populated regions (assumption 6.2), utility differentials between regions are eliminated by migration and an interior migration equilibrium is reached. A migration equilibrium exists if marginal benefits from the public goods are sufficiently small. The formal condition for existence is very similar to the last chapter (see equation 6.10), only that public goods do not depend on the initial population distribution but on the anticipated final locational pattern.

$$\frac{\partial(v^i - v^j)}{\partial n_i} = \begin{cases} \frac{c_i(n_i)}{n_i^2} + \frac{c_j(n_j)}{n_j^2} + \frac{f_n^i - \frac{f^i}{n_i}}{n_i} + \frac{f_n^j - \frac{f^j}{n_j}}{n_j} < 0 & \text{with rents to residents} \\ \frac{c_i(n_i)}{n_i^2} + \frac{c_j(n_j)}{n_j^2} + f_{nn}^i + f_{nn}^j < 0 & \text{with eq. prop. shares.} \end{cases} \tag{7.9}$$

Assuming that the above first and second-order conditions determine a global optimum, the economic interpretation of the decentralized migration equilibrium is as follows. With non-myopic voting, citizens are aware of the free migration restriction and know that the final migration equilibrium is characterized by the same utility level for the whole population. Therefore, in maximizing individual utility, voters maximize the welfare of the whole economy. However, because of decentralized financing the socially optimal solution cannot be reached. The migration equilibrium is generally not only characterized by inefficiencies in public good provision, but also by an inefficient locational pattern. If spillovers are present, these two inefficiencies are closely linked, since locational inefficiency implies that $A_i \neq A_j$, which distorts the supply of the upstream public good. This interrelation follows from the first-order conditions for public good provision. Thus, a rule where the public goods are provided according to the Samuelson rule, with decentralized voting, leads to a migration equilibrium with lower utility than a migration equilibrium where the locational pattern and the public good provision is distorted. Note that a deviation from the Samuelson rule is only beneficial if spillovers are present. For downstream voters a deviation from the Samuelson rule always reduces their utility. This holds for an over-provision as well as an under-provision.

The population distribution is socially inefficient if the social net-benefit of an immigrant to a region, $f_n^i - y_i$, deviates between the upstream and the downstream region. With rent distribution to residents and A_i defined as above, it is clear that locational inefficiency directly leads to inefficient public good supply, because $\frac{A_1}{A_2} \neq 1$. For rent distribution to land owners, locational inefficiency implies that $\frac{c_1}{n_1} \neq \frac{c_2}{n_2}$, since $f_n^i - y_i = f_n^i - (f_n^i + \frac{r_i + r_j}{\bar{n}} - \frac{c_i}{n_i})$. With $\frac{c_1}{n_1} \neq \frac{c_2}{n_2}$ it follows that $\frac{A_1}{A_2} \neq 1$ since $A_i = \frac{c_i(g_i)}{n_i} + \frac{n_i n_j (f_{nn}^i + f_{nn}^j)}{\bar{n}}$.

In a two region setting there are two possibilities for locational inefficiency. The first one is a larger social net-benefit of an immigrant in the upstream than in the downstream region, $f_n^1 - y_1 > f_n^2 - y_2$. In this case it is socially efficient that more people reside in the upstream region, but with the given institutional setting there are no such migration incentives. Thus, the population of the upstream region will be too small and that of the downstream region too large. The second possibility of locational inefficiency is a larger net-benefits in the downstream region, which result in a downstream population that is too small.[2]

With a locationally inefficient migration equilibrium, whether the upstream public good is over- or under-supplied compared to the Samuelson rule depends on the quotient $\frac{A_1}{A_2}$. With over-populated regions, as implied by assumption 6.2, the fraction $\frac{A_1}{A_2}$ is positive, since A_i as well as $\frac{A_i}{n_i}$ have the same (negative) sign for both regions. Therefore locational inefficiency is accompanied by the following distortions in public good provision.

- $\frac{A_1}{A_2} < 1$ and $\kappa_2 > 0$: The net-benefit of an immigrant to the upstream region is larger than to the downstream region. With regard to the Samuelson rule, this induces an under-supply of the upstream public good. The under-supply has a positive effect on the equilibrium population size of the upstream region.[3]
- $\frac{A_1}{A_2} < 1$ and $\kappa_2 < 0$: There is a larger net-benefit in the upstream region and the upstream public good is over-supplied. With negative spillovers the deviation from the Samuelson rule favors the upstream population. For a given population distribution there is a positive effect on the upstream utility and a negative effect on the downstream utility. This has a positive effect on the upstream population size in the migration equilibrium.
- $\frac{A_1}{A_2} > 1$ and $\kappa_2 > 0$: There is a larger net-benefit in the downstream region. Given the positive spillovers there is an over-supply of the upstream public good. This has a positive effect on the downstream population size compared to decentralized public good provision according to the Samuelson rule.
- $\frac{A_1}{A_2} > 1$ and $\kappa_2 < 0$: There is a larger net-benefit in the downstream region. With the negative spillover there is an under-supply of the upstream public good. The under-supply has a positive effect on the downstream population size.

It can be summarized that a larger net-benefit in the upstream region, $\frac{A_1}{A_2} < 1$, leads to a deviation from the Samuelson rule that favors the upstream region, whereas the opposite holds for a larger net-benefit in the downstream region.

[2] As Wellisch (1993; 1994) and also Boadway and Flatters (1982) show, it is possible to solve this problem by inter-regional transfers. Such transfers can equalize the social net-benefit of an immigrant across regions and promote the efficient supply with public goods. A migration equilibrium with $f_n^1 - y_1 > f_n^2 - y_2$ requires a net-transfer from region 2 to region 1 since the later has the higher social net-benefit of an immigrant.

[3] The effect is positive since inserting the first-order condition into the migration response yields $\frac{\partial n_1}{\partial g_1} = \frac{\frac{n_1 u_{g1}^1 + \frac{A_1}{A_2} n_2 u_{g1}^2}{n_1} - u_{g1}^1 + u_{g1}^2}{\frac{A_1}{n_1} + \frac{A_2}{n_2}} = \frac{n_2 u_{g1}^2}{A_2}$, which is negative for positive spillovers.

The comparative static effects of a marginal increase of spillovers on the allocation in the migration equilibrium are not as easily determined as with myopic voting. Spillovers, denoted with the parameter κ_2, do not only affect migration at the second stage but also the public good provision at the first stage. Under decentralization the effect on the equilibrium level of the upstream and downstream public goods for interior solutions is given by:

$$\begin{aligned} \frac{dg_1}{d\kappa_2} &= \quad n_2 \frac{u^2_{\kappa_2}[\overbrace{A_2^2 n_1 c_2'' u^1_{g1}}^{+} - u^2_{g1}\overbrace{(c_2'' C - A_1 n_1 n_2 (u^2_{g2})^2)}^{?}] + \overbrace{A_1 A_2 (A_1 n_2 + A_2 n_1) c_2'' u^2_{g1\kappa_2}}^{-}}{|J| A_2^2 (A_1 n_2 + A_2 n_1)} \\ \frac{dg_2}{d\kappa_2} &= n_2 u^2_{g2} \frac{u^2_{\kappa 2}[-A_2^2 n_1 c_1'' + A_2 n_1 n_2 u^1_{g1} u^2_{g1} + A_1 n_2^2 (u^2_{g1})^2] - A_1 n_2 (A_1 n_2 + A_2 n_1) u^2_{g1} u^2_{g1\kappa 2}}{|J| A_2^2 (A_1 n_2 + A_2 n_1)} \end{aligned} \tag{7.10}$$

$$\text{with } C = \begin{cases} A_1 A_2 [\bar{n} + n_1 - n_2 \frac{n_1 f^1_{nn}}{A_1} - n_1 \frac{n_2 f^2_{nn}}{A_2}] & \text{with rents to residents} \\ A_1 A_2 [n_1 - n_2 \frac{n_1 \frac{\partial A_1}{\partial n_1}}{A_1} - n_1 \frac{n_2 \frac{\partial A_2}{\partial n_2}}{A_2}] & \text{with equal property shares} \end{cases}$$
$$|J| = -c_2'' |H_1^1| - \frac{A_1 n_2^2 (u^2_{g1})^2 (u^2_{g2})^2}{A_2^3} .$$

Total differentiation of the free migration restriction and inserting comparative static results for $\frac{dg_1}{d\kappa_2}$ and $\frac{dg_2}{d\kappa_2}$ yields the impact of spillovers on the population size of the regions

$$\frac{dn_1}{d\kappa_2} = -n_2 c_2'' \frac{u^2_{\kappa 2}[-A_2^2 n_1 c_1'' + A_2 n_1 n_2 u^1_{g1} u^2_{g1} + A_1 n_2^2 (u^2_{g1})^2] - A_1 n_2 (A_1 n_2 + A_2 n_1) u^2_{g1} u^2_{g1\kappa 2}}{|J| A_2^2 (A_1 n_2 + A_2 n_1)} . \tag{7.11}$$

The sign of the denominators is negative if $|J| = -c_2'' |H_1^1| - \frac{A_1 n_2^2 (u^2_{g1})^2 (u^2_{g2})^2}{A_2^3} > 0$. This condition restricts marginal benefits from public goods to sufficiently small levels. As in the social optimum, a number of partial derivatives are part of the comparative statics. In addition, the marginal changes in utility towards an immigrant to a region play a prominent role since these changes are given by $A_i = n_i \frac{\partial v^i}{\partial n_i}$. Thus, for the current level of generality the interplay of the different effects is complicated. However, a few characteristics can be found.

- The impact of spillovers on the amount of the upstream public good is ambiguous. As indicated by the brackets, the different terms of the enumerator do not have the same sign. It is also not straightforward to use the impact of spillovers on $u^2_{\kappa 2}$ and u^2_{g1} to find ranges of spillovers with unambiguous comparative static effects.
- Downstream public good provision is efficient for a given size of the population. The impact of spillovers depends, therefore, solely on the size of the population of the regions and the sign of $\frac{dg_2}{d\kappa_2}$ is always the opposite of $\frac{dn_1}{d\kappa_2}$.
- For positive spillovers the enumerator is clearly negative, which leads to a negative impact of spillovers on the upstream population size if $|J| > 0$. For sufficiently negative spillovers this impact may become positive. Thus, the upstream population size may have an inverted U-shape, in spillovers. With an inverted U-shape the maximum size of the downstream population is reached for negative spillovers.

The results of decentralized non-myopic voting can be summarized in the following proposition.

Proposition 7.1 *A decentralized political-economy approach under the assumption that voters are aware of the correct migration responses does not generally lead to socially efficient public good provision and a socially efficient locations pattern of individuals in the migration equilibrium. This result does not depend on the rent distribution scheme.*

7.1.2 Centralization

Under centralization there is a single jurisdiction in charge of public good provision in both regions. With the political-economy approach, there is majority voting on upstream as well as downstream public good provision at the first stage of the game. Costs of public good provision are shared within the jurisdiction on an equal per capita basis. With the two alternative rent distribution schemes, income in region i is given by

$$y_i = \begin{cases} \frac{f^i(n_i,\bar{x})}{n_i} - \frac{c_i(g_i)+c_j(g_j)}{\bar{n}} & \text{with rents to residents} \\ f_n^i + \frac{r_i+r_j}{\bar{n}} - \frac{c_i(g_i)+c_j(g_j)}{\bar{n}} & \text{with equal property shares.} \end{cases} \tag{7.12}$$

At the second stage, individuals decide on their location. Solving the game by backward induction yields the equilibrium allocation.

At the second stage, an equilibrium distribution of individuals, without complete concentration of the population in one region, requires that all individuals have the same utility, $y_i + u^i(g_i, g_j) = y_j + u^j(g_i, g_j)$, and that nobody has an incentive for relocation.

Changes in public good provision induce migration. Total differentiation of the free migration restriction yields migration response functions, denoted by $n_i = n_i(g_i, g_j)$, that capture changes in the population size of a region in response to changes in public good provision. These migration responses hold for any given supply level of public goods, as long as no complete concentration of individuals in one region occurs. By the implicit function theorem, the derivatives of the upstream population size are given by

$$\begin{aligned} &\frac{dn_1}{dg_1} = -\frac{u_{g1}^1 - u_{g1}^2}{\frac{A_1}{n_1} + \frac{A_2}{n_2}} \\ &\frac{dn_1}{dg_2} = \frac{u_{g2}^2}{\frac{A_1}{n_1} + \frac{A_2}{n_2}} \\ &\text{with } A_i = \begin{cases} f_n^i - \frac{f^i}{n_i} & \text{with rents to residents} \\ \frac{n_i n_j (f_{nn}^i + f_{nn}^j)}{\bar{n}} & \text{with equal property shares.} \end{cases} \end{aligned} \tag{7.13}$$

In a two region economy, the downstream population size responds in the opposite way to the upstream population size. The denominator of the migration responses is the sum of marginal changes in utility in response to an immigrant to a region. If regions are over-populated so that assumption 6.2 of the last chapter holds, this sum is negative and the denominator has a negative sign. The sign of the enumerator does not depend on the level of public goods as with decentralized provision. With centralized provision, public goods are financed by a common budget and taxes do not appear in the enumerator.

An increase of the downstream public good increases the downstream utility, implying that the sign of the enumerator is positive. With centralized provision, the cost of the public goods are shared equally among all voters. Therefore it is only the additional downstream utility that influences the utility differential between the two regions. This would be different if utility where not linear in the private good that finances the public goods. A utility differential in favor of the downstream region induces migration to the downstream region and the sign of $\frac{dn_1}{dg_2}$ is negative.

The upstream public good has a positive effect on upstream utility and, depending on spillovers, either a positive or negative effect downstream. If the upstream marginal public good benefit is larger upstream than downstream, which might be violated in cases of very large positive spillovers, upstream utility increases more than downstream utility and the enumerator is positive. This leads to migration to the upstream region, $\frac{dn_1}{dg_1} > 0$. The migration response depends on the spillovers; it is large for very negative spillovers and small for positive spillovers.

At the first stage citizens vote on public goods. Proposals are adopted by a simple majority rule. Individuals vote at their initial location and take potential migration at the second stage into account. Therefore voters see the population distribution as a function of the supply of public goods, $n_i = n_i(g_i, g_j)$. The function $n_i(.)$ is the correctly anticipated migration response, whose derivatives are given by equation 7.13. In a centralized jurisdiction, two public goods need to be determined by voting. As in the previous chapters it is assumed that there are sequential votes on the supply of the upstream and downstream public good. It is assumed that the first vote is on the public good in region i and the second on the public good in region j. Since migration responses from the second stage are considered, the voting decisions are not dominant strategies as with myopic voting, and therefore the sequence of voting may be important. Solving the game by backward induction, the second vote, on the public good in region j considers migration responses and takes the public good in region i as given. The median voter from region m, which can be either the upstream or downstream region, has the utility function $y_m + u^m(g_i, g_j)$ and faces the following optimization problem in voting on the supply of the public good in region j:

$$\begin{aligned} &\max_{g_j \in \mathbb{R}_+} \; y_m + u^m(g_i, g_j) \\ &\text{with } n_m = n_m(g_i, g_j);\; y_i, y_j \geq 0;\; i, j, m \in \{1, 2\};\; i \neq j. \end{aligned} \tag{7.14}$$

The resulting first-order condition for g_j^c is given by

$$\begin{aligned} &-\frac{c_j'(g_j)}{\bar{n}} + u_{gj}^m + \frac{A_m}{n_m}\frac{dn_m}{dg_j} \leq 0 \quad g_j \geq 0 \text{ and } g_j \frac{\partial(y_m + u^m)}{\partial g_j} = 0; \\ &i, j, m \in \{1, 2\};\; i \neq j. \end{aligned} \tag{7.15}$$

Inserting the migration responses as derived from the free migration restriction, the first-order condition for g_j^c turns out to be independent from the location of the median voter (the location of the majority region). It reads as:

$$n_j u_{gj}^j + \frac{A_j}{A_i} n_i \, u_{gj}^i = c_j'(g_j) \frac{n_j + n_i \frac{A_j}{A_i}}{\bar{n}} \,; \quad i, j \in \{1,2\}; \quad i \neq j \,. \tag{7.16}$$

The above first-order condition determines a reaction function, $g_j = R_j(g_i)$, that captures how the second voting decision depends on the outcome of the first vote. Total differentiation of the first-order condition of g_j yields the slope of the reaction function

$$\frac{\partial R_j}{\partial g_i} = \begin{cases} \frac{n_i n_j D u_{gi}^i (u_{gj}^j - u_{gj}^i)}{-\frac{c_j''}{\bar{n}}(n_i A_j + n_j A_i)^3 + n_i n_j D (u_{gj}^j - u_{gj}^i)^2} & \text{with rents to residents} \\ \frac{u_{gi}^i (u_{gj}^j - u_{gj}^i)}{c_j''(f_{nn}^i + f_{nn}^j) + (u_{gj}^j - u_{gj}^i)^2} & \text{with equal property shares} \end{cases} \tag{7.17}$$
with $D = A_1 A_2 (n_2 \frac{n_1 f_{nn}^1}{A_1} + n_1 \frac{n_2 f_{nn}^2}{A_2} - 2\bar{n})$.

With equal property shares, the sign of the reaction function is positive for sufficiently small (negative) spillovers. A positive sign indicates that the public goods are strategic complements. For sufficiently large spillovers the derivative is negative and the public goods are strategic substitutes. The same also holds for residency-based rent distribution with a negative D. The term D may become positive if f^i is very concave so that f_{nn}^i is very negative and $f_{nn}^i \ll \frac{1}{n_i}(f_n^i - \frac{f^i}{n_i})$.

The first vote on g_i takes the second vote and the migration responses into account. The optimization problem and the first-order condition for g_i are therefore given by

$$\begin{aligned} &\max_{g_i \in \mathbb{R}_+} \; y_m + u^m(g_i, g_j) \\ &\text{with } n_m = n_m(g_i, g_j);\; g_j = R_j(g_i);\; y_i, y_j \geq 0;\; i, j, m \in \{1,2\};\; i \neq j, \end{aligned} \tag{7.18}$$

$$\begin{aligned} &-\frac{c_i'(g_i) + c_j'(g_i)\frac{\partial R_j}{\partial g_i}}{\bar{n}} + u_{gi}^m + u_{gj}^m \frac{\partial R_j}{\partial g_i} + \frac{A_m}{n_m}\left(\frac{dn_m}{dg_i} + \frac{dn_m}{dg_j}\frac{\partial R_j}{\partial g_i}\right) \leq 0 \\ &g_i \geq 0 \text{ and } g_i \frac{\partial(y_m + u^m)}{\partial g_i} = 0\,, \quad i, j, m \in \{1,2\};\; i \neq j. \end{aligned} \tag{7.19}$$

Assuming that the median voter anticipates the correct migration responses and the correct slope of the reaction function, the first-order condition for public good provision in region i simplifies to:

$$n_i u_{gi}^i + \frac{A_i}{A_j} n_j \, u_{gi}^j = c_i'(g_i) \frac{n_i + n_j \frac{A_i}{A_j}}{\bar{n}}\,, \qquad i, j \in \{1,2\};\; i \neq j\,. \tag{7.20}$$

As in the vote for g_j, the first-order condition for g_i turns out to be the same no matter where the median voter is located. Also the sequence of voting has no influence on the voting outcome. Thus the assumption of sequential voting is not crucial in the present context, since the most preferred allocation of public goods is the same for all voters and voting cycles do not occur. Note that the initial population distribution has no influence on the voting outcome, since the median voters are representative voters with respect to preferences and their ability to anticipate the correct migration responses.

With the assumption of the same property shares of land of all citizens, A_i equals A_j, since $\frac{n_i n_j (f^i_{nn}+f^j_{nn})}{\bar{n}} = \frac{n_j n_i (f^j_{nn}+f^i_{nn})}{\bar{n}}$. Therefore the fraction $\frac{A_i}{A_j}$ is unity and the public goods are provided according to the Samuelson rule. In addition the migration equilibrium is locationally efficient, since the net-benefit of an immigrant to a region $(f^i_n - y_i)$ is the same in both regions because $f^i_n - (f^i_n + \frac{r_i+r_j}{\bar{n}} - \frac{c_i+c_j}{\bar{n}}) = f^j_n - (f^j_n + \frac{r_i+r_j}{\bar{n}} - \frac{c_i+c_j}{\bar{n}})$. Thus the outcome is the same as in the social optimum. This is not the case with residency-based rent distribution, since A_i does not generally equal A_j and the upstream and the downstream supply of the public goods are inefficient as is the locational pattern.

The second-order conditions can be derived for the optimization problem of a representative voter for the first and second vote on g_i and g_j, respectively. A local maximum as an interior solution requires a negative definite Hessian matrix. For the two one-dimensional optimization problems and residency-based rent distribution this leads to

$$\begin{aligned}
&|H^i_1| = -\frac{c''_i}{\bar{n}} - \frac{c''_j (u^i_{gi} - u^j_{gi})^2 n_i n_j D}{\bar{n}|H^j_1|(A_i n_j + A_j n_i)^3} < 0 \\
&|H^j_1| = -\frac{c''_j}{\bar{n}} + \frac{(u^j_{gj} - u^i_{gj})^2 n_j n_i D}{(A_j n_i + A_i n_j)^3} < 0 \\
&\text{with } D = A_i A_j (n_j \frac{n_i f^i_{nn}}{A_i} + n_i \frac{n_j f^j_{nn}}{A_j} - 2\bar{n}).
\end{aligned} \tag{7.21}$$

D is negative unless f^i is very concave so that f^i_{nn} is very negative and $f^i_{nn} \ll \frac{1}{n_i}(f^i_n - \frac{f^i}{n_i})$. With a negative D, the second-order sufficient conditions may be violated for high marginal benefits from the public goods or for negative or small positive values of spillovers. Thus, the combination of low marginal public good benefits and large positive spillovers makes it more likely that the second-order sufficient conditions are met.

For equal property shares the second-order sufficient conditions for a local maximum lead to the following requirements for the first and second vote on g_i and g_j. The condition $|H^i_1| < 0$ is in fact the same requirement as $|\bar{H}_5| < 0$, which was the crucial condition for the social optimum (see equation 6.3).

$$\begin{aligned}
&|H^i_1| = -c''_i - \frac{c''_j (u^i_{gi} - u^j_{gi})^2}{-|H^j_1|(f^i_{nn}+f^j_{nn})} < 0 \\
&|H^j_1| = -c''_j - \frac{(u^j_{gj} - u^i_{gj})^2}{f^j_{nn}+f^i_{nn}} < 0\,.
\end{aligned} \tag{7.22}$$

After voting on the supply of public goods, citizens can migrate at the second stage of the game. Since the supply of public goods at the first stage is optimized with respect to the anticipated final population distribution, migration takes place if the final population distribution deviates from the initial population size of the regions. With the assumption of over-populated regions (assumption 6.2), utility differentials between regions are eliminated by migration and an interior migration equilibrium is reached. This leads to the following conditions that hold for concave production functions (see also the explanation of equation 6.19).

$$
\begin{aligned}
\frac{\partial(v^i-v^j)}{\partial n_i} &= \frac{f_n^i-\frac{f^i}{n_i}}{n_i}+\frac{f_n^j-\frac{f^j}{n_j}}{n_j}<0 && \text{with rents to residents}\\
\frac{\partial(v^i-v^j)}{\partial n_i} &= f_{nn}^i+f_{nn}^j<0 && \text{with equal property shares.}
\end{aligned}
\tag{7.23}
$$

Assuming that the above first and second-order conditions determine a global optimum, the centralized migration equilibrium has the following characteristics. Due to the free migration restriction the utility of every individual is the same. Since non-myopic voters are aware of this restriction, they are not only maximizing their own utility but also the welfare of the whole economy. With equal property shares, the migration equilibrium is socially efficient, since the fraction $\frac{A_i}{A_j}$ is unity which ensures that the Samuelson rule holds for public goods and indicates that the social net-benefits of an immigrant are equalized across regions.

With residency-based rent distribution, the migration equilibrium may not be efficient. The first-order conditions for public good provision (see equation 7.20) show that locational inefficiency is accompanied by an inefficient supply of public goods. In the migration equilibrium there will be an over- or under-supply of public goods with regard to the Samuelson rule. Since $A_i = f_n^i - \frac{f^i}{n_i}$ is always negative for concave production functions, the quotient $\frac{A_1}{A_2}$ is always positive.

- $\frac{A_1}{A_2} < 1$: For negative and sufficiently small positive spillovers this distortion causes an over-supply of the upstream public good and an under-supply of the downstream public good. Since public goods are financed by all individuals, the combination of an over- and under-supply clearly increases the upstream population and decreases the downstream population. For very large positive spillovers there may not be an over-supply of the upstream public good anymore. However, the under-supply of the downstream public good is independent of the spillover level.
- $\frac{A_1}{A_2} > 1$: For negative and sufficiently small positive spillovers this distortion causes an under-supply of the upstream public good and an over-supply of the downstream public good. Since public goods are financed by all individuals, the combination of an under- and over-supply clearly decreases the upstream population and increases the downstream population. For very large positive spillovers there may not be an under-supply of the upstream public good anymore, but the over-supply of the downstream public good remains.

The fraction $\frac{A_1}{A_2}$ can be seen as a measure of locational inefficiency, since the deviation of the fraction from unity is a measure of how large the social net-benefits of an immigrant to a region deviate between regions. With rent distribution to residents, the fraction does not directly depend on public goods and spillovers, since $\frac{A_1}{A_2} = \frac{f_n^1 - f_1/n_1}{f_n^2 - f_2/n_2}$. Depending on the type of production function one can find that inefficient locational choices and inefficient public good provision mitigate or amplify each other. For production functions with $\frac{\partial(f_n^i - \frac{f_i}{n_i})}{\partial n_i} < 0$, the partial derivative of the marginal net-benefit of an immigrant to a region is negative.[4] For this type of production function the deviation

[4] The derivative is given by $\frac{\partial(f_n^i - \frac{f_i}{n_i})}{\partial n_i} = f_{nn}^i - \frac{1}{n_i}(f_n^i - \frac{f^i}{n_i})$.

from the Samuelson rule in public good provision reduces locational inefficiency, since the difference in the net-benefits $(f_n^i - y_i) - (f_n^j - y_j)$ decreases. With $\frac{\partial(f_n^i - \frac{f_i}{n_i})}{\partial n_i} > 0$, the partial derivative of the marginal net-benefit of an immigrant to a region is positive. In this case the deviation from the Samuelson rule in public good provision increases the difference in the net-benefits $(f_n^i - y_i) - (f_n^j - y_j)$. Thus, for this type of production function inefficient public good supply and locational inefficiency exacerbate each other.

Locational inefficiency implies that the relocation of an individual can be Pareto-improving, since the net-benefit of an immigrant to a region is not the same for both regions. However, for a given locationally inefficient migration equilibrium no individual can improve his utility by migration. An immigrant to the region with the higher net-benefit improves aggregated welfare for a given level of public good supply. With the given tax and rent distribution scheme, the welfare gains from migration are, however, unevenly distributed, since after migration the population of the origin region is better off than the population of the immigration region. Since a migrant does not improve his utility, there exists a locationally inefficient migration equilibrium. A locationally inefficient migration equilibrium indicates that the tax scheme is imperfect. The population of the region with the higher marginal net-benefit pays too much for public goods and the population with the lower net-benefit pays too little.[5] To mitigate this drawback of the tax scheme, the provision of public goods deviates from the Samuelson rule. The public good is over-supplied in the region that pays too much tax and it is under-supplied in the region which pays too little tax.

A comparative static analysis shows the impact of spillovers on the equilibrium allocation under centralization. There are two first-order conditions for upstream and downstream public good provision. Together with the free migration restriction the comparative static effects can be determined. With equal property shares, the comparative statics are the same as in the social optimum (see equation 6.4 in the last chapter). For rent distribution to residents and interior solutions, the unidirectional spillover κ_2 influences upstream and downstream public good provision as follows:

$$\begin{aligned} \frac{dg_1}{d\kappa_2} &= n_2 \frac{-n_1 c_2'' u_{\kappa 2}^2 (u_{g1}^1 - u_{g1}^2)(A_1 n_2 + A_2 n_1) D + u_{g1\kappa 2}^2 A_1 [c_2''(A_1 n_2 + A_2 n_1)^3 - \bar{n} n_1 n_2 (u_{g2}^2)^2 D]}{|J| \bar{n} (A_1 n_2 + A_2 n_1)^4} \\ \frac{dg_2}{d\kappa_2} &= \frac{n_2 n_1 u_{g2}^2 D\, [c_1'' u_{\kappa 2}^2 (A_1 n_2 + A_2 n_1) - \bar{n} n_2 u_{g1\kappa 2}^2 (u_{g1}^1 - u_{g1}^2) A_1]}{|J| \bar{n} (A_1 n_2 + A_2 n_1)^4} . \\ |J| &= \frac{c_1'' c_2''}{\bar{n}^2} - \frac{[c_2''(u_{g1}^1 - u_{g1}^2)^2 + c_1''(u_{g2}^2)^2] n_1 n_2 D}{\bar{n}(A_1 n_2 + A_2 n_1)^3} \end{aligned} \tag{7.24}$$

Total differentiation of the free migration restriction and inserting comparative static results for $\frac{dg_1}{d\kappa_2}$ and $\frac{dg_2}{d\kappa_2}$ yields the impact of spillovers on the size of the upstream region:

$$\frac{dn_1}{d\kappa_2} = \frac{n_1 n_2 c_2'' [c_1'' u_{\kappa 2}^2 (A_1 n_2 + A_2 n_1) - \bar{n} n_2\, u_{g1\kappa 2}^2 (u_{g1}^1 - u_{g1}^2) A_1]}{|J| \bar{n}^2 (A_1 n_2 + A_2 n_1)^2} . \tag{7.25}$$

[5] As with decentralized public good supply, the problem of locational inefficiency could be completely solved by inter-regional transfers.

With $J > 0$ the denominator of all three comparative statics is positive.[6] D can be positive or negative. It is positive if f^i is very concave so that f^i_{nn} is very negative and $f^i_{nn} \ll \frac{1}{n_i}(f^i_n - \frac{f^i}{n_i})$. Without further qualifications to the spillover level, the comparative statics are ambiguous. As mentioned with respect to the comparative statics of the decentralized migration equilibrium, most partial derivatives depend on the spillover level. Assuming, as for the social optimum, that the second-order derivatives of the production and cost functions are not significantly influenced by spillovers, two expressions remain. $u^1_{g1} - u^2_{g1}$ is decreasing in spillovers since u^2_{g1} is proportional to the spillovers level. The expression is positive unless spillovers are very large and marginal public good benefits in the downstream region are large. $u^2_{\kappa 2}$ is positive and depends on the supply level of the upstream public good. Concentrating on these two effects the influence of spillover is as follows.

- With a positive denominator, the sign of the enumerator indicates how the spillover level influences g_1. If D is zero, the impact of spillovers on the amount of g_1 is positive. If D is sufficiently positive or negative, the comparative static may become ambiguous. Large marginal public good benefits and strong negative spillovers tend to strengthen the impact of D on the comparative static.
- The impact of changing spillovers on downstream public good provision is qualitatively the same (the opposite) to that on the upstream population size if D is positive (negative).
- The first term in the square brackets of the enumerator increases in spillovers for $\frac{\partial g_1}{\partial \kappa_2} > 0$. The second term decreases. This is the same pattern as in the social optimum and may imply an inverted U-shaped form of the upstream population size in spillovers if the denominator is positive.

Proposition 7.2 *Centralized simple majority voting, under the assumption that voters anticipate the correct migration responses and the correct reaction function, and assumption 6.2, leads to an allocation that is most preferred by all voters independent of their initial location and the sequence of voting.*

i) With equal property shares the migration equilibrium is socially efficient.

ii) With residency-based rent distribution the migration equilibrium is not generally socially efficient. If the migration equilibrium is locationally efficient without spillovers and if the downstream population size is U-shaped in spillovers with it's maximum without spillovers, the locational pattern is increasingly inefficient in spillovers as long as $\frac{\partial(f^i_n - f_i)}{\partial n_i}$ *has the same sign for all equilibrium allocations.*

Part i) of the proposition states what was found above. With equal land shares owned by all citizens, the centralized migration equilibrium is socially efficient.

Part ii) of the proposition states that efficiency is not always given for residency-based rent distribution. Inefficiencies are present for most spillover levels and under certain

[6] If there would be simultaneous voting on g_1 and g_2, the second-order condition would in fact require $J > 0$ for an interior maximum.

conditions it holds that negative as well as positive spillovers increase the locational inefficiency of the migration equilibrium.

With locational inefficiency, one of the following inequalities holds: $f_n^1 - y_1 \lesseqgtr f_n^2 - y_2 \Leftrightarrow f_n^1 - \frac{f_1}{n_1} - \frac{c_1+c_2}{\bar{n}} \lesseqgtr f_n^2 - \frac{f_2}{n_2} - \frac{c_1+c_2}{\bar{n}} \Leftrightarrow f_n^1 - \frac{f_1}{n_1} \lesseqgtr f_n^2 - \frac{f_2}{n_2}$. It is apparent that locational efficiency depends solely on the regional production functions and not on the cost shares from the public goods. If the term $f_n^i - \frac{f_i}{n_i}$ is strictly monotone in labor and has the same sign of the slope for both regional production functions, locational efficiency is possible for exactly one population distribution. All other equilibrium population distributions are locational inefficient. The further the deviation from the one efficient population distribution, the larger the locational inefficiency of the migration equilibrium. If the downstream population size is U-shaped in spillovers, there is a range of spillovers where an increase in spillovers increases locational inefficiency and another range where the opposite holds. Assuming that purely local public goods induce a locationally efficient migration equilibrium that is characterized by the smallest downstream equilibrium population (the minimum of the U), negative as well as positive spillovers imply locational inefficiency. Therefore larger positive or negative spillovers increase locational inefficiency. With regard to the downstream public good, it was found above that the extent of locational inefficiency determines the deviation from the Samuelson rule. For the upstream public good, an increase in locational inefficiency does not always increase the deviation from the Samuelson rule.

It is somehow surprising that the inefficiencies of centralized supply of public goods may increase rather than decrease in spillovers. This result—which only holds for residency-based rent distribution—is contrary to what was found in the previous chapters and what is established in the literature on fiscal federalism. However, one can note that it is not primarily the spillover that causes the inefficiency, but rather the inefficient population distribution. If there would be a mechanism to ensure locational efficiency, the supply of the public goods would be efficient independent of the level of spillovers.

7.1.3 Decentralization or centralization?

Based on the analysis of decentralized and centralized voting the two federal organizations can be compared. With rent distribution to land owners, who own land by equal property shares, the social optimum is reached for centralization. Thus, decentralized supply of the public goods cannot yield better outcomes than the centralized supply and centralization is the recommended federal setting. This result shows that it is crucial to know if voters are aware of migration flows or not. Ignorant voters—as assumed in the previous chapter—only consider their own utility and the political-economy majority constellation drives the results with centralized voting. Since decentralization avoids the exploitation of the minority, this federal setting was better for most spillover values. With non-myopic voting, citizens are aware that the majority cannot exploit the minority, since migration equalizes the utility within the whole economy.

With residency-based rent distribution the comparison of decentralization and centralization is less clear. A comparison cannot only rely on the first-order conditions and the comparative static properties of the different migration equilibria, but it must also consider the absolute utility level of the migration equilibrium. This is possible with a functional specification of the model. The same assumptions are made as for the social optimum (see section 6.2.2) and the utility is given by $y_i + \lambda(g_i + \kappa_i g_j)$, the regional production functions by $n_i - \frac{n_i^2}{2\bar{x}}$, and the cost functions of the public goods by $\frac{g_i^2}{2}$. The explicit solutions of the migration equilibria for decentralization and centralization with rent distribution to residents are given in the appendix to this chapter. The following discussion illustrates the role of spillovers for a given parameter set of marginal public good benefits, λ, land endowments, $\bar{x}$, and the total population size, $\bar{n}$. In addition, the appendix also illustrates the influence of marginal public good benefits on the equilibrium allocation.

A decentralized migration equilibrium exists if $\frac{\partial(v^1(n_1)-v^2(n_1))}{\partial n_1} < 0$. Inserting the equilibrium population size into the derivative yields

$$\begin{aligned} &\frac{\partial(v^1(n_1)-v^2(n_1))}{\partial n_1} = \bar{x}\lambda^2 - 2 + \frac{(\bar{x}\lambda^2+E-1)^2}{4\,\kappa_2^2\,\lambda^2\bar{x}} < 0 \\ &\text{with } E = [1 + \lambda^2\bar{x}(\lambda^2\bar{x}(1-4\kappa_2) + 4\kappa_2(1+\kappa_2) - 2)]^{\frac{1}{2}}. \end{aligned} \tag{7.26}$$

With high marginal benefits from public goods or a large land endowment there may not be a migration equilibrium under decentralization. A graphical illustration the existence condition is given in the appendix (see figure 7.9). The following comparison of decentralization and centralization is made for parameter values that allow inner solutions. For these parameter values the decentralized migration equilibria exist. Existence of the migration equilibrium is given for public good provision under centralization.

The preceding and also the following analysis focuses on interior solutions. The graphical illustration of the equilibrium allocation in the appendix shows the parameter constellations for which corner solutions are relevant. Beside spillovers, different marginal benefits from public goods are considered. Large marginal benefits from public goods and negative spillovers lead to corner solutions without upstream public good provision. These corner solutions occur for a range of parameters for decentralized provision and also for socially optimal provision (see figure 7.7 and 6.2). However, it is not relevant for centralized provision, as figure 7.10 shows. Corner solutions are not only possible with no upstream public good provision, but also with the complete concentration of the population in the downstream region.

Below are graphical illustrations of the allocations of both federal settings and the social optimum and how they depend on the spillover level. All other parameters are assumed to be constant. For the illustrated parameter range, the second-order conditions for interior solutions are satisfied. For decentralization and upstream public good provision, this is illustrated in figure 7.8 of the appendix. For downstream public good provision, the second-order condition is always satisfied. With centralized voting the second-order conditions, as stated by the Hessian determinants, are satisfied, since they reduce to the conditions $|H_1^j| = -\frac{1}{\bar{n}} < 0$ and $|H_1^i| = \frac{1}{\bar{n}^2} > 0$ because the term D in equation 7.22 is zero.

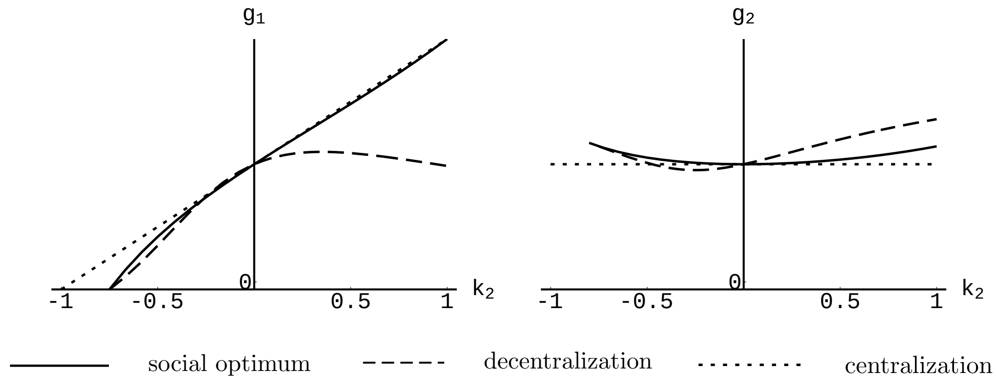


Figure 7.1: Comparison of public good provision with non-myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$

Upstream and downstream public good provision is illustrated in figure 6.5. Without spillovers, the decentralized and centralized supply pattern is the same as in the social optimum. If spillovers are present, both federal settings provide larger or smaller amounts than the socially optimal supply levels. The most obvious deviation occurs for decentralized provision and positive spillovers. Note that sup-optimal public good provision does not necessarily imply a deviation from the Samuelson rule, since this rule can be followed also for very inefficient locational patterns.

As discussed above, a deviation from the Samuelson rule is accompanied by locational inefficiency. An illustration of the magnitude of locational inefficiency is given in figure 7.2, which shows the fraction $\frac{A_1}{A_2}$ for decentralized and centralized voting. With the functional specification, the fraction $\frac{A_1}{A_2}$ is unity for purely local public goods so that both federal settings are locationally efficient if no spillovers are present. With decentralized voting, $\frac{A_1}{A_2}$ exceeds unity for negative spillovers. Only the corner solution without the upstream public good (and no spillovers) achieves locational efficiency. As argued in the section on decentralization (7.1.1), this implies that the social net-benefit of an immigrant to the downstream region is larger than to the upstream region, along with an under-supply of the upstream public good. For positive spillovers, $\frac{A_1}{A_2}$ is below unity, which also induces an under-supply of the upstream public good. Locational inefficiency is very large for intermediate negative spillovers or for strong positive spillovers. Under centralization, the fraction $\frac{A_1}{A_2}$ is less than unity if spillovers are present. This implies (see section 7.1.2) an under-supply of the downstream public good. The upstream public good is over-supplied as long as spillovers are sufficiently small. As stated in proposition, 7.2 locational inefficiency is large when spillovers are extreme.

The population size of the upstream region has an inverted U-shape in spillovers for socially optimal provision as well as with decentralized or centralized supply. Spillovers have a larger impact on the population size for both federal settings than for the social optimum, since the range between the respective maximum and minimum upstream population size is larger.

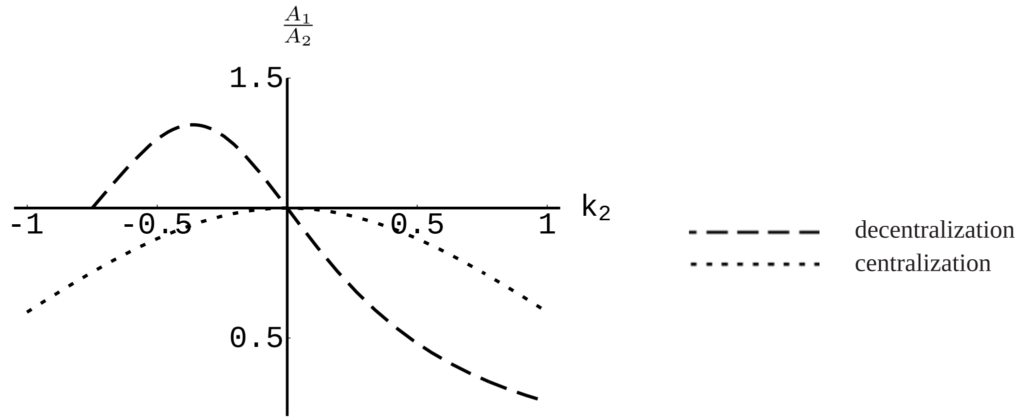


Figure 7.2: Locational efficiency with non-myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$

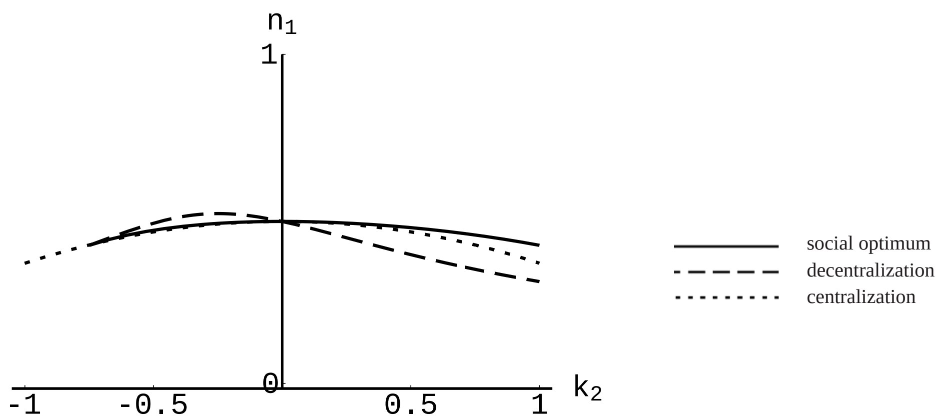


Figure 7.3: Comparison of population distribution with non-myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$

Utility increases in spillovers. This is the case for the social optimum as well as decentralization and centralization. There is only a very small deviation from the social optimum for centralization, whereas decentralized public good provision falls short of the social optimum for positive spillovers, particularly if they are large.

After this brief overview, both federal organizations are described in more detail below. The main drawback of decentralization is the low upstream supply with the public good when spillovers are positive. This reflects the missing opportunity of downstream citizens to pay for the upstream provision. With negative spillovers, decentralized provision is close to the social optimum. Thus, there is an asymmetry between positive and negative spillovers. Whereas it is very inefficient for the upstream voters to increase the provision for positive spillovers, it is possible to decrease the supply for negative spillover without accepting a large deviation from the socially optimal utility level. For very negative spillovers, decentralized provision leads to a corner solution without upstream

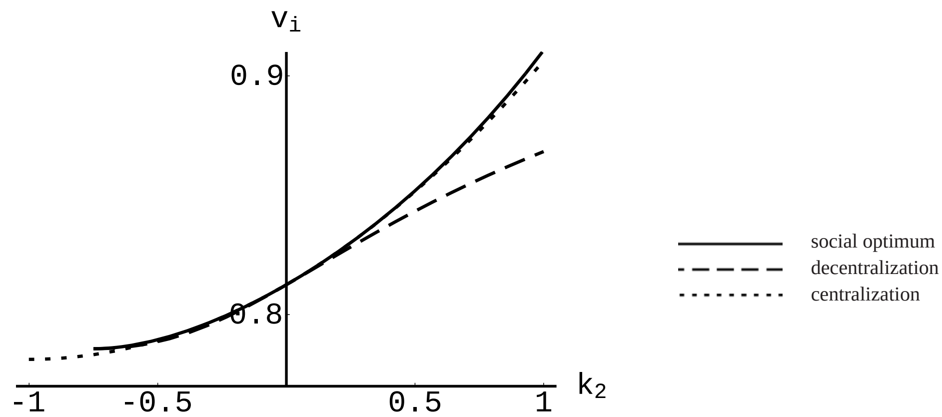


Figure 7.4: Comparison of utility with non-myopic voting for $\lambda = 0.5$, $\bar{n} = 1$, and $\bar{x} = 1$

provision. The corner solution is reached for the same spillover level as in the social optimum. For this corner solution, decentralization reaches the social optimum, since the utility level is also the same. With decentralized jurisdictions and interior solutions, the downstream public good is provided according to the Samuelson rule, therefore the deviation from the social optimum reflects the inefficient population distribution across regions. The upstream population size first rises and then falls in spillovers, and the maximal size is reached for negative spillovers. The deviation from the socially optimal upstream population size is particularly large for high positive spillovers. This is not surprising, since citizens are drawn to the downstream region that receives the positive spillovers without having to pay for the upstream public good.

With centralized provision of the public goods, the deviation from the social optimum is relatively large for large positive or negative spillovers. However, the absolute deviation tends to be smaller than with decentralized provision, particularly with respect to the upstream public good. The deviation is also a deviation from the Samuelson rule, as figure 7.1 shows. This is directly apparent for the downstream public good since it does not change in spillovers at all, despite a changing locational pattern of the population. Thus, the illustrated allocations show that there is an under-provision of the downstream public good for positive as well as negative spillovers. In the preceding section on centralization (7.1.2) it was argued that distorted public good supply can mitigate locational inefficiency for regional production functions with the property $\frac{\partial(f_n^i - \frac{f_i}{n_i})}{\partial n_i} < 0$. For the production function $f^i(n_i) = n_i + \frac{n_i^2}{2\bar{x}}$ the derivative is given by $\frac{\partial(f_n^i - \frac{f_i}{n_i})}{\partial n_i} = -\frac{1}{2} < 0$, which implies that the distorted supply of public goods brings the fraction $\frac{A_i}{A_j}$ closer to unity. The distorted public good supply—an over-supply for most spillover values upstream and an under-supply downstream—influences locational choices in favor of the upstream region. Thus, without the distorted public good supply the upstream region would be even smaller than illustrated in figure 7.3.

For almost all spillover levels with interior solutions, centralization is superior to de-

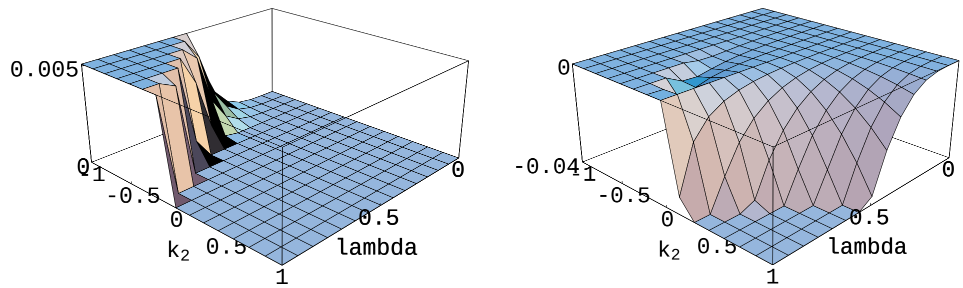


Figure 7.5: Utility difference between decentralization and centralization with non-myopic voting for $\bar{n} = 1$ and $\bar{x} = 1$. The vertical axis shows the utility difference $v^d - v^c$. Left: advantage for decentralization if $v^d - v^c > 0$. Right: advantage for centralization if $v^d - v^c < 0$. For large λ and negative κ_2 corner solutions are possible, invalidating the comparison between the federal settings.

centralization. This is in sharp contrast to the previous chapter where voters where not aware of migration responses. The utility difference of decentralized and centralized provision is illustrated in figure 7.5. This numerical comparison, which is based on a given total population and a certain land endowment, shows that centralization is superior to decentralization for most spillovers and marginal benefit levels. If the difference $v^d - v^c$ is negative, centralization is superior and if the difference is positive the opposite holds. Decentralization only leads to larger utility levels if there are negative spillovers and high marginal benefits. Note, however, that, for most of these parameter values, corner solutions occur for the socially optimal and decentralized allocations (no supply of the upstream public good). Therefore, for these parameter values, the illustrated comparison is not valid. In case of a corner solution without the upstream public good, decentralization leads to the social optimum, since the downstream public good is efficiently provided according to the Samuelson rule. With the corner solution, locational efficiency prevails as figure 7.2 shows. Thus, the centralized allocation without a corner solution (see figure 7.10) cannot be superior to the decentralized allocation for the relevant parameter values.

The preceding analysis that relied on numerical examples as well as on more general considerations leads to the following proposition that summarizes the results.

Proposition 7.3 *With simple majority voting, under the assumption that voters anticipate the correct migration responses and the correct reaction functions and assumption 6.2, the comparison of decentralization and centralization is independent of the initial location of voters.*

i) With equal land ownership of all individuals, a decentralized political-economy approach is never superior to a centralized approach since the latter achieves the socially optimal allocation.

ii) With rent distribution to residents and the adopted functional specification of the *production and cost functions, centralization is superior to decentralization if $v^d - v^c < 0$, and decentralization is superior to centralization if $v^d - v^c > 0$. Figure 7.5 shows that centralization is superior to decentralization for all positive spillover levels.*

7.2 Flood-prone areas

As with myopic voting, the model can be used to analyze flood-prone areas and the linkage between public flood defense and migration. Assuming again that region 2 is not exposed to flood risk, it follows that u^2_{g2} as well as u^2_{g1} are zero, since there is only one purely local public good in the economy.

The public good—flood defense—can again be supplied by a single issue authority or by a large jurisdiction that comprises the high-benefit region and the region without benefits. The optimization problems for these two settings are analogous to those of decentralization and centralization. The first-order conditions from equation 7.5 and 7.16 can be adapted to the case of only one public good that is provided in region 1. This leads to

$$\begin{aligned} & n_1 u^1_{g1} = c'_1(g_1) && \text{with a single issue authority} \\ & n_1 u^1_{g1} = c'_1(g_1)\frac{n_1 + n_2\frac{A_1}{A_2}}{\bar{n}} && \text{with a large jurisdiction} \\ & \text{with } A_i = \begin{cases} f^i_n - \frac{f^i)}{n_i} & \text{with rents to residents} \\ \frac{n_i n_j (f^i_{nn} + f^j_{nn})}{\bar{n}} & \text{with equal property shares.} \end{cases} \end{aligned} \tag{7.27}$$

In a single issue authority the public good is provided according to the Samuelson rule for both rent sharing schemes. Locational efficiency is not generally given, since no mechanism ensures that $f^1_n - \frac{f^1 - c_1}{n_1} = f^2_n - \frac{f^2}{n_2}$ for residency based rent distribution or that $f^1_n - (f^1_n + \frac{r_1+r_2}{\bar{n}} - \frac{c_1}{n_1}) = f^2_n - (f^2_n + \frac{r_1+r_2}{\bar{n}})$ with equal property shares. In a large jurisdiction with equal property shares, any migration equilibrium is locationally efficient, since $f^1_n - (f^1_n + \frac{r_1+r_2-c_1}{\bar{n}}) = f^2_n - (f^2_n + \frac{r_1+r_2-c_1}{\bar{n}})$. Thus, the fraction $\frac{A_1}{A_2}$ is unity and the public good is provided efficiently. With residency-based rent distribution this is not generally the case, since locational efficiency requires $f^1_n - \frac{f^1-c_1}{\bar{n}} = f^2_n - \frac{f^2-c_1}{\bar{n}}$.

Assuming that the first-order condition determines a global optimum, one can conclude that single issue authorities do not generally lead to efficient migration equilibria. Rather, this is possible with a large jurisdiction and equal property shares. Again, efficiency may not be given for residency-based rent distribution. However, whereas with myopic voting there was a rather general recommendation in favor of a single issue authority, just the opposite may be best with non-myopic voting and equal property shares, because a large jurisdiction is efficient.

By adopting functional forms, the equilibrium allocation of the two federal settings can be illustrated. A similar setting is assumed as before and the utility is given by $y_i + \lambda_i g_i$, the regional production functions by $n_i - \frac{n_i^2}{2\bar{x}}$, and the cost function for the public good by $\frac{g_1^2}{2}$. The public good is purely local, so that no spillovers are present.

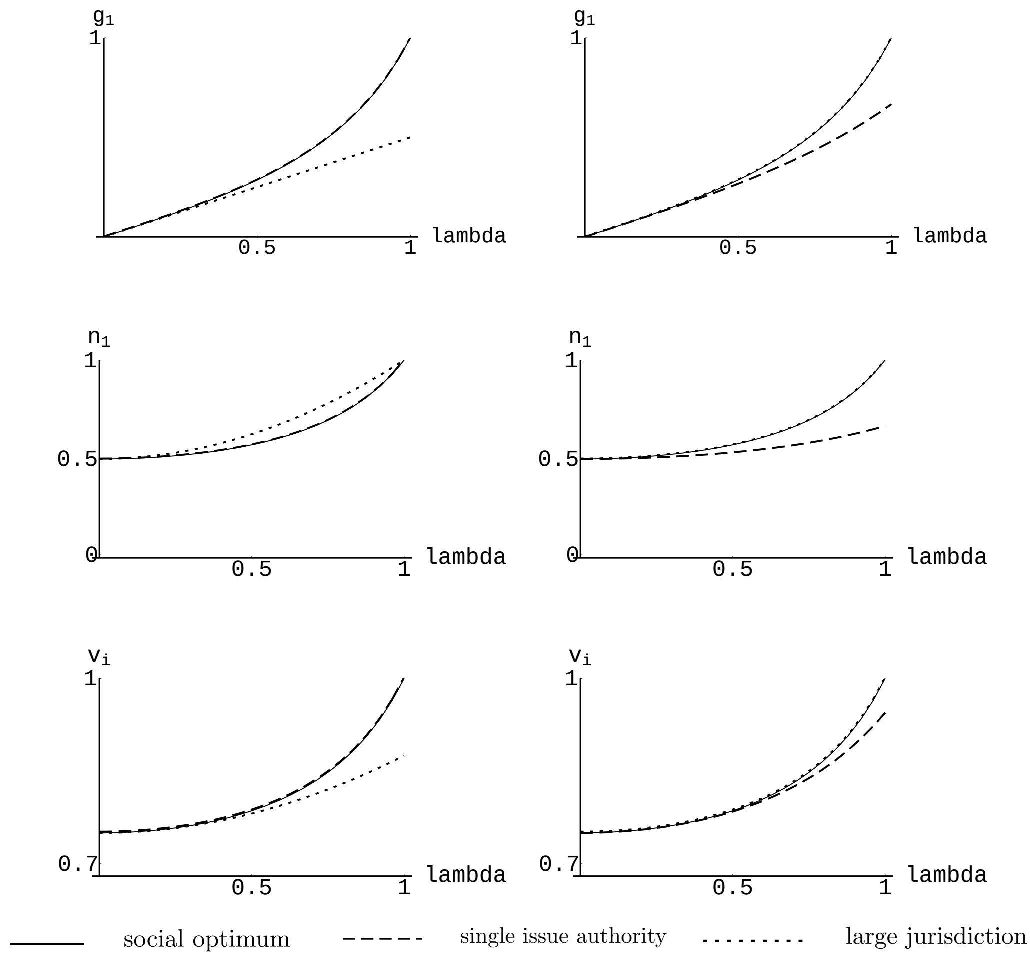


Figure 7.6: Flood-prone areas and the migration equilibrium with non-myopic voting for $\bar{n} = 1$, and $\bar{x}_1 = \bar{x}_2 = 1$. Left: residency-based rent distribution. Right: equal property shares. *Lambda* stands for λ_1.

Since there is only one public good, it holds that $\lambda_1 > 0$ and $\lambda_2 = 0$. The explicit solutions of the migration equilibria for the social optimum, a single issue authority, and a large jurisdiction are given in the appendix to this chapter.

Figure 7.6 shows the impact of the marginal public good benefit in the high-benefit region on the migration equilibrium. The outcome is shown for residency-based rent distribution (left side) and equal property shares (right side). With equal property shares the allocation is efficient if the public good is provided within a large jurisdiction, and it is not efficient with a single issue authority. This follows directly from the first-order conditions. A single issue authority provides too little of the public good. With residency-based rent distribution, the single issue authority is efficient, whereas this is not the case with a large jurisdiction, because there is too little public good supply. Note that the efficient outcome with a single issue authority is only given with the specified functional form and may not hold for other cases.

Similar to the discussion in section 6.5, the effects of flood defense can be compared to a status quo without flood defense. As before, for a federal setting that achieves the social optimum, the following argument can be made: In situations of extreme land scarcity outside the flood plain, flood defense has a large positive impact on welfare and a small impact on human encroachment on flood-prone areas, compared to the status quo without flood defense. With abundant land outside the flood plain, the impact of flood defense on welfare is positive but small and the impact on human encroachment on flood prone-areas is large. As figure 7.11 in the appendix shows, this argument carries over to non-myopic voting and federal settings that do not achieve the social optimum.

One can conclude that non-myopic citizens vote for flood defense no matter if they live in a flood-prone area or not. The comparison of the two federal settings does not allow a general recommendation as to whether public goods with spatially heterogeneous benefits shall be provided by a large jurisdiction or a single issue authority. It is, however, possible to state that single issue authorities ensure an efficient supply of public goods, whereas they may fail to achieve locational efficiency. Large jurisdictions lead to efficient outcomes, if the rent distribution schemes promotes efficient locational choices. Flood defense tends to have a large impact on the population distribution when the potential welfare gains are low. The larger the marginal public good benefits, the less important the influence of land size outside the flood plain on the equilibrium utility level.

7.3 Concluding remarks

This chapter analyzed a local economy with free migration and non-myopic voters and found quite different results than the previous chapter with myopic voting (chapter 6). Non-myopic voters are aware of the free migration restriction and therefore vote for a supply pattern that approximates the social optimum. However, due to the financing restriction of a federal organization the social optimum is not always attainable. With unidirectional spillovers and depending on the federal setting the supply of public goods deviates from the Samuelson rule whenever the migration equilibrium is locational inefficient. Independent of the federal organizations it turned out that the initial population distribution (and the resulting political majority under centralization) has no influence on the equilibrium allocation. Unlike with myopic voting and also unlike the basic model without migration the advantages and disadvantages of decentralization and centralization are not monotone in spillovers implying that one cannot generally recommend decentralization for small and centralization for large spillover levels. Such a pattern was suggested in the earlier chapters. Given the “right” rent distribution scheme it even turned out that centralization may be generally efficient and that decentralization increasingly falls short of the socially optimal utility level as spillovers grow.

With non-myopic citizens there is no general recommendation that flood defense shall be provided by a single issue authority. Even though single issue authorities are efficient in public good supply, they may trigger inefficient locational choices. In contrast, the outcome is efficient in a large jurisdiction and equal property shares.

The two chapters on local public goods and migration made a number of assumptions that may be relaxed or modified. First, given the sequence of events it was assumed that the final residents pay for public goods. If it is the initial population of a region that pays taxes, locational decisions are not influenced by the cost-shares for public goods. This weakens the case for the complete concentration of all citizens in one region because migration is not driven by the promise of lower taxes. The migration equilibrium is not generally characterized by equal utility of all citizens but only by equal utility of those citizens with the same initial location. Thus, also with non-myopic voting the initial population has an influence on the final outcome. Second, the sequence of voting and migration can be modified. With a reversed timing of events—migration before voting—some arguments of the previous discussion can be used. With voting at the second stage it is always beneficial to just consider the individual cost-shares and benefits and neglect spillovers to other regions, since locational choices are already made. This will be anticipated at the first stage and incentives for relocation are only absent with one of the equilibrium locational patterns found in the chapter on myopic voting (chapter 6). These patterns depend on the federal organization. Thus, in a sequential game with voting at the second stage there is no disciplinary effect of migration on the supply decisions of public goods. Another variation of the game are simultaneous public good and locational decisions. However, with a political-economy approach the voting procedure is not well defined, as it is not clear at what location each citizen is voting. A third assumption was made regarding flood-prone areas. Beside the possibility of public flood defense, locations in and outside the flood plain had the same basic characteristics. In reality citizens living in flood-prone areas suffer from (expected) flood damages. At the same time flood-prone areas might be more productive—e.g. more fertile agricultural land—than land outside the flood plain. Such differences can easily be incorporated into the model, leading to more general results. However, the basic effects of public flood defense and the considerations regarding the federal organizations will remain unchanged with such extentions.

7.4 Appendix

Decentralization and unidirectional spillovers

The equilibrium allocation for the adopted functional form and residency-based rent distribution is given by

$$
\begin{aligned}
g_1^d &= -\frac{2\lambda\bar{n}(\lambda^2\bar{x}-1)(\lambda^2\bar{x}+E-1)\kappa_2}{(\lambda^2\bar{x}+E-1)^2-4\,\kappa_2\,\lambda^2\bar{x}(\lambda^2\bar{x}+E-1)+4\,\kappa_2^2\,\lambda^2\bar{x}\,(1+E)}\\
g_2^d &= \frac{\bar{n}\,\lambda+4\,\bar{n}\,\kappa_2^2\,\lambda^3\bar{x}\,(\lambda^2\bar{x}-1)}{(\lambda^2\bar{x}+E-1)^2-4\,\kappa_2\,\lambda^2\bar{x}(\lambda^2\bar{x}+E-1)+4\,\kappa_2^2\,\lambda^2\bar{x}\,(1+E)}\\
y_i^d &= 1-\frac{n_i^d}{2\bar{x}}-\frac{(g_i^d)^2}{2n_i^d}\\
n_1^d &= -\frac{4\,\bar{n}\,\kappa_2^2\,\lambda^2\bar{x}\,(\lambda^2\bar{x}-1)}{(\lambda^2\bar{x}+E-1)^2-4\,\kappa_2\,\lambda^2\bar{x}(\lambda^2\bar{x}+E-1)+4\,\kappa_2^2\,\lambda^2\bar{x}\,(1+E)}\\
v_i^d &= \frac{\bar{n}(\lambda^2\bar{x}-1)(\lambda^2\bar{x}(3-2\kappa_2)+E-3)+4\bar{x}(\lambda^2\bar{x}(2-\kappa_2(2-\kappa_2))-2)}{4\bar{x}(\lambda^2\bar{x}(2-\kappa_2(2-\kappa_2))-2)}\\
&\text{with } E=[1+\lambda^2\bar{x}(\lambda^2\bar{x}(1-4\kappa_2)+4\kappa_2(1+\kappa_2)-2)]^{\frac{1}{2}}
\end{aligned}
\tag{7.28}
$$

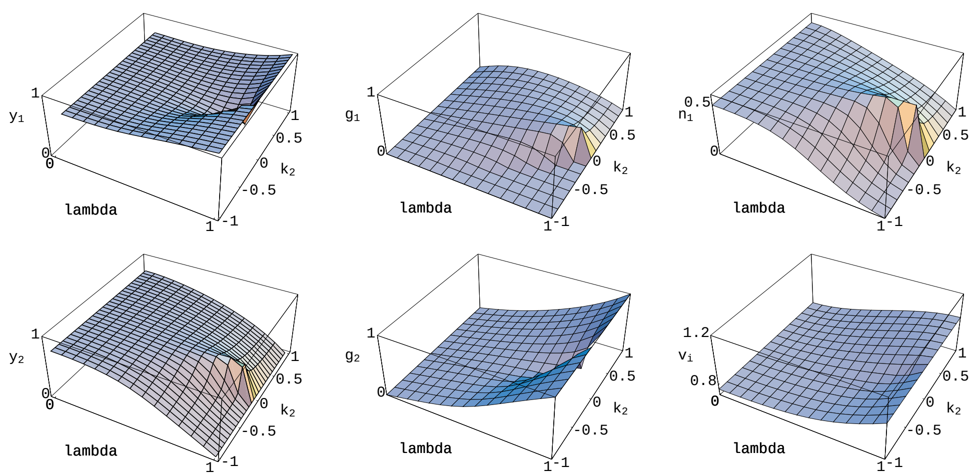


Figure 7.7: Decentralized equilibrium allocation with non-myopic voting for $\bar{n}=1$ and $\bar{x}=1$

A corner solution of the population or one of the public goods implies that all corresponding combinations of spillovers and marginal benefits lead to allocations that are either not feasible or not optimal. For the graphical illustrations, corner solutions occur for high marginal benefits and negative spillovers (front corners of the allocation) for the upstream public good. Figure 7.8 shows the second-order condition for the upstream public good for the parameter range under consideration. Since H_1^1 is negative for these values, the first-order condition determines a maximum. As found in the main text, the second-order condition for downstream public good provision is met for all preference parameters and spillovers.

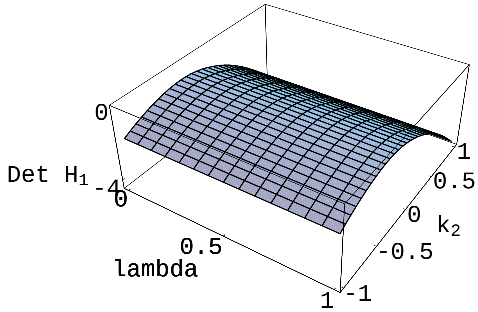


Figure 7.8: Second-order condition for g_1 for decentralized non-myopic voting for $\bar{n} = 1$ and $\bar{x} = 1$

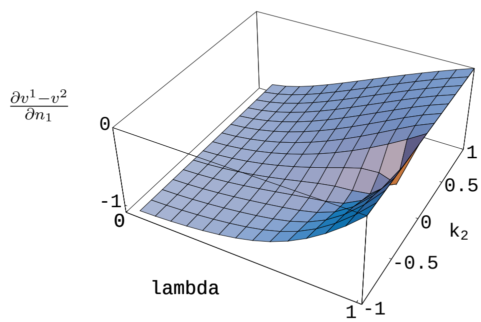


Figure 7.9: Existence of a decentralized migration equilibrium with non-myopic voting for $\bar{n} = 1$ and $\bar{x} = 1$. If $\frac{\partial(v^1 - v^2)}{\partial n_1} < 0$, there is an interior migration equilibrium for interior solutions of g_1^d, g_2^d, y_1^d, y_2^d.

Centralization and unidirectional spillovers

The equilibrium allocation for the adopted functional form and residency-based rent distribution is given by

$$\begin{aligned}
g_1^c &= \tfrac{\bar{n}\lambda(1+\kappa_2)}{2} \\
g_2^c &= \tfrac{\bar{n}\lambda}{2} \\
y_1^c &= 1 - \bar{n}\tfrac{\lambda^2\bar{x}(2+\kappa_2(2-\kappa_2))+2}{8\bar{x}} \\
y_2^c &= 1 - \bar{n}\tfrac{\lambda^2\bar{x}(2+\kappa_2(2+3\,\kappa_2))+2}{8\bar{x}} \\
n_1^c &= \tfrac{\bar{n}(1-\kappa_2^2\lambda^2\bar{x})}{2} \\
v_i^c &= 1 + \bar{n}\tfrac{\lambda^2\bar{x}(2+\kappa_2(2+\kappa_2))-2}{8\bar{x}}\,.
\end{aligned} \tag{7.29}$$

The allocation is illustrated in figure 7.10 which shows that no corner solutions occur for the chosen parameter range.

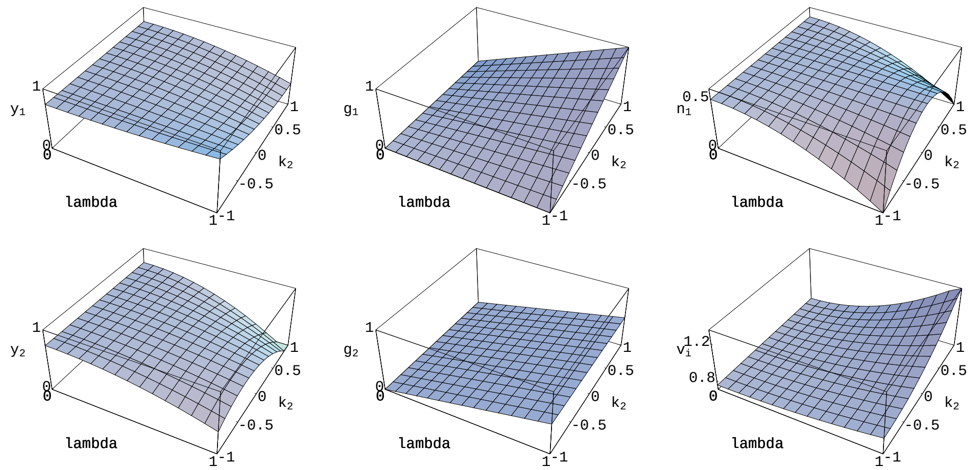


Figure 7.10: Centralized equilibrium allocation with non-myopic voting for $\bar{n}=1$ and $\bar{x}=1$

Flood-prone areas

The equilibrium allocation for the adopted functional form and residency-based rent distribution is given by

$$
\begin{array}{lll}
 & \text{social optimum and} & \text{large jurisdiction} \\
 & \text{single issue authority} & \\
g_1 = & \frac{\bar{n}\lambda_1\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} & \frac{\bar{n}\lambda_1\bar{x}_1}{\bar{x}_1+\bar{x}_2} \\
n_1 = & \frac{\bar{n}\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} & \bar{n}\bar{x}_1\frac{\bar{x}_1+\bar{x}_2+2\lambda_1^2\bar{x}_1\bar{x}_2}{(\bar{x}_1+\bar{x}_2)^2} \\
v_i = & 1-\bar{n}\frac{1-\lambda_1^2\bar{x}_1}{2(\bar{x}_1+\bar{x}_2)-2\lambda_1^2\bar{x}_1\bar{x}_2} & 1-\bar{n}\frac{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1^2}{2(\bar{x}_1+\bar{x}_2)^2} .
\end{array}
\tag{7.30}
$$

The equilibrium allocation for the adopted functional form and equal property shares is given by

$$
\begin{array}{lll}
 & \text{single issue authority} & \text{large jurisdiction} \\
g_1 = & \frac{\bar{n}2\lambda_1\bar{x}_1}{2(\bar{x}_1+\bar{x}_2)-\lambda_1^2\bar{x}_1\bar{x}_2} & \frac{\bar{n}\lambda_1\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} \\
n_1 = & \frac{\bar{n}2\bar{x}_1}{2(\bar{x}_1+\bar{x}_2)-\lambda_1^2\bar{x}_1\bar{x}_2} & \frac{\bar{n}\bar{x}_1}{\bar{x}_1+\bar{x}_2-\lambda_1^2\bar{x}_1\bar{x}_2} \\
v_i = & 1-\bar{n}\frac{4\bar{x}_2+\bar{x}_1(4-4\lambda_1^2(\bar{x}_1+\bar{x}_2)+\lambda_1^4\bar{x}_1\bar{x}_2)}{2(\lambda_1^2\bar{x}_1\bar{x}_2-2(\bar{x}_1+\bar{x}_2))^2} & 1-\bar{n}\frac{1-\lambda_1^2\bar{x}_1}{2(\bar{x}_1+\bar{x}_2)-2\lambda_1^2\bar{x}_1\bar{x}_2} .
\end{array}
\tag{7.31}
$$

A large jurisdiction achieves the social optimum if all citizens own the same land share. The same holds for a single issue authority and rent distribution to residents with the adopted functional specification. The social optimum is illustrated by the upper part of figure 6.9.

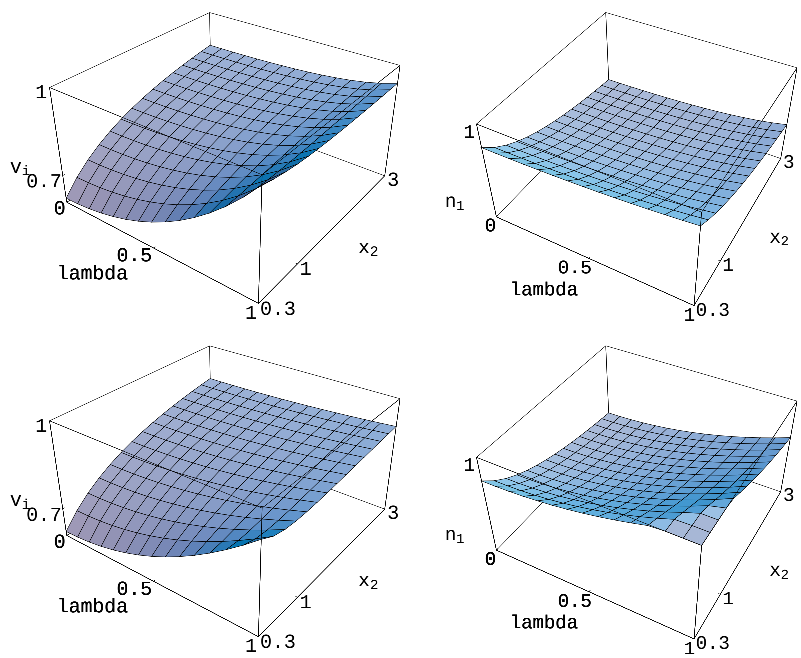


Figure 7.11: Utility and population size depending on land outside the flood plain for non-myopic voting and $\bar{n} = 1$, $\bar{x}_1 = 1$. Upper part: single issue authority and equal property shares. Lower part: Large jurisdiction and resideny based rent distribution.

Chapter 8

Conclusions

8.1 Summary of results

Two observations were the starting point of this dissertation. First, despite past efforts in flood defense, there is no absolute flood protection. Large damaging floods occurred in the past and can be expected in the future. In addition, the current understanding of climate change suggests that weather extremes will become more frequent, with the likely consequence of more severe flooding in the future.

These observations led to a study of flooding and flood management in Germany (chapters 2 and 3) that found two spatial characteristics of flood defense that challenge the federal organization. Firstly, unidirectional spillovers challenge a decentralized provision of flood defense, because the interests of downstream riparians are neglected by upstream jurisdictions. Secondly, jurisdictions that extend over areas in and outside the flood plain are asked to efficiently provide public flood defense. This public good is beneficial for one group of citizens and has no direct benefits for the rest of the population. Both characteristics challenge the federal organization in different ways that also depend on whether there is the possibility of migration or not.

These challenges led to a theoretical analysis of local public goods with unidirectional spillovers and heterogeneous benefits. Aiming to capture the essence of public flood defense, the model considered an upstream and a downstream region. Following the lead of recent contributions to fiscal federalism, the supply of public goods was interpreted as the outcome of voting decisions. By adopting simple majority voting as the decision rule, this approach focused on the fundamental interest conflicts of upstream and downstream citizens as well as citizens living in and outside of flood-prone areas.

Chapter 5 introduced the model and investigated different jurisdictional organizations of public good provision. Four different decision-making structures were compared: classical decentralization or centralization (based on jurisdictions containing voters both with and without benefits of the public goods) and decentralized or centralized single issue authorities (whose jurisdictions, by definition, contain only voters with high benefits). Single issue authorities come into question for providing flood defense, since efficient flood defense measures and their benefits are located in the natural flood plain. Decentralized jurisdictions separate upstream and downstream voters, whereas a centralized jurisdiction comprises both groups.

The analysis was—at heart—the comparison of second-best settings, since all federal organizations have their own shortcomings. Decentralized jurisdictions neglect transfrontier spillovers and over- or under-provide the public goods. Centralized jurisdictions suffer from the dominance of the majority. Contrary to what one might intuitively think, it is not so much the upstream public good that is flawed with centralized voting, but primarily the downstream public good, without spillovers, that causes large inefficiencies. The downstream public good is either extremely over- or under-provided.

Inefficiencies resulting from an uneven distribution of benefits within a region may call for single issue authorities. In general, inefficiencies are particularly large when the majority and the minority group of the population are of similar size. If no upstream-downstream spillovers are present, it is always the best to establish single issue authorities, because they avoid inefficient majority decisions. If spillovers are present, single issue authorities are not the general recommendation. Jurisdictions with heterogeneous benefits are good, if there are large positive spillovers and if there is a small minority without benefits from public goods. The no-benefit minority drives public good provision up, which is good when spillovers are positive.

The comparison of the four federal settings—under the assumption of equally populated upstream and downstream regions and the same preferences for public goods—leads to the result that centralized jurisdictions are never the first choice when unidirectional spillovers are present. In most cases decentralized single issue authorities are superior, except when positive spillovers are sufficiently large or the no-benefit minority is sufficiently small. Then classical decentralized jurisdictions are the best federal organization.

Centralized jurisdictions yield better results when central standards are introduced. Central standards that require a uniform supply or a uniform consumption level of public goods were found to have very different consequences. Whereas uniform public good supply does not make centralized voting superior to decentralized voting when spillovers are unidirectional, a uniform consumption requirement can make centralized jurisdictions superior to decentralized ones. Partial centralization is a second option for improving centralized voting outcomes. Since the downstream public good is purely local, partial centralization, through centralized voting on upstream public good provision, only makes central jurisdictions superior to decentralized jurisdictions if spillovers are large enough. However, with negative spillovers, it depends on the majority region if partially centralized voting is favorable. Whereas an upstream majority prefers an inefficiently high level of public goods, a downstream majority favors no supply, which is more efficient.

The basic model assumed a given location of voters. This can be unrealistic when public good benefits are unevenly distributed across regions and migration is not restricted, as is usually the case within a country. Free and costless migration was introduced in chapter 6. Symmetry assumptions with respect to the preference and production side of the economy were made in order to concentrate on unidirectional spillovers and their impact on the migration equilibrium under different federal organizations. In addition, public goods benefits were assumed to be evenly distributed within a region, reducing the possible federal settings to (classical) decentralization and centralization. As voters were assumed to be myopic with respect to migration, the effect of public goods on locational choices was neglected and the provision of public goods followed the established pattern of the basic model. After voting citizens were allowed to relocate.

By specifying functional forms and assuming that the initial and the final population distribution were the same under decentralization, federal organizations could be compared for the case of the same initial population distribution. Decentralization is superior for most spillover levels, since centralization suffers from an inefficient, majority preferred, supply pattern of public goods. Centralization is only superior for large unidirectional spillovers. Political-economy conditions and the federal organization also drive the spatial distribution of the population. With decentralized supply that neglects spillovers, the population size of the upstream region decreases in spillovers. This pattern also holds for centralization with an upstream majority, but is not a general property for a downstream majority. Under centralization, the majority region attracts a large population share, which tends to be a stronger influence on the locational pattern than spillovers. The migration equilibrium is locationally efficient under centralization if all citizens own the same share of land and rents flow to land owners. Locational efficiency is neither given with residency-based rent distribution and centralization nor under decentralization under both rent distribution assumptions.

In a two region model, with only one public good, it was possible to investigate single issue authorities and their implication on human encroachment of flood-prone areas. The alternative federal setting under consideration was a large jurisdiction that comprised both high and no benefit voters. With the adopted functional forms and symmetry assumptions, it turned out that a single issue authority is better than a large jurisdiction with unevenly distributed public benefits. A single issue authority has a positive effect on the equilibrium utility. In contrast, a large jurisdiction provides flood defense inefficiently and may just change the locational pattern without having a positive welfare effect.

Chapter 7 assumed non-myopic voters and found quite different results than for myopic voting. Non-myopic voters are aware of the free migration restriction and therefore vote for a supply pattern that approximates the social optimum. However, due to the financing restriction of a federal organization, the social optimum is not always attainable. With unidirectional spillovers and depending on the federal setting, the supply of public goods deviates from the Samuelson rule whenever the migration equilibrium is locationally inefficient. Independent of the federal organizations, it turned out that the initial population distribution (and the resulting political majority under centralization) has no influence on the equilibrium allocation. Unlike with myopic voting and also unlike the basic model without migration, the advantages and disadvantages of decentralization and centralization are not monotone in spillovers. This implies that one cannot generally recommend decentralization for small and centralization for large spillover levels. Such a pattern was suggested in the earlier chapters. Given the 'right' rent distribution scheme it even turned out that centralization may be generally efficient and that decentralization increasingly falls short of the socially optimal welfare as spillovers grow.

With non-myopic citizens there was no general recommendation that flood defense shall be provided by a single issue authority. Even though single issue authorities are efficient in public good supply, they may trigger inefficient locational choices. In contrast, the outcome is efficient in a large jurisdiction with equal property shares.

It lies in the nature of a theoretical analysis that it makes a number of simplifying assumptions to reduce complexity. While some assumptions are standard for an economic analysis, others can be discussed in more detail.

First, the model was a political-economy approach, which assumed direct voting on the supply of public goods. Of course this is a heroic assumption when looking at a particular public good such as flood defense. There are more sophisticated political-economy approaches to fiscal federalism, for example with a representative democracy. However, the choice of simple majority voting as a social decision rule offers a perspective that reveals the basic asymmetry of public good supply with unidirectional spillovers. This perspective was believed to be useful in reconsidering public flood defense. The reality of public flood defense may seem to suggest a model that captures a weaker version of the interest conflict between upstream and downstream citizens than was the case in the basic model. Allowing for migration, as an extension to the basic model, led to more moderate outcomes, where the supply patterns of public goods seemed to serve voters at their final location much better than was the case in the basic model with a fixed locational pattern. In reality there is another mechanism that is likely to lead to outcome that do not conform with the clear cut results of the basic model. The existing public flood defense is not the result of a once and for all decision, but has gradually developed over time, since most flood defense measures are long-lived investments. Thus, the status quo is not no flood protection at all, but rather a given level of protection with the possibility of small and large additional projects that improve the protection level. As time goes by, political-economy conditions may change, giving new opportunities for the implementation of projects. However, in such a situation it is likely that local benefits and costs and the political constellation are the driving forces of the decision in favor or against an improvement of public flood defense.

Second, the model considered only one public good per region. This simplifies the analysis since in reality there is a bundle of measures that can be undertaken to improve flood protection. In the basic model it is easy to integrate this complexity by interpreting the critical spillover levels as cut-off levels. All measures that entail smaller spillovers are then provided by one federal setting (for example decentralization) and measures with larger spillovers by another (for example centralization). A similar interpretation of the spillover parameter is made by Lorz and Willmann (2005). Such an interpretation of the model is not possible in a migration context, since locational choices are driven by the overall (public good) utility. It would be possible to interpret the public good of a region as the aggregation of a bundle of public goods. Spillovers and benefits would then be the average of the bundle. However, unbundling the public goods and supplying public goods by different federal levels would require a more complex modeling approach.

Third, the model was deterministic in nature and did not consider public flood defense in the context of risk management. The introductory chapter on flood management (chapter 2) pointed out that public flood defense primarily reduces the probability of a flood and is therefore a form of self-protection. In contrast, locational choices determine the flood loss potential and are therefore a form of self-insurance. The analysis showed the clear linkage of public flood defense and locational choices: A high level of regional flood defense tends to increase the population size of that region.

8.2 Policy implications

The theoretical analysis has implications for actual flood management. Before discussing these policy implications it is useful to point to limitations of the study that go beyond the ones mentioned above. In the words of Oates (1999, 1145):

"While the existing literature in fiscal federalism can provide some general guidance [...], my sense is that most of us working in the field feel more than a little uneasy when proffering advice on many of the decisions that must be made on the vertical fiscal and political structure. We have much to learn!"

Given the high level of abstraction of the presented theoretical analysis, it is difficult to disagree with Oates. However, complementary to the theoretical study, this dissertation also analyzed the institutional organization of flood management in Germany. The combination of both makes the following discussion possible.

The discussion of flood management in Germany showed that there is very little effective cooperation between jurisdictions on the same federal level. There are hardly any economic linkages that would allow one jurisdiction to co-finance flood defense measures that are implemented in other jurisdictions, even if a downstream jurisdiction receives the primary benefits of upstream measures. Therefore the federal organization has an important influence on flood defense.

The theoretical analysis of different federal organizations comprises alternative approaches that made different assumptions regarding migration. This leads to the question: What is the right model? The free migration assumption seems particularly restrictive when considering an upstream region, such as the Upper Rhine, and a downstream region, such as the Lower Rhine, which are located far apart. The model with a given location of individuals seems therefore more realistic than the free and costless migration approaches. In the discussion on flood-prone areas, it is realistic to assume high mobility between flood risk zones. For large cities near rivers, such as Cologne or Mannheim, it seems realistic to assume a high degree of mobility between parts that are exposed to flood risk and other parts that are not exposed.

One guiding question of the analysis asked, if flood defense shall be provided through decentralized or centralized decision making. The theoretical analysis was skeptical with regard to centralized provision of flood defense, because the downstream public good was either excessively over- or under-supplied with a given location of voters. Since there are different sized rivers, centralized provision can refer to different federal levels. For large, first-order water bodies the central entity is the federal government and the *Bundesländer* are the decentral jurisdictions. For smaller, higher order water bodies, the respective central level will be, in most cases, a *Bundesland* whereas the decentralized jurisdictions would be on the communal level. The political discussion focuses primarily on the spillovers on first-order rivers, such as the Rhine or the Elbe.

The new Flood Protection Act strengthened the role of the federal level, since it introduced a common flood protection level that shall be reached throughout in Germany (according to WHG § 31d it is now the goal to achieve a uniform flood protection level against a Q_{100}-flood, see section 3.1). Defining centralization as it was discussed in the model, such a central standard is not a regime shift toward centralization, since the financing of flood defense still rests on decentral jurisdictions. A central standard may increase flood defense, however there is little reason to believe that this increase is efficient. Downstream jurisdictions still only controll downstream flood defense, which is a purely local public good. If a standard forces an increase in downstream flood defense, this is inefficient, because the downstream jurisdiction was free to choose its optimal flood defense level also without a standard. If the upstream jurisdiction increases its flood protection level, it may or may not be welfare improving. Flood defense measures with negative spillovers are counter-productive. Higher levees, for example, are beneficial for the upstream region, but they have negative effects downstream. Retention basins have positive spillovers, but their local effect is likely to be smaller than higher levees, which makes them not the measures of choice for an upstream jurisdiction that wants to improve its own flood protection level. Thus, a central standard with decentralized financing does not promote a desirable expansion of upstream measures with positive spillovers, and it does not avoid the implementation of measures with negative spillovers. Finally, a central standard is likely to interfere with downstream flood defense, which is a purely local public good.

The theoretical analysis suggested another model of central standards. A central standard combined with a central budget for public good financing can be superior to decentralization. With shared costs, upstream riparians also consider (negative) spillovers, because they influence the costs of downstream public flood defense. The theoretical results also suggested that a central flood protection standard has its advantages when spillovers are negative, whereas it inefficiently reduces downstream public good supply when spillovers are very positive. This inefficiency of a common standard arises because of the asymmetrical nature of the problem. Whereas upstream flood protection is only possible by upstream public flood defense, downstream flood protection can result from upstream as well as downstream measures. This asymmetry holds for the two region as well as the multi-region case.

The Flood Protection Act strengthens the legal protection of the remaining flood plain that is not protected by levees (on WHG § 31b.2, see section 3.1). In Germany, in many cases only a small share of the natural flood outline remains unprotected and still functions as a flood plain. Therefore, the protection of these scarce areas from undesirable land-use changes has a high priority, since a further wealth accumulation has the likely consequence of additional levees and more negative spillovers to downstream locations. Despite this positive effect, it can be critically noted that the areas behind existing levees constitute the critical land for an improvement of public flood defense.

Areas protected by levees form the potential for regulated or unregulated flood basins with positive spillovers to downstream locations.

In addition to standards, the Flood Protection Act introduced flood protection plans (according to WHG § 31d, see section 3.1), which shall be developed on the basis of the whole watershed. It may turn out that this cooperation requirement is enough to foster the implementation of efficient projects. However, since there were no restrictions on voluntary inter-jurisdictional cooperation in the past, one has to regret that no clear legal provisions were introduced that induce the optimal location of flood defense measures along a river.

One may suspect that the federal standards that where introduced by the Flood Protection Act do not primarily address the problem of spillovers. Since extreme— and rare— floods are the main challenge for flood management, a common, legal flood protection level may intend to set clear goals for public flood defense, since the federal government believes that local policy makers underestimate the risk of flooding. It is well known that the awareness of the flood hazard decreases continuously after a flood event. It only takes seven years after a flood for the risk estimation to return to the same low level as before the flood (IKSR 2002, 12). Similar observations with regard to rare risks are made and discussed by Kunreuther (1996) and Kunreuther and Pauly (2003).

The theoretical analysis also considered partial centralization, where only the upstream public good is provided centrally and the downstream public good is decentralized. Such partial centralization has its advantages if strong positive spillovers are present, but performs poorly for negative spillovers and an upstream majority. Therefore, partially centralized provision can be suggested for flood defense measures with strong positive spillovers. This leads to a situation where a downstream flood defense measure is financed and implemented by the downstream riparians. At the same time upstream flood defense measures at the beginning of a river involve upstream as well as downstream riparians in decision making and financing. It is only for measures with negative spillovers and a upstream majority that such a jurisdictional organization leads to very inefficient outcomes.

There is one part of flood management with a big influence on upstream-downstream spillovers that usually is, by and large, neglected in discussions of flood defense. Levee failure is a well known and also common phenomenon. There are numerous examples where a levee failure at one place prevented damage at other locations. However, despite the fact that this linkage is common knowledge, there is no serious discussion if the decisions that—inescapably—have to be made, are efficient or not. Is it more efficient to risk a levee failure at a highly populated urban area, or is it better to intentionally break a levee at a sparsely populated part of a river? Of course this is a difficult question! Currently it is the local level that is primarily responsible for emergency measures in case of flooding. This reflects a decentralized federal setting that avoids the excessive inefficiencies that are present under a centralized setting and unidirectional spillovers. However, the theoretical analysis showed that some centralized decisions can lead to better outcomes than decentralized solutions.

A second guiding question of the analysis asked, if flood defense shall be provided by single issue authorities that separate areas in and outside the flood plain. This question gained practical importance in recent years, since the insurance industry has established a risk-zoning system (on the system, ZÜRS, see section 3.3.2) and the Flood Protection Act requires the responsible authorities to provide public flood risk maps. Thus, the exposition to flood risk will be much more transparent in the future than it has been in the past.

The river basin approach is one first step to separate high and no benefit groups in flood defense. The separation of different river basins avoids an extreme spatial incongruence of benefits and cost-sharing. The separation of water basins was discussed in connection with the recent European Water Framework Directive. However, the decision was not to form new river basin authorities, but rather to strengthen coordination within the existing federal structure (see section 3.2.2). Since public flood defense and other water related issues are, by and large, managed by the same authorities, the chance was missed to reduce the benefit heterogeneity within jurisdictions in charge of flood defense. In addition, one can note that river basin authorities would also fail to abolish benefit heterogeneity completely, because they would include the whole catchment area, not just the flood plain.

With high mobility between the flood plain and adjoining areas, policy implications can be drawn from the models that capture migration. The model with free and costless migration found a clear linkage of flood defense and locational decisions. Of course the precise form of the linkage depends on the federal organization, however, the theoretical study clarified that better flood protection leads to human encroachment on flood-prone areas. Whereas such a *"levee effect"* is often seen critically in the literature on flood management (see section 3.3.3), the theoretical analysis does not generally suggest that the *"levee effect"* is inefficient.

According to the theoretical study it is, in fact, rather difficult to specify conditions when it is beneficial to establish single issue authorities on flood-prone areas. Already in a simple setting with one flood-prone area and another area outside the flood plain there are no clear cut results. Depending on the voting behavior, if voters are myopic or non-myopic, the rent distribution scheme, and the regional production functions, a jurisdictional separation can be advisable or not. Beside welfare implications, the federal organization affects locational choices. Flood defense, that is provided and financed by single issue authorities, leads to a smaller population size living in flood-prone areas than large jurisdictions where people outside of flood-prone areas also pay for flood defense.[1]

It is this insight from the theoretical analysis that raises serious doubts as to whether a federal flood protection standard improves flood management. Even worse, one has to fear that additional flood protection, provided by heterogeneous benefit jurisdictions, leads to further human encroachment on flood-prone areas. The co-financing of flood defense by people outside the flood plain makes flood prone areas more attractive. This

[1] Only myopic voting and a no-benefit majority in a large jurisdiction result in fewer people located in the flood plain than under a single issue authority. However, this would imply that no public flood defense is provided; a situation not very common in reality.

leads to further wealth accumulation in high-risk zones and limits the scarce space for retention basins.

If there is no exogenously required flood protection level, the migration chapters showed that there are some cases for which the introduction of flood defense has a large impact on welfare and a small impact on the population distribution, but there are also other cases for which the opposite holds. This argument relies on a comparison of a migration equilibrium with flood defense and a status quo without flood defense. With an extreme scarcity of land that is not exposed to flood risk, flood defense has a high impact on welfare and a relatively low impact on the population distribution. With a large endowment of land outside the flood plain, flood defense has a small impact on welfare but a large impact on settlements in flood-prone areas. In the latter situation the welfare loss of restricting such settlements is low. Such a policy could be achieved by having single issue authorities and not large jurisdictions provide flood defense. As the theoretical analysis suggested, single issue authorities may even be able to achieve the social optimum in some cases.

There are a number of reasons in favor of some kind of restriction of human encroachment on flood-prone areas. First, the benefits of public disaster aid are clearly concentrated in flood-prone areas, setting incentives for further settlements if such help is also expected in the future. As long as flood insurance with risk-related premiums is not wide spread, potential public disaster relief plays an important role and is likely to bias locational choices.[2] Second, wetlands, which are typically located in flood-prone areas, are public goods with inter-regional spillovers. Human encroachment intensifies land-use conflicts in the flood plain and may lead to a too low valuation of the benefits of wetlands. However, these arguments refer to a situation that is far from first-best. If these inefficiencies can be addressed directly, better outcomes can be expected in many cases.

A third guiding question of the analysis asked, if the problem of upstream-downstream spillovers and spatially heterogeneous benefits from flood defense can be seen independently from each other or not. In the model without mobility, there was an interdependency, because heterogeneous benefits within a jurisdiction were good for some spillover values.

The theoretical analysis relied on a deterministic approach that did not consider uncertainty. As was pointed out before, public flood defense primarily reduces the probability of a flood and locational choices determine the flood loss potential. Because of this better flood defense—which tends to increase human encroachment on flood-prone areas—has a clear influence on the risk profile of flooding: Flooding becomes a low-probability, high-impact event. With this effect, higher public flood defense leads

[2] Only if disaster relief would aim to achieve locational efficiency could one argue that it is efficient. However, the analysis showed that locational efficiency is a rather demanding concept, since it compares the net-benefits of an immigrant to a region, across regions. It seems more likely that flood disaster relief is driven by other considerations. Garrett and Sobel (2003) (see section 3.3.2), for example, provide empirical evidence for the United States that nearly half of the disaster relief is motivated politically rather than by need.

to a flood risk profile that is often considered undesirable. For a risk classification in a policy context see, for example, the classification of the German Advisory Council on Global Change (WBGU 2000). Even if one refrains from such a normative statement, it follows from the analysis that a high flood protection level triggers land-use decisions that favor high flood losses in extreme floods, raising the question of who has to carry these losses.

As a final remark one can express hope that some of the policy implications have the chance to fall on fruitful ground. Of course, it is a general problem that many insights in the economic literature are of limited use for decision-making, since models are too abstract and do not fully account for all interdependencies of real life. However, due to new approaches in water policy in general (the implementation of the Water Framework Directive), and due to the introduction of the river basin approach to flood defense in particular, flood management is in a phase of transition with the chance to correct some of the mistakes made in the past.

8.3 Extensions

In the context of this dissertation some topics can be suggested for future research.

In the course of the analysis it became all too often evident that the empirical basis of flood management is weak. This is true despite some large scale flood events in the past. There is some knowledge of the absolute magnitude of flood damage, but there is no consistent estimation method, nor a unified method of sectoral or spatial disaggregation, that allows a comparison in time or space.

Increasing human settlements in flood-prone areas are often seen as a key problem in flood management. However, since the empirical basis is weak, there is little insight in whether there are certain regional hot spots, where the phenomenon is particularly problematic. The dissertation provided some tentative evidence on aggregated land-use trends in flood plains. However, there is little knowledge on the driving forces of these changes. It would be an enormous help to know if land-use changes are driven by flood defense measures, land-scarcity outside the flood plain, the institutional setting, or other factors.

From an economic perspective it would be desirable if decisions on flood defense measures could rely on a sound quantitative assessment of costs and benefits. Such an assessment needs to take spatial spillovers into account. Since flood events are rare, simulation models play a crucial role in supporting decisions. It will be important to find ways of addressing the uncertainty that is, and most likely will continue to be, attached to the underlying hydrological models. It is not efficient if the discussion on the internalization of spillovers stops already at the point where the 'right' hydrological model is chosen.

On the theoretical level, the dissertation aimed to apply recent political-economy contributions on fiscal federalism to the case of flood management. It became evident that the focus on the special features of flood defense—unidirectional spillovers and spatially heterogeneous benefits—required a highly stylized model.

To generalize the conclusions, it would be useful to consider the multi-region case, where there is not just one upstream and one downstream region that is considered, but multiple regions that are located along a river. It may also be interesting to study a tree-shaped river system, where a river at a downstream location is fed by more than one upstream tributary.

The model used here considered two extreme cases of mobility: either there was no mobility at all or mobility was perfect by being free and costless. Realistically there is an intermediate degree of mobility, which could be incorporated into a more complex setting. In such a setting it would also be interesting to explore variations of non-myopic voting, which do not assume that voters always correctly anticipate the migration responses. Under realistic conditions, voters (or decision makers in general) can be expected to imperfectly anticipate migration responses.

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