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The Influence of Migration on Adaptation and Mitigation - a Political Economy Approach

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Preliminary version, please do not quote

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Abstract

Climate change driven migration has been considered for a long time as something that has to be prevented at all costs. The focus has been to find the optimal mitigation and adaptation mixture and migration, which can be seen as adaptation measure as well, has not been considered yet. However, with rising sea levels due to the climate change this matter becomes more and more important. This paper analyses the effect of migration on other adaptation measures and on mitigation from a political economy perspective. Mitigation is represented by an ecotax while adaptation is represented by a dike. In our model, we focus on a coastal region where individuals are heterogeneous in income and location and where flood risk exists. A main result is that the option to move away decreases the political support for mitigation while the effect on adaptation can be positive or negative.

Keywords: migration, adaptation, mitigation, political economy

JEL Codes: D70, Q54, R23

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1. Introduction

14.7 million people had to leave their homes in 2015 due to weather-related hazards. Among these are 8.3 million migrants that had to relocate because of floods (IDMC, 2016). These numbers will be probably increased by the climate change and in particular by rising sea levels. The IPCC projected the global mean sea level to rise between 0.26 and 0.98 meters by 2081 - 2100 compared to 1986 - 2005. Here, 0.28m is the lower bound of the 95% confidence interval for the low emission scenario while 0.98m is the upper bound of the 95% confidence interval for the high emission scenario (Church et al., 2013). Another problem for coastal zones is subsidence which amplifies the effects of a rising sea level. For example, Tokyo's mean cumulative subsidence was 4.250m between 1900-2013 (Erkens et al., 2015). With 10 percent of the world's population living in so called Low Elevation Coastal Zones¹ the predicted sea level rises can cause a lot of migration. Under a 4 degree Celsius warming scenario, even 470 to 760 million people could be affected (Strauss and Levermann, 2015).

Nevertheless, migration had been neglected in environmental policy analysis for a long time. At first, only mitigation which mostly consists of emission reduction was considered as possible instrument to fight climate change. There were several reasons why adaptive measures like building dikes were not the first choice. One reason was that for some decision maker adaptation would look like surrendering to the climate change (Parry et al., 1998). This view started to change since the 1980s (Schipper, 2006). Migration, however, has not been seen as possible adaptation measure because only the negative consequences has been seen. Recently, more and more scientists argue that this is a mistake, for instance Black et al. (2011). The Foresight (2011) Report studies effects of environmental changes on migration and argues that policy makers have to examine the positive and negative sides of migration. For instance, they argue that preventing migration could make things worse since it would entrap people in risk zones. This paper will not discuss whether there are positive or negative effects of climate change driven migration but will study the influence that the mere option to migrate could have on the political outcome regarding other adaptation and mitigation measures. The argument goes as follows. People will consider moving away if the expected damage from climate change is high enough. If they keep this migration option in mind this could influence

¹Low Elevation Coastal Zones (LECZ) are defined as “*area contiguous with the coastline up to a 10-metre rise elevation*” (McGranahan et al., 2007)

their preferences for protective measures so that they don't want it any more or at least not as much as before. This could be at least one reason why not enough mitigation effort is undertaken.

To analyse the effect a two staged political economy model is used. The focus lies on a coastal region where individuals differ in income and residence. On the first stage, individuals have to decide whether they want to build a dike. The dike is financed by a linear income tax and the decision about the dike is made through majority voting. It lowers the damage impact from the flood and represents therefore adaptation. On the second stage, they vote on the mitigation level which will be decided by the median voter and has an effect on the flood probability. Furthermore, individuals have the option to move away which is associated with transportation costs. Individuals are rational and maximize their utility on each stage. Regarding mitigation we find that the option to move away decreases the median voter's mitigation level. The reason for this lies in the different marginal benefit of mitigation if individuals acknowledge their moving option. Furthermore, we find that the median voter's preferred mitigation level with and without migration is lower than the social planner's mitigation level without migration. This is the case because the social planner maximizes the sum of all utility functions. The effect of migration at the adaptation stage is not clear if mitigation and adaptation compete with each other as damage reduction instruments. In the situation where having a dike leads to even more mitigation, migration has a negative impact on mitigation and adaptation.

This paper contributes to two strands of literature. The first strand is about the interaction between adaptation and mitigation. From a macroeconomic perspective Tol (2007) studies how the impacts of a rising sea level can be influenced through adaptation and mitigation. He uses an integrated assessment model for this reason and concludes that the benefits of adaptation regarding sea level rise exceed the costs many times over. Kane and Shogren (2000) analyse the link between adaptation and mitigation within an endogenous risk model. The authors argue that there can be as well interior solutions, i.e. a mix between adaptation and mitigation, as corner solutions, where there is either only adaptation or mitigation. In our model, we analyse the interaction between migration, coast protection, and mitigation. As far as we know this is the first attempt to create such a model. In this setting, individuals who live at a coastal region can choose between moving further away, building a public financed dike and a mitigation level.

The second strand that my paper contributes to is about the political economy

of climate change. A good amount of literature on the economics of climate change concentrates on environmental regulation, and a lot of research has been done to find efficient regulation instruments from a normative perspective. But in reality we see that these instruments, like pigouvian taxation, are often not implemented or at least not the way they were supposed to (Oates and Portney, 2003). An early contribution to this strand of literature is Buchanan and Tullock (1975). They argue that firms prefer rather direct regulation than environmental taxation because these regulations can be seen as barriers to entry. Aidt (1998) also investigated the influence of lobby groups on the shape of environmental regulation. Habla and Roeder (2013) analyse the political economy of ecotax reforms by means of a overlapping generations model. A model which looks at the political economy of adaptation instead of mitigation is provided by Anbarci et al. (2005). They investigate how a country's inequality in income and its per capita level of income can affect the number of fatalities during an earthquake. Our contribution to this strand of literature is to look into migration as possible factor that can alter the political outcome.

This paper is structured as follows. Section 2 explains the model environment. In section 3 we derive the social optimum and in section 4 we study the two stages of the political process. In section 5 some critical assumptions are being discussed.

2. The model

Consider a coastal region where individuals with different income y_i and different initial locations \hat{x}_j are exposed to a flood risk. \hat{x}_j is the distance between the sea and the location where the individuals live at the beginning. For simplification, we assume that individuals live only at two locations at the beginning, namely far (f) and close (c) to the sea, and belong to two income types. Thus, individuals have a low income y_l or a high income y_h and as initial locations $\hat{x}_j = \hat{x}_f$ or $\hat{x}_j = \hat{x}_c$. The fractions of every type are shown in the following table where $\theta_l + \theta_h = 1$, $\lambda_c + \lambda_f = 1$ and the population mass is normalized to one.

	Distance	
	close \hat{x}_c	far \hat{x}_f
high y_h	$\theta_h \lambda_c$	$\theta_h \lambda_f$
low y_l	$\theta_l \lambda_c$	$\theta_l \lambda_f$

Table 1: Distribution for the four types of individuals

The probability for a flood is represented by π and is assumed to be independent

of the location. This is the probability of occurrence. The damage that is done by the flood is represented by $\alpha(\hat{x}_j)$. It is assumed that the damage is higher the closer the location to the sea is ($\alpha(\hat{x}_c) > \alpha(\hat{x}_f)$). Total expected damage is given by $L_{ij} = \alpha(\hat{x}_j)\pi y_i$ so that we have an income proportional loss. In the case with just four types the loss ranking is $L_c > L_f$, $L_h > L_l$ and $L_{hc} > L_{lf}$.

To protect themselves from the flood, the inhabitants of the coastal region have three options. The first one is climate change mitigation. The mitigation level is represented by M . One can think of afforestation or investing in new green technology that reduces greenhouse gas emissions. This effort is associated with costs $C_M(M)$ and is financed by a linear income tax respectively ecotax τ .² It is assumed that this measure can slow down rising sea levels and thus reduce the flood probability π , which can be formalized as $\frac{\partial \pi(M)}{\partial M} < 0$. We suppose a diminishing effect $\frac{\partial^2 \pi(M)}{\partial M^2} > 0$.

A second option is to install coast protection measures. For instance, a dike can be built where D can take the value 1 if it's built or 0 otherwise. This is an adaptive measure since it lowers the damage α with $\alpha(\hat{x}_j, D = 1) < \alpha(\hat{x}_j, D = 0) \forall \hat{x}_j$. It costs $C_D(D)$ and is financed by the same linear income tax τ as the mitigation effort.³

The last option for protection is migration. People can move away to reduce their expected flood damage. This is associated with total transportation costs $T = t(x_{ij} - \hat{x}_j)^2 + F$ where t is the cost parameter, x_{ij} is the new location of choice, F are the fix costs and $T(0) = 0$. The damage reduction can be formalized as $\frac{\partial \alpha(x_{ij})}{\partial x_{ij}} < 0$. Furthermore, it is assumed that $\frac{\partial^2 \alpha(x_{ij})}{\partial x_{ij}^2} > 0$ and $\lim_{x_{ij} \rightarrow \infty} \alpha(x_{ij}) = 0$ which means that the positive effect of moving away is diminishing and converging to zero.

The expected utility function for each individual is

$$U_{ij} = (1 - \tau)y_i - t(x_{ij}(D, M) - \hat{x}_j)^2 - F - \alpha(x_{ij}(D, M), D)\pi(M)y_i. \quad (1)$$

The decision process is illustrated in figure 1. At the first stage, people decide about building a dike. Since it's a discrete choice the decision is made through majority voting. At the second stage there is a voting on the optimal mitigation level respectively ecotax rate. The median voter decides which amount of mitigation is

²We assume that $\frac{\partial C_M(M)}{\partial M} > 0$ and $\frac{\partial^2 C_M(M)}{\partial M^2} > 0$.

³We assume that $C_D(D = 1) > C_D(D = 0)$ and that there are no interactions between the costs of mitigation and adaptation.

implemented. In both stages individuals know their optimal location choice. Since we assume rational individuals who can anticipate the outcome from subsequent stages we have to use backwards induction to determine every individual's optimal choice.

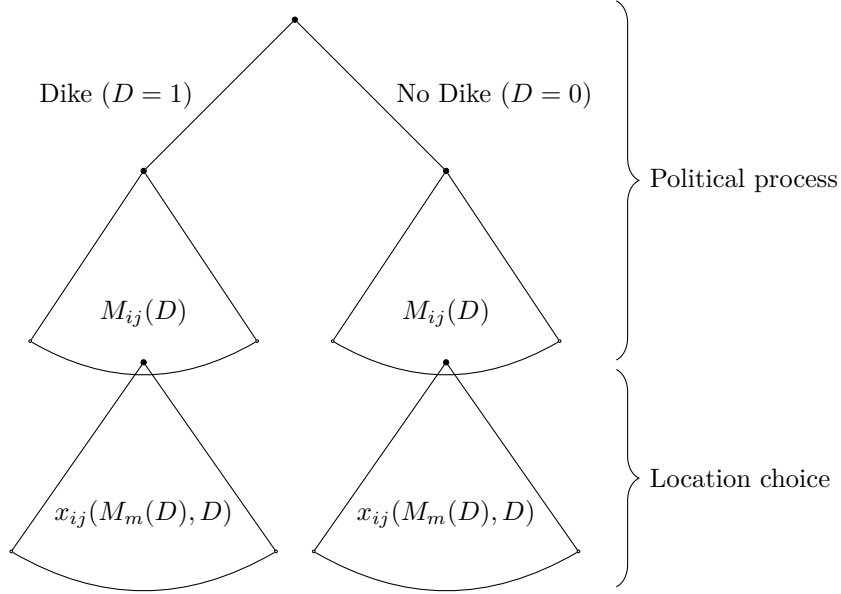


Figure 1: Individual ij 's decision problem

2.1. Migration choice

Before we can get the indirect utility functions we need to determine individual ij 's optimal location choice. Individuals take the mitigation level and the dike decision as given and consider moving away to a safer location that is farther away from the coast. Since moving away is not only associated with transportation costs but fix costs as well individuals have to decide at first if choosing any $\Delta x_{ij} = x_{ij} - \hat{x}_j > 0$ is better than choosing $\Delta x_{ij} = 0$. This is the extensive margin. On the intensive margin the following utility function is maximized with respect to the location x_{ij} .

$$\max_{x_{ij}} U_{ij} = (1 - \tau)y_i - t(x_{ij} - \hat{x}_j)^2 - F - \alpha(x_{ij}, D)\pi(M)y_i \quad (2)$$

The FOC is given by

$$\frac{\partial U_{ij}}{\partial x_{ij}} = -\frac{\partial \alpha(x_{ij}, D)}{\partial x_{ij}}\pi(M)y_i - 2t(x_{ij} - \hat{x}_j) = 0. \quad (3)$$

This can be rewritten as

$$-\frac{\partial\alpha(x_{ij}, D)}{\partial x_{ij}}\pi(M)y_i = 2t(x_{ij} - \hat{x}_j) \quad (4)$$

The left-hand side (LHS) of (4) represents the marginal benefit and the right-hand side (RHS) the marginal costs from moving one unit further away. Let $x_{ij}^*(D, M)$ be the optimal location for individual ij .⁴ To determine the influence of D on the location choice one can compare the FOCs. The marginal benefit of moving away is higher without dike than with one if

$$\frac{\partial\alpha(x_{ij}, D = 0)}{\partial x_{ij}} < \frac{\partial\alpha(x_{ij}, D = 1)}{\partial x_{ij}}. \quad (5)$$

This condition holds naturally due to the assumptions $\alpha(x_{ij}, D = 1) < \alpha(x_{ij}, D = 0) \forall x_{ij}$ and $\lim_{x_{ij} \rightarrow \infty} \alpha(x_{ij}) = 0$. Since the marginal costs of moving away are not changing with a dike a higher marginal benefit leads to a greater x_{ij} . Thus it can be stated that $x_{ij}^*(M, D = 1) < x_{ij}^*(M, D = 0)$.

Lemma 1 *With a dike the preferred location x_{ij}^* is closer to the sea than without one.*

To analyse the effect of mitigation on the location decision we can use the implicit function theorem which gives us ⁵

$$\frac{\partial x_{ij}^*(D, M)}{\partial M} = \frac{\alpha_x \pi_M y_i}{-\alpha_{xx} \pi y_i - 2t} < 0. \quad (6)$$

The denominator must be smaller than zero since it is the second order condition regarding the optimal location. Because the damage decreases in the sea distance and the flood probability with a higher mitigation the numerator must be greater than zero. Hence, individual ij 's optimal location decreases with more mitigation. The effect of transport costs on the migration decision is given by

$$\frac{\partial x_{ij}^*(D, M)}{\partial t} = \frac{2(x_{ij}^* - \hat{x}_j)}{-\alpha_{xx} \pi y_i - 2t} \leq 0 \quad (7)$$

which implies that higher transport costs reduce migration or have no impact if they don't want to move away.

⁴The second-order condition holds. See Appendix A.

⁵ $\alpha_x = \frac{\partial\alpha(x_{ij}^*, D)}{\partial x_{ij}^*}$, $\alpha_{xx} = \frac{\partial^2\alpha(x_{ij}^*, D)}{\partial x_{ij}^{*2}}$, $\pi_M = \frac{\partial\pi(M_{ij})}{\partial M_{ij}}$

On the extensive margin individuals compare their utilities where $\Delta x_{ij} > 0$ with the utility where $\Delta x_{ij} = 0$. If $V_{ij}(\Delta x_{ij} > 0) > V_{ij}(\Delta x_{ij} = 0)$ their optimal location is $x_{ij}^*(D, M)$. Otherwise they choose \hat{x}_j .

Lemma 2 *The preferred location x_{ij}^* is the closer to the sea the higher the mitigation level M is.*

Now, we can examine the location choice with our four types of individuals. This is important for the next stages where the median voter is determined. Regarding the income, the incentive for moving away is higher for the high income type. Analogously, the individual that lives closer to the coast has a higher benefit of moving away than the one that lives further away. Hence,

$$\Delta x_h > \Delta x_l \text{ and } \Delta x_c > \Delta x_f. \quad (8)$$

From (8) it follows that

$$\Delta x_{hc} > \Delta x_{lc}, \Delta x_{hf} > \Delta x_{lf} \text{ and } \Delta x_{hc} > \Delta x_{lf}. \quad (9)$$

The ranking between Δx_{lc} and Δx_{hf} is not clear. In order to compare the destination choices we need the additional assumption that

$$\hat{x}_c + \Delta x_c < \hat{x}_f. \quad (10)$$

This means that the individuals who live close to the coast will move to a new location that is always closer to the coast than the original location of the f -type. Since we have quadratic transportation costs and the distance between the c - and f -type is great enough this assumption shouldn't be too restrictive. With this information we can state the following complete ordering of preferred locations:

$$x_{lc}^* < x_{hc}^* < x_{lf}^* < x_{hf}^*. \quad (11)$$

2.2. Economic equilibrium

An economic equilibrium is characterized by a balanced public budget. The government collects income taxes and invests its funds into adaptation and mitigation. Hence, the government's budget constraint is

$$\sum_i \theta_i y_i \tau = C_D(D) + C_M(M) \Rightarrow \tau(D, M) \quad (12)$$

By substituting (12) and the optimal location choice $x_{ij}^*(D, M)$ into (1) we get individual ij 's indirect utility function

$$V_{ij} = (1 - \tau(D, M))y_i - t(x_{ij}^*(D, M) - \hat{x}_j)^2 - F - \alpha(x_{ij}^*(D, M), D)\pi(M)y_i. \quad (13)$$

3. Social optimum

Before we get to the voting procedure the social optimum benchmark is determined. The utilitarian social planner maximizes the sum of all individuals' utilities W with respect to mitigation and adaptation.

$$\max_{M, D} W = \sum_i \sum_j \theta_i \lambda_j V_{ij}(D, M) \quad (14)$$

The FOC with respect to the mitigation level M and with the help of the envelope theorem is given by

$$\frac{\partial W}{\partial M} = -\frac{\partial \tau(D, M)}{\partial M} \bar{y} - \frac{\partial \pi(M)}{\partial M} \sum_i \sum_j [\theta_i \lambda_j \alpha(x_{ij}^*(D, M), D) y_i] = 0. \quad (15)$$

From (15) it follows that the social planner chooses the optimal amount M^{SP} where the marginal costs of mitigation equals the sum of all individuals' marginal benefits.⁶ In order to decide about building a dike, he compares the utility functions. Only if $W(D = 1) > W(D = 0)$ he will build the dike. This is the case if the sum of total damage reduction from the dike exceeds the total costs.

4. Analysing the political process

In this section we want to analyse the the political process on every stage. Since individuals are perfectly rational we have to use backwards induction and thus begin with analysing the second stage.

4.1. Second stage - mitigation

At the second stage the choice about the dike is taken as given but the individual can anticipate his optimal location choice. Hence, he maximizes his indirect utility

⁶We assume that the second-order condition holds. See Appendix A.

function with respect to M_{ij} :

$$\begin{aligned} \max_{M_{ij}} V_{ij} = & \left(1 - \tau(M_{ij}, D)\right)y_i - \alpha\left(x_{ij}^*(M_{ij}, D), D\right)\pi(M_{ij})y_i \\ & - t\left(x_{ij}^*(M_{ij}, D) - \hat{x}_j\right)^2 - F \end{aligned} \quad (16)$$

The FOC is given by

$$\begin{aligned} \frac{\partial V_{ij}}{\partial M_{ij}} = & -\frac{\partial \tau(M_{ij}, D)}{\partial M_{ij}}y_i - \alpha\left(x_{ij}^*(M_{ij}, D), D\right)\frac{\partial \pi(M_{ij})}{\partial M_{ij}}y_i \\ & - \pi(M_{ij})\frac{\partial \alpha\left(x_{ij}^*(M_{ij}, D), D\right)}{\partial x_{ij}^*(M_{ij}, D)}\frac{\partial x_{ij}^*(M_{ij}, D)}{\partial M}y_i \\ & - 2t\left(x_{ij}^*(M, D) - \hat{x}_j\right)\frac{\partial x_{ij}^*(M_{ij}, D)}{\partial M} = 0. \end{aligned} \quad (17)$$

Using the Envelope theorem the FOC can be written as

$$\frac{\partial \tau(M_{ij}, D)}{\partial M_{ij}}y_i = -\alpha\left(x_{ij}^*(M_{ij}, D), D\right)\frac{\partial \pi(M_{ij})}{\partial M_{ij}}y_i. \quad (18)$$

An optimal ecotax choice $M_{ij}^*(D)$ for individual ij can be determined implicitly and the median voter decides the amount $M_m(D)$ ⁷ that will be implemented. The LHS of (18) can be interpreted as marginal costs of having a higher ecotax rate and the RHS as marginal benefit. The size of the preferred ecotax rate depends on the dike decision. Building a dike will have a direct and an indirect effect on $M_{ij}^*(D)$. By assumption, a dike decreases the damage for all locations which lowers the marginal benefit of mitigation and hence a lower ecotax rate respectively mitigation level is chosen. The indirect effect works through the optimal location choice. As described in the migration choice section the effect of having a dike on the location decision is negative. Thus, people are staying closer to their original location than in a world without dike. This however will increase the expected damage which leads to a higher marginal benefit for mitigation and to a higher preferred ecotax rate.

Lemma 3 *The effect of having a dike on the preferred mitigation level M_{ij}^* is ambiguous.*

⁷We assume that the second-order condition with respect to M holds. See Appendix A.

Transport costs change the optimal mitigation choice through the anticipated location:

$$\frac{\partial M_{ij}^*(D)}{\partial t} = \frac{\alpha_x \pi_M}{\text{SOC}_{M_{ij}}} \frac{\partial x_{ij}^*(M_{ij}, D)}{\partial t} > 0. \quad (19)$$

With higher transport costs less people will move away. This again will increase the marginal benefit of mitigation and hence lead to more mitigation.

To identify the median voter we need to look at each type's preference for mitigation. From (11) we know the preferences for moving away. These preferences have an effect on the mitigation decision for each individual because it changes the marginal benefit of mitigation through the damage function. From (18) and the assumption $\frac{\partial \alpha(x_{ij})}{\partial x_{ij}} < 0$ we know that the marginal benefit is higher the farther away one lives. Thus, we get an inverted ranking for the mitigation levels:

$$M_{lc}^* > M_{hc}^* > M_{lf}^* > M_{hf}^* \quad (20)$$

According to McGranahan et al. (2007) ten percent of the world's population live in low elevation coastal zones. Furthermore, we can say that the fraction of low income households is larger than the fraction of high income households. With this information, we can identify the median voter which has to be a low income type household that lives far away from the coast: $M_m = M_{lf}^*$.

We can compare the median voter's solution to the solution with no migration. To determine the optimal mitigation level without migration, transportation costs are supposed to be infinitely high. This would be the case if, for instance, migration is prohibited by the government. Without migration the marginal benefit for mitigation is higher as the expected damage is higher. However, the preferred mitigation level without migration is still lower than the social optimal level without migration. The reason for this lies in the unequal distribution of income and location. The average income \bar{y} is higher than the median income y_m and the average location \bar{x} is closer to the sea than the median location x_m . Since the social planner maximizes the sum of utilities the social optimal mitigation level is higher than the median voter's solution in the case with infinitely high transport costs. Proposition 1 summarizes this result.

Proposition 1 *The median voter's preferred mitigation level with migration M_m is lower than the preferred mitigation level without migration $M_m|_{t \rightarrow \infty}$. Both levels are below the social optimal mitigation level without migration $M^{SP}|_{t \rightarrow \infty}$.*

4.2. First stage - adaptation

At the first stage individuals decide about building a dike. They anticipate the political outcome from the subsequent stage and choose to build the dike if their indirect utility function with dike is higher than the indirect utility function without dike:

$$V_{ij}(D = 1) > V_{ij}(D = 0) \quad (21)$$

The indirect utility function at this stage is

$$\begin{aligned} V_{ij}(D_{ij}) = & (1 - \tau(M_m(D_{ij}), D_{ij})) y_i - \alpha(x_{ij}^*(M_m(D_{ij}), D_{ij}), D_{ij}) \pi(M_m(D_{ij})) y_i \\ & - t(x_{ij}^*(M_m(D_{ij}), D_{ij}) - \hat{x}_j)^2 - F. \end{aligned} \quad (22)$$

We can see in (22) that D_{ij} effects the utility function through multiple stages. As long as we don't define the functions explicitly we can't say if the dike is built or not but we can compare the tendency that an individual will vote for the dike. The tendency that one individual of type ij is in favour of the dike compared to another individual depends on the difference in the indirect utility functions with and without a dike $\Delta V_{ij}(D) = V_{ij}(D = 1) - V_{ij}(D = 0)$.

At first, we compare the household type that lives close to the coast with the one that lives far away from it. We know from the migration stage that a c -type individual will move farther away than a f -type individual and that he will be still closer to the coast than the f -type. Together with equation (5), this implicates that the net benefit from building a dike is higher for the c -type household. Thus, an individual that lives close to the coast will vote sooner for a dike than someone that lives far away:

$$\Delta V_c(D) > \Delta V_f(D). \quad (23)$$

Let us now turn to the comparison between high income and low income households. Since the damage is proportional to the income there will be no direct effect of the income on the propensity that someone will vote for the dike. However, we know from the migration choice that high income households have a higher incentive to move away and by moving away, the net benefit of a dike decreases. From this indirect effect it follows that a low income individual will be sooner in favour of a

dike than a high income individual:

$$\Delta V_l(D) > \Delta V_h(D). \quad (24)$$

With (23), (24) and the assumption (10) we get the following ranking for the four types:

$$\Delta V_{lc}(D) > \Delta V_{hc}(D) > \Delta V_{lf}(D) > \Delta V_{hf}(D) \quad (25)$$

Now, one can think of a scenario where each $\Delta V_{ij}(D)$ is positive and therefore the dike is build. Analogously it is possible that every $\Delta V_{ij}(D)$ is negative. But it is also possible that only the ones who live near the coast will have a positive difference while the ones that live far away will have a $\Delta V_f(D) < 0$. Since 90% of the people live far away, the dike won't be built. As long as there are more people located far away from the coast than near the coast and the fraction of low income households is higher than the fraction of high income households we need the *lf*-type to vote for the dike to get a majority for the dike.

Again, we want to compare the situation without migration with the situation with migration. In order to do so we need to think about the influence of transport costs on the utility difference with and without a dike. We know that higher transport costs lead to less migration on the intensive margin. But it is possible that someone lives that far away that even with $t = 0$ the marginal benefit of moving away is smaller than the fix costs F of moving. In this situation, transport costs have no effect on his location decision and hence there will be no effect on his tendency to vote for a dike.

We also know that someone that lives close to the coast has an incentive to move farther away from the coast than someone who lives far away from it. In the case where someone moves away with moderate costs and won't move with infinitely high costs the effect of t on the utility difference $V_{ij}(D)$ is not clear. The reason for this is that less migration has two effects on this stage. Being closer to the sea leads to a higher expected damage which increases the incentive to build a dike. But at the same time we know that a higher expected damage leads to a higher mitigation level on the subsequent stage and that the effect of having a dike on the mitigation level is ambiguously. If the effect of having a dike on the median voter's mitigation level is negative ($\frac{\partial M_m(D)}{\partial D} < 0$) it is possible that migration leads to a higher tendency to build a dike. The reason for this is that moving away lowers

the marginal benefit of protection and that more mitigation and having a dike leads to less migration. Hence, adaptation and mitigation compete with each other in reducing the expected damage and we get a substitution effect. However, if having a dike leads to more mitigation the migration option will decrease the political support for both adaptation and mitigation. The following proposition summarizes these results.

Proposition 2 *If having a dike leads to less mitigation then the effect of migration on the tendency to vote for a dike is ambiguously. In the case where having a dike leads to more mitigation the option to move away lowers the tendency to vote for a dike.*

5. Discussion

5.1. Utility Function

Using linear utility functions gives us the advantage that we don't have to consider two income states but can just subtract the expected damage from the income. With a concave utility function this wouldn't be possible and it would be nearly impossible to derive the results analytically. The main difference between linear utility functions and concave ones is the missing risk aversion but we argue that this could only change the magnitude but not the direction of the effect.

5.2. Damage Function

The reason why we use a damage function with two components is that adaptation and mitigation reduce the expected damage differently. Mitigation is defined as "*an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.*" while adaptation on the other hand is defined as measure that lowers the "*the process of adjustment to actual or expected climate and its effects.*" (IPCC, 2014). This means that mitigation lowers the probability that the damage will occur while adaptation lowers the damage but won't change the probability.

6. Conclusion

This paper studied the effects of migration on adaptation and mitigation from a political economy perspective. We have shown that the option to move away changes the political outcome. The median voter's mitigation level is lower if he anticipates

moving away than in the case where he doesn't have the option. Both levels are below the social planner's optimal level without migration. The effect of migration on adaptation measures is not clear. It is possible that migration leads to a higher or lower propensity that someone is in favour of a dike. It depends on the interaction between adaptation and mitigation. If having a dike leads to more mitigation then migration lowers both mitigation and adaptation. If however mitigation and adaptation compete with each other migration can increase or lower adaptation. It depends on the size of the substitution effect.

Appendix

A. Second-order conditions

$$\text{SOC}_{M_{ij}} = \frac{\partial^2 V_{ij}}{\partial M_{ij}^2} = \underbrace{-\frac{\partial^2 \tau(D, M_{ij})}{\partial M_{ij}^2}}_{<0} - \underbrace{\frac{\partial \alpha(x_{ij}(M_{ij}, D), D)}{\partial x_{ij}}}_{>0} \underbrace{\frac{\partial x_{ij}(M_{ij}, D)}{\partial M_{ij}}}_{<0} \underbrace{\frac{\partial \pi(M_{ij})}{\partial M_{ij}}}_{<0} - \underbrace{\alpha(x_{ij}(M_{ij}, D), D) \frac{\partial^2 \pi(M)}{\partial M_{ij}^2}}_{x < 0} \quad (26)$$

$$\text{If } \frac{\partial^2 \tau(D, M_{ij})}{\partial M_{ij}^2} + \alpha(x_{ij}(M_{ij}, D), D) \frac{\partial^2 \pi(M)}{\partial M_{ij}^2} > \frac{\partial \alpha(x_{ij}(M_{ij}, D), D)}{\partial x_{ij}} \frac{\partial x_{ij}(M_{ij}, D)}{\partial M_{ij}} \frac{\partial \pi(M_{ij})}{\partial M_{ij}} \Rightarrow \frac{\partial^2 V_{ij}}{\partial M_{ij}^2} < 0 \quad (27)$$

$$\text{SOC}_x = \frac{\partial^2 V_{ij}}{\partial x_{ij}^2} = -2t - \frac{\partial^2 \alpha(x_{ij}, D)}{\partial x_{ij}^2} < 0 \quad (28)$$

$$\frac{\partial^2 W}{\partial M^2} = \underbrace{-\frac{\partial^2 \tau(D, M)}{\partial M^2} \bar{y}}_{<0} - \underbrace{\frac{\partial^2 \pi(M)}{\partial M^2} \sum_i \sum_j [\theta_i \lambda_j \alpha(x_{ij}^*(D, M), D) y_i]}_{<0} - \underbrace{\frac{\partial \pi(M)}{\partial M} \sum_i \sum_j \left[\theta_i \lambda_j y_i \frac{\partial \alpha(x_{ij}^*(D, M), D)}{\partial x_{ij}^*(D, M)} \frac{\partial x_{ij}^*(D, M)}{\partial M} \right]}_{\substack{>0 \\ <0 \\ <0}} \quad (29)$$

$$\text{If } \frac{\partial^2 \tau(D, M)}{\partial M^2} \bar{y} + \frac{\partial^2 \pi(M)}{\partial M^2} \sum_i \sum_j [\theta_i \lambda_j \alpha(x_{ij}^*(D, M), D) y_i] > \frac{\partial \pi(M)}{\partial M} \sum_i \sum_j \left[\theta_i \lambda_j y_i \frac{\partial \alpha(x_{ij}^*(D, M), D)}{\partial x_{ij}^*(D, M)} \frac{\partial x_{ij}^*(D, M)}{\partial M} \right] \quad (30)$$

$$\Rightarrow \frac{\partial^2 W}{\partial M^2} < 0 \quad (31)$$

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