Deltares

Building with economic nature

Market based instruments for risk management to promote spatial adaptation to climate change

Tatiana Filatova

1202029-013

Deltares

Title
Building with economic nature

Project	Reference	Pages
1202029-013	1202029-013-VEB-0001	36

Version	Date	Author	Initials	Review	Initials	Approval	Initials
	oct. 2011	Tatiana Filatova		Herman van der Most		Cees van de Guchte	

State
final

Deltares

Title
Building with economic nature

Project	Reference	Pages
1202029-013	1202029-013-VEB-0001	36

Summary in Dutch

"BUILDING WITH ECONOMIC NATURE":
Marktinstrumenten voor risicomanagement bij een toenemende behoefte aan ruimtelijke adaptatie als gevolg van klimaatverandering

Het huidige overstromingsrisicobeheer in Nederland wordt geconfronteerd met drie uitdagingen. De eerste is het prijskaartje dat hangt aan de aanpassingen die nodig zijn doordat de kans op extreme gebeurtenissen is toegenomen. De Nederlandse overheid is verantwoordelijk voor het verbeteren van structurele verdedigingsmaatregelen. Daarnaast moet de overheid na een ramp compensatie betalen en alle stijgende kosten dragen. Er is geen gedeelde verantwoordelijk tussen de overheid en inwoners wat veiligheid betreft. Mensen hebben hierdoor de neiging om niet-veerkrachtige locatiekeuzes te maken. Hierdoor dragen ze in feite bij aan een verhoging van de risico's. De mogelijkheid van de overheid om de huidige controlegebaseerde aanpak van risicobeheer voort te zetten komt door deze economische dynamiek in gevaar .

De tweede uitdaging is dat de toenemende vraag naar ruimte, als gevolg van bevolkingsgroei en economische groei, het landschaarste probleem urgent maakt. Een restrictie op het gebruik van potentieel gevaarlijke gebieden, als reactie op overstromingsgevaar, is niet erg praktisch voor een klein dichtbevolkt land als Nederland. Er zijn dus meer flexibele oplossingen nodig om elk stukje land te kunnen gebruiken. Het kan bijvoorbeeld kosteneffectief zijn om economische activiteiten toe te laten in gebieden met een hoog risico, mits de extra kosten gedragen worden door mensen die er voor kiezen om daar te zijn. Communicatie over deze risico's is hierbij essentieel.

Dit brengt ons bij de derde uitdaging. Recent onderzoek heeft uitgewezen dat de individuele risicoperceptie van overstromingen in Nederland laag is. Een lage risicoperceptie houdt zowel een laag acceptatieniveau in van bepaalde structurele beschermingsmaatregelen die botsen met private belangen (zoals aanspraak op land binnen het programma Ruimte voor de Rivier) als het niet voorbereid zijn op een ramp. Diverse wetenschappelijke- en overheidsrapporten benadrukken de noodzaak het individuele risicobewustzijn te verhogen. Het vinden van een effectieve manier om de risico's te communiceren is moeilijk. Dit rapport geeft een overzicht van economische maatregelen die als aanvulling kunnen dienen op de structurele beschermingsmaatregelen die nodig zijn gezien de drie uitdagingen. Deze maatregelen kunnen helpen bij het ontwerpen van een klimaatbestendige risicobeheerstrategie die in overstemming is met het individueel economische gedachtegoed.

Het huidige risicobeheer in Nederland richt zich uitsluitend op geplande adaptatie. Het is een mix van twee beheersingsbenaderingen: (a) strikte ruimtelijke planning met een verbod op ontwikkeling in bepaalde gedeelten en (b) door de overheid gefinancierde hoogwaterbeschermingsmaatregelen (dijken, zandsuppletie) voor bijna alle economisch belangrijke gebieden. Dit beleid is op veel manieren effectief, maar het zorgt ook voor vaste, inflexibele ruimtelijke uitkomsten. Het biedt geen mogelijkheden om gebruik te maken van autonome aanpassingen op individueel niveau gebaseerd op de dynamiek van het economische systeem.

Title
Building with economic nature

Project	**Reference**	**Pages**
1202029-013	1202029-013-VEB-0001	36

Overheidsinvesteringen in hoogwaterbeschermingsmaatregelen, met als hoogtepunt de implementatie van het Deltaplan, hebben gezorgd voor de hoogste veiligheidsnormen van de hele wereld. Hierdoor is zowel de bevolking als de economische activiteit in risicogebieden ongekend snel gestegen. Dit verloopt in lijn met het “building with economic nature”: kust- en deltagebieden bieden een aantrekkelijke omgeving met werkgelegenheid in de nabijheid en hebben een hoge culturele waarde. Deze sterke economische krachten zorgen voor een stijging van de vraag naar land en leggen druk op de plannen of ruimtelijke inrichting om arealen in risicogebieden aan te wijzen voor ontwikkeling. De inspanning om het totale risico te verminderen door de kans op voorkomen te verlagen wordt ongedaan gemaakt door deze kapitaalsvermeerdering in risicovolle gebieden. Nederland wordt geconfronteerd met een vicieuze cirkel: extra investeringen in hoogwaterbescherming leiden tot meer hoogwaardige ontwikkelingen in overstromingsgevoelige gebieden. Hierdoor zijn meer investeringen nodig in veiligheid met als gevolg dat er opnieuw ontwikkeling in het gebied plaatsvindt.

Maatregelen tegen overstromingen zijn noodzakelijk in bepaalde gebieden. Als deze maatregelen geheel door de overheid worden gefinancierd zodat de individuele verantwoordelijk niet gestimuleerd wordt, zullen ze onvermijdelijk de vraag/locatie beslissingen uit balans brengen in het voordeel van overstromingsgevoelige gebieden. Hierdoor wordt het individuele risicobewustzijn nog meer verlaagd. Kosten voor klimaataanpassingen zullen alleen maar toenemen met het huidige beleid. Dat komt doordat het beleid onbedoeld marktkrachten in werking zet die de prijzen van bezit verhogen en nieuwe ontwikkelingen in overstromingsgevoelige gebieden stimuleren. Hiervoor in de plaats zouden marktinstrumenten (*market-based instruments, MBI’s)* gebruikt kunnen worden. Dat zijn op de markt gebaseerde hulpmiddelen die gebruikt kunnen worden om belanghebbenden te betrekken bij het creëren van prikkels voor lokale bijdragen van ontwikkelaars, bedrijven en huishoudens die voordeel hebben van hoogwaterbeschermingsmaatregelen.

MBI’s zijn regelingen die bepaald gedrag aanmoedigen door middel van marktsignalen. Dit rapport beschrijft vijf verschillende prijs- en kwantiteit gebaseerde MBI’s voor risicomanagement: belastingen, subsidies, verzekering, verhandelbare rechten en overdraagbare ontwikkelingsrechten oftewel TDR’s (*transferable development rights*). MBI’s brengen prikkels voort die ervoor zorgen dat individuen in hun eigen belang handelen en tegelijkertijd als collectief een sociaal gewenst resultaat te leveren. Risicomanagement beleid kan dus ontwikkeld worden met het bouwen met de economische natuur in gedachten.

MBI’s worden gekenmerkt door (i) flexibiliteit and efficiency bij ruimtegebrek. MBI’s garanderen dat elke vierkante meter land zo efficiënt mogelijk wordt gebruikt en geëxploiteerd tegen de hoogste alternatieve kosten, (ii) lagere maatschappelijke kosten, (iii) in tegenstelling tot de uniforme standaarden van op controle gebaseerd beleid, promoten MBI’s de meest kosteffectieve oplossing voor personen met verschillende voorkeuren voor locaties, risicopercepties and financiële mogelijkheden, (iv) mogelijkheid om deelname van belanghebbenden in samenwerking met overheden te stimuleren en om te komen tot de meest innovatieve, rendabele oplossing die de adaptatiekosten verlagen. Als we deze voordelen in overweging nemen, is het de moeite waard te bedenken hoe ze als aanvulling kunnen dienen op de huidige, op controle gebaseerde, aanpak en hoe ze de effectiviteit van deze aanpak kunnen verhogen. Vooral gezien de aanpassingen die nodig zijn door de klimaatverandering.

Deltares

Title
Building with economic nature

Project	Reference	Pages
1202029-013	1202029-013-VEB-0001	36

Het rapport geeft een overzicht van de theoretische onderbouwing van elk van de vijf MBI's en de mogelijkheden die ze bieden om personen te stimuleren om klimaatbestendige keuzes te maken die overeenkomen met hun persoonlijke belangen. Hoe effectief een MBI is hangt grotendeels af van het ontwerp en de implementatie ervan. Het rapport behandelt voornamelijk het gebruik van de vijf MBI's voor overstromingsrisicobeheer in Nederland, Amerika, Groot-Brittannië, Duitsland, Frankrijk en Nieuw-Zeeland. Bepaalde MBI's, zoals verzekering tegen overstromingen, worden veel toegepast en bieden sterke empirische argumenten om conclusies te trekken over het ideale gebruik ervan. Andere MBI's, zoals verhandelbare rechten, komen alleen voor als één van de scenario's in een simulatiemodel dat toegepast wordt in Engeland, daardoor zijn hiervan minder leerzame ervaringen beschikbaar.

We sluiten af met de discussie hoe MBI's gebruikt kunnen worden om ruimtelijke adaptatie tegen klimaatverandering te stimuleren en hoe het gebruik van MBI's ervoor kan zorgen dat de risico's in een bepaald gebied gelijk blijven en tegelijkertijd de drie uitdagingen van het huidige overstromingsbeheer overwinnen. Doordat de kans op gevaar toeneemt, kunnen bepaalde MBI's belangrijker en beter haalbaar worden dan nu het geval is. Denk hierbij aan belastingen met geografische differentiatie van het veiligheidsniveau, subsidie voor het vestigen in veilige gebieden, verhandelbare rechten die snelle reacties en innovatieve regelingen promoten en TDR's die winstgevend worden.

Het idee om beleid te ontwerpen met bouwen met de economische natuur in gedachten, speelt een belangrijke rol bij de aanbevelingen 2 en 3 van het Deltacommissierapport. Proactief beleid gebaseerd op MBI's kan erg nuttig zijn voor de buitendijkse gebieden en nieuwe ontwikkelingen in laaggelegen overstromingsgevoelige gebieden. Zo kunnen individuele keuzes aangemoedigd worden die resulteren in maatschappelijk voordelige oplossingen. Met behulp van de MBI's zouden beleidmakers ontwikkelingen in overstromingsgevoelige gebieden kunnen toestaan, maar zouden dit individuele economische gedrag kunnen sturen met behulp van marktwerking, zodat politiek gewenste uitkomsten bereikt worden. Beleid gericht op controle aangevuld met MBI's helpt om de maatschappelijke kosten voor klimaatadaptatie te verlagen. Daarnaast verhoogt het de individuele risicoperceptie en zorgt het ervoor dat schaarse ruimte efficiënt gebruikt wordt. Een combinatie van publieke en private ruimtelijke adaptatie kan meer opleveren dan elk afzonderlijk. In het overheidsbeleid zouden natuurlijke wetten gebruikt moeten worden die het economische gedrag sturen (mensen reageren wel op prijsprikkels). Beleidsmakers kunnen kiezen voor klimaatbestendige gebiedsontwikkeling met in gedachten *bouwen met de economische natuur*.

Title
Building with economic nature

Project	**Reference**	**Pages**
1202029-013	1202029-013-VEB-0001	36

Summary in English

BUILDING WITH ECONOMIC NATURE:
Market based instruments for risk management under the growing need for spatial adaptation due to climate change

Current Dutch flood risk management faces three challenges.

Firstly, the adaptation to increasing probabilities of extreme events will be costly. In the Netherlands the government is responsible for improving structural defense measures and paying compensations in the case of a disaster, thus, it will bear all the raising costs. The lack of shared responsibility for safety between government and individuals creates strong stimuli for people to make climate-unresilient location choices and effectively contribute to growing risks. This economic dynamics threatens the ability of government to continue with the current control-based approach to risk management.

Secondly, increasing demand for space due to population and economic growth puts the issue of land scarcity upfront. Restricting use of hazard-prone areas by withdrawing land from use in response to flood risks is unpractical in a small very densely populated country like the Netherlands. More flexible solutions for the use of every piece of land are needed. For example it might be cost-effective to allow economic activity in high-risk zones if extra costs are born by individuals who choose to be there. It is vital, although, that these risks are communicated.

This brings us to the third challenge: as several recent surveys showed, individual perception of flood risk in the Netherlands is low. Low risk perception implies both low acceptance level of certain structural defense measures that are in conflict with private interests (i.e. land claims within ‘ruimte voor rivieren’ program) and lack of preparedness for disaster. Various governmental and scientific reports highlighted the need to increase individual risk awareness but finding an effective way to communicate risk is difficult. This report provides a review of economic measures that can be complementary to the structural defense measures in responding to these three challenges. They can help in building climate-resilient risk management strategy in line with “economic nature”.

The current risk management in the Netherlands focuses exclusively on planned adaptation. It is a mixture of two command-based approaches: (a) strict spatial planning that forbids developments in certain zones, and (b) governmentally-funded flood defense measures (dikes, sand nourishments) for most economically-vital areas. While this policy is effective in many respects, it produces fixed inflexible spatial outcomes and lends no opportunity to employ autonomous adaptation in the individual level based on the dynamics of the economic system.

Governmental investments in flood defense measures, especially intensive with the implementation of the Delta-plan, have delivered the highest safety standards in the world. As a result, the population and economic activities in hazardous zones increased at an unprecedented rate. This goes very much in line with “economic nature”: coastal and delta areas provide rich environmental amenities, proximity to jobs, and have high cultural value. These powerful economic forcers drive demand for land and put pressure on spatial planners to assign areas in hazard-prone zones for development. The efforts to decrease overall risk by lowering the probability of occurrence can be wiped out by this boost of capital at risk.

Deltares

Title
Building with economic nature

Project	**Reference**	**Pages**
1202029-013	1202029-013-VEB-0001	36

Netherlands faces a vicious circle: additional investments in flood protection drive more high-value developments to flood-prone areas, which justifies further investments in safety, and triggers another wave of development. Flood defense measures are vital in certain locations. However, if they are financed entirely by the government and do not stimulate individual responsibility, they will inevitably distort demand/location decisions in favor of flood-prone areas, and will further lower individual risk perception. Climate adaptation costs only rise with the current policies that unintentionally unleash market forces to increase property prices and stimulate new developments in flood-prone areas. Instead market-based instruments (MBIs) can be used to engage stakeholders by creating incentives for local contributions from developers, firms and households who benefit from flood defense measures.

MBIs are regulations that encourage certain behaviors through market signals. This report discusses five types of price- and quantity-based MBIs for risk management: taxes, subsidies, insurance, marketable permits and transferable development rights (TDRs). MBIs create incentives for individuals to act in their own interests while collectively delivering socially-desired outcomes. Thus, risk management policies may be designed with “economic nature” in mind.

MBIs are characterized by: (i) flexibility and efficiency under scarcity of space. MBIs guarantee that every sq. meter of land is used as efficiently as possible exploiting the highest opportunity cost; (ii) lower societal costs; (iii) in contrast to uniform standards of control-based policies MBIs promote most cost-effective solutions for individuals with diverse preferences for location, risk perceptions and financial possibilities; (iv) ability to promote stakeholders participation and cooperation with government in a search for most innovative cost-effective solutions reducing adaptation cost. Considering these advantages it is worth thinking how they could complement and reinforce the effectiveness of the current control-based approach, especially in the light of climate change adaptation.

The report provides an overview of the theoretical basis of each of the five MBIs, and of their opportunities to create incentives for individuals to make climate-resilient choices that are still in line with personal interests. The effectiveness of MBIs largely depends on their design and implementation. The main body of the report discusses the practice of use of the five MBIs for flood risk management in the Netherlands, USA, UK, Germany, France, Australia and New Zealand. Some of the tools, such as flood insurance, are commonly employed and provide strong empirical ground to make conclusions about the ideal way of its utilization. The others, such as marketable permits, exist only as one of the scenarios in a simulation model applied in the UK, and, thus, provide fewer lessons. We conclude with the discussion of how MBIs can be used to help promote spatial adaptation to climate change and achieve non-increasing risk while overcoming the three challenges of the current risk management policy. With increasing hazard probabilities some MBIs (such as taxes with geographical differentiation on the level of safety, subsidies for locating in safe areas, marketable permits promoting fast response and innovative arrangements, and TDRs that start to be affordable) can become more important and feasible than currently.

Title
Building with economic nature

Project	Reference	Pages
1202029-013	1202029-013-VEB-0001	36

The concept of designing policies with “economic nature” in mind is especially important for the Recommendation 2 and 3 of the Deltacomissie report. Proactive policy based on MBIs can be very useful for the outside-dikes areas and new developments in low-lying flood-prone areas to encourage individual choices that deliver socially beneficial solutions. With the help of MBIs policy-makers may allow developments in flood-prone zone but guide them by affecting individual economic behavior through market forces to deliver politically-desired outcomes. Control-based policies complemented with MBIs help to lower societal costs for climate adaptation, increase individual risk perception and allow most efficient use of scarce space. Combination of public and private spatial adaptation may achieve more than each one separately. Governmental policies should employ natural laws that guide economic behavior (e.g. people do react to price signals!). Policy makers may choose to *build* climate-resilient developments *with “economic nature”* in mind.

Contents

1 Introduction

The Netherlands is particularly vulnerable to flooding[1] since 70% of its Gross National Product is generated in coastal areas (Veraart et al. 2007). Historically flood risk management was carried out top-down, and for centuries Dutch government was responsible for building and maintaining flood defense infrastructure. The question, however, is: how much of the capital would not have been at risk and would be located in safer[2] areas if centralized safety measures were not in place?

The current risk management in the Netherlands is a mixture of two approaches, which are command-based in their essence: (i) strict spatial planning that forbids developments in certain zones, and (ii) governmentally-funded flood defense measures (dikes, sand nourishments) for most economically-vital areas. Spatial planning has been successfully used in the Netherlands to prohibit developments in environmentally-sensitive or high-risk zones. The flood-prone areas where development is allowed are protected at certain safety standard assured by the various flood defense infrastructures. However, increasing demand for space from firms and households due to population and economic growth put the issue of scarcity of land upfront. Indeed, the Netherlands is one of the most densely populated countries. In a small country with very limited space for development withdrawing land from use in response to flood risks is unpractical. More flexible solutions for the use of every piece of land are needed. For example it might be cost-effective to allow economic activity in high-risk zones if extra costs are born by individuals who choose to live there rather than by the society as a whole.

Each flood-prone zone where developments are allowed is assigned a certain safety standard reinforced by law (Wet op de Waterkering 1995). High safety standards (i.e low probabilities of flooding) ranging from 1:250 to 1:10.000 are guaranteed by various flood defense measures (dikes, dune reinforcements, sand nourishments). Governmental investments in flood defense measures, especially intensive in the last 50 years with the implementation of the Delta-plan, delivered the highest safety standards in the world. Simultaneously, the population and economic activities in hazard zones increased at a speed never observed before (Lescrauwaet et al. 2006). This goes very much in line with economic nature: coastal and delta areas provide the richest environmental amenities, proximity to jobs, have high cultural value, and now they are also safe at no extra expense for those who directly enjoy these location advantages. Thus, there are powerful economic forcers that drive demand for land and put pressure on spatial planners to assign areas in hazard-prone zones for development. These safety standards can also easily become obsolete when environmental conditions change, e.g. because of changing climate, Moreover, the efforts to decrease overall risk[3] by lowering the probability of occurrence can be wiped out by the boost of economic developments. Netherlands, as other countries throughout the world, faces a challenge of a vicious circle: additional investments in flood protection drive more developments in flood-prone areas putting more capital at risk, which gain more power to

---

[1] *Flooding, which is caused either by a break of a dike or high water levels, has two physical effects: inundation and erosion. Here when we say flooding (or flood) we assume both effects.*

[2] *Throughout the paper we will use two terms "risky" (or "high-risk") area and "safe" area. Depending on the scale of the application (national, regional, urban) these terms might be linked with: a) nationally: flood-prone areas vs. safe areas; b) regionally (several dike rings – all prone to flooding but with different probability): area which is more defendable; c) at the level of a municipality near the coast or river bank: the outside-dikes areas vs. areas protected by dikes.*

[3] *Risk = probability * effect*

justify further investments in safety and trigger another wave of development (Wiener 1996; Barnhizer 2003; Kunreuther and Pauly 2006; Filatova et al. 2011). Flood defense measures are vital in some locations. However, if they are financed entirely by the government and do not assume or stimulate individual responsibility, they will inevitably distort demand/location decisions in favor of flood-prone areas. Government will not be able to curb risks if the distortions in land markets due to flood defense measures are not understood. One may argue that stopping investments in flood protection implies curbing economic development. Naturally, economic development is important. However, it is vital to develop in a sustainable climate-resilient way. The point this paper makes is that governmental investments in flood protection that lead to clustering of high economic stakes in one location are strategically dangerous. Diversification and not putting all the eggs in one basket is the golden rule of any successful investment portfolio. Even the best protection in the world only reduces risk to some acceptable level but does not eliminate it entirely (Costa 1978). Think of Fukushima disaster: when small probabilities are realized the consequences may be devastating. One needs to do everything to reduce probabilities, but has to also consider the worst case scenario to design policies that reduce potential damages where possible.

The current risk management policy based on command-and-control measures aggravates three main problems: growing scarcity of space, increasing costs of flood protection, and low perception of flood risks. These challenges become even more pronounced in the light of climate change. According to different scenarios climate change will cause sea level to rise by 20-110 cm by the year 2100 (de Bruin et al. 2009) and create greater variability of river discharges (Bresser et al. 2005). Adaptation to climate change is inevitable and is costly (Stern 2008). The adaptation costs rise even more with the current policies that unintentionally unleash market forces to increase property prices and stimulate new developments in flood-prone areas. Increasing flood protection or potential retreat from flood prone areas become extremely costly. It is recognized that governments alone cannot afford to bear all the costs. Governments should engage stakeholders and create incentives for local contributions from developers, firms and households who benefit from flood defense measures (Defra 2010). Economics of climate change distinguishes among two levels of adaptation: planned (public) and autonomous (individual) (World Bank 2009). Planned governmental adaptation may include a combination of command-based and market-based instruments (MBIs), which create the rules for microeconomic dynamics. Autonomous adaptation happens as individual businesses and households respond to price signals and give raise to more climate-resilient aggregated outcomes. Spatial adaptation cannot proceed in a way, which does not involve individual stakeholders and provides no means for them to contribute with individual adaptations. This report aims to explore the opportunities to employ autonomous adaptation provided by the dynamics of the economic system for climate resilient policy. Specifically we focus on the following question: in the light of growing demand for space and increasing climate-induced risks, how can the efficiency of space use be improved by employing MBIs (in addition to the control-based instruments) to promote autonomous adaptation?

Promoting individual adaptation does not contradict the solidarity principle and collective responsibility for safety. Flood protection is a public good, and it is most cost-efficient to construct structural defense measures collectively rather than individually. The question is how to find the right way to include everyone in sharing responsibility and to avoid free riding? Should everyone participate on the same conditions, or should we contribute to public safety according to the beneficiary principle? For example, 23% of houses in coastal areas in Zeeland are second homes (Lescrauwaet, et al. 2006). Thus, the most well off members of the society enjoy these attractive locations, which are made safe at the costs of the society as a whole. Here solidarity seems to compromise social equity.

The benefits of using MBIs to tackle the challenges of climate change are widely discussed among scientists (Goers et al. 2010) and policy-makers (Stavins 2003; COM 2007). Most attention is paid to climate change mitigation (i.e. reduction of CO_2 emissions) but little attention is given to these measures in application to adaptation. Yet, the ability of MBIs to stimulate individual choices that support policy-goals makes them suitable to support spatial adaptation in flood-prone areas in parallel with command-and-control measures. Various MBIs (subsidies, insurance, marketable permits, etc.) create incentives for individuals to act in their own interests while collectively delivering socially-desired outcomes. Thus, risk management policies may be designed in line with “economic nature”.

The instruments for flood risk management to be included in the policy toolbox strongly depend on the environmental and socio-economic conditions of a country. In the Netherlands there is a big difference in the nature of flooding in protected vs. unprotected, outside-dikes areas. The legally protected areas have very low probability of flooding but if it does happen the consequences can be disastrous. In the outside-dikes areas probability of flooding is much higher, while potential damage is much lower. If we consider MBIs just as tools to spread and share flood risk (e.g. by means of insurance) then from the first glance, they are very likely to be effective in the outside-dikes areas. A more thorough analysis is needed to estimate the feasibility of MBIs for risk sharing in the protected areas (Kok et al. 2002; Botzen and van den Bergh 2008). However, if we think of MBIs as of a tool to stimulate relocation to safe areas or to assure that construction of dikes or strengthening of dunes is done according to the beneficiary principle, then MBIs are likely to guarantee economic-efficiency in both protected and outside-dikes areas.

The report proceeds as follows. We first provide a brief review of urban economics literature to illustrate the economic logic behind location decisions and to show the role that flood risks play. The types and principles of various MBIs are discussed in the subsequent section. Then we look at the experiences of different countries with various market instruments applied in flood-prone areas. The report concludes with a summary of positive and negative lessons and suggestions for the use of different MBIs in the light of increasing climate-induced risks.

2 Economic theory

Coastal and delta areas were historically developed due to their proximity to marine and river transportation. Further developments occur close to historic cities driven by several forces. On the one hand, businesses benefit from agglomeration attracting more households by increasing employment opportunities and higher wages (Fujita and Thisse 2002). On the other hand, coastal and delta areas provide important environmental amenities, which are highly valued by households (Bin et al. 2008). Thus several economic forces work to attract more development to the areas where risks are constantly growing due to climate change.
It is important to understand how policies may encourage individual spatial adaptation in flood-prone areas that is in private interests and that collectively meets policy goals. To answer this question we first briefly review spatial economics to define the factors that affect individual location choice.

2.1 Urban economics and decisions under uncertainty

Individual location or land-use choice is treated as a constrained maximization problem in economics. A rational consumer (e.g. household) makes his choice of location by maximizing his utility subject to budget constrain. Specifically, households choose locations at a certain distance from the central business district (CBD) based on the maximum utility they receive from land and other consumption goods under their budget constraint (Alonso 1964; Brueckner 1987):

$$\max U(z,s,d)\ ,\quad \text{s.t. } Y = z + s \cdot R(d) + T(d) \qquad (1)$$

Here, *z* is a composite good, *s* is a quantity of land/space floor, *U* is individual utility, *d* is the distance from the city centre, *R(d)* is the distance-dependent land/housing price, *Y* is a household's budget, and *T(d)* are commuting costs at distance *d*. The model assumes that land is allocated to the highest bidder via land market. The individual demands of homogeneous consumers (Equation 1) are summed to form the aggregated demand. The aggregated demand for land matched with aggregate supply of land in equilibrium defines the optimal land prices and spatial structure of the city.

Coastal and delta areas are known for their rich environmental amenities, which are highly valued by households (Shabman et al. 1998; Bin, et al. 2008). Wu (2001) extends the standard monocentric urban model to account for the impact of seaside view on land prices and spatial pattern. Site-specific coastal amenities enter the utility function and, thus, influence the choice of a spatial good by individuals. If everybody wants to live close to the beach or river waterfront then the aggregated demand for land in this area increases and so do prices (D* vs. D in Figure 1). Thus, the theoretical model of Wu shows the economic logic behind empirically observed positive willingness to pay for the seaside view or beachfront.

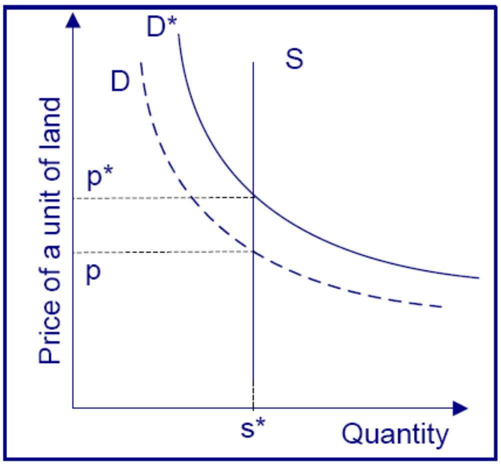

Figure 1: Higher demand and price because of the attractiveness of a seaside location

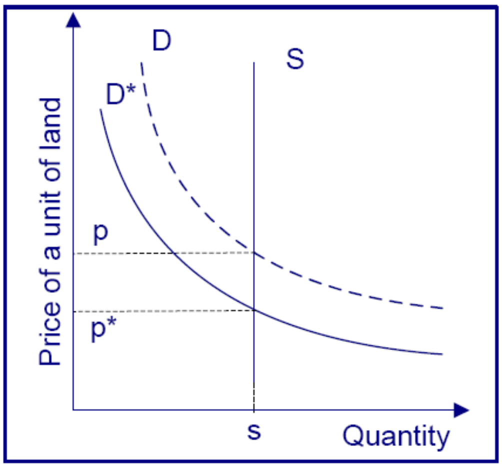

Figure 2: Lower demand and price because of the risk of flood in a seaside location

Here D is demand, S is supply, p is price. Subscript * symbolize the change of the situation from the base (no amenities / no risk). Supply curve for a land market is often shown as a vertical line[4], since the amount of existing land in a certain area is fixed.

Under conditions of uncertainty (such as probabilistic flooding) a consumer maximizes his expected utility (Varian 1992). If economic agents are aware of the risk of flooding or erosion, then the proximity to the coast/river might serve as a repulsive factor. The aggregated demand for land decreases pushing land prices down (D* vs. D in Figure 2).
Several authors proposed an analytical model to track this process. MacDonald et al. (1987) outlined an aspatial model of location choice in a flood-prone area. Individual utility depends on location specific characteristics and a composite good. There assumed to be two states: no flooding or flooding with corresponding probabilities of occurrence. The monetary loss due to flooding enters budget constraint in the state when flooding happens. A rational consumer chooses a location to live by maximizing his expected utility subject to budget constraint.
Tatano et al. (2004) proposed an aspatial model for a city divided into two zones: safe and vulnerable to natural disaster. Utility of an individual choosing a location depends on a composite good, housing service and level of amenities, which is a binary variable symbolizing one state if no disaster happens and another if it does. Households maximize their expected utility under budget constraint. Loss in the case of a disaster does not enter budget constraint but is reflected in the lowered level of amenity. In addition, households are assumed to have subjective expectations for the vulnerability of a disaster. The authors concluded that if risk perception biases exist, then a market cannot result in the efficient allocation of land in the city.
Frame (1998) extends the monocentric model of Alonso by differentiating locations by both distance to CBD and flood risk. Financial damages that depend on the severity of loss enter households' expected utility function. Locations with higher risk provide lower expected utility for households in equilibrium, leading to decrease in land price.

---

[4] *No matter how much someone would be willing to pay for a piece of land, additional land could not be created. Also, even if no one wanted all the land, it still would exist as a free good.*

To summarize: the choice of location in a coastal town with flood/erosion-prone and safe areas is formulated as the maximization of expected utility, or Von Neumann-Morgenstern utility function:

$$EU = p \cdot U(s^*, d, z^*) + (1-p) \cdot U(s, d, z) \qquad \text{s.t.} \quad Y = z + s \cdot R(d) + T(d) \qquad (2)$$

Here, *p* is the probability of flood/erosion, s* - reduced quality of housing due to flooding (non-monetary damage), z* - reduced amount of composite goods one can afford for his budget net of damage costs (monetary damage)..

It is important to realize that coastal amenities and flood risks are spatially correlated. It implies that in practice both risks and amenities capitalize in land prices driving them in opposite directions. Specifically, the correlation between risk and amenities biases estimates of land price discounts due to risk in hedonic price analysis, while the value of amenities may be underestimated (Bin, et al. 2008). Internationally the evidence of property price discounts due to natural hazard risk is mixed (Shabman, et al. 1998; Barnhizer 2003; Bin, et al. 2008; Lall and Deichmann 2009). Two main reasons of the failures to capitalize risks in land/property prices are: (i) spatial correlation with coastal/riverside amenities, (ii) presence of flood defence measures (dikes, sand nourishments).

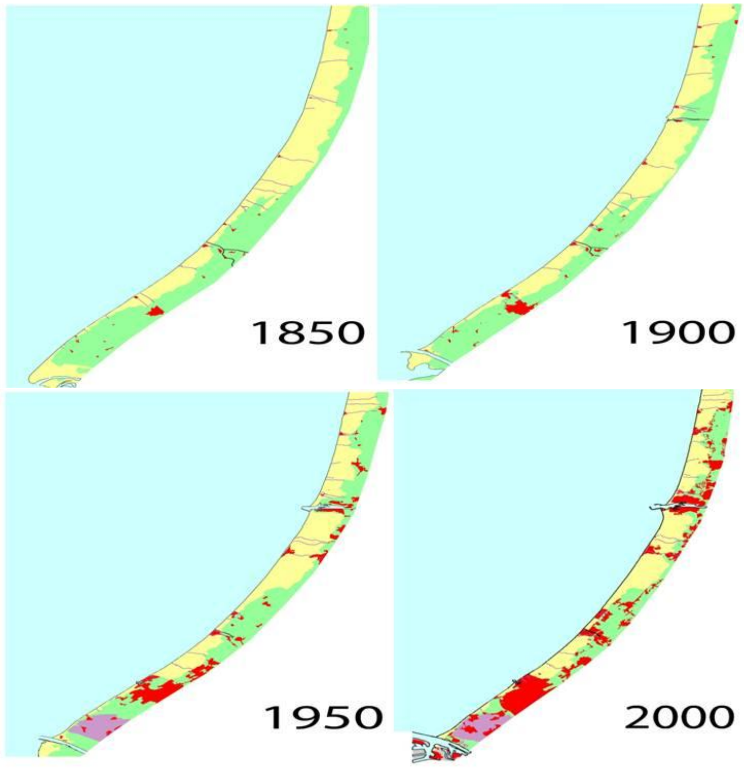

Figure 3: Growing urbanization (in red) along the Dutch coast

To our knowledge there is no hedonic study done in the Netherlands to check the impacts of both amenities and flood risks on land prices simultaneously. However, some indirect evidence suggests that flood risks play a minor role in the location choice in coastal areas compared to other centripetal forcers (environmental amenities and agglomeration forces). In particular, urbanization of the Dutch coast considerably increased, especially during the last 50 years (Figure 3).

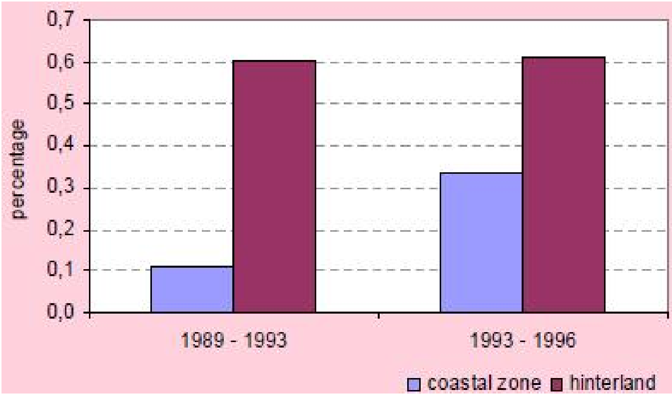

Figure 4: Area converted from non-developed to developed land uses in the Netherlands. Source: (Lescrauwaet, et al. 2006)

The rate of urbanization was increasing faster along the Dutch coast than in the hinterland reaching 0.31% between 1993-1996 (Lescrauwaet, et al. 2006) (Figure 4).
Note, that in 1990 the Dutch government made a decision to maintain the coastline at the level of 1990 by means of repairing annual erosion with intensive sand nourishments (1e Kustnota, 1990).
In addition to spatial patterns, property prices also indicate growing demand for coastal areas. The average price of properties at the coast is higher than the average for coastal provinces. Specifically, in the province of Zuid-Holland the difference between average property prices along the coast and those more landward, was € 99 400 in 2005 (Lescrauwaet, et al. 2006).
If time horizon is important for individual location choice, then time discounted utility is applied. Consequently, when both uncertainty and time are essential, individuals are viewed as maximizing their expected discounted utility (Shabman, et al. 1998):

$$DEU = \sum_{t=1}^{T} \frac{EU_t}{(1+r)^{t-1}} \qquad (3)$$

here variable *r* represents the individual's personal rate of time preference (or a discount rate of a representative consumer), which is assumed to be constant over time, and *T* is the individual's planning horizon.

2.2 Individual rationality and low-probability high-consequences events

Urban economics models presented above are based on the conventional economic assumption of a rational representative consumer. However, many studies in psychology question the rationality of an individual especially when making decisions for low-probability high-consequences events (Kahneman and Tversky 1979; Slovic 1987). Let us consider a small example. The safety standard guaranteed by law in the Noord-Holland province in the Netherlands is 1:10.000 years. The value at risk in the outside-dike areas[5] in a coastal town of Bergen aan Zee is €63 mln (1997 prices) (Rijkswaterstaat 2005). According to a rational decision maker the expected loss here will be:

1:10.000 * €63.000.000 = €6.300 – low-probability high-consequences event

Imagine a situation when flooding/erosion happens annually but damage for the whole city is quite moderate (e.g. €6.300):

1:1 * €6.300 = €6.300 – high-probability low-consequences event

Since the expected loss of both events is the same, a rational expected utility model will treat them the same way.
Evidence from surveys and lab experiments with human subjects illustrated that people have hard time understanding probabilities (Kahneman and Tversky 1979; Slovic 1987). They

[5] *Areas outside-dikes are not protected with safety standard as the rest of the province. The actual probabilities of flooding are currently not known. Moreover, it is believed that citizens are not aware that their house is not protected at the equal level of safety compared to the rest of the town/province. Thus, we will use the probability of 1:10000 for this illustrative example.*

usually treat risky situations not as an analysis (i.e. expected utility) but as feelings (Slovic et al. 2004). Empirical studies also reveal that the perception of risk increases after an event (Kaiser et al. 2004) and gradually reduces in the long-term, if the event does not occur periodically (Chivers and Flores 2002). For the above example this implies that a probability of 1:10.000 is likely to be perceived as zero, making expected annual loss zero instead of €6.300. For the zone with frequent flood individual risk perception is updated annually and is likely to be correct:

$$0 * €63.000.000 = €0 \quad \Leftrightarrow \quad 1:1 * €6.300 = €6.300$$

An individual who does not comprehend low-probability event would choose a location in the first zone leading to the boosting growth of capital at risk. Therefore, a feeling of safety will bias rational choice in flood-prone areas and attract more developments in the risk zone leading to disastrous consequences if the hazard occurs (Tatano, et al. 2004; Filatova et al. 2009).

The subjective beliefs about the probabilities, causes, and effects of flood events in the future depend on the experience, income, education and other socio-economic individual characteristics (Sjoeberg 2000). Experimental economics has proven that subjective risk perceptions very much depend on how the risky situation is framed (Kahneman and Tversky 1979). In fact subjective probability can be a part of microeconomic model (Varian 1992). Individual demand for land depends on the individual perception of hazard probability, income and preferences for location attributes (e.g. amenities, proximity to work, etc). However, aggregation of individual demands for land shaped by subjective probability of hazard is difficult. Nevertheless, the understanding of the psychology of decisions making under uncertainty is penetrating into the economic discussion about locations in flood-prone areas (Shabman, et al. 1998; Kunreuther and Pauly 2006).

In summary, land markets in flood-prone areas are likely to exhibit the following two phenomena: (i) flood risk and environmental amenities are spatially correlated and vanish each other impact on land prices and put pressure on further development in flood-prone areas; (ii) individuals may have subjective beliefs about the probability of hazard what leads to biased results in land markets (e.g. economically inefficient developments in high-risk areas). Understanding of actual risks and their projected increase due to climate change is vital in making location choices that produce climate-resilient outcomes.

Communication of these risks is not an easy task. In addition, the impacts on the aggregated demand may still be ambiguous: greater risks decrease demand and prices what in turn increases demand (Frame 1998). With too much other sources of uncertainty the ambiguity concerning the changes in demand due to changes in risks is the last thing policy-makers need when designing risk management policy. In contrast, such MBI as actuarial flood insurance changes demand for land in flood prone areas in a determinate fashion (Frame 1998). Specifically, households are compensated for the actuarial site-specific insurance premiums by the decrease in the land/property price (similar to the trade-off between travel costs and land price (Alonso 1964)). In this case lower land prices do not involve growth of demand for high risk areas. Thus, individuals acting in their own interests collectively deliver socially-desired outcome of non-decreasing risk.

The next sections discuss how MBIs may help fixing market failures in the case of low risk perceptions or incorrect expectations about future risks, which individuals or developers may have.

3 Market-based instruments for managing hazard-prone areas

MBIs are regulations that encourage behavior through market signals, rather than through explicit control directives (Stavins 2003). Grounded in the economic principles of supply-demand interactions MBIs may help improving environmental management, including the use of hazard-prone areas. Through price signals these instruments encourage individual behaviors that are in the interests of individual economic actors (e.g. firms or households) and that collectively help to achieve policy objectives. For flood-prone areas changes in individual behavior may include individual spatial adaptation (e.g. growing demand for safer areas resulting in fewer and cheaper developments in high-risk areas) or risk reduction (e.g. insurance or waterproofing buildings), which eventually help achieve lower flood risk (probability*effect) for policy-makers.

3.1 Comparison with control-based instruments

MBIs are effective in promoting individual choices that help meet policy goals only if designed and implemented correctly. As will be shown below there could be some undesirable consequences if MBIs are not implemented appropriately. A natural question is: why bother if control-based policies (such as spatial planning) showed to be adequate on many occasions? There are several advantages of MBIs in comparison to command-and-control policies:

1. <u>Flexibility and efficiency</u>: while forbidding residential and commercial land use in flood-prone areas certainly keeps risks low, completely banning developments in such country as the Netherlands where 70% of GDP is earned in the areas below sea level (Veraart, et al. 2007) is unrealistic. Considering extreme scarcity of space and increasing demand for land a more flexible solution seems appropriate. Powered by market forces MBIs remove economically inefficient developments from floodplains. At the same time anybody who wants to enjoy coastal/river amenities and is ready to bear financial consequences of respective risks can locate in the flood-prone area without extra costs transferred to a society as a whole. Thus, MBIs guarantee that every sq. meter of land is used as efficiently as possible exploiting the highest opportunity cost.
2. <u>Low societal costs</u>*:* as discussed by Clinch (2010) zoning involves significant administration and enforcement costs borne by taxpayers. In application to environmental policies MBIs are considered to be flexible means for achieving policy objectives at the lowest costs to society (Stavins 2003; COM 2007). On the one hand, this happens because of the nature of MBIs, which transfer part of the decision process to individuals. In case of flood-prone developments it also transfers responsibility for risks (and potential costs) to individual who wish to locate there. On the other hand, spatial planning sometimes results in ‘overzoning’ (Mason 1979) and creates neighborhood externalities by rising land/property values for the area where development is allowed at the expense of landowners whose development rights are denied (Clinch and O'Neill 2010).
3. <u>Accent on individual heterogeneity</u>: control based measure that ban any activity in the risk zone creates a uniform standard for all actors. However, individuals are heterogeneous in their preferences for location, risk perceptions and financial possibilities. Aggregating these individual demands and trying to optimize for some representative consumer may lead to policy failures (Kirman 1992; Filatova, et al. 2009). The greater the degree of heterogeneity among economic actors, the more useful are MBIs since they promote cost-effective solution for everyone (Stavins 2003).

4. Stakeholders involvement and private-public partnership (PPP): successful risk management of floodplains needs active integration of stakeholders and development of strategic management approaches that promote participation (European Commission DG ENV 2010). Dutch centralized policies focused on zoning, investment in technical defense measures and nourishments, and governmental relief payment in the case of disaster via the 'Calamities and Compensation Act' (WTS) provides all the disincentives for stakeholders to make any effort to reduce risks at the individual level. Policies should provide institutional arrangements that promote greater stakeholders participation. This is especially vital in the light of climate change, which requires high adaptation cost and calls for even close cooperation of government and local communities and establishment of PPP. MBIs that affect individual economic behavior may help deliver socially-desired outcomes. In addition, MBIs encourage innovation among individual land/property owners by urging them to search for individual cost-effective solutions.

Originated by the community feeling in tackling flooding and erosion hazards for centuries, regulatory command-and-control measures for risk management dominate in the Netherlands. While MBIs for environmental management gain increasing attention worldwide[6] (Stavins 2003; COM 2007; Defra 2010; Goers, et al. 2010), their potential seems to be ignored in Dutch risk management policy. Considering the advantages of MBIs (especially in the light of climate change adaptation) it is worth thinking how they could complement and reinforce the effectiveness of the existing approach. This paper does not mean to show that MBIs are the ultimate solution for any problem[7]. Instead, this paper aims to show the added value which MBIs could provide for risk management if combined with traditional control-based instruments such as spatial planning or structural defense measures.

3.2 Types of market-based instruments

There are three main types of MBIs: price-based (tax, subsidy, insurance), quantity-based (marketable permits or transferable development rights) and market friction (green labeling, liability rules) approaches (National MBI Forum ; Stavins 2003; Clinch and O'Neill 2010; Mori 2010). At this moment we do not see much potential of the market friction approach to affect land use and property prices in flood prone areas (and consequently potential flood damage) and will not discuss it further. These MBIs can be used complimentary to control-based instruments (spatial planning and structural defense measures).

I. Price-based instruments

Taxes: provide an incentive for individuals to internalize negative external costs that are caused by their activity. In application to environmental management these are usually known as 'Pigouvian' taxes. Pigouvian tax (equal to marginal external costs) is often applied in emissions management to balance private and social interests – the 'polluter pays principle'.

---

[6] *Also see the Australian government-funded program: http://www.marketbasedinstruments.gov.au/ In addition the web-site also offers a decision-support tool for policy-maker to help decide whether MBI is an appropriate tool for some specific problem at hand: http://www.marketbasedinstruments.gov.au/Publicationsproducts/DesignerCarrotsdecisionsupporttool/DecisionSupportTool/tabid/276/Default.aspx*

[7] *Unregulated market alone cannot effectively serve environmental management and may exhibit various market failures.*

To be applied to coastal or river flood risk management, a tax would need be introduced to internalize the adverse effects of developments within high risk areas[8] (Turbott and Stewart 2006) – to become the “acquirer/land-user pays principle”. Such tax needs to differentiate among various probabilities of hazard and should differ among locations (be high in high-risk zone and low in safe) (Mori 2010). The benefits of applying preferential taxation have been discussed for decades (Godschalk and Brower 1985). Taxes or tax breaks serve to discourage or provide incentives for (re)developments in the zone where probability of hazard is high versus safer zone. Alternatively, various tax rates can be charged from households and firms residing closer/further from the dike or nourished beach based on the benefits they receive from this protection.

Subsidies: give a value to the external benefits of economic activities, so that economic actors take them into account and change their behavior to increase positive environmental impacts (COM 2007). While the demand for land increases in the subsidized safe areas, the demand for risky locations goes down decreasing land prices and pressure to develop there, and consequently decreasing costs for flood protection in the long term. Such subsidies depend on location and, thus, can be combined with spatial planning. It is vital to differentiate between perverse subsidies and socially-beneficial subsidies (Bagstad et al. 2007). Perverse subsidy can be an unintentional side-effect of another policy that distorts market signals and discourages socially-optimal use of resources, e.g. land. Beneficial subsidies decrease divergence between social benefits and individual costs by making these costs below market value. Thus, government may decide to provide direct or indirect price support to individuals if their actions help achieve socially-desirable outcomes. Subsidies come in different forms (e.g. consumer vs. producer, on-budget vs. off-budget) and may not always be recognized as such (van Beers and van den Bergh 2001).

Insurance: aims to eliminate economically-unwarranted use of flood-prone area, while not prohibiting uses that has merit (Krutilla 1966). Insurance serves as a risk-sharing and risk communication device to help individuals rationalize their land-use choices in flood-prone area. As a risk-sharing mechanism insurance allows individuals to occupy locations, which market alone will qualify as too risky to develop (Bagstad, et al. 2007). By means of pooling risks, insurance guarantees protection from financial losses in the case of a disaster. In addition, flood insurance serves as a risk-communication mechanism (Lave and Lave 1991; Chivers and Flores 2002; Kunreuther and Pauly 2006; Filatova, et al. 2011). Specifically, if individuals ignore or underestimate risks associated with location, compulsory insurance with premiums proportional to private and social cost of occupancy of flood-prone area helps individuals to make a rational decision. People are more likely to integrate financial risk burdens in their decision-making than a notion of probabilistic hazard event, especially if it is low-probability high-consequences event. Thus, if risks are correctly priced in premiums, insurance allow location in hazard-prone areas for those who are ready to bear risks without increasing a burden on taxpayers. In practice insurance is often complimentary to structural defense measures.

---

[8] These developments produce adverse effects because individuals who locate along a riverside or a coastline enjoy amenities of the location at the expense of taxpayers’ money that needs to be invested to protect them.

Potential effect of price instruments on flood risk: a) on individuals: with the introduction of tax/insurance/subsidy total costs of living in high-risks zones will first go up compared to the safe area. As markets start to work demand for land/properties in high risk areas goes down together with prices. As a result owners of properties in high-risk zones will be compensated for additional costs by this price discount. At the same time, demand for land/properties in safe areas goes up accompanied by prices. Higher housing prices create stronger incentives for developers to invest in safe areas and lower pressure on spatial planners to develop in high-risk zones. b) for the government: lower prices in high-risk areas lead to lower potential direct damage from flooding and less pressure to develop there. Additional funds from flood-tax can be invested locally in technical safety measures (dikes/sand nourishments) creating means to partially transfer flood protection costs to actual beneficiaries. In the case of on-budget subsidy, the government will have additional costs (no costs in case of off-budget subsidy) and additional benefits of avoiding additional investments in safety (or reduction in these investments) due to non-increasing (or decreasing) demand and prices (i.e. stakes at risk) in high-risk areas.

II. Quantity-based instruments

Marketable (tradable) permits system: establishes an overall level of resource use and allocates it among economic actors in the form of permit either through ‘grandfathering’ or sale (Stavins 2003). Those owners of the resources who do not use their quota completely may sell the excess of the resource to others. Tradable permits are mainly known in application to emission management but could also be applied to define a threshold for the proportion of flood-prone area to be developed. Mori (2010) proposes a scheme in which government issues the socially-optimal amount of marketable permits for developing risk zones (thus, in combination with spatial planning). Amount of marketable permits should differ per zone depending on the probability of hazard occurrence or other criteria (e.g. smaller quantity of marketable permits along upstream river). The market further allocates available land to the highest opportunity costs.

Transferable development rights (TDR) approach: assigns a cap on the quantity of development and divides the area into the ‘receiving zone’ and ‘sending zone’. Landowners get a ‘right to use’ and ‘right to develop’ land. Landowners in the ‘sending zone’ cannot utilize their development rights but may sell them to someone in the ‘receiving zone’ (Clinch and O'Neill 2010). Since TDRs discourage development of ‘sending zones’ without limiting the possibilities of landowners to exhibit their rights to sell land for development, they are often employed in nature conservation programs to relieve the opposition of current landowners. In application to flood-prone areas TDRs may help removing developments from high-risk areas by means of shifting the development right either landwards or into a more defendable location (Turbott and Stewart 2006). As such TDRs can be part of a managed retreat program. It serves complimentary to spatial planning as a device to redistribute costs of retreat within a society instead of putting them on landowners in preservation areas.

Both quantity-based instruments can be seen as a hybrid between control-based and MBIs. By controlling the quantity of developments marketable permits and TDRs promote individual economic behavior that mitigates the adverse effects of uncontrolled market without inequality cause by zoning.

Potential effect of quantity instruments on flood risk: a) on individuals: flexibility and freedom given by market are maintained. Through markets land is allocated to the highest opportunity costs. Landowners in high-risk areas are not discriminated and have equal development rights, which they can sell. b) for the government: can achieve limited developments in flood prone area employing the advantages of markets and their possibilities to promote autonomous adaptation to climate change.

4 Current state of the use of MBIs in the Netherlands and international experience

Various MBIs are used worldwide to affect developments in risk areas. While searching for examples we tried to cover both scientific literature and governmental reports. However, our attempts were limited language-wise (only literature in English was covered) and time-wise. Below we briefly review existing MBIs in various countries with respect to whether they encourage or discourage socially-responsible behavior in flood-prone areas.

4.1 Netherlands

Tax: historically Dutch water boards (regional government bodies) collected taxes from landowners to cover costs for the maintenance of dikes (Programme directorate Room for the River 2007). Water boards carry out their water quality and flood protection activities financed through local taxes (almost 95% of costs) (Lazaroms and Poos 2004). These taxes are charged according to the `benefit principle': the beneficiaries pay a water board taxes proportionally to their interests. Thus different stakeholders (farmers, residents, industries) may be charged different taxes by the same water board. The 25 Water boards are independent authorities and use their own system of taxation. Some Water boards used to charge ‘dike-tax’: households who live in proximity to the dike pay an additional tax since they are the ones who benefit most from the proper maintenance of a dike. Others do not charge tax on water defenses (waterkeringszorg) if a property is on so-called high grounds (hoge gronden lijn’). However, water defense tax has been as low as €0.15 per each €2,500 of property value[9], what is negligibly small compared to other housing costs.

Subsidy: Current risk management policy provides a lot of perverse subsidies that push developments into the high-risk zone. The implementation of the Delta Plan after the last 1953 coastal flooding and annual sand nourishments provided a very high level of flood protection of the existing developments. However, the investments in infrastructure lead to an unprecedented urbanization of coastal land (Lescrauwaet, et al. 2006).

Insurance: private insurance from heavy local precipitation is offered in the Netherlands, and is sometimes bundled with insurance against property, furniture and assets damage. All uninsurable risks, except damage from saltwater floods, are covered via the governmental relief program guaranteed by WTS. A decision whether to provide WTS relief payments is often based on the political will and public pressure (Botzen et al. 2010).

Insurance from flooding or erosion does not exist in the Netherlands. An option to extend insurance coverage for coastal flood risks at the scale of the whole Netherlands is argued to be unattractive due to the potential high damage from flooding and impossibility to cover all insurance claims (Kok, et al. 2002). However, a recent study showed that certain insurance arrangements can be feasible in the Netherlands and that Dutch households are willing to pay for flood insurance (Botzen and van den Bergh 2008).

TDRs: Within the Dutch program ‘Room for the River’ the government plans to set back several dikes along main rivers and arrange space for the controlled flooding to cope with the higher river discharges. In some location these plans overlap with agricultural or residential land use (Room for the River 2006). In these cases government buys land from individual landowners or offers them another land lot as a replacement[10].

[9] See http://www.lococensus.nl/algemene_onderdelen/tarieven/tarieven_rijn_en

[10] http://www.rijkswaterstaat.nl/wegen/wetten_en_regelgeving/onteigeningswet/

4.2 EU

Taxes: Mori (2010) estimates optimal tax rates to capture negative externalities (in terms of loss of ecosystems services and costs of flood risk) that upstream landowners in Yorkshire, UK impose on downstream ones by constructing dikes. The outcome is a range of tax rates different for different zones what reflects direct benefits a landowner receives from the engineering safety measures.

Insurance: citizens of many EU countries have an opportunity to buy flood insurance. Several studies provide an overview of various insurance schemes in EU countries (see Appendix A, Figures A.1 and A.2), which we would not repeat here. We just provide a brief overview of the flood insurance schemes of three countries: UK, France, and Germany.
Flood insurance in Germany is optional. Insurance premiums differentiate on risk level although properties in high-risk zones end up with very high premiums. Combining these two facts and the precedent of government relief provision after 2002 floods, flood insurance has quite a low penetration rate (Thieken et al. 2006; CEA 2007). Nevertheless, the scheme creates stimuli for private damage-reducing measures by offering deductibles.
In France flood insurance (a part of the CATNAT system) is compulsory, what reduces adverse selection (i.e. the phenomena when mainly landowners which are most at risk participate). In addition, insurance system runs in a form of PPP what makes it effective and affordable: with reinsurance for regular risks and government coverage of catastrophic losses (de Marcellis-Warin and Michel-Kerjan 2001; Schwarze and Wagner 2007). However, premiums are uniform what minimizes the individual incentives to live in safer zones. At least the French insurance system offers deductibles in exchange for damage-reducing measures.
UK insurance system is sometimes referred to as ‘Gentlemen’s agreement’: the state government maintains flood defences while insurance companies compensate in the case of flood (Huber 2004). Government does not provide any refund in the case of a disaster. The flood insurance is bundled with other natural hazards and is obligatory when closing mortgage, but is not compulsory by law. Although the premiums were supposed to discriminate upon actual probability of hazard, in reality they did not reflect the real risks (The Economist Jul 26th 2007). The UK floods of the last years forced to review the ‘Gentlemen’s agreement’ and pushed government to improve flood defense if it wants insurance companies to offer coverage for individuals.

Marketable permits: while not implemented, marketable permits to minimize adverse effects of hard flood protections measures are considered for the UK (Mori 2010).

4.3 USA

Tax: American system offers at least two tax breaks, which in fact encourage urbanization in coastal areas (Bagstad, et al. 2007). First, owners of second homes (which constitute a large share of coastal properties) get interest and property tax deductions. On a top of unleashing developments in flood-prone area, this tax undermines the equity issue: wealthy individuals bear lower costs for their second-homes while these costs are spread over all taxpayers who finance the maintenance of flood defenses and subsidized insurance. Second, in attempt to provide a relief to those who suffer during the disaster there is an income tax deduction offered for the costs of the uninsured losses. The side effect of this tax measure is a disincentive to purchase flood insurance and to enjoy leaving in coastal areas while costs of this action are put on a society as whole.

Preferential taxation for risk zones is proposed in the USA. Morgan and Hamilton (2010) propose a hedonic model that estimates local property tax rates to capture the benefits local residents receive from the beach nourishment projects in Florida. Authors estimated value capture tax based on the distance to the beach that approximates the distribution of benefits. In practice although there is a little evidence that any of the states have preferential taxation (Pigouvian taxes) depending upon the externalities generated by the owners of properties in flood-prone areas. Nevertheless, for other risks tax system in some does allow to charge Pigovian taxes. In particular, Berkely city levies a 1.5% transfer tax on the transaction of a property located in seismic zone (Kunreuther and Pauly 2006). This fund can be partly used to upgrade the property to withstand seismic risks.

<u>Subsidies</u>: US system provides a lot of perverse subsidies that encouraged urbanization of flood-prone areas. They come in a form of perverse subsidies to coastal areas (subsidized insurance and safety measures such as levies) and secondary effects of subsidies for other economic sectors (subsidized infrastructure such as roads and subsidies to gas and oil industries). Extraordinarily subsidies to offshore energy extraction industry (including property tax exemption, lower energy costs compared to residents, reduced costs of hazardous waste clean up) boosted developments along Louisiana coast (Bagstad, et al. 2007). In addition, as reviewed by Bagstad et al. publicly-funded highways built in 1960s-70s as well as other infrastructure development subsidies (e.g. electrical system loans) lured developments in coastal areas. Although pursuing an opposite aim, the levies-construction programs of the U.S. Army Corps of Engineers lead to the growth of economic developments in flood-prone areas and increase in overall risk (Barnhizer 2003; Kunreuther and Pauly 2006). Such government ‘givings’ in fact transfer costs of landowners living in hazard-prone areas to the taxpayers at large.
Coastal Barrier Resources Act (CBRA) introduced in 1982 prevents perverse subsidizing of coastal development by prohibiting federal spending for roads, water, wastewater, or other infrastructure in some designated areas (Bagstad, et al. 2007). In this case costs of living in these areas are fully borne by individuals who chose to do so. Despite the fact that CBRA has some shortcomings, it effectively reduced the incentives to develop in hazard-prone zones while not forbidding economically-efficient developments (Barnhizer 2003).

<u>Insurance</u>: the US National Flood Insurance Program (NFIP) operates on a voluntary basis. Premiums for new developments are established based on the Flood Insurance Rate maps (FIRMs) to reflect the actuarial flood risks. However, when NFIP was introduced in 1968 it was initially offered to existing residents at subsidized rates to increase participation (Barnhizer 2003). This was supposed to be eliminated with time but instead subsidized insurance firmly established itself in a market through grandfathering. Today the insurance premium for the properties exposed to considerable flood risk is up to 70% subsidized ((Bagstad, et al. 2007): actual risks are estimated to be about $2000 while residents pay only $585). In addition, voluntary nature of insurance creates an adverse effect when only properties at highest risk got covered (often at the subsidized rates that do not reflect real risks). Also, insurance premiums are based on the statistical historic records of probability of occurrence rather than projected future losses. Adverse selection and backwards-looking estimation of rates lead to the fact that for example repetitive loss properties account for 40% of NFIP insurance payments while representing only 2% of insured properties.

TDRs: are common in the US for nature conservation projects (Turbott and Stewart 2006). Since coastal areas provide rich environmental amenities and value of its ecosystem services is the highest compared to other ecosystems (Costanza et al. 1997), TDR initiatives for managed retreat from flood prone area can go hand in hand with nature conservation. For example, in Rhode Island coastal-wetland landowners are compensated for restrictions on use of their land via TDRs (Godschalk and Brower 1985). In the US managed retreat from river floodplain showed to provide dramatic costs-savings (e.g. costs of relocating a small town were about the same as one time flood relief payment to families in St. Charles County, Missouri) while there are concerns that costs of coastal properties might be might higher to make it cost-efficient (Bagstad, et al. 2007).

4.4 Australia and New Zeeland

Insurance: flood insurance in Australia is voluntary, region-specific (i.e. it might be difficult to find a flood insurance policy in some regions[11]), and very fragmented. Where available, premiums are based on the risks estimated based on historic and predicted flood occurrence. Flood risks are mapped within the national flood information database (NFID), although accuracy of flood maps may vary among communities (Sullivan). However, not all flood risks are covered everywhere or due to high risks premiums might be unacceptable either to residents or insurers. In some States it is a requirement to provide flood risk information to potential residents during property purchasing processes, what reduces information asymmetry. Government offers disaster relief, what might discourage individuals to buy insurance.

Insurance coverage in New Zealand is also region-specific. Depending on the individual insurer a policy may cover costal flooding and erosion, but it is considered unlikely for insurance industry to cover the effects of sea level rise (Turbott and Stewart 2006).

TDRs: beachfront properties are very expensive making financial feasibility of exchange with receiving landward areas difficult. In addition, due to continuous coastal nourishments hazardous event happen rarely and flood risks do not capitalize in property prices (Turbott and Stewart 2006).

In Australia buy-back scheme for houses in flood-prone areas is operating for several years. For example, Brisbane City Council launched a scheme to buy out homes in 2006 (Australian Associated Press 2011). Before the recent floods, about 45 homes were acquired and demolished. However, it seems that the history repeats itself: in 1974 the government bought back hundreds of flood-prone properties in Brisbane.

[11] *http://www.economywatch.com/insurance/flood/australia.html*

5 Lessons learned: pros and cons of application of different MBIs

Various MBIs are employed to affect developments in flood-prone areas. Experience of different countries reveals positive effects of well-designed policies as well as adverse unforeseen effects of inadequately-structured MBIs, from which we can learn. Here we summarize positive and negative lessons obtained from the use of MBIs with respect to flood risks management.

5.1 Taxes

Advantages:

- If tax rate differentiates upon probability of flooding (based on geographical characteristics), it rewards developments in safer areas breaking the self-reinforcing cycle than government has to increasingly invest in flood defences. If tax rate differentiates upon benefits received from flood protection measures, it allows government to collect charges based on the 'benefit principle' and provides extra funds to invest locally. Thus, direct beneficiaries pay more reducing externality borne by general public.
- Compared to other MBIs taxes are the most familiar to people (everyone pays taxes) and can be integrated in the existing tax collection system. This makes a change in tax rate from uniform to differential or even an introduction of a new tax more natural and easier to introduce.
- Preferential taxation may be introduced gradually to existing residential area, e.g. a sale tax could include some share that differentiates on probability of disaster (see example of Berkley tax). This tax can be further used to invest on safety measures locally.
- Zonal taxes help internalize spatial externalities (in terms of external costs of flood risk) imposed by upstream landowners on the downstream ones (Mori 2010). This may also be considered for costal areas on the border of soft and hard flood defenses.
- When applied to a market good with inelastic supply (such as land) taxes are especially effective in allocating the good to its highest value (Bagstad, et al. 2007).

Disadvantages and adverse effects:

- Zonal taxes will require a division in zones. The decision concerning in how many zones to subdivide, according to what principle (in theory it should be balance of marginal costs and benefits, but it practice they are difficult to quantify) may involve additional transaction costs (Mori 2010).
- Tax needs to be consistent among municipalities to avoid negative neighborhood externalities (if there are different taxes among municipalities than it would drive developments in the municipality with the lowest tax instead of rewarding settlements in safe areas).
- Tax breaks on second homes (many coastal properties are second homes) create incentives for the growth of capital at risk. While they benefit only wealthy people, the costs of coastal protection (e.g. coastal nourishments or construction and maintenance of defense measures) put the burden on all taxpayers.
- US tax deductions on uninsured property losses create a direct incentive to avoid buying private insurance at the costs of taxpayers.

5.2 Subsidies

Advantages:

- Stimulates urbanization of safe areas not by means of punishing location in high-risk zones but rather by providing a direct reward to low-risk ones.
- Assures a balance between short-term private and long-term societal needs: it might be worth to invest funds today to support development centers in safer areas. The triggered market forces will catch up with time and work to attract urbanization to new or renovated centers without subsidies (because of employment opportunities and other agglomeration forces) while allowing savings on flood protection in high risk zones.
- With the introduction of the US CBRA the government maintained an opportunity to provide subsidized infrastructure almost everywhere except high-risk coastal barriers. It created a strong incentive to develop anywhere but in coastal barriers. As a result only developments that proved profitable despite extra costs for the infrastructure and for occasional flood damage took place, leaving many barrier islands undeveloped (Barnhizer 2003). This was achieved without forbidding any development as a result of preferential subsidizing of safer areas while rejecting subsidy to high-risk ones.

Disadvantages and adverse effects:

- Require additional funds.
- Some subsidies (especially for agricultural sector) may encourage overregulation or support of economic activities that will never become profitable (Smith and Montgomery 2003).
- Various industrial (offshore energy and gas) and infrastructural (roads, defense measures) subsidies have secondary effects that make them perverse subsidies boosting flood-prone developments. Such government givings subsidize developments and lead to the growth of capital at risk.

5.3 Insurance

Advantages:

- When it is not possible to completely ban developments in flood-prone area because of scarcity of space, flood insurance may serve as a risk sharing instrument to cover occasional damages.
- Coastal and riverside areas provide rich environmental amenities and hedonic price research demonstrated that people are willing to pay for them. Presence of flood risks is not a reason to forbid developments in flood-prone area, if beneficiaries of location amenities are ready to pay themselves for the risks they take.
- Flood insurance is a perfect risk communication device. A monthly insurance payment delivers much clearer message about risks than a vague 1:10.000 year probability.
- Insurance deductibles stimulate individuals to take damage prevention measures and promote innovation in mitigation. This serves as a strong driver decreasing costs of flooding if it occurs (CEA 2007).
- Insurance pool can quickly offer funds necessary to provide disaster relief reducing (CEA 2007).
- Insurance is a straightforward domain for PPP. On the one hand, insurers and government may work together to increase individual flood risk awareness (CEA 2007). On the other hand, a combination of insurance, reinsurance and governmental coverage of catastrophic losses may be an effective PPP to constitute a risk pool (Kunreuther and Pauly 2006).

Disadvantages and adverse effects:

- If insurance is subsidized (e.g. US), then contrarily to its initial aim it encourages the developments in hazard-prone areas. Subsidized insurance is offered at below-market price. Thus, it does not only hide the actual societal costs of living in the hazard-prone areas. Instead it increases them both by providing the insurance subsidy and by attracting new capital at risk, which may need to be refunded via governmental relief payment programs.
- Properties with repetitive loss got insured at the same rates as before. This stimulates developers to buy land in damaged areas at a cheap price, redevelop it and sell at high prices that do not reflect real risks (Bagstad, Stapleton et al. 2007). The 2004 Flood Insurance Reform Act in the USA attempts to solve this problem by denying insurance to the properties that suffered 3 times with cumulative claim damages of $15000 or more.
- Insurance premiums that are uniform or do not differentiate for actuarial flood risk may bias economic location decisions. Moreover, premiums should not only differentiate among various probabilities of disaster (e.g. UK) but should reflect the actual risk. If insurance rates do not price risks correctly, an insurance company will bear losses in the case of disaster.
- Non-compulsory flood insurance leads to information asymmetry among residential buyers and sellers (70% of buyers learn that their new house is in flood prone areas only at the moment of contract signing and 21% after (Chivers and Flores 2002)).
- Non-compulsory flood insurance also leads to the adverse selection of mainly the most risky properties to be insured.
- Speculators and temporary residents have no incentive to buy voluntary flood insurance. Yet, they are (as every other resident of a hazard-prone area) protected by dikes and could count on the governmental relief payment program.
- Grandfathering the insurance premiums from the old owners who paid below-market premiums keeps the subsidized developments in a market forever.
- Non-coordinated actions among parties involved in insurance (ABI and UK government) or spatially-fragmented policies (Australia) do not provide accurate information for individuals searching for a house to make a rational choice.

5.4 Marketable permits

Advantages:

- Limit the amount of developments up to an optimal level (determined by the government) with the flexibility of markets.
- Applicable for both developed and undeveloped areas not prohibiting urbanization completely but allowing the market to control its exact location and price.
- Provide undeveloped space along the coast/river ecosystem services (including natural flood protections systems such as wetlands or dunes).

Disadvantages and adverse effects:

- The choice of the size and number of zones is sensitive: having smaller zones is beneficial since probability estimates are more accurate but it makes a market for permits smaller and less competitive and less efficient (Mori 2010).

5.5 TDRs

Advantages:

- Limit the amount of developments up to an optimal level (determined by the government) without compromising on the rights of landowners of high-risk areas.
- TDRs provide financial incentives for owner in hazard-prone areas to move (Turbott and Stewart 2006). Naturally, they would not want to abandon their property without compensation.

- After the disaster they provide stimuli for relocation vs. rebuilding (Bagstad, Stapleton et al. 2007). Thus, TDRs used within the managed retreat save governmental funds from the repetitive loss cycle.
- Provide space along the coast/river ecosystem services (including natural flood protections systems such as wetlands or dunes).

Disadvantages and adverse effects:

- For TDRs to be financially self-sufficient land in the receiving zone should be more expensive than in the donor area (Turbott and Stewart 2006). However, prices of coastal properties are usually much higher than prices for properties landwards (especially if flood risks are not perceived). This might require governmental financial support.
- Alternatively the problem of exchanging more expensive coastal land lots to the cheaper landwards lots may be solved via uneven area exchange between donor and receiving areas (e.g. in proportion of 1:2). Under general scarcity of space getting twice more land away from the coast in exchange for one coastal lot might not always be feasible.

6 Discussion: climate change and perspectives of using MBIs

Climate change posts many new challenges for communities residing in coastal and delta areas. Projections of sea level rise vary between 20cm and 110 cm for the year 2100 (de Bruin, et al. 2009). There is also greater variability of river discharges expected (Bresser, et al. 2005). Adaptation to climate change is inevitable and will require efforts on both public and individual level (Stern 2008). Combination of spatial adaptation and strengthening of flood defense measures are the key components here. MBIs can play an important role in promoting spatial adaptation at the individual level as well as provide alternative financial schemes to finance structural defense measures. Policy-makers may use various economic instruments to create a framework to guide individual economic actions (i.e. locations choices) towards socially-desirable state (i.e. less capital at risk). At the same time, the beneficiary-pays principle of MBIs provides extra funds to invest in sand nourishments or dike improvements. Based on the review of positive and negative experiences with MBIs we summarize the recommendations for the use of each of them. We also highlight the attributes that may make them more effective in achieving policy-goal of decreasing total risk in the light of climate change.

6.1 Suggestions for the employment of taxes

- For the areas with no man-made flood defense measures (dikes, sand nourishments): tax rate should discriminate upon the hazard probability based on geographical characteristics. Higher tax rates in the areas with higher chance of flooding create stimuli for the developments in safer areas.
- In the areas with man-made defense measures taxes should be designed based on the 'benefit principle'. The tax rates, which direct beneficiaries of a safety measure pay, should be proportional to the distance (the closer one lives the more he pays). This also provides extra funds to invest in risky areas locally.
- To avoid over-administration different tax rates might be estimated not for every single location but for a certain zone. In the Netherlands there are existing institutions (such as Water Boards who act locally) that may be used as a platform for implementing preferential flood-safety taxation.
- Tax may be introduced gradually at the moment when property changes an owner. In this case grandfathering of the old tax rate shall be explicitly banned.
- Some authors propose to use land instead of property as a tax base (see Bagstad (2007) for review). It is believed to encourage the use of underutilized land and limit sprawling into high-risk areas.
- When established, 'safety land tax system' might provide tax deductions in exchange for private investments on mitigation (e.g. floodproofing houses).
- Tax deductions for second homes in flood-prone areas should be prohibited.
- Proactive assignation of tax rates: areas where probabilities of flooding are expected to increase due to climate change might have higher tax rates compared to the current rates. If chance of a hazard grows everywhere then tax rates might reward location in more defendable areas or in the areas which will be affected the latest.

6.2 Suggestions for the employment of subsidies

- While originally pursuing a goal of public safety governmentally-funded infrastructure (dikes) and other safety measures (sand nourishments) eventually take a form of perverse subsidies as reviewed in section 4. It is important to realize that this perverse subsidy lead to the boom of coastal developments at risk in contrary to the government's original goal of decreasing risks (as experienced by USA, Netherlands). Since safety is a public good and use of governmental funds is unavoidable on such projects, the circle of growing flood risks may be reversed by employing a Pigouvian tax with the 'benefit principle' as discussed above. Another suggestion is to eliminate such perverse subsidies completely (Pilkey and Young 2005), what is unfeasible in the Netherlands (since 70% of GDP is produced in hazards-prone areas). Alternatively, a share of local costs for safety measures should increase (originally was 25% in the USA (Bagstad, et al. 2007)).
- Other perverse subsidies for businesses (tax breaks for oil and gas industries, agricultural subsidies for land in flood-prone areas) should be eliminated. Often such subsidies benefit a selected group of wealthy and/or politically well-connected individuals at the expense of all taxpayers (Bagstad, et al. 2007).
- Subsidies should aim to support some ecologically or socially important developments that may be not economically efficient originally. However, to avoid support and propagation of economically-inefficient developments forever subsidies are always recommended to be introduced temporary and only to support socially/environmentally beneficial developments at the first stage (van Beers and van den Bergh 2001). In this way they create a necessary economic springboard for developments. With time when economic forces catch up and boost developments further, the subsidies need to be removed out of the system. Therewith, activates that remain economically unviable will phase out.
- It has been observed that land use change is path-dependent, that is current spatial development choices are limited by the land-use decisions made in the past. In the context of climate change this means that subsidizing development in safe or more defendable areas today can further make them attractive without subsidies tomorrow.

6.3 Suggestions for the employment of flood insurance

The first three principles from the list below were in fact the necessary conditions advocated by economists in 1960s when US NFIP was just launched (Krutilla 1966). Unfortunately none of three was met, what made NFIP so inefficient.

- To avoid low penetration and adverse selection of only the most risky properties the flood insurance system needs to be compulsory.
- To exclude information asymmetry both buyer and seller must know the costs of flood insurance. The disclosure of actual hazard probabilities needs to be reinforced by law (Chivers and Flores 2002).
- Insurance premiums should reflect the real site-specific risk. Market forces rather than political or special groups' interests should form the effective insurance rates (Barnhizer 2003). Moreover, premiums that are uniform or averaged over some area fail to price risks accurately.
- Governmental subsidy for flood insurance undermines the whole nature of insurance. Subsidized below-market value premiums not only fail to serve as a risk pool but also have an adverse effect of biasing individual risk perception and attracting developments to high risk zones.
- While some authors strongly suggest that government exits insurance business completely (Bagstad, et al. 2007), others support the idea of PPP for flood insurance (Huber 2004; Kunreuther and Pauly 2006; CEA 2007). In the multi-layer PPP arrangement government insures only large-scale catastrophic losses in the form of reinsurance, catastrophic bonds or multi-state insurance pools (see Table 1).

Table 1: PPP arrangements for comprehensive natural hazard insurance. Source: (Kunreuther and Pauly 2006).

Layer	Who pays the costs
1. Self insurance	Property owner
2. Private insurance	Insurance companies
3. Risk transfer	Reinsurance and capital markets
4. Governmental funds	Government

Such schemes need to be used with caution to provide protection from catastrophic losses only and not to slip to subsidizing insurance premiums for high-risk areas.

- Combination of voluntary flood insurance and availability of governmental disaster relief payments create all the stimuli for people to avoid buying insurance and fully rely on the government to refund losses (Schwarze and Wagner 2007). Thus, insurance schemes based on PPP can be applied only for compulsory insurance.
- Insurance system may provide discounts for those who invest in mitigation.
- Insurance helps individual to make a rational choice only if it is not fragmented and is consistent thought the country (at least for such country as the Netherlands).
- Rates for the repetitive loss properties should adapt accordingly (e.g. the 2004 Flood Insurance Reform Act in the US, (Bagstad, et al. 2007)).
- In countries where insurance differentiates upon actual risks the actuarial insurance premiums are based on backward-looking historic records. However, probabilities of hazard are changing with climate change. Thus, to promote spatial adaptation insurance needs to assign risk-based premiums based on the projected probabilities, which might be regularly updated when uncertainty about climate change effects is decreasing.
- Adaptation to climate change requires additional funds and cooperation between government and individuals (Stern 2008). Flood insurance with premiums adapting to increasing climate-induced risks engages individuals in taking responsibility for location in flood-prone zone (Defra 2010). Naturally, changing costs structure is an effective signal to communicate climate change threads (Huber 2004).

6.4 Suggestions for the employment of marketable permits

We are not aware of the cases of use of marketable permits in practice. However, there are hypothetical studies based on real-world data that highlight their added value for risk management, especially in the light of climate change (Mori 2010). Also, the experience of marketable permits used for other environmental management problems can also provide some insights for drawing suggesting (Stavins 2003).

- Zones with different probabilities of hazard should be assigned different number of tradable permits.
- Zones should not be too small to allow enough number of permits issues and guaranteeing competitive trading.
- It is better to limit the governmental intervention in the trade process itself. According to Stavins (2003) a necessity to get a government approval of individual trades increases uncertainty and transaction costs and eventually discourages trading.
- Marketable permits are most effective when the heterogeneity of development costs is high, since this creates gains from trade for potential participants.
- More flexible arrangements are more adaptive, which is vital in the light of climate change. In contrast to zoning that regulates every piece of land, marketable permits delegate much freedom to individuals. Instead of governmental involvement in every decision, action is taken locally between buyers and sellers, who quicker adjust to changing environment allowing for more innovative and adaptive solutions.

6.5 Suggestions for the employment of TDRs

Due to high prices of waterfront land/property TDRs can hardly be financially feasible if used alone. Thus, they are usually used in combination with other MBIs:

- Eliminating perverse subsidies that boosted coastal developments and properties prices will drive coastal land/property prices down. Introduction of taxes or insurance for high-risk areas will have similar effect of decreasing property prices. This may make the transfer of land between coastal high-risk donor area and safer receiving zone financially feasible.
- The participation of sites with recurring floods (or areas with projected high risks due to changing climate) in TDRs can be improved if insurance system presumes increasing premiums for repetitive loss properties (for future high risk areas).
- TDRs may be used at a district level to manage a retreat of a part of a city where other high-value parts of the city may serve as a receiving area (Turbott and Stewart 2006).
- After the removal of properties from a flood-prone area, the ban on building new infrastructure and housing should be enforced.
- Even if TDRs seem not financially feasible considering current risks, the situation might reverse with increasing frequency and magnitude of flooding due to climate change. If these risks eventually capitalize in waterfront property prices, then TDRs become not only politically necessary but also financially attractive.

Various combinations of MBIs can be used to guide individual economic actions towards socially-desirable state. For example, Kunreuther (2006) suggests using tax penalties on properties that do not have continuous insurance coverage (in the case voluntary flood insurance is established). UK Defra (2010) advises government to engage local communities on adaptation, especially to increase contribution of private developers. This may take a form of a land tax or decrease in governmental subsidy for infrastructure (mainly flood defenses) from which developers benefits most or a combination of the two. If residents in flood-prone areas cannot afford insurance or tax then TDRs can be used to help them move to safer areas where it is affordable for them to live (Bagstad, et al. 2007).

6.6 Reflection on the recommendations of the Deltacomissie

Deltacomissie 2008 gave 12 recommendations on the strategy the Netherlands can undertake in the light of increasing climate change risks. Naturally, it is necessary to raise safety level of technical defense measures. However, we believe that a policy that motivates individuals to differentiate among locations based on the level of risk they take is absolutely essential. This is especially relevant for Recommendations 2&3 (“Plans for new urban development” and “Areas outside the dikes”) which rely on individual responsibility. It is imprudent to assume that it is enough to state that “Costs of building must be borne by those who benefit from them and must not be passed on to society as a whole” (Recommendation 2) or that “residential owners of new development in unprotected areas lying outside the dikes should be responsible for measures to avoid adverse consequences” (Recommendation 3). First of all, there is a big difference between flood risk as perceived by individuals and policy-makers (Filatova, et al. 2011). Secondly, the Dutch population has low risk perception (Bočkarjova et al. 2008; Krywkow et al. 2008; Terpstra and Gutteling 2008) that may lead to economically inefficient investments in high-risk areas (Filatova, et al. 2009). Without additional policy stimuli (i.e. assured higher safety) individuals who underestimate risks will invest there and in case disaster happens societal pressure might be high enough to make government pay the bill. Proactive policy based on MBIs can be very useful for outside-dikes areas and new developments in low-lying flood-prone areas to encourage individual choices that deliver socially beneficial outcomes. Policies that aim to protect individuals and assure attractive investment environment while avoiding free-riding are really a combination of ‘carrots’ and ‘sticks’ (Lall and Deichmann 2009).

7 Conclusions

According to IPCC, damage from natural disasters rapidly increased over the past decades mainly due to the growth of capital concentrated in flood-prone areas (Nicholls et al. 2007). With all the intensive governmental subsidies for infrastructure (roads, navigation paths and flood defense measures), with agglomeration forces and recreational amenities in coastal and delta areas, this is not surprising. Governmental command-based policy that forbids development in some zones and offers protection with flood defense measures in others, triggers economic behavior that is counter to the overall policy goal of reducing risk. It launches a cycle of capital growth in risky areas attracted by improved safety, which then claims even larger shares of governmental funds for defense measures as capital investments further grow. This positive feedback results in higher possible damage if disaster does occur. Yet, individual behavior is very rational in this case: individuals enjoy location advantages with no extra costs. Growing demand and high prices boost the desire of developers to expand urbanization in flood-prone areas and put pressure on spatial planners to assign neighboring preserved areas for development. There are no incentives for individuals to make choices that lead to more climate-resilient outcomes. Thus, local parties benefit at the expense of all taxpayers leading to endlessly growing costs for public adaptation to increasing climate-induced risks.

In addition, prohibiting developments in certain areas is inflexible. In a small country like Netherlands withdrawing land from use in response to flood risks may be unpractical and will become tenser as land becomes scarcer. Consequently, planned development restrictions may not only create additional space scarcity but also miss the opportunity to employ autonomous adaptation leaving no opportunities for individual choice.

Governmental actions that are to assure adaptation to risks associated with climate change unintentionally distort land markets and trigger economic forces that lead to further concentration of capital at risk. Unless ‘rules of the game’ change flood risks will keep growing (Barnhizer 2003). MBIs provide the means to engage individuals and provide price signals that can be used to guide autonomous adaptation. Such measures as preferential taxes, non-perverse subsidies, flood insurance, marketable permits and TDRs may be useful for flood risk management. With the help of MBIs policy-makers may allow developments in flood-prone zone but guide them by affecting individual economic behavior with market forces to deliver socially-beneficial outcomes.

Flood protection is a public good, and as most public goods often suffers from free-riding. Structural defense measures and MBIs are most effective when used complimentary with each other. The former are vital in the Netherlands to reduce probability of a disaster. The latter guarantees that everyone contributes to financing this public good according to the beneficiary principle. Individuals are often short-term looking and focus on satisfying their needs rather than on considering how their choices affect sustainability and resilience of the society as whole. Thus, it not enough to construct flood protection measures. Policy makers also need to create stimuli, for example with MBIs, to promote individual adaptation and drive individual choices towards socially-beneficial outcomes.

Extensive international experience of using MBIs in flood-prone areas provides many useful lessons. First of all, MBIs provide much flexibility and efficiency, often come at lower societal costs compared to the control-based instruments, make advantages of the individual heterogeneity in preference, risk perceptions and incomes, and most importantly engage stakeholders in working together to achieve policy goals. Secondly and most importantly, implementation of MBIs should be designed very carefully. MBIs used in practice rarely followed the recommendations, under which economists designed them (e.g. US NFIP at the end did not satisfy any of the three conditions that Krutilla (1966) found essential). Other MBIs that have been used to manage risks, in fact subsidized developments in hazard-prone areas instead of safe areas. Nevertheless, up till now many countries have had experience of use and misuse of MBIs, so there is a good ground to gather lessons and to learn to design this MBIs in the appropriate way. Thirdly, MBIs are not to replace traditional command-and-control measures. Conversely, MBIs need to be applied in combination with control-based measures to compensate for the drawbacks of each other. For example, beach nourishments provided by the government can be combined with a Pigouvian-like tax that is distant-depended from the coast. Such tax assures that those who benefit most from the erosion-prevention measures contribute most to its financing. On the one hand, this creates additional financial means to support nourishments. On the other hand, it offers an incentive for people to move to safer areas. In addition, overpriced property prices that did not originally capitalize erosion risks will go down reducing not only potential direct damage (which again government might need to refund) but also incentives for developers (and consequently pressure of spatial planners) to convert undeveloped land.

With increasing costs of adaptation to climate change, policy-makers need to engage local stakeholders in adaptation. The current policies trigger economic choices that work against the policy goals, i.e. towards increasing risks and costs of adaptation. Specifically, government needs to invest more in safety measures to protect or acquire (in case of potential retreat) high-value properties, which values are so high because actuarial flood risks were not capitalized due to past governmental subsidies. To save on adaptation costs policy-makers may use MBIs to provide means for individuals to make more climate-resilient spatial choices and share responsibility. This will help collecting financial means from direct beneficiaries of safety measures today. In addition, when market starts to work and once risks are capitalized in property prices, the prices will reflecting potential future damages.

MBIs create conditions in which individuals make decisions that are in there interest, while at the same time, collectively, they work towards achieving certain policy goals. Individuals always have a choice of locating in the risky areas if benefits of living there are higher compared to costs or moving to safer and more affordable places (Kunreuther and Pauly 2006). Moreover, the costs of properties in coastal areas are high now because risks are not reflected in the price but are borne by a society as a whole. With time if MBIs are present (e.g. tax or insurance) market will incorporate the actuarial risk in the price. The resulting price discount is a compensation to property owners for additional costs of site-specific risk (similar to the trade-off between travel costs and land price) (Frame 1998). Certainly individuals living in the risky areas may see losses in the transition period due to market revaluation of properties. It might be more productive to compensate these one-time losses of residents rather than maintaining the vicious circle of increasing risks and investments in defence measures.

Whether to create incentives for individuals to take responsibility for flood risks in the light of climate change or whether the society as a whole keeps paying for all the risks, including the risks owners of second homes face, is of course a political choice, which is beyond the scope of this report. The main aim of this paper is to shed light on the economic processes that a policy can unconsciously trigger, and put to work against the sole purposes of the policy. There is certainly no single solution for every problem and MBIs are not a panacea either.

Nevertheless, their ability to affect individual choice and guide it to most socially-beneficial outcomes opens a significant potential to employ MBIs for climate change adaptation policies. Combination of public and private spatial adaptation may achieve more than each one independently. Governmental policies should employ basic economic behavioral principles (e.g. people do react to price signals!) to help achieving more climate-resilient landscapes. There are natural laws that guide economic behavior and they can be used to encourage or discourage particular land market outcomes (either spatial pattern of development or land/property prices). Policy-makers may choose to *build* climate-resilient developments *with economic nature*.

References

Alonso, W. (1964). Location and Land Use. Cambridge, MA: Harvard University Press.

Australian Associated Press (2011). Council wants help buying back flood-prone homes. Brisbane Times. **January 25**.

Bagstad, K. J., K. Stapleton and J. R. D'Agostino (2007). "Taxes, subsidies, and insurance as drivers of United States coastal development." Ecological Economics **63**(2-3): 285-298.

Barnhizer, D. A. (2003). "Givings recapture: Funding public acquisition of private property interests on the coasts." Harvard Environmental Law Review **27**(2): 295-375.

Bin, O., J. B. Kruse and C. E. Landry (2008). "Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market." The Journal of Risk and Insurance **75**(1): 63-82.

Bočkarjova, M., A. van der Veen and P. A. T. M. Geurts (2008). How to Motivate People to Assume Responsibility and Act upon Their own Protection from Flood Risk in the Netherlands if They Think They are Perfectly Safe? Society for Risk Analysis - Europe Valencia, 22-25 September 2008.

Botzen, W. J. W. and J. C. J. M. van den Bergh (2008). "Insurance against climate change and flooding in the Netherlands: Present, future, and comparison with other countries." Risk Analysis **28**(2): 413-426.

Botzen, W. J. W., J. C. J. M. van den Bergh and L. M. Bouwer (2010). "Climate change and increased risk for the insurance sector: a global perspective and an assessment for the Netherlands." Natural Hazards **52**(3): 577-598.

Bresser, A. H. M., M. M. Berk, G. J. van den Born, L. van Bree, F. W. van Gaalen, W. Ligtvoet, J. G. van Minnen and M. C. H. Witmer (2005). The effects of climate change in the Netherlands. Bilthoven, Netherlands Environment Assessment Agency**:** 112pp.

Brueckner, J. K. (1987). The Structure of Urban Equilibria: a Unified Treatment of the Muth-Mills Model. Handbook of Regional and Urban Economics. E. S. Mills. Amsterdam, Elsevier Science Publishers B.V. **2:** 821-845.

CEA (2007). Reducing the Social and Economic Impact of Climate Change and Natural Catastrophes. Insurance Solutions and Public-Private Partnerships. Brussels**:** 48p.

Chivers, J. and N. E. Flores (2002). "Market Failure in Information: The National Flood Insurance Program." Land Economics **78**(4): 515-521.

Chouli, E., E. Aftias and J. C. Deutsch (2007). "Applying storm water management in Greek cities: learning from the European experience." Desalination **210**(1-3): 61-68.

Clinch, J. P. and E. O'Neill (2010). "Assessing the Relative Merits of Development Charges and Transferable Development Rights in an Uncertain World." Urban Studies **47**(4): 891-911.

COM (2007). Green Paper on market-based instruments for environment and related policy purposes. 140, 28.3.2007. Brussels, DG for Environment & DG for Taxation and Customs Union.

Costa, J. E. (1978). "The Dilemma of Flood Control in the United States." Environmental Management **2**(4): 313-322.

Costanza, R., R. d'Arge, R. de Groot, S. Farberk, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Suttonkk and M. van den Belt (1997). "The Value of the World's Ecosystem Services and Natural Capital." Nature **387**: 253-260.

de Bruin, K., R. B. Dellink, A. Ruijs, L. Bolwidt, A. van Buuren, J. Graveland, R. S. de Groot, P. J. Kuikman, S. Reinhard, R. P. Roetter, V. C. Tassone, A. Verhagen and E. C. van Ierland (2009). "Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives." Climatic Change **95**(1-2): 23-45.

de Marcellis-Warin, N. and E. Michel-Kerjan (2001). The Public-Private Sector Risk-Sharing in the French Insurance "Cat. Nat. System". CIRANO Working Papers 2001s-60. Montréal, CIRANO.

Defra (2010). Government response to the conclusions and recommendations of the Environmental Audit Committee: Adapting to Climate Change, Sixth Report of Session 2009-10. UK, The Stationery Office Limited on behalf of the Controller of Her Majesty's Stationery Office**:** 20p.

European Commission DG ENV (2010). Science for Environmental Policy: Coastal Management. Brussels. **19**.

Filatova, T., J. P. M. Mulder and A. van der Veen (2011). "Coastal risk management: how to motivate individual economic decisions to lower flood risk?" Ocean & Coastal Management **54**: 164-172.

Filatova, T., A. van der Veen and D. Parker (2009). "Land market interactions between heterogeneous agents in a heterogeneous landscape—tracing the macro-scale effects of individual trade-offs between environmental amenities and disamenities." Canadian Journal of Agricultural Economics **57**(4): 431-459.

Frame, D. E. (1998). "Housing, natural hazards, and insurance." Journal of Urban Economics **44**(1): 93-109.

Fujita, M. and J.-F. Thisse (2002). Economics of agglomeration. Cities, industrial location and regional growth, Cambridge University Press.

Godschalk, D. R. and D. J. Brower (1985). "Mitigation Strategies and Integrated Emergency Management." Public Administration Review **45**: 64-71.

Goers, S. R., A. F. Wagner and J. Wegmayr (2010). "New and old market-based instruments for climate change policy." Environmental Economics and Policy Studies **12**: 1-30.

Huber, M. (2004). Reforming the UK Flood Insurance Regime. The Breakdown of a Gentlemen's Agreement. LSE CARR Discussion paper: 18, ESRC Center for Analysis of Risk and Regulation**:** 25p.

Kahneman, D. and A. Tversky (1979). "Prospect Theory:An Analysis of Decisions under Risk." Econometrica **47**(2): 263-292.

Kaiser, G., S. Reese, H. Sterr and H.-J. Markau (2004). COMRISK Subproject 3: Public Perception of Coastal Flood Defence and Participation in Coastal Flood Defence Planning. Final Report. Kiel, Germany**:** 1-212.

Kirman, A. P. (1992). "Whom or what does the representative individual represent?" Journal of Economic Perspectives **6**(2): 117-136.

Kok, M., J. K. Vrijling, P. H. A. J. M. van Gelder and P. Vogelsang (2002). Risk of flooding and insurance in The Netherlands. Flood Defence. B. Wu, Z.-Y. Wang, G. Wanget al. New York, Science Press. **Volume 1:** 146 - 154.

Krutilla, J. V. (1966). "An Economic Approach to Coping with Flood Damage." Water Resources Research **2**(2): 183–190.

Krywkow, J., T. Filatova and A. van der Veen (2008). Flood risk perceptions in the Dutch province of Zeeland: does the public still support current policies? FLOODrisk 2008, The European Conference on Flood Risk Management Oxford, UK.

Kunreuther, H. and M. Pauly (2006). "Rules rather than discretion: Lessons from Hurricane katrina." Journal of Risk and Uncertainty **33**(1-2): 101-116.

Lall, S. V. and U. Deichmann (2009). Density and Disasters: Economics of Urban Hazard Risk. Policy Research Working Paper The World Bank. **5161:** 50pp.

Lave, T. R. and L. B. Lave (1991). "Public Perception of the Risks of Floods: Implications for Communication." Risk Analysis **11**(2): 255-267.

Lazaroms, R. and D. Poos (2004). "The Dutch Water Board Model." Water Law **15**(3/4): 137-140.

Lescrauwaet, A.-K., L. Vandepitte, E. Van den Berghe and J. Mees (2006). Europese duurzaamheidsindicatoren voor kustgebieden in Nederland: een eerste inventarisatie. VLIZ Special Publication, 31. Ostende, Belgium, Vlaams Instituut voor de Zee 128 pp.

MacDonald, D. N., J. C. Murdoch and H. L. White (1987). "Uncertain Hazards, Insurance, and Consumer Choice: Evidence from Housing Markets." Land Economics **63**(4): 361-371.

Mason, G. (1979). "Deregulation of Urban Land Markets - Note on the Alternatives to Zoning." Annals of Regional Science **13**(2): 54-66.

Morgan, O. A. and S. E. Hamilton (2010). "Estimating a Payment Vehicle for Financing Nourishment of Residential Beaches using a Spatial-Lag Hedonic Property Price Model." Coastal Management **38**(1): 65-75.

Mori, K. (2010). "Can we avoid overdevelopment of river floodplains by economic policies?: A case study of the Ouse catchment (Yorkshire) in the UK." Land Use Policy **27**(3): 976-982.

National MBI Forum. Retrieved June, 2011, from http://www.marketbasedinstruments.gov.au/.

Nicholls, R. J., P. P. Wong, V. R. Burkett, J. O. Codignotto, J. E. Hay, R. F. McLean, R. S. and C. D. Woodroffe (2007). Coastal systems and low-lying areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M. L. Parry, O. F. Canziani, J. P. Palutikof, v. d. L. P.J. and H. C.E., Cambridge University Press, Cambridge, UK: 315-356.

Pilkey, O. H. and R. S. Young (2005). "Will hurricane Katrina impact shoreline management? Here's why it should." Journal of Coastal Research **21**(6): Iii-Ix.

Programme directorate Room for the River (2007). Room for the River: Safety for four million Dutch Citizens. Utrecht.

Rijkswaterstaat (2005). Risicobeheersing in kustplaatsen: Beheersing van kansen en gevolgen van kustafslag en overstroming tijdens zware storm in buitendijks gebied. Den Haag, Ministerie van Verkeer en Waterstaat

Room for the River (2006). Spatial Planning Key Decision: Room for the River. Approved decision. Utrecht.

Schwarze, R. and R. Wagner (2007). "The Political Economy of Natural Disaster Insurance: Lessons from the Failure of a Proposed Compulsory Insurance Scheme in Germany." European Environment **17**: 403–415.

Shabman, L., K. Stephenson, E. Thunberg and B. Dietz (1998). Comparing Benefit Estimation Techniques: Residential Flood Hazard Reduction Benefits in Roanoke, Virginia. IWR REPORT 98-R-2. Alexandria, USA, Institute for Water Resources, U.S. Army Corps of Engineers: 1-124.

Sjoeberg, L. (2000). "Factors in Risk Perception." Risk Analysis **20**(1): 1-11.

Slovic, P. (1987). "Perception of Risk." Science **236**: 280-285.

Slovic, P., M. L. Finucane, E. Peters and D. G. MacGregor (2004). "Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality." Risk Analysis **24**(2): 311-322.

Smith, W. and H. Montgomery (2003). "Revolution or evolution? New Zealand agriculture since 1984." GeoJournal **59**: 107–118.

Stavins, R. N. (2003). Experience with market-based environmental policy instruments. Handbook of Environmental Economics. K.-G. Muller and J. R. Vincent, Elsevier Science B.V. **1:** 355-435.

Stern, N. (2008). The Economics of Climate Change: The Stern Review. Cambridge, Cambridge University Press.

Sullivan, K. "Flood Insurance in Australia – some useful information." Insurance Council of Australia Retrieved November, 2010, from http://www.insurancecouncil.com.au/Portals/24/Issues/Current%20Issues%20Brief%20-%20Flood%20Insurance.pdf.

Tatano, H., K. Yamaguchi and N. Okada (2004). Risk perception, location choice and land-use patterns under disaster risk: long-term consequences of information provision in a spatial economy. Modelling spatial and economic impacts of disasters. Y. Okuyama and S. Chang, Springer**:** 163-181.

Terpstra, T. and J. M. Gutteling (2008). "Households' Perceived Responsibilities in Flood Risk Management in The Netherlands." Water Resources Development **24**(4): 551–561.

The Economist (Jul 26th 2007). Building on sand. Time to use insurance to stop people building on flood plains.

Thieken, A. H., T. Petrow, H. Kreibich and B. Merz (2006). "Insurability and mitigation of flood losses in private households in Germany." Risk Analysis **26**(2): 383-395.

Turbott, C. and A. Stewart (2006). Managed Retreat from Coastal Hazards : Options for Implementation. Environment Waikato Technical Report. **48:** 97p.

van Beers, C. and J. C. J. M. van den Bergh (2001). "Perseverance of perverse subsidies and their impact on trade and environment." Ecological Economics **36**(3): 475-486.

Varian, H. R. (1992). Microeconomic Analysis, W. W. Norton.

Veraart, J. A., S. Brinkman, J. E. M. Klostermann and K. P., Eds. (2007). Climate Changes Spatial Planning. Introduction to the Dutch National Research Programme. CcSP-Brochure. Wageningen, the Netherlands.

Wiener, J. D. (1996). "Research opportunities in search of federal flood policy." Policy Sciences **29**(4): 321-344.

World Bank (2009). The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates. The Global Report of the Economics of Adaptation to Climate Change Study.**:** 109pp.

Wu, J. (2001). "Environmental Amenities and the Spatial Pattern of Urban Sprawl." American Journal of Agricultural Economics **83**(3): 691-697.

A Appendix

This Appendix presents the extracts from reviews of insurance availability and some other economic stimuli methods for EU countries by various authors.

Belgium	Household flood damage is compensated by a public catastrophe fund. Supplementary private and commercial insurance is offered by private insurers at market rates, often embedded into commercial all-risk policies. The density of private insurance is less than 10 per cent.
France	Mandatory coverage of all natural hazards (except for storm, hail storm and snow pressure) as part of the general buildings and contents insurance, and car insurance. A uniform surcharge (12%) is charged on the premium turnover of private insurers in these branches and passed through to the Casse Centrale de Réassurance (CCR), the state-owned mandatory re-insurer. Reinsurance is provided at a fixed rate; catastrophic losses are state guaranteed. Deductibles to home owners are minimal (e.g. 380 Euro per damage to buildings) but rise significantly with repeated damage. The insurance density is close to 100 per cent.
Great Britain	Pure private insurance based on risk equivalent premiums so that highly risk exposed buildings pay high premiums. Deductibles are minimal (eg. GBP50 for home owners). A high density of insurance (75% of private buildings, 95–100% of all mortgage credits) is achieved because banks demand flood insurance to secure mortgages.
Netherlands	Private insurance against marine flooding is prohibited; riverine floods can be insured. Since all uninsurable risk is covered by a national catastrophe fund, the private insurance density is small.
Italy	Pure private insurance (comparable to Germany); very low density of insurance (e.g., only about 5 per cent of buildings are insured), state aid to flood victims is provided on an ad hoc basis.
Austria	Private and commercial damage is compensated by an income-tax-based federal catastrophe fund, generally to 50%. Supplementary coverage can be bought from private insurers at variable high premiums, depending on the contracted deductible. The private insurance density is high as regards storm, hail storm and snow pressure, but small (less than 15%) otherwise
Spain	Comprehensive mandatory coverage against all natural hazards and other 'extreme events' (terrorist attacks, political unrest etc.). Premiums are collected by private insurers and channelled through to the Consorcio de Compensación de Seguros (Consorcio), a state monopoly insurer (de facto). Premiums are calculated as a percentage of general buildings, car and accident insurance. The Consorcio is subsidized by the state, e.g. exempt from corporate tax. The federal government grants an unlimited excess loss guarantee. Private insurers could formally compete as re-insurers on a non-subsidized basis but have to contribute a certain percentage of the premium income to the Consorcio. Private insurance is non-existent in practice. The insurance density is high, depending on the density of the branches of insurance that are taxed. Deductibles are about 10% of the damage but limited to a maximum sum.
Switzerland	Mandatory insurance for buildings and contents. Coverage is limited to 50 Mill. CHF (approx. 30 Mill. Euro) per damage and 550 Mill. CHF (approx. 300 Mill. Euro) per occurrence. Catastrophic losses exceeding the occurrence limit are shared on a pro rata basis (based on the sum insured). Deductibles are limited to 10 per cent or CHF 2000 (1500 Euro), but minimally CHF 200 per damage. Re-insurance is provided by a mandatory membership reinsurance pool. The density of insurance is close to 100 per cent.
Liechtenstein	Mandatory insurance against fire and all natural hazards for all buildings worth more than 5000 Swiss Francs (approx. 3200 Euro) if a concrete exposure of risk is given. Home owners can be exempt from this mandate if they can prove that they are not risk exposed. Private insurers have a duty to contract and are forced to join a national pool of insurers; they retain a residual risk of 15%. Insurance premiums are state regulated. The insurance density is near 100 per cent.

Figure A.1: A review of natural hazard insurance availability in Europe by Schwarze and Wagner (2007), p.411

Events covered	AT	BE[(1)]	CH	CZ	DE	DK	ES	FI	FR	GB	GR	IT	NL	NO	PL	PT	SE	TR
Storm	O	C[(2)]	C	O	O	O	P	O	C	O	S	N	O	P	O	O	O	O
Cyclone / Hurricane	O	C[(2)]	C	N	O	O	P	O	C	O	S	N	O	P	N	O	O	O
Floods	O	C	C	O	S	N	P	O	C	O	S	O	N	P	O	O	O	O
Hall	O	O	C	O	O	O	O	O	O	O	S	O	O	S	O	C[(2)]	O	S
Water damage	O	O	O	O	O		O	O	O	O	O	O	O	O		O	O	O
Landsides	O	C	C	O	S	O	S	O	C	O	S	O	S	P	O	O	O	O
Snow	O	O	C	O	S	O	O	O	O	O	S	O	O	O	O	N	O	O
Frost	O	O	O	O	O	O	O	N	O	O	S	O	O	O	O	N	O	N
Avalanche	O	N	C	O	S	N	O	O	C	N	N	O	N	P	O	N	O	N
Drought	O	N	N	S	N	N	S	N	C	N	N	N	N	N	N	N	O	N
Subsidence	O		N	O	S	N	S	N	C	O	S	N	N	N	O	O	O	O
Earthquakes	N	C	O	O	O		P		C	O	O	N	N	P	O	O	O	C
Forest fires	S	N	N	N	O	O	S	O	S	N	S	N	O	O	O	O	O	S
Volcanic eruption	N			O	O		P		C	N	O	N	N	P	O	O	O	
Lightning	O			O	O		O	O	O	O	O	O	O	O			O	O

(1) In accordance with the law of 17 September 2005, published in the Monitor *(o.l)* on 11 Octobre 2005.
The rate of penetration of cover is not yet known
(2) For large undertaking only

Key (type of insurance cover):

C : compulsory cover by law
P : Obligatory pool
O : Optional cover
S : Cover proposed but not greatly taken out
N : Non-existant

Rate of penetration of cover:

: >= 75%
: between 25% and 75%
: between 10% and 25%
: <10%
: cover not known

Figure A.2: A review of natural hazard insurance availability and its penetration rate in Europe by CEA (2007), p.25

	Pilot projects	Regulation restrictions	Discharge control	Discharge fees/penalties	Stormwater fees	Tax brakes/ fees reduction	Public subsidies	Information campaigns
Sweden	+	+	+		+	+		+
Denmark	+	+	+		+	+		+
The Netherlands	+	+	+	+	+		+	+
Germany	+	+	+	+	+	+	+	+
England	+	+	+	+	+	+		+
France	+	+	+	+			+	+

Figure A.3: A review of methods applied for the promotion of stormwater source control techniques in Europe by Chouli et al. (2007), p.66