

The impacts of climate change can be analysed with the same economic assessment tools used for analysing the impacts of changing economic conditions. The fundamental concept is that impacts of climate change will affect the behaviour of economic agents, who will adapt autonomously, but autonomous adaptation is not always the optimal solution. This paper explains that by analysing the behaviour of people as a consequence of climate change, the resulting scenarios can help policy-makers in designing policies where autonomous adaptation does not reflect a social optimum. However, economic analyses of this topic are still scarce. The importance of concentrating on such analyses is that structural change is a continuing process in all European economies, but climate change may contribute to faster and more vigorous changes with corresponding challenges for policy-makers.

What do we know about the economics of adaptation?

Asbjørn Aaheim and Marianne Aasen

Introduction

An attempt to summarise the state of knowledge about social and economic challenges related to climate change, for example based on the latest IPCC reports, would probably give the impression that impacts, adaptation and vulnerability are a question of interactions between people and institutions within small local communities (IPCC, 2007a), whereas mitigation can be addressed by political analyses and economics (IPCC, 2007b). In most economic studies, the motivation behind mitigation is presented as that of limiting greenhouse gas emissions to a given target (see e.g. Weyant, 1999 and Chesnaye & Weyant, 2007).

With documentation of the costs of mitigation, it is also necessary however to do economic evaluations of impacts and adaptation options in order to set appropriate targets. An increasing number of so-called 'integrated economic analyses' of climate change have therefore been conducted in recent

years. Early studies, such as Nordhaus (1991) and Cline (1992), aimed at economic assessments of the impacts of climate change. Recognition of the fact that adaptation may reduce the costs of impacts substantially has more recently led economists to also address the potential benefits of adaptation options (see e.g. Tol, 2002). The bulk of the literature on adaptation and vulnerability emphasises, however, that adaptation has to be considered in a broader perspective. Economic implications are, in fact, rarely dealt with in this literature, which focuses more on how stakeholders interact and learn from each other.

On the other hand, economics is, in general, a tool for analysing adaptation to changes in economic constraints with reference to assumptions about how economic agents behave. If one can tell how climate change affects economic constraints, adaptation can be analysed and understood by economics. From the

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Asbjørn Aaheim is a research director at CICERO. He has published a papers on integration of environmental impacts in macroeconomic models and optimal control of natural resources. *Marianne Aasen* is a PhD student at CICERO. She is an environmental economist, and studies the effects of combining monetary incentives with information measures in environmental policies.

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point of view of policy-making, the advantage of this approach is that it helps our understanding of what economic agents do autonomously to adapt to climate change and thereby allows us to identify cases where a public policy strategy for adaptation may be required. The purpose of this note is to show how adaptation is driven by climate-induced changes in economic constraints, and to point out political challenges on the way towards adequate and smooth adaptation.

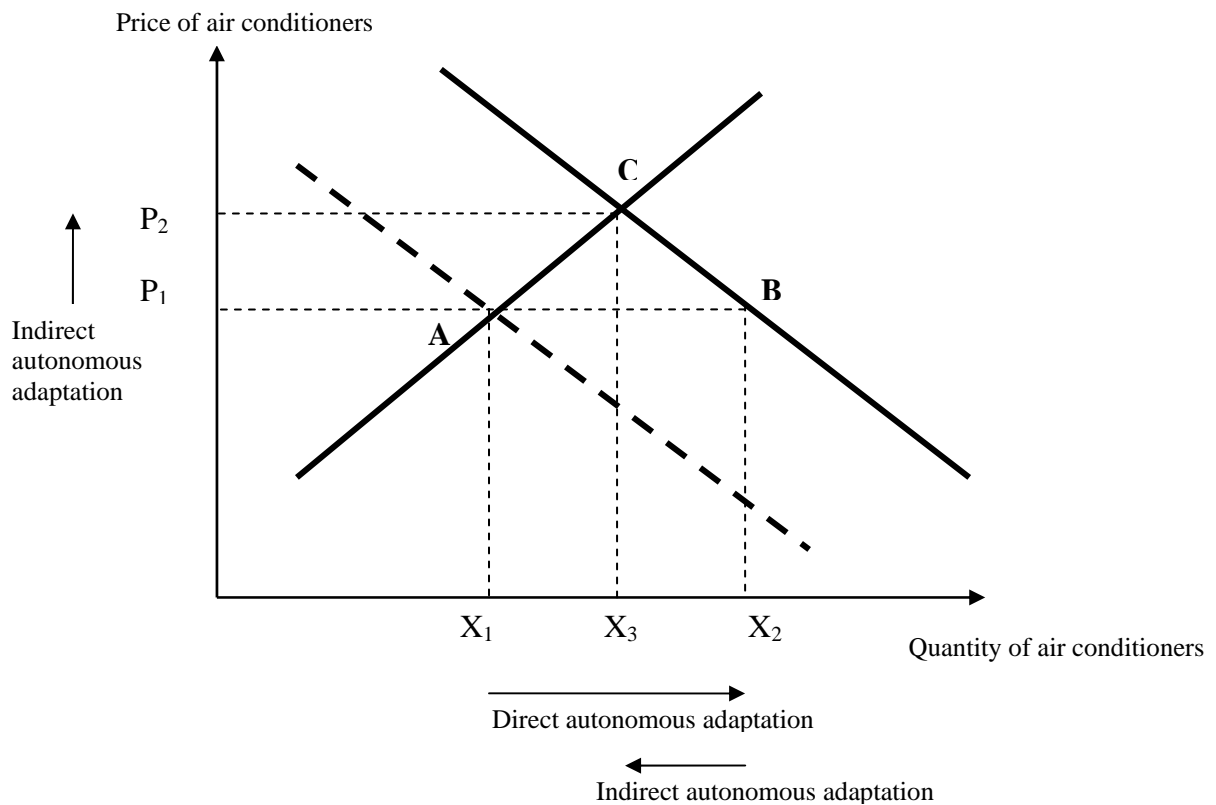
Autonomous adaptation

Autonomous *direct* adaptation can be described as changes that economic agents make when confronted with climate change. These changes can be shifts in the composition of input needed to produce the same output, for example the needs to use more fertilizer to produce the same amount of crop per unit of land after as before climate change. Or, these changes can be due to consumers who for example increase the use of private car

transportation to go to work if global warming leads to more rainy days. The first type of change is interpreted as changes in the technology of the economy where the producers are the market actors who adapt to climate change. The second type of change is interpreted as shifts in the preference structure of the consumers in the economy.

Autonomous *indirect* adaptation is the market response resulting from autonomous direct adaptation. When the supply and demand curve shifts because of climate change, the supply of the affected goods and services will no longer be equal to demand, and prices and quantities will therefore be adjusted until a new equilibrium is attained. This means that the relative prices of all goods and services are affected, which gives rise to a range of indirect effects. These two steps of autonomous adaptation in the economy, direct and indirect, are illustrated in Figure 1. The example chosen is a market for air conditioners, where the demand increases due to an increase in temperature.

Figure 1. An illustrative example of direct and indirect autonomous adaptation



The initial situation (before climate change) in this market of air conditioners is **A**, where quantity demanded is X_1 and the price is P_1 . The upward line from origin is the supply curve of air conditioners. The two parallel lines crossing the supply curve are initial demand (dotted) and new demand for air conditioners. With an increase in temperature, a larger share of the consumers in this market demand air conditioners to maintain their

preferred level of indoor comfort. The increase in aggregated demand in the market for air conditioners is illustrated in the outward shift from the stippled line to the parallel. The change in quantity demanded is the increase from X_1 to X_2 .

This shift is an example of what we call direct autonomous adaptation, which gives a new situation **B**, with excess demand for air conditioners and hence

a market in disequilibrium. The restoring of equilibrium gives a third situation, **C**, in our stylised illustration, where the quantity demanded is X_3 and the price of air conditioners has increased from P_1 to P_2 . This adjustment back to equilibrium, or the *market effects* from direct autonomous adaptation, is an example of what we call indirect autonomous adaptation.

Challenges for public policy

If all economic transactions were carried out as explained in economics textbooks, in which markets are perfect and economic agents respond consequently and instantaneously to shifts in the environment, the best and most efficient way to adapt would be to let each and everyone take his/her own responsibility and act according to his/her own beliefs. Public bodies and proactive public strategies for adaptation would be superfluous, in principle. In analyses of impacts and adaptation to climate change, the problem would be limited to that of determining the correct parameters for modelling, which itself is challenging enough.

It is important to have this in mind, because it signifies the fact that a lot of adaptation to climate change will take place without public policy interference. To the extent that impacts of climate change can be related to production technologies and consumers' preferences, autonomous adaptation is also inherent in traditional economic analysis of market behaviour. However, the full potential for adaptation to climate change will not be utilised by the markets alone. In cases where the presumptions for perfect markets are violated, public policy strategies become essential. It is therefore useful to examine circumstances under which adaptation to impacts of climate change happens under imperfect market conditions. These can be classified as cases where the adaptation measure is a *public good*, when the *transaction costs* are large and when adaptation requires that primary factors of productions will have to be moved physically (*immobility*).

Public goods

Many potential adaptation measures are public goods. These are measures that, if implemented, will benefit more than one economic agent. Among typical public goods adaptation measures we can mention dikes, land-slide entrenchments, road and railway constructions and protection walls against floods. Moreover, means to improve knowledge and institutional capacity, such as risk assessments, evacuation plans and land-use planning, are public goods. Problems that arise when public goods are traded in traditional markets with individual decision-making have been acknowledged among

economists since the 1930s, when Pigou (1932) pointed out that air pollution is a public bad that should be subject to taxation. However, it was not before the 1970s and 1980s that allocation of public goods attracted major attention among economists, although the rise in interest in public choice theory can be associated with Buchanan's (1954) criticism of the view that decisions of the state can be analysed as if made by a single person.

The basic problem with public goods is that if adaptation strategies are based solely on autonomous adaptation, the amount of implemented measures will be lower than the socially beneficial amount. This is because the full cost of the measure is placed on the agent who implements it, whereas this agent receives only a part of the benefit. Individuals will therefore lack incentives to invest in a public good. The standard solution to this problem is to make agents cooperate and/or to leave the decision to a public body, which in our case means to make adaptation an issue for the public authorities.

However, developing adaptation strategies for climate change will have to be based on expectations about impacts. From an economic point of view, a reasonable principle for an adaptation strategy would be that the expected marginal cost of climate change covers the marginal cost of public adaptation measures. It may be easy to obtain a consensus on this principle, but given the vast uncertainty about the impacts, there will be different opinions as to what is to be expected. Palm (1995) points out that experience is probably the most important factor behind people's realisation of risk, and that realising risk also means that the perceived risk becomes higher. People who are exposed to natural hazards are, therefore, likely to consider the risk as being higher than those who are not exposed. If so, those exposed to high risk are willing to pay more for the public good than the actually implemented amount. This may spur implementation of public goods by private agents with a possible benefit to others, but also with a neglect of possible negative externalities. Both are potential sources of ineffectiveness.

In particular, protection against slides and floods often implies that the masses are led away from an exposed spot. The risks in the surrounding area thereby increase with possible higher risk of damage to other agents, without being evident at first sight. For example, slide entrenchments may change the direction of slides and increase the vulnerability of buildings outside the protected area. The risk of floods can be reduced by removing potential damming in one area, but with an increase of flood risk downstream. A public adaptation strategy should therefore aim at high confidence in risk assessments and provide information to exposed people in order to achieve consensus about the level of risk. This

reduces the potential for conflicting views among people, thereby reducing also the potential for ineffective adaptation.

Transaction costs

The existence of transaction costs is associated with Coase's (1937) distinction between tasks performed by the firm and tasks performed by the market, but may also be related to Buchanan's criticism of the view that public decisions can be analysed as if made by individual persons. In general, transaction costs comprise all costs incurred in making an exchange of goods and services, such as the provision of information, learning to use it, building partnerships and negotiations. Transaction costs are necessary to make the exchange of goods and services happen. However, being subject to institutional factors and skills, among other factors, they may also depend on who delivers what to whom. This makes the 'unit cost', which is essential in defining the point of reference in economics, a rather vague concept. In order to point out cost-effective strategies of adaptation, it is necessary also to examine the transaction costs.

Adaptation to increased frequency of natural disasters provides a case with potentially high transaction costs. Adaptation measures for natural hazards are often public goods, and central governments do take responsibility for implementing means of prevention and protection in most European countries. Being subject to public policy priorities, adaptation strategies will reflect more issues than just the achievement of cost effectiveness. Natural hazards are usually considered as random events, where innocent victims suffer great losses. It is a common view that those who happen to be rammed should at least be spared the economic burden of their losses. This is why public bodies in most countries cover losses of damage after natural disasters, including non-public goods.

The challenge in this respect is that single agents who do not pay, or do not expect to pay, the full cost of damages do not have the right incentives to implement a private-good means for adaptation either. This is the background for moral hazard in economics. Private-goods adaptation measures may be the means to strengthen the construction of buildings or decisions about the placement of buildings. For example, the incentive for a private-property owner to build in a landslide-prone spot with a view or at the shore of a river with the risk of flooding is higher if he expects that the damage from landslides or floods is covered by someone else.

In most countries, this implies that private agents may apply for development in risky zones that should not be developed, but it is up to the local authorities to approve or reject the proposed project. Thus, if local authorities take the responsibility for the economic loss of natural hazards, the process of approvals would in principle assure a cost-effective adaptation strategy. However, the responsibility is, at best, unclear in European countries. Incentives for local authorities to approve development are, on the other hand, clear in most cases. The decision to develop is therefore easily decoupled from the risk of hazards.

Appropriate adaptation strategies will save societies from economic losses related to climate change. Even without climate change, there seems to be a potential for cost savings in cases of extreme weather events by clarification of responsibilities, and the search for incentives for individuals to implement private-good measures to protect their own property. Under climate change the extra costs of disincentives and unclear responsibilities may become huge, and the need for appropriate adaptation strategies correspondingly important, for example by encouraging planning procedures to avoid development in risky areas.

Immobility

In an ideally competitive market, the potential for autonomous adaptation is significant. Capital can be moved about freely, labour is fully mobile and natural resources are national endowments that contribute equally to communities without economic resources as to communities with economic resources. Services may, moreover, be produced in one place and demanded in another. The real world is, of course, more constrained, and the question is then whether and when adaptation to climate change is impeded because of such constraints and what can be done to facilitate adaptation.

Natural resources and attractions of economic value are, in general, sensitive to changes in climate. The economic activities they generate are usually placed close to where the resources are found, either for historical reasons, such as for fisheries, or because it is necessary, such as for tourism. Some local communities thereby become heavily dependent on the climate, and relatively marginal climatic changes may substantially change the value of specific natural conditions: Changes in ocean temperature may affect fish stocks substantially (Toreisen & Østvedt, 2000), the attractiveness of beach resorts depends on a relatively narrow range of day temperatures during the summer (Hein, 2007) and the best ski resorts are places where it is cold enough to keep the snow from Christmas to Easter, but not too cold to deter skiers.

Even moderate climatic changes may, therefore, affect a large share of these local communities.

Because of the dependency of the affected economic activities, the socioeconomic consequences are also likely to be more serious than if similar effects occur in larger and economically more diversified communities. The immediate result of a decline in economic activity is lower income and unemployment. Having lost the core activity, there are few alternatives in local communities. Thus, people will have to move to get a new job. The resulting unemployment is therefore likely to last for a longer period if it occurs in rural districts than urban areas. Older employees, in particular, may have to retire early.

Similar differences can be predicted also for the loss of value of real capital. The drop in prices of commercial and private buildings will be larger because the possibilities of finding buyers is less when the core activity closes down and people move out of the area. In addition, the core activities constitute the basis for many other economic activities. Various kinds of services, for example, will be affected harder in a small community than in a larger community. The customers in larger communities are likely to be recruited from a broader range of economic sectors, thereby making them less vulnerable.

Structural changes are a continuing process in all European economies, but climate change may contribute to faster and more vigorous changes with corresponding challenges to policy-makers. Encouraging flexibility of local communities will, in general, enhance the adaptive capacity of local communities. This may be stimulated by facilitating establishment of new business, education and post-education as well as programmes for local restructuring. But attention also to the possibility of local unemployment and social exclusion will have to be a part of the adaptation strategy.

Concluding remarks: An overview of potential adaptation measures

Adaptation to climate change has clear similarities with economic behaviour, and may also be understood and analysed within the framework of economic analysis. As economic agents interact and achieve a socially acceptable outcome through markets, they will also adapt to climate change autonomously without interference from a central authority. The final impacts of climate change are thereby moderated.

The need to develop adaptation strategies by central authorities emerges under imperfect market conditions, such as when the adaptation measure is

a public good or if the transaction costs related to adaptation are large. Two factors seem to be of vital importance for the magnitude of the transaction costs. The first is the extent and character of the uncertainty about the impact of climate change, as uncertainty extends the room for diverging views and conflicts of interest among agents. The second factor relates to the fact that adaptation takes time, and substantial losses may accrue in the meantime.

Despite the close relationship between standard economic analysis and analyses of adaptation to climate change, very little is known about the economic potential for adaptation strategies or the economic costs of adaptation options. The message of this note is that the design of adaptation strategies should address areas where autonomous adaptation is insufficient, and where public intervention is therefore required. The design of adaptation strategies is therefore closely related to the impacts of climate change. Economic analyses of impacts are still relatively scarce, and the basis for analysis of adaptation is therefore weak.

It is, however, possible to provide an overview of climate change impacts in order to sort out possible areas of interest with respect to the design of adaptation strategies. Table 1 lists possible impacts from climate change by sector and possible adaptation measures, classified according to our description of direct and indirect autonomous adaptation and adaptation initiated by public institutions. The three columns under 'Autonomous direct' indicate which economic agent is adapting: 'Consumer', 'Producer' or 'Public'. The last column gives examples of autonomous indirect adaptation that may follow from the direct adaptation.

Such a table may be used to sort out topical areas for the design of adaptation strategies. Although consumers and producers will adapt autonomously, public intervention may be advantageous in some cases. For example, education and information campaigns may be needed to facilitate the switch to drought-resistant species, whereas regulation of fertilizer is likely to happen smoothly without public intervention. As discussed above, the adaptation strategy will in some cases depend on predefined responsibilities. In countries where the health sector is mainly a public domain, for example, health effects will necessarily constitute a part of a public strategy for adaptation. This may be the case also in countries where the health sector is mainly a private domain, but the point of focus will be different. Where health is a public domain, the adaptation strategy includes capacity-building and prioritising tasks within the health sector. Countries with emphasis on private health care may limit the focus more on prevention, e.g. through vaccination programmes for vector-borne diseases.

Table 1. Examples of climate change impacts and types of adaptation

Impacted sector	Specific impact	Adaptation measure	Autonomous direct			Autonomous indirect
			Consumer	Producer	Public	
Agriculture	Drought	i) Switch to more drought-resistant species		X		Increased price of less drought-resistant species Increase in price of fertilizer
	Drainage of nutrients	i) Increase use of fertilizer ii) Support scheme for fertiliser for vulnerable farmers		X	X	
Transport	Increase in precipitation	i) Increased use of cars ii) Increase public transport capacity	X		X	
Tourism	Higher temperatures in warm destinations	i) Switch to less warm destinations	X			Higher unemployment in tourist sector in warm destinations
	Less snow in ski destinations	i) Rebuild for recreation			X	
Electricity	More precipitation	i) Increase production capacity ii) Decreased use of electricity for heating		X		Decrease in price of electricity Decrease in price of electricity
	Higher temperatures		X			
Health	Heat waves	i) Increase use of health services	X			Increase in price of health services
	Vector-borne diseases	ii) Vaccination programmes Increase capacity in health sector			X	
Building sector	Land slides	i) Entrenchments			X	Higher wages in health sector
		ii) Prepare evaluation plan			X	
		iii) Establish alternative routes			X	

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