Economic Models for Inland Navigation in the Context of Climate Change

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CHAPTER 5

CONCLUSION

5.1 Summary

Climate change is expected to influence many aspects of life in the future. Besides the increased occurrence of natural disasters like floods, droughts, and hurricanes, economic activity is expected to be affected more gradually. Climate change is often associated with changes in weather patterns, and more likely increased costs, and increased uncertainty. Transport, agriculture, and tourism are commonly mentioned sectors that are directly affected by climate change. In this dissertation the focus is on the influence of climate change on transport by inland navigation. In the Rhine area in North-Western Europe climate change is expected to cause more extreme and volatile water levels. Extremely low water levels result in capacity decreases, and extremely high water levels in navigation halts. Both capacity decreases and navigation halts imply increases in costs and the occurrence of economic welfare losses.

Measures against climate change may be categorized into mitigation and adaptation measures. Mitigation is associated with the prevention of climate change or softening the change in climate. Transport, considered as a polluter, enters the discussion of climate often through mitigation when the reduction of the emission of greenhouse gases is discussed. Adaptation in the climate change context means the adaptation of the various economic actors to the new environment after climate change. In this dissertation the focus is on adaptation strategies for the inland navigation sector. Adaptation measures (or strategies) can be categorized into public and private measures. Economic welfare analysis is useful to evaluate the efficiency of these types of adaptation measures. In Chapter 2, for example, infrastructure adjustment, which is a public adaptation measure, and barge-size choice, which is a private measure, are both evaluated within the same welfare economic analysis.

Another aspect that is stressed in this dissertation is the influence of imbalances in transport flows between regions on adaptation to climate change. In freight transport, imbalance in goods flows between regions is a commonly observed phenomenon, known as the backhaul problem. Imbalances in demand for transport between regions result in differences in freight prices between regions. In regions where demand for transport is higher, freight prices will also be higher. Climate change is expected to increase the costs of transport, and the direction-dependent freight prices will change accordingly. This will imply different impacts or costs for different regions or countries. Measures, like infrastructure adjustments, that require joint investment will then give benefits that differ by countries. This means that it is important to study imbalance to achieve a fair split of costs according to benefits in this type of adaptation.

The remainder of this conclusion proceeds as follows. In Section 5.2, we summarize the results and provide the answers on the research questions. In Section 5.3 we formulate the implications for adaptation to climate change in this sector. We end the dissertation with Section 5.4, where recommendations for follow-up research are made.

5.2 Results and answers to the research questions

This dissertation addressed the following two research questions:

1. What is the optimal barge-size adjustment for barge operators to cope with climate change, and what are the implications of climate change for investments in inland waterway infrastructure by the public sector?

2. What is the impact of climate change on freight prices in the inland navigation market in the presence of direction dependent freight imbalances?

In order to address the first research question, in Chapter 2 we formulated a theoretical model which described the low water-level uncertainty in the inland navigation market. With this model we are able to derive the optimal barge size, as an example of private adaptation, and the optimal investment in infrastructure, as an example of public adaptation. Given certain simplifying assumptions, we derived the optimal barge size analytically. An increase in the convexity of cost functions, the concavity of the capacity function, and the probabilities of low water levels is then shown to imply the choice for smaller barges.

In the current market however, it is shown by means of numerical analysis that there are incentives to almost double the current barge size. This suggests that the current market is *not* in its steady state, which could be explained by the long lifetime of barges that are currently in use. Thus, climate change does not provide a reason to stop the current trend towards larger barges. However, if we assume that the barge size is optimal before climate change, the model predicts that there will be a slight tendency to decrease the barge size when climate change occurs. The latter result is rather intuitive. Due to climate change, low-water levels, and consequently lower capacities, will occur more often. Barge operators then respond by reducing a part of the capacity which is used less often.

The government may also take public adaptation measures to decrease the potential harm caused by climate change. In this study we have focused on investments in infrastructure, such as dredging, and found a benefit-cost ratio higher than 1 (before and after climate changes). Thus, this suggests that welfare would increase if the government increases investments in infrastructure.

When studying the 'net' effect of climate change, which means that we assume that barge-size choice and the investment in infrastructure is optimal before climate change, we observe that the barge sizes may decrease slightly when only barge-size adjustments are considered. However, the increases in infrastructure investments are still considerable. This would mean that, after climate change, public adaptation may be a more important instrument than private adaptation when the situation is optimal before climate change. Combined barge-size adjustment and infrastructure investment yields a gain in expected welfare that is more than the sum of the gain in expected welfare when the two measures are taken separately. This 'super-additivity'-property can be attributed to the opportunity for barge operators to hold even larger barges in the new environment where low water is less harmful for their capacities. However, for the situation after climate change, when starting from an optimized situation, super-additivity no longer holds.

A sensitivity analysis with respect to the elasticity of the demand and the cost function of infrastructure investment shows that the optimal barge-size choice is rather invariant and remains at the double of the current representative size. The amount to invest in infrastructure, however, rather depends on the level of the cost of investment and of the elasticity of the demand function.

The central theme in Chapters 3 and 4 was the impact of climate change on freight prices under imbalance. This addressed the second research question. Chapter 3 followed a theoretical approach to answer this question. A matching model was applied innovatively to the traditional 'backhaul' literature, which is the classical term for the literature of imbalances in transport demand. This added the aspect of imperfect information to the search process. Imperfect information was shown to explain the existence of positive backhaul prices in the presence of imbalanced flows, which have been reported to be zero in the classical literature.

In a two-location transport model, two types of equilibrium were distinguished: the balanced equilibrium, where carriers have a load factor of 1 in both directions and, the imbalanced equilibrium, where the load factor from the low demand region is zero for a part of the carriers. For a wide range of numerical parameters the resulting equilibrium was imbalanced, which is also the more interesting one from an empirical perspective. In the imbalanced equilibrium, the round trip transport cost is fully borne by the customers in the high demand location. However, positive backhaul prices result due to carriers' compensation for expected search time.

A numerical example was presented where the chosen parameter set was taken such that certain segments of the inland navigation market between the Netherland and Germany are represented. Furthermore, we studied, numerically, the effect of reduction in travel speed due to extreme water levels, e.g. as a result of climate change, leading to higher trip durations. The high demand flow in this market is the flow from the Netherlands to Germany. German customers importing goods from the Netherlands were shown to predominantly pay for the increased costs of transport, whereas the Dutch customers (demanding transport from Germany) will hardly pay for the increase in costs. This strongly suggests that Germany will benefit relatively more from investments in infrastructure in order to prevent delays in transport.

In order to generalize the result in the above example where a region with high demand for transport is relatively worse off under climate change, the following intuition was given. In the imbalanced equilibrium, (which is more plausible empirically than the balanced case), all costs associated with navigating, whether full or empty, are carried by the region with high demand for transport (for example, Germany). If the costs of transport increase because of climate change, these costs will, as long as the equilibrium remains imbalanced, again be carried by the region with high demand for transport (German regions). Regions with a high demand for transport will therefore benefit relatively more from measures that reduce the effects of climate change.

Chapter 4 provided an empirical estimation of the effects of low water levels on freight prices under the presence of imbalance. In order to do this, we used a data set for barge operators in the inland navigation market in North-Western Europe, which consists mainly of trips with the Netherlands and Germany as origins and destinations. About 50 per cent of all physical trade between these countries is transported by inland navigation.

Our first finding is that regional imbalances play a much more prominent role than route imbalances in the determination of freight prices in the market studied. Our main finding is that a 1 standard deviation increase in the ratio of the export and import cargo flows in the region of origin increases the price for inland waterway transport from this region by about 7 per cent. For a series of sensitivity analyses this effect seemed robust.

Some regions in the studied inland navigation market may be typified as ‘exporting’ regions as more trips with cargo depart than arrive into this region. These are mainly the regions along the North Sea coast, including the sea ports of Amsterdam, Rotterdam and Antwerp. Most bulk cargo enters Europe via these ports by maritime transport, and is then transported further to the hinterland making use of inland waterway transport. ‘Importing’ regions are typified similarly. The regions are located in the hinterland, and do not export bulk goods on a large scale, as they tend to export manufactured goods and services to the seaport regions. This causes an imbalance in the physical transport flows between seaports and hinterland, and therefore the number of inland waterway transport trips with cargo. This results in higher freight prices per tonne from the seaports to their hinterland. This is in line with the findings of Chapter 3, when seaports are taken as the region with high demand for transport.

5.3 Policy implications for adaptation strategies

Our analysis yields conclusions on both private and public adaptation to climate change. We conclude that both types of adaptation may be useful to cope with climate change, and that combinations of both types of adaptation may lead to welfare-improving outcomes.

We used barge-size adjustment as an example of private adaptation, and found that in the market there is an incentive to considerably increase the current barge size, both before and after climate change. As these incentives are strong, there seems to be a less important role for the public sector regarding this adaptation strategy.

As an example of public adaptation we used investments in infrastructure investment. The analysis of investment in infrastructure had two aspects. First, the optimal level to invest in infrastructure was determined. Secondly, an equity aspect was studied. A fair basis was formulated to divide costs between countries for international infrastructure projects. While our model could be used for any type of infrastructure investment, including dredging, canalizing, or reservoir building, the focus in the presented example was on dredging. For values of the input parameters that are chosen to be in line with reality, our calculations show that the benefit-cost ratio for investments such as dredging is likely to be higher than 1, and is therefore beneficial for society.

The equity aspect is addressed by the observation that, in perfectly competitive markets, those regions with the highest reductions in freight price benefit most in terms of welfare. As the main determinant of difference in freight prices between regions we used imbalances in the demand for transport between regions. As is intuitive, freight prices are higher in regions with a high demand for transport.

The results indicate that, as a result of climate change, customers who are located in regions that attract large transport flows will experience an increase in transport cost when compared with customers located in regions attracting low transport flows demand for transport. This would mean that in an international context different regions or countries would benefit differently from investments such as those for infrastructure. More specifically, customers located in regions with high demand for transport will be saved from relatively greater losses due to climate change if investments in infrastructure are made. In an international context, a fair split of the costs of investments should take account of imbalances in demand for transport between regions. Fairness would imply that the larger share of the costs should go to the countries with high demand for transport.

5.4 Recommendations for follow-up research

We start our recommendations for follow-up research with suggestions for possible improvements of the research in this dissertation. This is followed by recommendations for follow-up research for a broader range of topics.

In Chapter 2 we performed a welfare analysis to evaluate the choice of barge size and the amount to invest in infrastructure. The numerical example concentrated on investments in the form of dredging. While this was sufficient for our purposes in order to formulate the model, for different policy advice purposes new numerical examples could be given for investments in canalizing or in the building of reservoirs. The efficiency of the strategies could then be compared. If necessary for more precise policy advice, more realism could be added to the model used to improve predictions about behaviour and adaptation strategies in this market. While relaxing any of the simplifications in the theoretical setting would lead to more realism, here we mention just a few. For example, more realism could be added to the water-level probability distribution. This would reflect capacities in more detail and also would make inference about risks more realistic. The addition of a future market would also lead to a closer reflection of reality. Also other aspects of the contractual agreements between barge operators and their customers could be added.

In Chapter 3 too, more realism could be added into the model in order to report more precisely on the policy measures that governments need to undertake. More realism could take the form of more realistic production processes by customers or be achieved by introducing the possibility for barge operators to search or be searched while navigating. A possibly useful extension might be to integrate the models of Chapter 2 and 3, and report the optimal amount to invest in infrastructure in conditions of imbalance, and the fair division between two or more cooperating countries in an international context.

In Chapter 4 the interaction effect of climate change and imbalance on freight prices could be studied. Another extension could be a check on the transferability of the results, by using data from different time periods and different countries.

Recommendations for follow-up research on ‘different’ topics can be categorized into the modelling of high water levels, on the one hand, and the evaluation of other adaptation strategies against climate change, on the other. The focus in this dissertation has been on low water levels. Low water levels reduce capacities, while high water levels imply navigation halts. In the current climate setting navigation stops hardly occur (at most on a few days per year). In future climate settings, however, high water levels could play a more significant role in this market. The inclusion of high water levels may lead to quite different results since barge operators are likely to become temporarily unavailable on the transport market, and no revenue is generated. Further, welfare analyses could be done to evaluate adaptation strategies, possibly in the presence of imbalance.

More research could be done to evaluate other adaptation strategies. Other adaptations can be categorized into adaptation by barge operators and adaptation by customers. In Chapter 2, barge-size choice was evaluated as an adaptation strategy for barge operators,. The choice of barge size can be seen as a part of more complete ‘fleet-management’-strategies. Adaptation strategies within this fleet-management may be new barge design to increase capacities and choice of fleet composition, which could mean the use of barges of different size and design.

Besides barge operators, the position of customers of barge operators is also affected by climate change. The behaviour of the customer was implicitly present in the demand functions, but has been rather underexposed in this dissertation. For example, customers are affected by climate change through increases in the freight price, and the availability and reliability of transport. A more explicit modelling of customers may lead to new insights into their adaptation behaviour to climate change. In order to do this, an assessment of the current situation of the customer could be made. The utility function of customers representing their preference for the different aspects of transport such as costs and uncertainty could be obtained by a stated preference research study. After incorporating the influence of climate change into such a utility function, adaptation strategies for customers could be evaluated. Change in stock-keeping behaviour and the possible relocation of customers to areas which depend less on inland navigation could be studied. Modal-shift was studied by Jonkeren et al. (2009).

An adaptation strategy that concerns both barge operators and customers would consist of changes in the terms of agreements for transport. These terms include agreements on financial compensation and degrees of transport obligation under extreme low and high water-levels. In addition, the analysis of future contracts might lead to different results. For example, in the future market in the Rhine area, barge operators receive a price surcharge per tonne if there are low water levels as a compensation for their decrease in capacity. The adaptation of such a contract to climate change could make the market more attractive for barge operators, and have welfare-improving effects.