Extreme weather events in Finland – a dynamic CGE-analysis of economic effects

Abstract

Due to the climate change, the frequency and magnitude of extreme weather events, such as flooding and droughts, are predicted to increase in many parts of the world. Extreme weather events may cause significant material and human losses. In our study, we wanted to investigate how these events would affect the Finnish economy as a whole and what would be the economically optimal strategy for both the prevention and aftermath. Until recently damage and risk assessments tended to focus on direct costs only. Our study, however, takes into account both the direct and indirect effects.

We based our analysis on two cases of regionally diversified flooding events in Finland. In the first one we studied a heavy rainfall event in the capital city Helsinki, and in the second one a river flooding case in a smaller industrial town Pori. These locations differ by their economic structure in themselves and in relation to the rest of the economy. Helsinki has bigger economy in overall with higher share of service industries than Pori. Helsinki also exports more of its commodities to the other regions in the country. Based on an earlier assessment, we were able to formulate direct and indirect economic shocks caused by the capital loss for two separate magnitudes of flooding events. We used a dynamic regional CGE-model for Finland, VERM to simulate the economic effects. VERM has bottom-up structure with 20 regions (NUTS3-level) and 46 industries. With the model, we compared three different strategies for compensating the losses. In the first one, the industries themselves were responsible for their repair costs. Two alternative scenarios portrayed the cases where public authorities and private insurance sector financed the rebuilding, respectively.

We found that the most efficient way to recover from a flood is to let the industries themselves pay the bill– the alternative scenarios both lead to less efficient recovering paths. Rebuilding happens fastest in the insurance sector scenario, but this fast rebuilding option seems to be the most inefficient one as well since it drives investment prices to a very high level. In all cases, the flooding will cause permanent negative deviation from the baseline GDP level and an increase in employment. GDP decreases mostly due to capital loss and employment increases mostly because of increased demand for construction industry. Even after 15 years, a structural shift to more labor intensive economy is visible in our results. We also found out that the long term overall effects are likely to be at least two times higher than the initial effects caused by the flood and thus the initial damage should be considered as an underestimation of the real costs. An interesting and also a bit controversial result was a regional disparity that we found – although the direct losses of Helsinki floods are smaller than those of Pori, the effects for the entire economy were much larger. This is caused by the capital region's stronger connections with the other parts of the country. This result indicates that if we are to consider the measures for preparing for the floods we should not only look at the amount of direct and indirect losses but also the significance of the region for the whole economy.

Introduction

Due to the climate change, the frequency and magnitude of extreme weather events, such as flooding and droughts, are predicted to increase in many parts of the world. Extreme weather events may cause significant material and human losses. In our study, we wanted to investigate how these events would affect the Finnish economy as a whole and what would be the economically optimal strategy for both the prevention and aftermath. The study was continuation for TOLERATE[1] research project (Perrels et al. 2010) that was set to investigate how extreme weather events should be dealt with in the context of climate change adaptation in Finland. In Finnish context floods and droughts stand out as the most prominent extreme weather events and we chose floods for our example. TOLERATE concentrated on the natural scientific basis of the flood hazard in two locations, Pori and Salo, and preliminary assessment of socio-economic impacts. The continuation that we present in this paper, IRTORISKI research project focused on deepening the economic analysis of the events by extending it to macro and regional level impacts and assessment of strategies for both recovery and prevention. We implemented our study in framework general equilibrium modeling. This paper presents only the modeling results of the project. Virta et al. (2011) summarize the results of the whole project.

Material and Methods

We based our analysis on two cases of regionally separated flooding events in Finland. In the first one we studied a heavy rainfall event in the capital city Helsinki (population ca. 590 000), and in the second one a river flooding case in a smaller industrial town Pori (population ca. 83 000). Helsinki is located by the coast of Baltic Sea in southern part of the country and has experienced floods during heavy rainfall. Pori is located on the estuary of Kokemäenjoki River in south-west of country, which make it the most likely location in Finland to encounter large scale damage during a flooding event. These locations differ by their economic structure in themselves and in relation to the rest of the economy. Helsinki has bigger economy in overall with higher share of service industries than Pori. Helsinki also exports higher share of its commodities to the other regions in the country.

Based on the results of TOLERATE, we were able to form direct and indirect economic shocks caused by the capital loss for two separate magnitudes of flooding events. Magnitudes of a flood can be classified by the return periods, which measure the period of years that it takes in average to encounter a flood of such magnitude. E.g. a flood of ten years in the return period (R10) is likely to occur once in ten years based on historical evidence. However, we did not take into account any effects that climate change might have for magnitudes of floods in the future but generally it has been predicted that probability for more extreme weather events will be higher in the future and thus the predictions we used might be considered conservative.

We applied for Helsinki once in 10 years and once in 100 years return periods (R10 and R100). For Pori we used somewhat less frequent return periods, R50 and R250. Different nature of damages in these locations justifies the disparity in magnitudes; industrial capital likely to be destroyed in Pori requires longer investment periods than simpler repair work likely to happen in Helsinki case. Thus even once in 250 years occurrence is not unreasonable to consider for a long term investments needed in Pori. The corresponding

[1] TOwards LEvels of Required Adaptation To cope with Extreme weather events.

shocks are presented in Table 1. In this case, the damage to the capital stock is the direct effect and the indirect effects are the rest of the effects caused by the loss of capital stock. In our analysis we evaluated further indirect effects that industries not directly affected had to face because of the effects listed in table 1.

Table 1. Damage profiles for the studied flooding cases.

	Helsinki		Pori	
	R10	**R100**	**R50**	**R250**
Duration (days)	1	1	15	25
Limited access period (months)	0.25-0.5	1-3	1	2-4
Duration of rebuilding (months)	3	12	9	15
Capital damage (M€):				
housing	10	40	100	240
commercial services	5	20	6	35
public services	5	20	8	45
transportation infrastructure	3	15	1	10
energy infrastructure	3	15	0	5
Production losses due to limited access:				
production days	4 weeks	12 weeks	4 weeks	12 weeks
share of annual production	0.1 %	0.6 %	0.2 %	0.9 %
Changes in unit costs during limited access:				
transportation	20	40	20	40
energy	100	100	0	100
Extra costs for households (M€)	0	2	10	13

Model

We used a dynamic regional CGE-model for Finland, VERM to simulate the economic effects. VERM has bottom-up structure similar to TERM-model and it has 46 industries and 20 regions (NUTS3-level). Helsinki and Pori are both economic centers for their regions, Uusimaa and Satakunta, respectively. The model has recursive dynamic structure, where investment behavior determines the growth path of the economy. For our study, the investment activity is the key feature in the model. Investments will increase in industries in which expected rate of return grows. Rate of capital growth in an industry is higher than historically only if the rate of return is at higher level as well. This is what happens with destroyed capital stock due to e.g. flood – lower than equilibrium level of capital stock will induce investments and help rebuilding process to commence. Thus, the reconstruction after the shock happens automatically in the model. The structure of the VATTAGE-model, which is a single-region version of VERM, is described in more detail in Honkatukia (2009).

Scenarios

With the model, we compared three different strategies for compensating the losses against business as usual (BAU) case where no flood occurs. In the first one (BASE), the industries themselves were responsible for their repair costs. Two alternative scenarios portrayed the cases where public authorities (PUBLIC) and private insurance sector (INSURANCE) financed the rebuilding, respectively. In BASE, the decrease in the capital stock will induce the industries affected by the flood to start investing more than in the equilibrium situation. This will lead to increased demand for investment commodities and thus to higher investment costs throughout the economy. However, the base scenario is unrealistic one since in reality the industries typically have insurances that will relieve them from at least part of the recovery costs. On the other hand, at least with the most severe hazards, the public authorities might want to get involved and help the industries financially.

In PUBLIC scenario we made a transfer from central government to local government of the value of the destroyed capital stock. We did not assume that the local government should earmark the money for any particular industries or purposes but to use it most optimally to help the regional economy. This would leave room for creative destruction, since the financial help received does not need to be directed to the region's old industries and could be used for developing new ones. Downside is that the central government needs to collect the payments by increasing tax payments, which will affect the whole economy. Also, quite unrealistically, local public authorities are presupposed to make economically optimal decisions. In INSURANCE scenario we set the industry that produces financial and insurance services to pay the bill of reconstructing the destroyed capital stock. This will cause an increase in the price of the commodity produced by that particular industry and that will be felt throughout the economy.

Results

Effects for flooded regions – BAU scenario

We set the flood to happen in year 2011 and then followed the recovery path until year 2020. The main results of the local effects in the base scenario are presented in tables 2 and 3 for Helsinki and Pori, respectively. In all of the cases we can see an initial drop in economic activity in all of the cases ranging from 0.13 % (Helsinki R10) to 1.67 % (Pori R250). In the long run, the regional GDP will end up at only a slightly lower level than without flood. That is, as we will see, only possible on account of changes in production structure.

We can find immediate decreases in capital and labor incomes in both of the regions. Capital stock obviously (since the exogenous shocks we applied!) decreases immediately after the flood and remains lower than in the BAU case until year 2020. Investments fall the same year as the flood occurs, but will start growing the year after when the recovery commences. Investments keep increasing even in year 2020. Investment growth wanes in the course of time in Helsinki. In Pori, however, the investments seem to end up on a permanently higher level being almost 20 % higher in cumulative terms in R250 case at year 2020. The main reason for still increasing investments is the capital stock that still has not reached the level of BAU case and in Pori even high level of new investments is not enough to bring the capital stock nearer to BAU case. The initial shock is after all a high share of the annual investments in the BAU case.

Some of the lost capital is substituted with labor, since labor decreases rather moderately when compared to capital. Flood causes immediately some temporary shifts also in structure of labor as although total demand for labor decreases, it will increase in trade, transportation and public services industries. When the investment boom starts, labor is employed increasingly in construction. In overall, employment increases due to flood in the long run and economy shifts to a more labor intensive structure. Employment effects are more positive in Pori due to higher initial unemployment rate, which means more room for employment to adjust than in Helsinki. In the R250 case the employment will be 0.67 % higher in year 2020 than without the flood. All in all, capital labor ratio will decrease in all of the cases.

In Helsinki cases household consumption will decrease initially but will return close to BAU eventually. This indicates no long lasting effects on consumption. In Pori, however, the effects are much more persistent due to investments that continue growing long after the flood. Thus, for Pori, savings ratio will be increased permanently because of the flood. In Helsinki, the consumption effects are directly reflected in imports, which decrease initially but will return quite soon close to the BAU case. The same changes appear in Pori and along with decreased overall consumption, which can be interpreted as higher share of imports in consumption. Exports grow in all of the cases because of boom in investment industries also increases their exports.

Table 2. Main results of the Helsinki cases in BASE scenario (%-changes against BAU).

	R10			**R100**		
	2011	**2015**	**2020**	**2011**	**2015**	**2020**
GDP	-0.13 %	-0.01 %	-0.01 %	-0.88 %	-0.07 %	-0.04 %
Capital stock	-0.02 %	-0.03 %	-0.03 %	-0.10 %	-0.16 %	-0.14 %
Employment	-0.01 %	0.00 %	0.01 %	-0.09 %	0.00 %	0.03 %
Investments	-0.06 %	0.05 %	0.15 %	-0.35 %	0.27 %	0.71 %
Household consumption	-0.10 %	-0.01 %	0.00 %	-0.70 %	-0.03 %	0.00 %
Imports	-0.05 %	0.00 %	0.00 %	-0.34 %	-0.02 %	0.00 %
Exports	0.03 %	0.00 %	0.01 %	0.28 %	0.02 %	0.03 %

Table 3. Main results of the Pori cases in BASE scenario (%-changes against BAU).

	R50			**R250**		
	2011	**2015**	**2020**	**2011**	**2015**	**2020**
GDP	-0.39 %	-0.16 %	-0.11 %	-1.68 %	-0.53 %	-0.21 %
Capital stock	-0.44 %	-0.47 %	-0.52 %	-1.69 %	-1.79 %	-1.96 %
Employment	0.00 %	0.02 %	0.11 %	0.08 %	0.20 %	0.67 %
Investments	-0.18 %	1.06 %	3.22 %	-0.39 %	5.87 %	19.20 %
Household consumption	-0.39 %	-0.28 %	-0.30 %	-1.32 %	-0.77 %	-0.80 %
Imports	-0.03 %	-0.02 %	-0.01 %	-0.11 %	-0.05 %	-0.01 %
Exports	0.05 %	0.01 %	0.03 %	0.30 %	0.11 %	0.21 %

Effects for flooded regions – alternative scenarios

We ran simulations for alternative cases only in the more severe flooding cases in Helsinki (R100) and Pori (R250). In PUBLIC scenario we can see a small deterioration in economic productivity when compared to BASE scenario in Helsinki. In general the public help seems to have slightly negative effects for Helsinki. However, we can see favorable improvement in Pori in the long run. Government help is beneficial for employment and investments in Pori and it fortifies the shift to more labor intensive production structure and is thus beneficial for the region's development. Household consumption also increases in Pori. The result for Pori is easy to comprehend since the region receives a direct income transfer that is financed by all twenty regions. The result for Helsinki may seem curious at first. The explanation lies in Helsinki's importance for the rest of the economy. The amount of public help received is comparatively small and is financed by taxing. Higher share of taxes are collected from Helsinki than from Pori and therefore Helsinki faces the costs of the public policy more directly than Pori does. We will return to this theme in more detail later on when we discuss the effects for the whole economy and the regional disparities in the transition of effects. Table 4 summarizes the results for PUBLIC scenario.

Table 4. The main results for Helsinki and Pori in PUBLIC scenario (%-changes against BAU).

	Helsinki (R100)			**Pori (R250)**		
	2011	**2015**	**2020**	**2011**	**2015**	**2020**
GDP	-0.88 %	-0.08 %	-0.05 %	-1.68 %	-0.48 %	-0.15 %
Capital stock	-0.10 %	-0.16 %	-0.15 %	-1.69 %	-1.81 %	-2.02 %
Employment	-0.09 %	-0.01 %	0.01 %	0.08 %	0.24 %	0.75 %
Investments	-0.35 %	0.27 %	0.72 %	-0.39 %	6.33 %	20.72 %
Household consumption	-0.70 %	-0.02 %	0.00 %	-1.32 %	-0.44 %	-0.47 %
Imports	-0.34 %	-0.02 %	-0.01 %	-0.11 %	-0.06 %	-0.05 %
Exports	0.28 %	0.03 %	0.03 %	0.30 %	0.11 %	0.22 %

In INSURANCE scenario the reconstruction boom starts earlier, already during the year of flood. That happens partly due to scenario construction and the model dynamics taking steps by the years, but nevertheless conveys the more rapid reconstruction work caused by a third party intervention. In BASE scenario the reconstruction is financed by the industries themselves by their own saving which will take time. In the INSURANCE scenario the reconstruction starts sooner and is completed quicker. During that period the investments will be crowded out from the other industries and general investment costs in the economy will rise. This is can be seen by slower economic growth and eventual slump in investments after the reconstruction boom. The investment activity will stay below the BAU level permanently. The effects for both regions are clearly negative in all the aspects. In addition to reconstruction being exceptionally swift, it is financed through insurance sector that will have to increase fees for its services. Higher insurance fees are felt throughout the economy, which is clearly a negative, bottleneck-like effect of abruptly high costs for industries demanding insurance commodities. Table 5 summarizes the results for INSURANCE scenario.

Table 5. The main results for Helsinki and Pori in INSURANCE scenario (%-changes against BAU).

	Helsinki (R100)			Pori (R250)		
	2011	2015	2020	2011	2015	2020
GDP	-0.93 %	-0.11 %	-0.14 %	-0.13 %	-1.22 %	-1.78 %
Capital stock	-0.10 %	-0.18 %	-0.21 %	-1.69 %	-1.91 %	-1.88 %
Employment	-0.01 %	-0.04 %	-0.07 %	2.31 %	-0.56 %	-1.27 %
Investments	0.84 %	-0.31 %	-0.85 %	38.56 %	-12.71 %	-29.22 %
Household consumption	-0.75 %	-0.06 %	-0.06 %	-0.79 %	-1.03 %	-0.96 %
Imports	-0.55 %	0.00 %	-0.04 %	-0.75 %	-0.02 %	-0.14 %
Exports	0.21 %	0.02 %	-0.01 %	-0.04 %	0.07 %	-0.04 %

Effects for whole country

Based on the regional level results for Helsinki the best policy is to let the industries themselves take care of the reconstruction bill. Public intervention is beneficial for Pori. INSURANCE scenario is clearly the worst alternative in both of the cases. However, we still need to investigate the results at the whole economy's level. In table 6 we present the national level results for Helsinki and Pori cases for GDP. By comparing the regions we can see that the flood in Helsinki affects the rest of the country initially much more strongly than the Pori case does. This is due to Helsinki's importance for the whole economy. Later on the differences even out, but we have to bear in mind that the amount of capital damage experienced in Pori is much higher than in Helsinki. We will discuss the actual multiplier effect later on in the paper. When we compare the different policy responses, we can see that the laissez-fare BASE scenario fares best in all of the cases. Differences between BASE and PUBLIC scenarios are not evident initially but show up as a slower recovery process in PUBLIC scenario. Although Pori gains in PUBLIC scenario, the government intervention seems detrimental for the economy in whole.

Table 6. National level GDP effects for Helsinki and Pori (%-changes against BAU).

	Helsinki (R100)			Pori (R250)		
	2011	2015	2020	2011	2015	2020
BASE	-0.41 %	-0.04 %	-0.02 %	-0.11 %	-0.04 %	-0.01 %
PUBLIC	-0.41 %	-0.05 %	-0.04 %	-0.11 %	-0.06 %	-0.05 %
INSURANCE	-0.48 %	-0.06 %	-0.07 %	-0.35 %	-0.10 %	-0.12 %

Tables 7 and 8 present the national level results for the capital stock and employment, respectively. The results for capital stock present generally low figures at the national level. This is due to higher productivity for the capital in the same industries in other regions that makes their investments more profitable. This is likely to shift some of the production from flood areas to other parts of the country permanently. On the other hand the investments become more expensive for all of the industries. This shows clearly in INSURANCE scenarios which causes highest immediate increase in investment price level. Helsinki case affects the employment much more negatively than Pori case. This is natural, since Helsinki is more strongly connected to the other regions by trade and has less unemployed workforce readily to be employed. However, the decrease in employment persists longer in Pori case.

Table 7. National level capital stock effects for Helsinki and Pori (%-changes against BAU).

	Helsinki (R100)			**Pori (R250)**		
	2011	**2015**	**2020**	**2011**	**2015**	**2020**
BASE	-0.04 %	-0.07 %	-0.04 %	-0.07 %	-0.07 %	-0.02 %
PUBLIC	-0.04 %	-0.08 %	-0.06 %	-0.07 %	-0.08 %	-0.06 %
INSURANCE	-0.04 %	-0.10 %	-0.12 %	-0.07 %	-0.14 %	-0.21 %

Table 8. National level employment effects for Helsinki and Pori (%-changes against BAU).

	Helsinki (R100)			**Pori (R250)**		
	2011	**2015**	**2020**	**2011**	**2015**	**2020**
BASE	-0.18 %	-0.01 %	0.00 %	-0.07 %	-0.02 %	-0.01 %
PUBLIC	-0.18 %	-0.02 %	-0.02 %	-0.07 %	-0.05 %	-0.05 %
INSURANCE	-0.21 %	-0.03 %	-0.03 %	-0.13 %	-0.06 %	-0.07 %

In figure 1 we have depicted a multiplier that measures how the regional changes are reflected to the rest of the economy. The figure presents the ratio of the national level GDP loss to the initial regional capital damages. The national level GDP loss is calculated cumulatively and by discounting with 0.05 discount factor. In Pori case the multiplier seems to be approaching a value slightly above 2. This means that the initial capital loss causes twice as high losses in national level GDP in the long run. For the very first years the values are below one, which is an indication of the firms in other regions catching some of the markets lost by the firms facing difficulties in flooded areas. For Helsinki, the magnitude of flood has significance and for R10 case multiplier value is around 8 and for R100 approaching 12. Helsinki is important for the rest of the country through trade and that explains the much higher multiplier when compared to Pori.

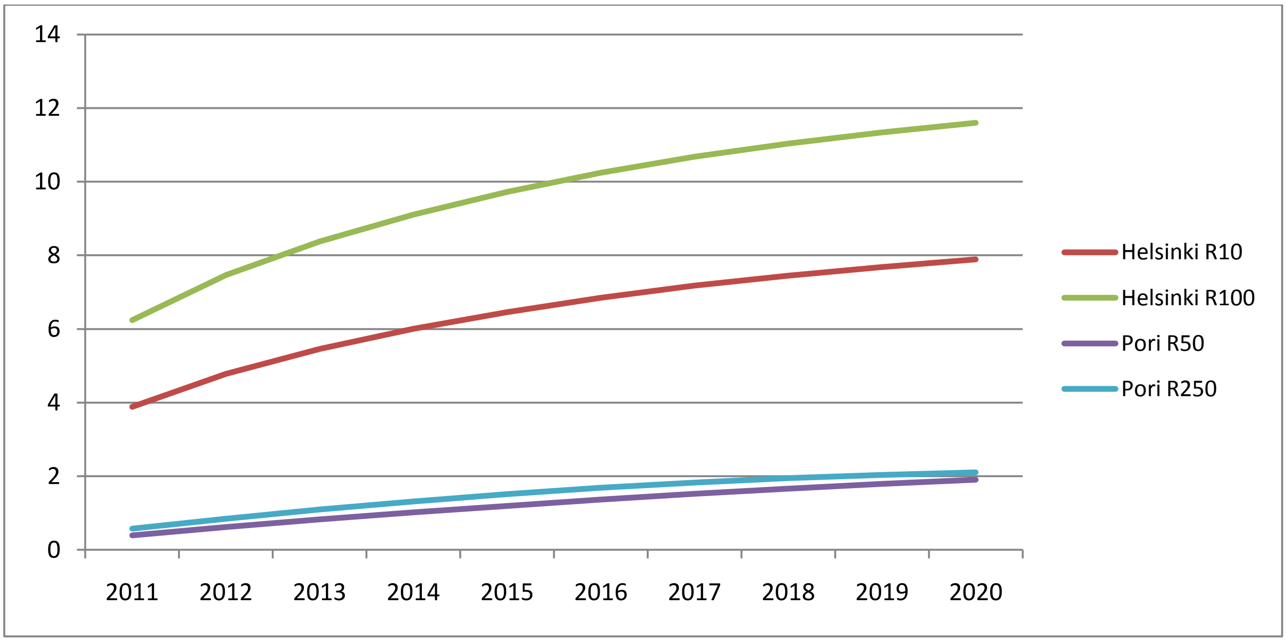

Figure 1. Regional-to-national level multiplier effect.

Discussion

In this paper we have investigated the possible effects of flood occurrences on regional and national economies in locations in Finland. Based on the results we were able to compare different strategies for recovering from the flood and for evaluating the prevention costs. For regions like Pori, we can see that government intervention might help a region to exploit the benefits of creative destruction. For Helsinki, however, we found that the government help will turn out costly. At the national level government help will cause more harm than benefits in all of the cases. This indicates that laissez-faire approach would be best policy in such situations. However, such policy recommendation does not sound appealing to many because of the nature of such disaster. But we can clearly make this a case only for the recovery process and not for the immediate disaster relief for which the government intervention will remain the most reasonable option. We also found strong support for not letting the costs fall to the insurance companies. Our analysis does not include considerations about insurance companies' ability to pay for the abrupt hazards or even less of the reinsurance possibilities, but it nevertheless shows that the effects are negatively felt in rest of the economy because of raised insurance fees.

The regional-to-national level multiplier shows how a hazard in a central location has much stronger effect for the rest of the economy than a hazard in a peripheral location. This result indicates that when we want to consider how to be best prepared for such events, the protective measures for the central areas should have clear priority over the peripheral ones. Same might be true for regions having strategically important industries. This, however, was not in scope of our study, and would need further research.

However, the subjective individual welfare is likely to be different from the one of the society's. Welfare measure in the model is a simple one based on the output level of the economy. It does not take into account the subjectively felt decrease in welfare by those who face the floods most directly. Although moderate pace in reconstruction seems economically most efficient strategy, many agents are likely to prefer faster pace of reconstruction. On the other hand, those affected by the flood might have enough political power to protect their interests on receiving financial help from government although paying that assistance would not be beneficial for society as a whole. This applies to the case of Pori, which clearly is to gain from government help that would be costly to the society. The case thus presents an example of Arrow's paradox.

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