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I. Introduction

After a major flood there is often special attention to the impacts on vulnerable people and members of lower income groups. But there has been little systematic study of whether the poor suffer larger losses, in absolute or proportional terms, than the middle class or high-income groups. It may be that a flood acts like a regressive tax, and worsens income distribution in the areas where it strikes. But that cannot be taken for granted.

There are reasons to expect that floods may worsen economic inequality. Indigenous groups, whose income is generally lower than average, often have settlements on rivers and lakes for historical and other reasons. And in the initial development of a town or city, other things equal one would expect that higher income people would locate on higher ground. The poor in the floodplain, where land is cheaper, and the rich on the prize lots at the top of the hill is seen in the history of many towns and cities. However, this is not the whole story. Rivers and lakes were originally very important for transportation and commerce, and in some areas safe locations were not close to those important arteries. Hence, higher income people did not always choose to live in completely safe locations.[1] And, with the development of dike systems and other forms of flood protection it became much safer to locate in what were originally flood zones. Especially when combined with a lack of building lots elsewhere, this could lead to many middle class and higher income people moving into a floodplain, as has been the case on a large scale in Greater Vancouver, the urban area that we study as an example here.

Today we are seeing a rising frequency and severity of riverine flooding in many areas around the world. Together with sea level rise, this is causing or will soon cause flooding in areas that were previously judged safe because of their human-made protection or because they were above natural flood levels along inland waterways or on the coast. These trends are of course associated with the global heating that is causing climate change, and are expected to continue and worsen. It is possible that the result may be a change in the distributional impact of the "flood tax", making it more onerous but also more equally shared.

The first economic impact of flooding that one thinks of is property damage. Homes, businesses and public assets may all be damaged. In the case of homes and businesses one of course thinks of the impact on the owners. But others, for example tenants, will be affected too. Also some of this damage may be to "lifelines" - - transportation, water systems, electricity and other utilities - - which affect people irrespective of who owns the infrastructure. Most other damage may have distributional effects, including that to public facilities like schools and hospitals, which may result in interruption of important public services.

As if the damage to physical assets was not complex enough, there is a range of other impacts that can have distributional effects. These include temporary or permanent job loss, loss of business income or rent, physical or mental health impacts, increased cost of goods and services, costs of travel and accommodation if evacuated, and so on. While there have been many post-

[1] It is not entirely unusual to see impressive homes dating from the first half of the nineteenth century or earlier along the banks of the St. John River in New Brunswick or the St. Lawrence River in Quebec. When those homes were built, they were evidently in the most advantageous location for the time, despite the risk of flooding.

flood surveys that identify the existence of these indirect costs, we are not aware of any case in which the distribution of these costs across households according to their income has been estimated or recorded.

Flood damage may be offset by insurance payouts or by government compensation. How this would occur differs greatly between countries. In France, for example, flood insurance is a mandatory element of home insurance policies.[2] Next door, in Germany, there is no compulsion to have flood insurance and there is some government compensation. In the US, it is mandatory to have flood insurance, either under the National Flood Insurance Program or privately, if one has a federally insured mortgage and is located in a high-risk flood zone. In Canada, private overland flood insurance was not available and there was only the government's disaster financial assistance (DFA) – a form of free insurance that is subject to caps and the ineligibility of a range of damages, as described below. Today, quite a number of insurance companies are offering coverage, but only 34% of households had private flood insurance at last report (Insurance Bureau of Canada, 2019). The remainder, and all of those in high-risk flood zones where private insurance is not available, continue to have free coverage under the public scheme.

This paper tries to illustrate and illuminate the above aspects through a case study, that of possible future flooding in Greater Vancouver or simply "Vancouver" for short.[3] Vancouver is a city of about two million people located on Canada's west coast. It is the country's main Pacific port and the commercial and industrial hub of the province of British Columbia. Located at the mouth of the Fraser River, about 20% of its people and 18% of its economic activity are located in the river's floodplain, protected by dikes (Gertz, Davies and Black, 2019). The city also has a long oceanfront and concerns about future coastal flooding are growing. Vancouver allows an interesting case study displaying challenges shared by many other modern and dynamic cities worldwide that face an increasing threat of flooding.

The remainder of the paper is organized as follows. In the next section we review some previous studies on distributional aspects of flooding. Then in section 3 we discuss conceptual issues and our theoretical approach to studying distributional impacts of flooding. Section 4 presents the data that form the foundation for our analysis of the impacts of a hypothetical flood that would inundate the entire Vancouver floodplain. It also describes the DFA rules that would determine how public compensation was paid out after such a flood. Results for the Vancouver case are shown in Section 5. Section VI concludes.

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[2] See Sandink et al. (2016) and Insurance Bureau of Canada (2019) for details on the French system and that in the other countries mentioned in this paragraph.

[3] Greater Vancouver has 21 municipalities and one treaty First Nation. The City of Vancouver is one of the municipalities. Throughout this paper, we use "Vancouver" to refer to Greater Vancouver.

II. Distributional Aspects of Previous Major Urban Flooding

Hurricane Katrina devastated New Orleans in August 2005. Total economic damage has been estimated at $149 billion (Hallegatte, 2008) and at least 1,833 people were killed during the hurricane and subsequent flooding (Knabb et al., 2005). Large numbers in the poorer areas of the city were permanently displaced. It has been found that the residents of damaged areas were more likely to be black, unemployed, and living below the poverty line than those in areas without direct damage (Logan, 2006). Despite aid, the poorest and most vulnerable communities were never able to rebuild or return (Greenberg 2014). Tenants were disadvantaged after the flood as many rental properties were not repaired quickly, leading to a spike in rental prices (Gotham 2014). There was also a correlation between poverty and lack of flood insurance (Masozera et al. 2007).

At the end of October 2012 Hurricane Sandy (known informally as Superstorm Sandy) travelled up the eastern seaboard of the U.S., causing $65 billion in damage and killing 71 people. The impact was particularly severe in and around New York City. A spike in unemployment insurance applications was reported after the storm, but within four weeks UI applications were back to normal (United States Department of Commerce, 2013). Cohen and Liboiron (2014) report that tenants, immigrants, and people of colour struggled to repair their homes after Sandy due to a slow governmental grant process and that repairs to public housing were also slow.

Turning to Europe, risk management of flooding has often been based on cost-benefit analysis (Allaire, 2018). In the UK, government has decided which areas to allow to flood in order to spare others using a cost-benefit approach that has been criticized for not taking into account social vulnerabilities (Johnson et al., 2007). Persons with vulnerabilities have been found to be over-represented in ocean floodplains although not in river floodplains (Walker and Burningham, 2011). Cost-benefit analysis is not dominant everywhere, however. The Netherlands, for example, has focused on minimizing loss of life instead of cost-benefit analyses (Bouma et al. 2005).

In Canada, Simonovic (1999) found that the 1997 Winnipeg flood strategy was based on a cost-benefit analysis that did not adequately account for social vulnerabilities. The 2013 Calgary flood affected many wealthy residential areas and business centres (Cryderman, 2014). However, it has also been reported that several vulnerable population subgroups were affected in ways not experienced by others. Those who were homeless or on the verge of homelessness had a harder time finding shelter due to the increased demand for temporary residence and the reduction of housing availability (Van Rassel, 2014).[4] The indigenous community of the Sikiska Nation, located downriver from Calgary, was disproportionately affected by the flood. One in four residents needed to be evacuated as opposed to one in ten in Calgary. A majority of the houses lost access to safe water and the roads and sewage infrastructure were affected. In the reconstruction efforts, this community experienced further upheaval as the reconstructed houses

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[4] The Canadian Disaster Database reports that an estimated 100,000 people were evacuated during the Calgary area flooding.

were built in areas that did not coincide with the historical and cultural traditions, causing stress within the community (Patrick, 2017).

While Vancouver has not experienced a significant flood since 1948, it has been the subject of flood vulnerability studies due to its high flood risk. Oulahen et al. (2015a) produce social vulnerability indicators based on a household's risk factors and then use this index to create maps of social vulnerability for five cities in Metro Vancouver.[5] These maps illustrate the distributional aspect of flooding where the aftermath of a flood would be felt differently across the population depending on their vulnerability. Oulahen et al. (2015b) highlight another distributional aspect of flooding in Vancouver where new building regulations and property insurance requirements are not affordable to many people living in the floodplains and thus expose low-income people to higher potential damage in the event of a flood.

III. Conceptual Issues and Theoretical Approach

Distributional shocks can occur on the sources or uses sides of households' budget constraints. There can be uses side effects in the form of price increases during the period of a flood, or the unavailability of certain goods and services. We will refer to such impacts as a form of flood damage in the discussion here. Sources side effects can take the form of loss of income, insurance payouts or receipt of government assistance, and loss of asset value.

What time period to use in framing the analysis is always a question in distributional studies. If there were a perfect capital market and people were assumed to have utility functions defined over the expected path of consumption over the lifetime, one could use the lifetime as the period of analysis. In that framework, the welfare of an individual or family depends on lifetime income, L, composed of human wealth, H, lifetime transfer entitlements, T, and initial net worth, W:

(1) $L = H + T + W$

where H and T are net of direct taxes and important components of W include housing or home equity, E, and business equity B. People would be free to choose any lifetime consumption plan with present value not exceeding L, and would smooth consumption overtime by borrowing or saving. In other words, the life-cycle model of consumption (LCM) would describe their behaviour.

Flood shocks to lifetime income can come in various forms. One is simply income interruption during a flood and the recovery period from a flood, which reduces H and B a little. More serious may be uninsured damage to one's home, other real estate assets or business assets. Still more

[5] The indicators are based on ability to cope, ethnicity, access to resources, household arrangement, and built environment. These characteristics have been demonstrated to impact a household's ability to recover from a flood or natural disaster event.

serious could be loss of H due to illness or injury. Income losses could lead to partial compensation in the form of more T - - e.g. through employment insurance (EI) or welfare payments.[6]

While it may be possible to estimate the size of flood-related shocks to earnings and assets, estimating total lifetime income is difficult in part since it depends on expected future income flows. If one wanted to say what % of L had been lost due to flooding, estimates could be made, but they would be subject to a significant margin of error. One must also take into consideration that about 20% of the population is borrowing constrained (Hall and Mishkin, 1982; Mariger, 1987; Jappelli, 1990)[7] and banking services may be interrupted or hard to access during a flood. Hence, while it seems appropriate to treat the majority of people as LCM consumers, we should keep in mind that there are a significant number of people whose behaviour does not follow that model.

Fortunately, there is an approach to distributional analysis in the flood context that makes sense both for people who can still validly be modelled as life-cycle savers in the context of a flood and for those who can't. This is to direct attention at consumption impacts, and distribution of consumption, in the year of the flood.[8] It is true that for the life-cycle savers there will also be consumption impacts in future years, due to consumption smoothing, but even borrowing constrained people may have lasting consumption impacts, if the flood has a lasting effect on their incomes or assets. Deciding to set aside all impacts beyond the current year is a practical approach that focuses attention on a valid measure of current welfare, that is current consumption. It will not tell us everything about distributional impacts, but it should nevertheless be informative.

As set out in the next section we use 2011 census data in our case study for Vancouver. Since the census does not include consumption data we get a number for normal, i.e. pre-flood, consumption by estimating lifetime income and applying a simple version of the LCM. Since the census only has cross-section data this would be difficult to do on an individual or household basis, as we only have a one-year snapshot of income received. Hence, we prefer to average within census tracts. As outlined below, each census tract has about 5,000 people. Averaging incomes within a census tract gives a reasonable estimate of permanent income, providing us with a basis to estimate average lifetime income in a tract. Those estimates provide a basis for distributional analysis that would be absent with individual or household data, and also prevent us from being misled by transitory income components, which result in inequality in annual income considerably exceeding that in lifetime income.

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[6] In Canada, government disaster financial assistance (DFA) programs do not cover loss of income, so T does not get a boost from DFA. DFA that is paid to compensate for loss of B or E is included in the net impact on those forms of equity, rather than being counted here as an explicit transfer payment.

[7] These early studies estimated borrowing constraints given data on consumption. Later studies confirm that the percentage of the population that is borrowing constrained has remained roughly 20% (Gross and Souleles, 2002; Gorbachev and Dobra, 2009; Kim, Wilmarth, and Choi, 2016).

[8] Looking at consumption over the period of a year is somewhat arbitrary. It might be argued, for instance, that we should look at consumption over a shorter period, even just the flood and recovery period. However, the available income data are for a calendar year, and we do not have a good basis for estimating inequality in income or consumption over shorter periods.

The importance of averaging income within census tracts can be highlighted by considering the simple case in which the population within a census tract is homogeneous except that individuals and households differ in their transitory income. If they were all life-cycle consumers and all lost, say, 15% of the value of their home and contents after DFA compensation, there would be no true distributional effect within a census tract. However, with transitory incomes there would be inequality in annual income and losses would be larger as a % of measured income for lower income people, making it appear that flood damage to homes and contents had a disequalizing effect. With a population of forward-looking consumers mostly not subject to borrowing constraints, this would be highly misleading if the goal is to determine the effects on true economic inequality.

IV. Vancouver: Data and Disaster Financial Assistance Rules

Data

We use 2011 Census data for Greater Vancouver, which includes 453 census tracts that have an average population of 5,023 people. Of these census tracts, 46 are entirely in the floodplain while 41 are partly in the floodplain. We estimate that the total population residing in the floodplain is 436,640 while 1,838,985 people live outside the floodplain (Table 1). We divide the census tracts that are partially in the floodplain into the portions in and outside the flood plain, resulting in a total of 494 groups. Each of those groups can be further divided into owner and renter households.

Table 1 provides information on the characteristics of the 494 groups that we study. Mean income per person is very similar in the floodplain ($40,494) vs. outside ($40,420). However, the distribution of income across census groups differs – it is more equal in the floodplain. The fraction of persons living in groups with mean income less than $30,000 is only 9.9% in the floodplain but it is 17.2% outside the floodplain. And there is a similar difference at the top: 4.2% of those living in the floodplain are in census groups with mean income greater than $60,000 while that fraction is 8.4% outside the floodplain. Thus, it is not the case that low income people are over-represented in the floodplain, but it is true that high income people are under-represented there.

Looking at other characteristics, the floodplain and non-floodplain populations are quite similar in terms of household size, unemployment rate, % living in one-person households and average age. The small differences in these dimensions are that the floodplain population is slightly younger, has a few more people living in one-person households, has a lower unemployment rate, and has lower average household size. The largest difference is that one-person households are more common in the lowest income group in the floodplain (38.9%) than outside the floodplain (29.6%). Unemployment is also significantly lower for this income group in the floodplain (5.5% vs. 7.8%).

The most significant difference between the floodplain and non-floodplain populations for our purposes is that there is a considerably higher rate of home ownership in the floodplain: 77% vs.

67%. There is a difference in the same direction of at least 5% points in all income groups. This may reflect reluctance on the part of developers to build apartment buildings in the floodplain.

Following Gertz, Davies and Black (2019) we will consider a flood that inundates the entire floodplain, causing physical damage equal in value to 25% of the capital stock located there.[9] For simplicity, we will assume that neither households nor firms expect the flood and they do not expect it to be repeated. In the Vancouver case this is not unreasonable, as the floodplains are all diked and there has not been a really major flood since 1948. Also, it is reasonable to assume that if such a devastating flood did occur, people would expect the dikes and other flood protection to be rebuilt to a higher standard, making the likelihood of a future flood that would overcome the flood defences even smaller than it is now.

As explained in the previous section we use a simple version of the life-cycle model (LCM) to predict pre-flood or normal consumption. The average age of the population is close to 40 in all groups, so for simplicity we assume a uniform average age of 40 in our calculations. We also assume that everyone will retire at age 65 and die at age 85 with certainty. Expected future income equals current income.

We need to make an assumption about the borrowing ability of the representative household in each census group. Since being borrowing constrained is atypical, we assume that the representative household in each group can borrow, but we also recognize that there are certain consumption shocks during the flood and recovery period that cannot simply be offset by borrowing. Effectively, what happens is that prices for certain goods and services go up or they become unavailable, which is equivalent to their price going to infinity. To explain this fully one needs to recognize, that people consume Beckerian "commodities" that are produced with inputs of goods and their own time (Becker, 1965). The commodities that are particularly time intensive are those that we recognize as home production. Meals, for example, are produced in the home using food and appliances, utilities and time spent obtaining food, storing it, cooking, cleaning up afterwards and so on. When there is a flood, electricity and other utilities are likely to be unavailable. A proper cooked meal may simply become unavailable, or may only be found after making a difficult journey to a restaurant outside the flood zone and paying restaurant prices for a meal that would normally be produced at a lower cost at home. The cost of a wide range of other commodities normally produced and consumed in the home may also rise considerably, or become prohibitive.

Here we capture the effect of prices rising and goods and services becoming unavailable by assuming that some of the consumption shocks caused by a flood are "non-smoothable". We

[9] The assumption of 25% damage is not extreme. The Gertz et al. estimate of total capital damage of $14.6 billion in this case is similar to the number found by and the Fraser Basin Council (201X). Inundation of the entire floodplain could occur e.g. if there were a major earthquake - - something that Vancouver is believed to be "due" for. A major earthquake would likely cause multiple dike failures throughout the Fraser delta. Widespread flooding could also occur as a result of unusually heavy winter snowfall in the Fraser River catchment area combined with a rapid thaw and heavy rainfall during the spring freshet. In the future these threats are likely to be magnified by sea level rise, especially if flood defences are not improved sufficiently.

assume that these non-smoothable costs are partly a fixed amount common to all households and partly related to income, as described below.

While the value of homes is reported in the census, and we can impute mortgage debt using the results of the 2012 Survey of Financial Security (SFS), the value of home contents is not given in either of these sources. Evidence on the value of home contents in Canada is difficult to obtain, but the Association of British Insurers (ABI) reports the average value of contents. Their number is close to mean household income in the UK, so we have assumed that the value of home contents is equal to a year's household income in our calculations.[10] We assume that ratio holds in Vancouver.

Disaster Financial Assistance in British Columbia

The BC DFA program pays for 80% of total eligible damage exceeding $1,000 up to a maximum of $300,000. There are three types of recipients: home owners and tenants, small businesses and farm owners, and charitable organizations. Eligible expenses include damage to principal residences, and business or charitable premises as well as essential contents. For homes, eligible items are stipulated item-by-item and room-by-room. Casual labour used in cleanup, including the owner's own time, is also covered, at the minimum wage, up to 100 hours. Commercial services and rentals for cleanup are eligible at officially approved rates. Ineligible items include income loss (both labour earnings and business income) and many non-essential contents, including e.g. jewellery, art, books, collectables, and recreation equipment. Loss of land value and damage to roads are not eligible. Based on these limitations, we assume in the calculations reported below that only 50% of home contents and "non-smoothable" consumption shocks are covered by DFA in Vancouver. We also impose the $300,000 cap on total DFA payments.

Including condominiums, the average sale price of a home in Vancouver in recent years has been about $1 million, and detached houses sell for an average of around $1.5 million (Globe and Mail, July 4, 2019). This might suggest that a great deal of damage to homes is not covered by BC's DFA program. However, that is incorrect. Most of the cost of a home in Vancouver reflects the cost of land. Dachis and Thivierge (2018) present results that imply the average construction cost of a new single-family house home in Vancouver in 2011 was $419,000, which was only 32.3% of the average $1,298,000 price of such a home at the time.[11]

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[10]The Association of British Insurers reports that in 2018 the average value of home contents in the UK was GBP 35,000 https://www.abi.org.uk/news/news-articles/2018/02/britain-uncovered-the-average-uk-household-now-owns-35000-worth-of-stuff/ Mean household disposable income was reported as GBP 34,200 by Britain's Office for National Statistics: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/bulletins/householddisposableincomeandinequality/yearending2018

[11] The construction cost can be calculated from the numbers in Table 1 of Dachis and Thivierge (2018) and the two equations involving MPCC that appear in the text of the second paragraph of the Appendix to their paper, noting that EP, which reflects the margin developers earn as profit (17%, reported on p.8), equals 1.17 and the cost of barriers is $644,000 (last column of Table 1).

V. Vancouver Flood Study: Results

We present results here on the estimated direct distributional impacts on households of a flood that would inundate the entire floodplain of Greater Vancouver causing 25% damage to all houses and their contents. This includes income interruption and consumption losses that may result from damage to businesses or public facilities, but the distributional impact of losses of business equity are not considered since we cannot estimate those using the 2011 census data.[12]

Our first results are for the case where there is damage to houses and their contents only. The estimated effects of income interruption and "non-smoothable" consumption losses will be shown subsequently. Table 2 shows these results for Vancouver as a whole. The starting point, shown in the first column, is a no-flood distribution of consumption with a share of the top quintile (i.e. top 20% of persons) of 30.83% and a share of the bottom quintile equal to 12.81%. The Gini coefficient is just 0.1791, reflecting the fact that we are not including inequality *within* the owner or renter subgroups of our census groups. Mean consumption, found by imposing the simple life-cycle model described in the previous section, is $36,110 per person.

Table 2 shows that the distributional impacts of flooding are small, with or without compensation, when the only cost is damage to houses and contents. The small size of impact is due to the fact that there are two conflicting effects, neither of which is very large. The first is an increase in consumption inequality between people in the floodplain and those outside it. The second is a small decrease in consumption inequality within the floodplain due to the fact that the rate of home ownership is significantly lower in the lower income groups (Table 1). The small impact of DFA compensation is due to the fact that it weakens both of these effects.

Table 3 shows the effects in the floodplain only, again considering only damage to houses and contents. In this case we expect inequality to fall, due to home ownership rates being lower for lower income groups. That is indeed what is found, with the Gini coefficient declining from 0.1395 to 0.1391. Compensation almost completely removes those effects, showing that it is slightly disequalizing because of the higher home ownership rate among higher income groups. The flood acts like a mildly progressive wealth tax, and DFA compensation mostly wipes out that "tax".

The relatively small impact of damage to houses and contents either on inequality between the floodplain and the rest of the city, or within the floodplain, owes much to the assumption at this point that all residents are behaving according to the life-cycle model of consumption (LCM). Equity in housing plus the value of contents is, on average, a small fraction of lifetime income. Moreover, the 25% damage is just to the housing structure. Most of the value of a typical house in Vancouver in 2011 was the value of the land, which we assume is unaffected by the flood since it is not expected that the flood damage will recur. In the absence of compensation, the

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[12] For a full analysis it might be argued that one should consider the distributional impact of the increase in future taxes needed to pay for repairs to public facilities. Those costs would mostly be paid for by the provincial government, with a large subsidy from the federal DFAA program. Hence the impact on Vancouver residents would be relatively small.

estimated reduction in average lifetime income, and therefore in consumption under the LCM, for households in the floodplain is just 3.1% without compensation and 0.9% with compensation.

Table 4 shows the estimated distributional impacts for Vancouver as a whole when “non-smoothable” consumption costs are included. As mentioned earlier, we assume that these costs have a fixed component, common to all households and a component that is related to household income. In the run shown in Table 4, the fixed component equals one month’s average consumption, $2,917, and the second component equals one month’s income for the household, which averages $3,009.

Recall that in Table 2, when we did not have “non-smoothable” consumption losses, inequality changed very little for Vancouver as a whole. With those additional losses included, however, inequality increases noticeably, especially when there is no compensation. This is mainly because the gap between people in the floodplain and those outside the floodplain rises more due to the flood than it did without the “non-smoothable” consumption losses. Table 5 shows that the flood is now predicted to decrease average consumption in the floodplain in the year of the flood by $6,648, or 19%. But we also see that inequality within the floodplain now increases. Without compensation the Gini coefficient for consumption in the floodplain goes up from 0.1395 to 0.1426. And we now find that DFA compensation reduces inequality within the floodplain, in contrast to the case without “non-smoothable” consumption costs in which the compensation actually increased inequality in the floodplain. The explanation is that we are now recognizing the greater vulnerability of low income people, which means that the flood can no longer be looked on as a kind of progressive wealth tax. It now resembles the combination of a regressive income or consumption tax with a progressive wealth tax, in which the regressive element dominates.

VI. Conclusion

We have discussed the complex distributional impacts of flooding in a Canadian context. In addition to damage to capital, floods cause interruption of income, public services, health care, and the supply of consumer goods. The may of course also cause death and injury, including damage to mental health. Experience in Canada and other countries shows that impacts on lower income and vulnerable populations are often especially severe.

We have illustrated the possible distributional impacts of flooding through a case study of a hypothetical flood in the Vancouver area which would destroy 25% of the capital located in the floodplain. The modeling uses 2011 Census data and is based in the dynamic general equilibrium analysis in Gertz et al. (2018). We include income interruption and consumption losses but are unable to study the impact of the loss of business equity as it is not covered in the census. “Non-economic” impacts have also not been modelled.

In our first set of runs we assumed that although there were consumption losses, those could be smoothed over time by all households. With that assumption the distributional impacts of flooding either for Metro Vancouver as a whole or the floodplain alone are small, with or without disaster assistance. These results are altered when we taken into account borrowing constraints and barriers to securing goods and services during and immediately after a flood, introducing “non-smoothable” consumption losses. With this feature, if there was no disaster assistance the flood would increase inequality significantly both in Metro Vancouver as a whole and in the floodplain alone. When the Disaster Financial Assistance system is introduced most of that increase in inequality is reversed.

Table 1. Metro Vancouver Population Characteristics, 2011

Group Mean Income ($ thousands)	Population	Income per person ($)	Value of Dwelling, Owners ($)	Owners as % of Households	Unemployment Rate	% of One-person Households	Mean Age
I. In the Floodplain							
< 30	43,340	27,168	645,132	68	5.5	38.9	36.9
30-40	197,740	34,540	588,784	71	7.6	26.3	40.4
40-50	138,840	44,548	642,004	84	7.1	32.5	39.7
50-60	38,270	54,292	815,074	87	6.6	16.6	41.1
60+	18,450	76,727	1,182,466	86	7.2	26.5	40.1
TOTAL	436,640	40,494	666,022	77	7.1	29.4	39.9
II. **Outside the Floodpla**in							
< 30	316,335	27,134	539,664	53	7.8	29.6	40.6
30-40	730,240	34,799	600,448	66	7.2	30.5	40.1
40-50	493,140	44,028	650,716	71	7.4	23.3	41.1
50-60	145,215	52,305	919,136	70	7.0	24.9	40.0
60+	154,055	72,922	1,414,504	80	6.8	26.9	40.4
TOTAL	1,838,985	40,420	716,330	67	7.3	27.8	41.5

Table 2: Hypothetical Vancouver Distributional Flood Impacts on Consumption Per Person: Damage to Houses & Contents Only

Indicator	No Flood	Flood with 25% Damage and no Compensation	Flood with 25% Damage and DFA Compensation
Quintile 1 % share	12.81	12.84	12.82
Quintile 2 % share	15.97	15.94	15.96
Quintile 3 % share	18.71	18.67	18.70
Quintile 4 % share	21.68	21.68	21.68
Quintile 5 % share	30.83	30.87	30.84
Gini Coefficient	0.1791	0.1793	0.1792
Mean ($)	36,110	35,960	36,067
Median ($)	33,907	33,680	33,866

Table 3: Vancouver Distributional Flood Impacts on Consumption Per Person, Damage to Houses and Contents, Floodplain Only

Indicator	No Flood	Flood Without Compensation	Flood With DFA Compensation
Quintile 1 % share	14.11	14.11	14.13
Quintile 2 % share	16.94	16.90	16.92
Quintile 3 % share	19.38	19.34	19.37
Quintile 4 % share	21.52	21.50	21.52
Quintile 5 % share	28.06	28.08	28.06
Gini Coefficient	0.1395	0.1391	0.1395
Mean ($)	35,396	34,311	35,084
Median ($)	34,419	33,229	34,090

Table 4: Vancouver Distributional Flood Impacts Including "Non-smoothable" Costs

Indicator	No Flood	Flood Without Compensation	Flood With DFA Compensation
Quintile 1 % share	12.81	12.69	12.84
Quintile 2 % share	15.97	15.77	15.90
Quintile 3 % share	18.71	18.49	18.60
Quintile 4 % share	21.68	21.78	21.68
Quintile 5 % share	30.83	31.26	30.97
Gini Coefficient	0.1791	0.1851	0.1805
Mean ($)	36,110	35,194	35,696
Median ($)	33,907	32,426	33,243

Table 5: Vancouver Distributional Flood Impacts Including "Non-smoothable" Costs, Floodplain Only

Indicator	No Flood	Flood Without Compensation	Flood With DFA Compensation
Quintile 1 % share	14.11	14.13	14.17
Quintile 2 % share	16.94	16.85	16.89
Quintile 3 % share	19.38	19.16	19.27
Quintile 4 % share	21.52	21.37	21.45
Quintile 5 % share	28.06	28.49	28.22
Gini Coefficient	0.1395	0.1426	0.1404
Mean ($)	35,396	28,748	32,391
Median ($)	34,419	27,528	31,556

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