Policy options for natural disaster risk management

Modeling the economics of adaptation, insurance, contingency funds and debt reduction in the Caribbean

Presented by Gregor Schwerhoff, World Bank

Motivation

Objectives

- Develop policy options to achieve debt sustainability and address natural disaster risk in a pre-emptive manner
- Compare performance of four disaster risk management strategies: adaptation, insurance, contingency fund and debt reduction
- Study dynamic responses to hurricane shocks in different baseline and risk management scenarios

Model setup

Modeling approach

Macroeconomic modeling using MFMod

- Macrostructural model developed by World Bank (GMTMD)
- Model documentation available on request, working paper in preparation

Estimation and calibration

- Case study: Jamaica
- Extension to other Caribbean countries planned

Data sources

- MFMod database for macroeconomic data
- Emergency Events Database (EM-DAT), https://emdat.be/
- Acevedo (2016)

Fiscal rule

The government budget in standard MFMod

- Government revenue and expenses calibrated to historical data
- Jamaica has experienced strong reduction in debt recently
- -> Model predicts declining debt and eventually large government surplus

Targeting

- For more realism, targeting of “reasonable” budget deficit or debt level introduced
- Difficult to compare risk management strategies because of endogenous reaction

The government budget in this model version

- This model version: government expenses adjusted to achieve small budget deficit
- Debt stabilizes in long run, allows fair comparison

Aggregate consumption

Government consumption in standard MFMod version

- Government consumption calibrated to historical behavior
- Causes consumption to maintain constant share of government budget
- Government consumption used to purchase goods and labor (-> enters GDP)
- No “productive” function comparable to government investment
- No welfare loss from reducing government consumption
- Risk management becomes “free lunch” when financed by reducing gov. consumption

Government consumption in this model

- Government consumption enters household consumption:

$$C_t^E = \left[\alpha(C_t^P)^{\vartheta} + (1-\alpha)(C_t^G)^{\vartheta}\right]^{\frac{1}{\vartheta}}$$

- Based on Barro (1990), Marattin and Palestini (2014) and others

Modeling disaster risk management in MFMod

Four hurricane management strategies

Adaptation

- Construction (or improvement) of physical capital to reduce hurricane damage

Insurance

- Pay yearly insurance premium equal to expected damages plus insurance markup
- Receive full compensation of damages when hurricane hits

Contingency fund

- Separate account within government with savings
- Use of savings to pay for hurricane recovery

Debt repayment

- Debt repayment with the intention of obtaining fiscal space for hurricane recovery

1. Modeling adaptation

Examples for adaptation to hurricanes

- Sea defenses to protect infrastructure from waves
- Rainwater drainage systems to prevent flooding damages
- Building more robust infrastructure or reinforcing existing infrastructure

Damages

- Residual damages equals gross damages less the value of protection: $\frac{D_t}{Y_t} = (1 - P_t)\frac{GD_t}{Y_t}$
- Parts of capital stock is destroyed when there is no protection: $K_t = (1 - \delta)K_{t-1} + I_t - D_t$
- Assumption here: hurricane shock (of ten times the average yearly damage) every ten years

Adaptation capital

- Government invests a discretionary amount into adaptive infrastructure: $G_t^{Adp} = \sigma^{Adp} Y_{t-1}$
- The adaptation capital stock follows the perpetual inventory method: $K_t^{Adp} = (1 - \delta)K_{t-1}^{Adp} + G_t^{Adp}$

1. Protection level of adaptation

Protection level

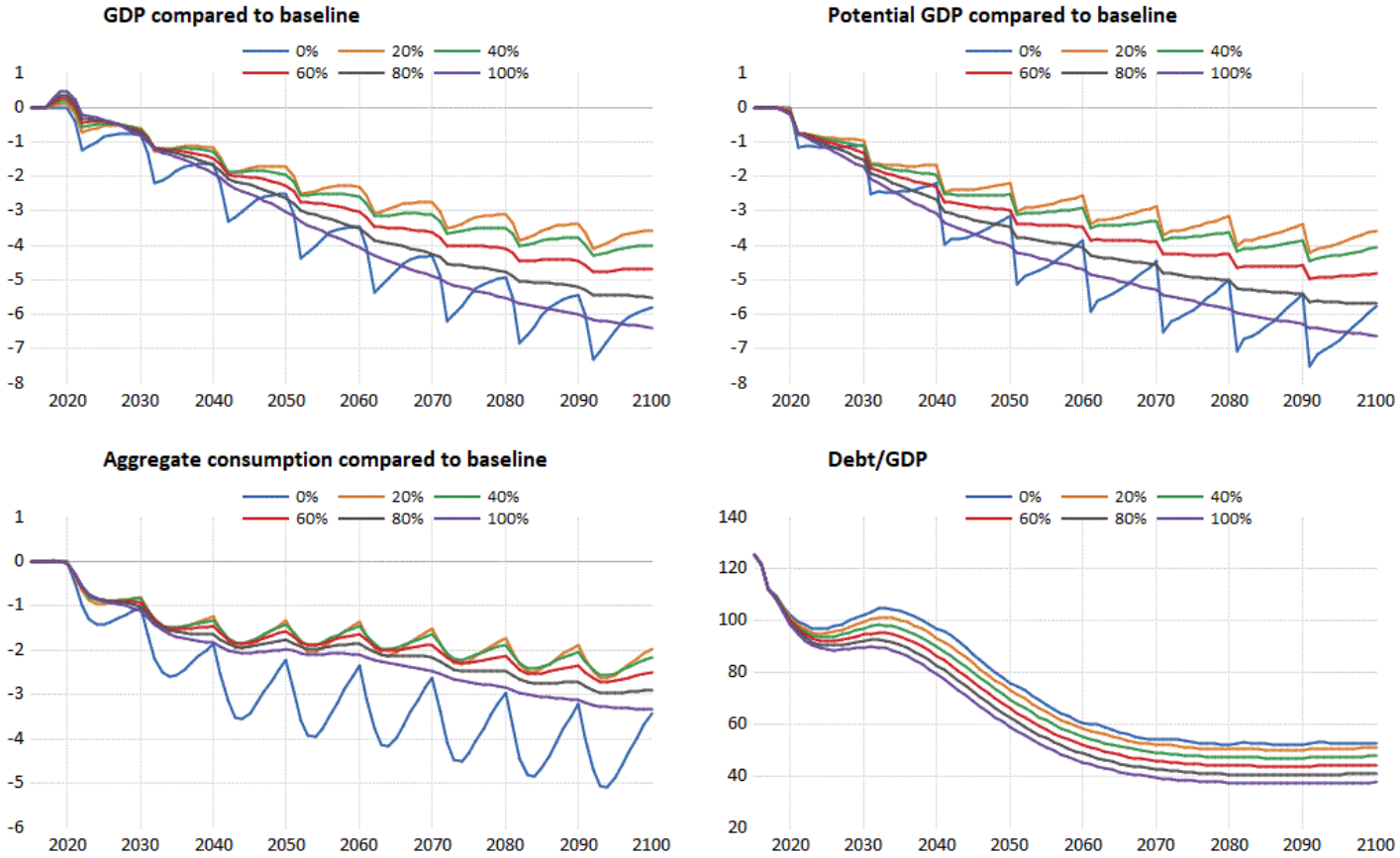
- Protection is a concave function of adaptation capital: $P_t = \left(\gamma \frac{K_t^{Adp}}{\bar{K}_t^{Adp}}\right)^{\alpha}$
- The maximum adaptation capital is equal to the expected damages: $\bar{K}_t^{Adp} = \left(\frac{\rho^D}{\delta}\right) Y$

Determination of the maximum reasonable adaptation investment

- Adaptation capital accumulation: $K_t^{Adp} = (1-\delta)K_{t-1}^{Adp} + G_t^{Adp}$
- The maximum the government would reasonably spend on adaptation capital is equal to the expected damages: $\bar{G}_t^{Adp} = \rho^D Y$
- From this we obtain the maximum steady state amount of adaptation capital a government would acquire: $\frac{\bar{K}_t^{Adp}}{\bar{G}_t^{Adp}} = \frac{1}{\delta} \rightarrow \bar{K}_t^{Adp} = \left(\frac{\rho^D}{\delta}\right) Y$

1. Adaptation in graphs: key variables

Comparison across different amounts of disaster management investment



- Adaptation given in percent of maximum adaptation
- Adaptation reduces net hurricane damage
- Concavity of protection function means that protection is built up quickly

2. Insurance against hurricane damages

Modeling of government buying insurance

- Insurance for additional government expenses caused by hurricanes
- Actuarially fair insurance: premium = expected damages

Key parameters

- insurance coverage θ
  - our assumption: $\theta = 100\%$ of hurricane damage
- markup charged by the insurer u^I
  - our assumption: $u^I = 5\%$ of insurance premium
- expected damages ρ^D
  - our assumption: $\rho^D = 1\%$ of nominal GDP
  - Calibration based on Acevedo (2016)

2. Modeling insurance in MFMod

Premium

- Government pays a set premium every year: $G_t^{Prem} = \theta(1 + u^I)\rho^D P_t Y_t$
- Premium increases every year
- Markup (equal to service fee) paid to insurance company, lost for domestic economy

Payout

- Insurance company covers all of insured damages: $R_t^{INS} = \theta * D_t$
- Government decisions not endogenous, but based on historical calibration
- Unprecedented events require specification of government reaction
- -> Insurance payout used to finance capital investments for five years

3. Hurricane contingency fund

Modeling of government paying into domestic disaster relief fund

- Similar to insurance, but markup payments remain in domestic economy
- In case of a large and early disaster, fund may not cover all costs

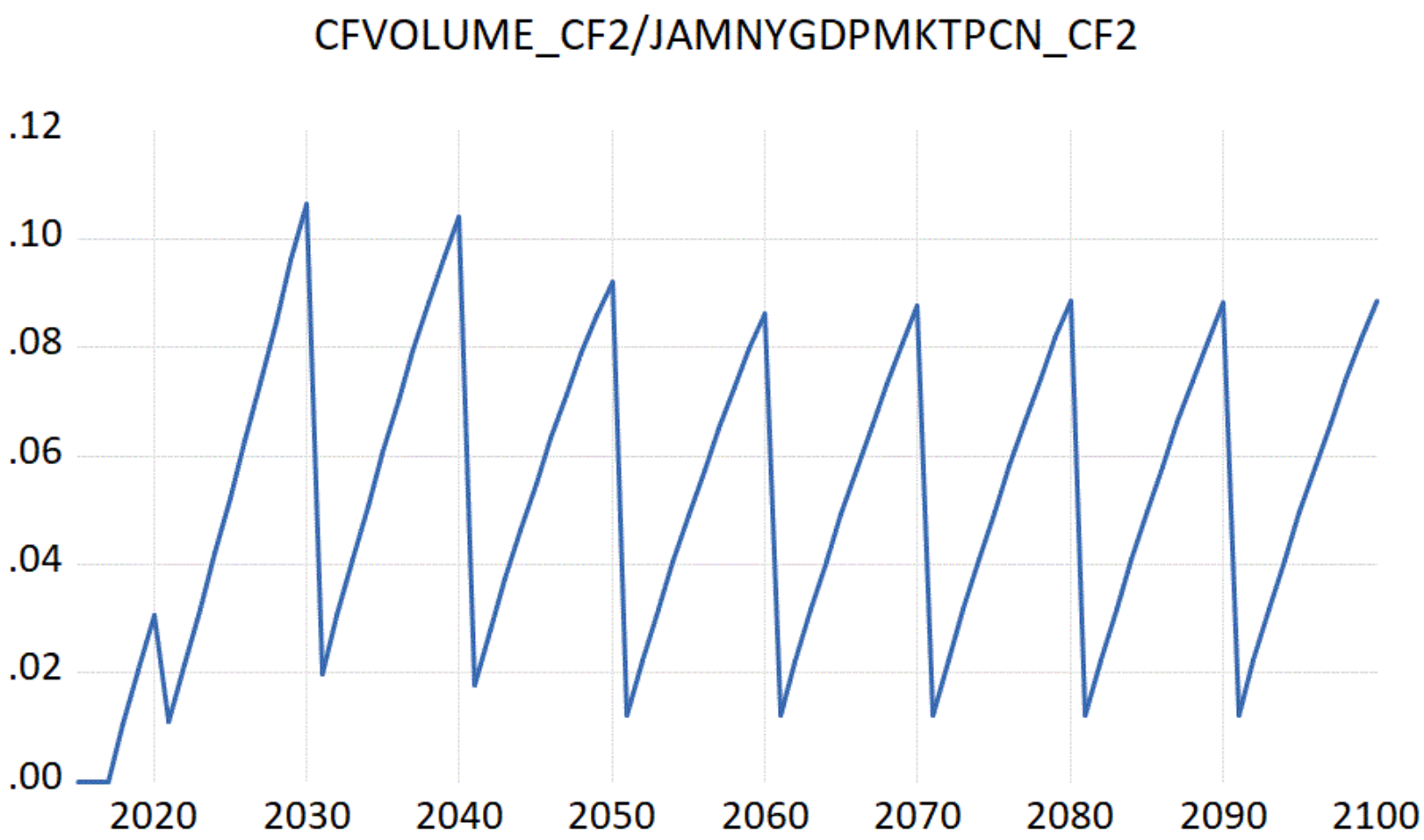
Model of contingency fund

- Government pays a set premium every year: $G_t^{Prem} = \theta(1 + u^{CF})\rho^D P_t Y_t$
- Fund volume given by $CF_t = CF_{t-1}(1 + i_t) + G_t^{Prem} - R_t^{INS}$
- Payout is constrained by fund volume

$$R_t^{INS} = D_t \quad if\ CF_t \geq D_t$$
$$R_t^{INS} = CF_t \quad if\ CF_t < D_t$$

- θ, and ρ^D calibrated as for insurance, $u^{CF} < u^I$
- Assumption that fund earns 2% interest rate per year
- Payout used to invest in capital for five years

3. Contingency fund in graphs: CF volume



- Contingency fund builds up with premium payments
- Fund gets (almost) exhausted at hurricane event

4. Debt repayment

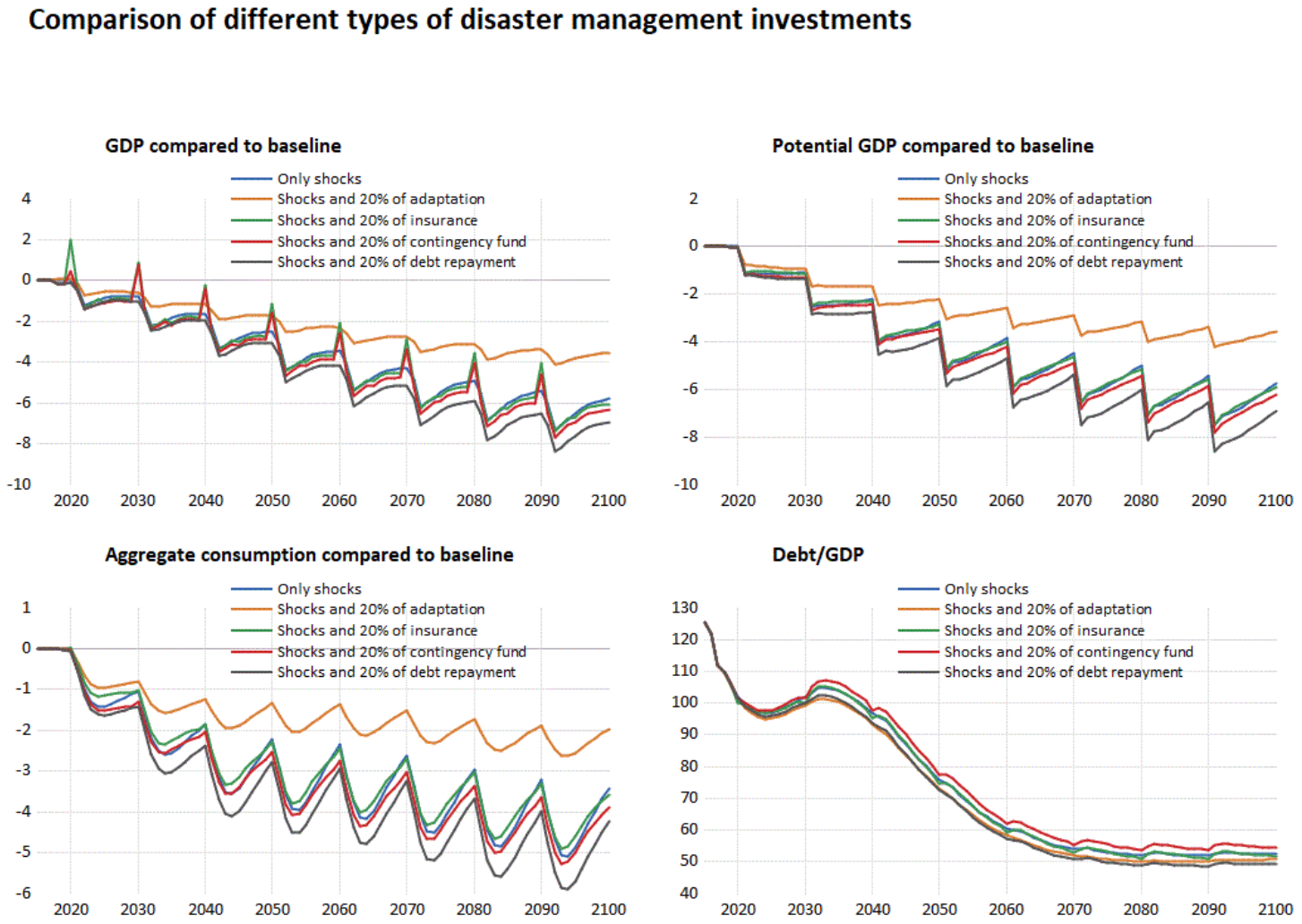
Modeling of debt repayment

- Similar to insurance, but markup payments used to reduce debt
- No insurance markups to be paid
- Interests rates on debt are falling as debt level falls

Model of debt repayment

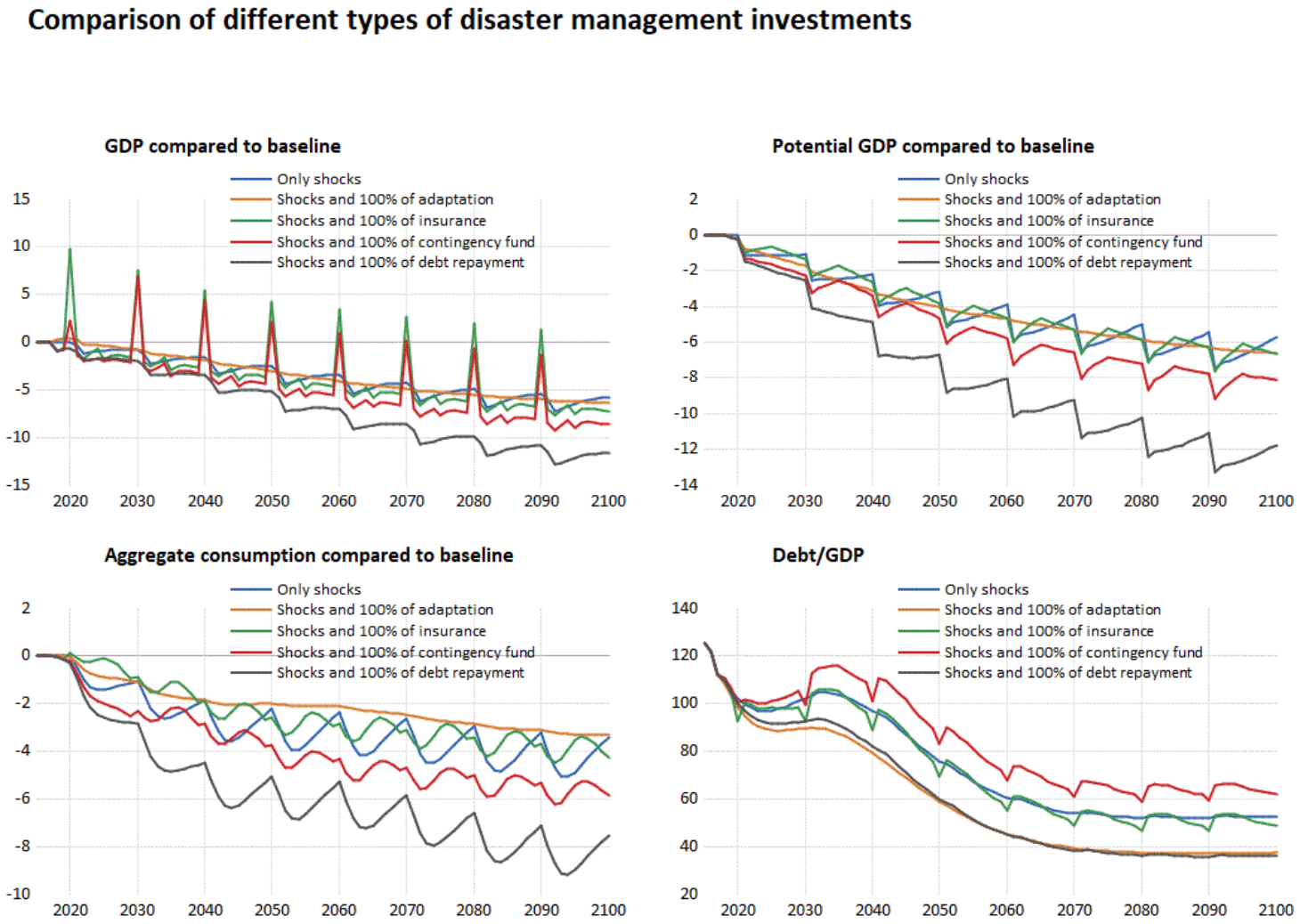
- Government the equivalent of insurance payment: $D_{t+1} - D_t = \theta \rho^D P_t Y_t$
- Recovery payments financed through additional debt
- Again, assumption that for five years, damage equivalent is invested
- Debt reduction and disaster recovery cancel out, zero net effect on debt
- θ and ρ^D calibrated as for insurance

Comparison of risk management



- Scenario: 20 percent of average hurricane damage is invested in four risk management options
- At low levels of investment, adaptation outperforms insurance mechanisms
- Reason: Concavity of protection function

Comparison of risk management



- Scenario: 100 percent of average hurricane damage is invested in four risk management options
- At high levels of investment, risk management fails to achieve improvement
- Reason: risk management expense equivalent to hurricane damage

Relative outcomes of strategies

Overall observation

- Risk management = intertemporal shift of resources

“Horse race” of risk management

- Adaptation smooths shocks, but investments cause gradual income loss
- Insurance payouts cause upwards spikes through additional revenue
- Contingency fund similar to insurance, but first two payouts are lower
  - Due to limited fund volume
- Debt repayment performs poorly in comparison
  - “missing” payout spikes
  - Effect of lower interest rates weak
  - Absence of insurance premium has no strong effect

Increasing realism

Welfare effect of risk management

- Risk management does not improve welfare substantially
- Why should it?

A (more) realistic representation of hurricane damage

- Hallegatte (2016): Through natural disasters the composition of the capital stock becomes highly suboptimal
- Damage to TFP?

Modeling the insurance payout

- How do countries use insurance payout? How *should* they?

The role of the finance source

Financing disaster risk management

Financing of risk management has important influence on results

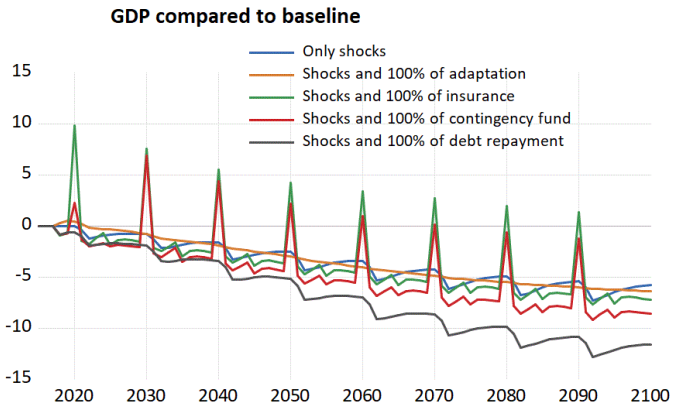
- We consider reduction in expenses
- Debt finance not viable in long term
- Increase in revenues also possible

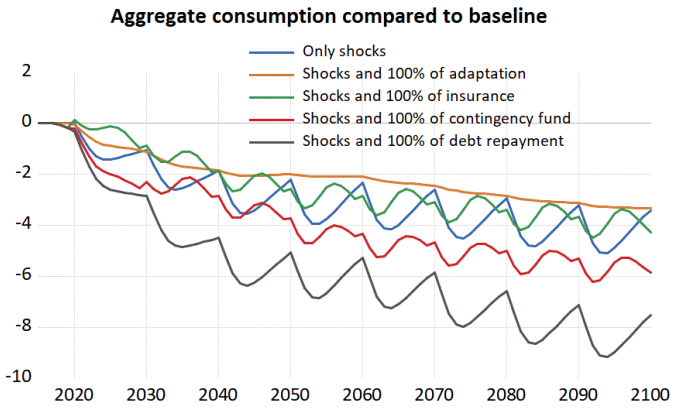
Investment vs. consumption

- Reducing investment is more expensive than reducing consumption
- Reducing consumption has a cost, however (see “aggregate consumption”)
- Economic optimization vs. political feasibility of reducing government consumption

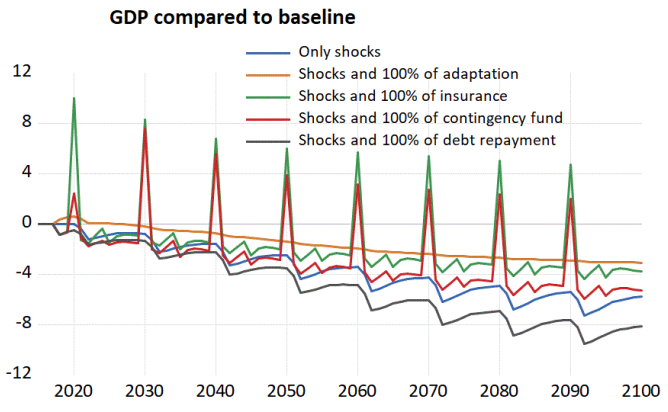
Comparison of risk management

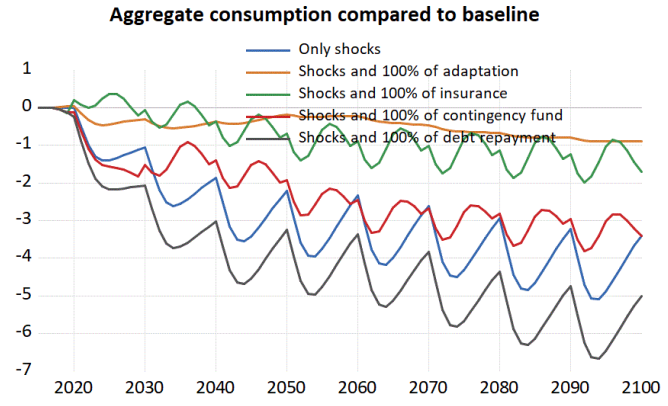
100% investment finance





50% investment + 50% consumption





- Comparison of four risk management strategies
- Left side: Financed by reducing government investment
- Right side: Financed 50/50 from investment and consumption
- Reducing consumption causes less loss in consumption
- Order of risk management remains
- Profitability of risk management improves

Conclusion

Next steps

- Probabilistic shocks drawn from calibrated distribution
  - Calibration of shocks with meteorological data and method of Acevedo (2016)
  - to replace decadal deterministic shocks
  - Illustration with fan charts
- Disruptive effect of hurricanes following Hallegatte (2016)
  - Difference between replacement cost and damage to production ability
  - Marginal productivity of capital vs. average productivity of capital
- Calibration
  - Insurance premium and interest rate of contingency fund
  - Calibration of protection function? Ideas welcome!
  - Government use of insurance payout? Duration of disaster recovery?
- Application to different countries and cross country comparison
  - Dependency of optimal risk management on country parameters

Conclusion

Innovations of this project

- Fiscal rule
- Welfare effect of government consumption
- Implementation of four risk management strategies and direct comparison

Main result

- Importance of modeling *disruptive* nature of natural disasters
- Central role of *financing* risk management
- Importance of the use of insurance payout (saving, consumption, investment)

References

Acevedo, S. (2016). Gone with the Wind: Estimating Hurricane and Climate Change Costs in the Caribbean Authorized for distribution, 9–35. Retrieved from https://www.imf.org/external/pubs/ft/wp/2016/wp16199.pdf

Barro, R. J. (1990). Government Spending in a Simple Model of Endogeneous Growth. Journal of Political Economy, 98(5, Part 2), S103–S125. https://doi.org/10.1086/261726

Hallegatte, S., & Vogt-Schilb, A. (2016). Are losses from natural disasters more than just asset losses? the role of capital aggregation, sector interactions, and investment behaviors. The World Bank. https://openknowledge.worldbank.org/handle/10986/25687

Marattin, L., & Palestini, A. (2014). Government spending under non-separability: a theoretical analysis. International Review of Economics, 61(1), 39–60. https://doi.org/10.1007/s12232-013-0187-z