Flooded House or Underwater Mortgage?

The Macrofinancial Effects of Climate Change and Adaptation

Yasmine van der Straten (University of Amsterdam & Tinbergen Institute)

1. Motivation

The urgency of climate change adaptation is becoming increasingly evident as:

1. *Mitigation* efforts remain inadequate;
2. Climatic impacts already intensify globally.

This raises the question of how we can contain climate-related damages.

Besides economic damages, physical risks directly impact real estate markets, as these risks are priced into house values and factored into lending and insurance decisions (e.g. Baldauf et al. 2020; Bernstein et al. 2019; Bakkensen and Barrage 2021; Giglio et al. 2021; Sastry 2022; Ge et al. 2022, Keys and Mulder 2024).

While a growing literature studies the macro-effects of adaptation ((e.g. Burke et al. 2024; Bilal and Rossi-Hansberg 2023; Fried 2022) , it remains unclear how financial incentives shape private adaptation efforts.

This paper: What are the macrofinancial implications of climate change and adaptation?

1. What is the direct effect of climate change on prices, and capital allocation?
2. Do we adapt efficiently given price signals?
3. Are there any indirect feedback effects due to financial constraints?

2. Households & Firms

Households: live for two periods. A fraction ϕ $(1-\phi)$ is high-skilled (low-skilled), h (l). Households get utility from housing (L) and a consumption good (c):

$$U_i = c_{i,t+1} + v\left(L_{i,t}\right) \qquad v' > 0, v'' < 0$$

Housing (habitat) is in inelastic supply due to land constraints (Saiz, 2010).

Firms: operate for one period, and produce the consumption good:

$$Y_t = A\left[\eta\left(H_t^{\alpha} h_t^{(1-\alpha)}\right)^{\rho} + (1-\eta)\left(K_t^{\alpha} l_t^{(1-\alpha)}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

using high-skilled labour (h), complementary to intangible capital (H, created by high-skilled entrepreneurs' effort), and low-skilled labour (l), complementary to physical capital (K, created upon investment).

3. Climate Risk

An extreme weather event occurs each period, and the probability that a given household or firm is hit by the event is denoted by $\gamma_t \in (0,1)$. Losses are idiosyncratic:

- $\xi_{i,t} \in (0,1)$: Losses suffered by household i in period t, as a fraction of housing capital $L_{i,t}$.
- $\xi_{f,t} \in (0,1)$: Losses suffered by firm f in period t, as a fraction of *physical* capital $K_{f,t}$.

$\rightarrow$ Expected losses conditional on being hit by the event are denoted by $\mu_L, \mu_K \in (0,1)$ respectively.

Climate damages reduce housing supply:

$$\bar{L}_{t+1} = \int_0^1 (1-\xi_{i,t})\, di \cdot \bar{L}_t \overset{\text{LLN}}{=} (1-\mu\gamma_{t+1}) \cdot \bar{L}_t$$

Physical capital losses reduce output:

$$\tilde{Y}_t = A\mathcal{F}(H_t, h_t, \tilde{K}_t, l_t), \qquad \mathcal{F}'_{\gamma}(H_t, h_t, \tilde{K}_t, l_t) \leq 0$$

4. Equilibrium

- Climate change *increases* house prices
$$p_t = \frac{(1-\mu\gamma_{t+1})\, p_{t+1} + v'(\bar{L}_t)}{(1+r_{t+1})}$$
and hence mortgage credit demand rises.
- Climate change *raises* the costs of borrowing:
$$(1+r_t) = A^{\rho}\alpha(1-\eta) \cdot \frac{\tilde{Y}_t^{1-\rho}}{((1-\mu\gamma_t)K_t)^{1-\alpha\rho}} \cdot l_t^{(1-\alpha)\rho}$$
and hence the volume of corporate debt falls.
- Climate risk *reduces* share prices:
$$e_t = \frac{d_{t+1}}{(1+r_{t+1})}$$
- Climate change *increases* the wage gap:
$$\frac{q_t}{w_t} = \frac{\eta}{1-\eta} \cdot \left(\frac{H_t}{(1-\mu\gamma_t)K_t}\right)^{\alpha\rho} \cdot \left(\frac{(1-\phi)l}{\phi h}\right)^{1-(1-\alpha)\rho}$$

5. Adaptation

Households invest in adaptation to reduce vulnerability to climatic impacts. Denote by $x_{i,t} \in [0,1)$ the choice of adaptation by household i in period t, which reflects the fraction of idiosyncratic losses prevented. Adaptation shifts the distribution of losses leftwards:

$$\mathbb{E}\left(\xi_{i,t+1}\right) = (1-x_{i,t})\mu\gamma_{t+1}$$

and thus reduces the reduces the rate at which the supply of houses falls. However, adaptation is increasing costly: $\psi_{i,t} = \frac{1}{2} L_{i,t} {x_{i,t}}^2$.

6. Optimal Adaptation

The unconstrained private choice of adaptation is:

$$x_{i,t} = \frac{\mu\gamma_{t+1} \cdot p_{t+1}}{(1+r_{t+1})}$$

The unconstrained private choice of adaptation is *efficient* if

1. Climate risk is accurately priced in the housing market.
2. Welfare of future generations is evaluated using the market discount rate.

$\rightarrow$ Price signals are sufficient in frictionless markets.

7. Financial Constraints

Rational creditors limit mortgage debt $(-S_{i,t})$ to the expected liquidation value of the collateral (Kiyotaki & Moore, 1997; Sastry, 2022). However, the adaptation investment is private information, and verification (also of maintenance) is prohibitively costly. Hence, investors form expectations on the choice of borrowers:

$$-(1+\hat{r}_{t+1})S_{i,t} \leq \left(1-(1-\mathbb{E}\left(\bar{x}_{l,t}\right))\mu\gamma_{t+1}\right) p_{t+1} L_{i,t}$$

The constrained private choice of adaptation is:

$$x_{l,t} = \frac{\mu\gamma_{t+1} p_{t+1}}{(1+r_{t+1})(1+\lambda_t)}$$

with $\lambda_t \geq 0$ the shadow value of the constraint.

Amplification:

1. Low-income households protect a *smaller fraction* of their housing capital, and remain *more exposed* to climatic impact.
2. The "adaptation" gap *widens* over time, as unequal adaptation further reduces habitat.

8. Policy Implications

A **societal shift** from constrained homeownership to a rental model with unconstrained owners could lead to more efficient adaptation:

- Benefits of adaptation are purely financial.
- Landlords have the (financial) incentive, and deep enough pockets, to adapt optimally.
- Requires rental markets to be perfectly competitive!

9. Insurance Markets

Insurance plays a key role in mitigating the impact of climate change on household wealth. However, insurance fundamentally differs from adaptation, since adaptation aims at prevention, whereas insurance provides monetary compensation after losses occur.

Denote by $\pi_{i,t} \in (0,1]$ the insurance choice variable of household i, at time t, where insurance only covers a fraction $\theta \in [0,1]$ of the losses.

Insurance is priced at its actuarial value, with a premium, z_t, for full coverage:

$$z_t = \frac{\theta \cdot (1-\mathbb{E}(x_{i,t}))\mu\gamma_{t+1} \cdot p_{t+1}}{(1+r)}$$

The private choice of adaptation becomes:

$$x_{i,t} = \frac{(1-\theta\pi_{i,t}) \cdot \mu_L\gamma_{t+1} \cdot p_{t+1}}{(1+r)}$$

i.e., insurance leads to the underprovision of adaptation, as it allows households to limit the downside of a disaster relatively cheaper (constant vs rising MC).

Trade-off: Moral hazard in adaptation increases inequality *across* generations, due to the reduction in habitat. While this may be prevented by reducing coverage (stiglitz & Weiss, 1981), a higher coverage reduces inequality *within* generations.