Flooded House or Underwater Mortgage?

The Effects of Climate Change and Adaptation on Housing, Income & Wealth.

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1. Motivation

Significance of climate change *adaptation* has become increasingly evident over the past years as:

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

Adaptation: adjustments in ecological, social or economic systems in response to actual or expected climatic impacts and their effects to moderate potential damages (UNFCCC).

How do climate change and adaptation affect household wealth?

2. Households & Firms

Households (unit mass): live for two periods, consume a non-durable good $c_{i,t}$ and housing, $L_{i,t}$ (at price p_t).

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

Households are either high- (ϕ) or low-skilled $(1-\phi)$.

Firms (unit measure): operate for one period, with shares issued at price e_t. Production process is:

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

High-skilled labour (h) is complementary to intangible capital (H, created by some high-skilled "entrepreneurs"), and low-skilled labour (l) is complementary to physical capital (K, created upon investment).

3. Climate Risk

An extreme weather event occurs in each period, with $\gamma_t \in (0,1)$ the probability that a given household or firm suffers damages. Losses are idiosyncratic:

- $\xi_{i,t} \in (0,1)$: Losses (as a fraction of $L_{i,t}$) suffered by household i in period t, $\xi_{i,t} \sim F(\xi_{i,t})$, i.i.d. across i.
- $\xi_{f,t} \in (0,1)$: Losses (as a fraction of $K_{f,t}$) suffered by firm f in period t, $\xi_{f,t} \sim G(\xi_{f,t})$, i.i.d. across f.

Expected losses when hit denoted by $\mu \in (0,1)$.

Housing Stock falls according to the law of motion:

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

Physical Capital Loss reduces 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. Pricing of Climate Risk

In equilibrium, **house prices** are given by:

$$p_t = \frac{(1-\mu\gamma_{t+1})\, p_{t+1} + v'(\bar{L}_t)}{(1+r_{t+1})}$$

the **wage ratio** is given by:

$$\frac{q_t^*}{w_t^*} = \frac{\eta}{1-\eta} \cdot \left(\frac{H_t}{(1-\mu\gamma_t)K_t}\right)^{\alpha\rho} \cdot \left(\frac{(1-\phi)\tilde{l}}{\phi\tilde{h}}\right)^{1-(1-\alpha)\rho}$$

the **costs of borrowing** are given by:

$$(1+r_t^*) = A^{\rho}\alpha(1-\eta) \cdot \frac{\tilde{Y}_t^{1-\rho}}{\left((1-\mu\gamma_t)K_t\right)^{1-\alpha\rho}} \cdot l_t^{(1-\alpha)\rho}$$

and **share prices** are given by:

$$e_t = \frac{d_{t+1}}{(1+r_{t+1})}$$

Climate-related damages:

– increase income inequality
– increase costs of borrowing, and
– reduce corporate leverage

Climate risk:

– reduces share prices;
– increases house prices if

$$-\left(v''(\bar{L}_j) \cdot \bar{L}_j\right) / \left(v'(\bar{L}_j)\right) \geq 1$$

and (then)

– increases mortgage debt.

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. Adaption, which constitutes ex-ante prevention, shifts the distribution of idiosyncratic losses to the left:

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

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

With adaptation, house prices are given by:

$$p_t + \frac{1}{2}{X_t}^2 = \frac{\left(1-(1-X_t)\mu\gamma_{t+1}\right) p_{t+1} + v'(\bar{L}_t)}{(1+r_{t+1})}$$

and the unconstrained private choice of adaptation is:

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

Unconstrained households adapt efficiently if

1. Climate risk is accurately priced in the market (beliefs are correct);
2. Welfare of future generations is evaluated using market discount rates.

6. Financial Constraints

Rational creditors limit mortgage debt ($-S_{i,t}$) to the (expected) liquidation value of the underlying collateral. Adaptation is non-contractible, so investors form expectations on the private 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 choice of adaptation of constrained, low-income households is given by:

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

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

Feedback effects: The private choice of adaptation of those who are financially constrained is lower than the private choice of adaptation of those who are unconstrained:

$$x_l^* < x_h^*$$

i.e. low-income households protect a smaller fraction of their housing capital, and hence remain more exposed to physical impacts!

Denote by Λ the adaptation gap, where

$$\Lambda = \frac{x_{h,t}^*}{x_{l,t}^*} = (1+\lambda_t)$$

The adaptation gap rises over time if the utility of housing, $v(L_{i,t})$, is characterized by constant relative risk aversion.

7. Mortgage Default

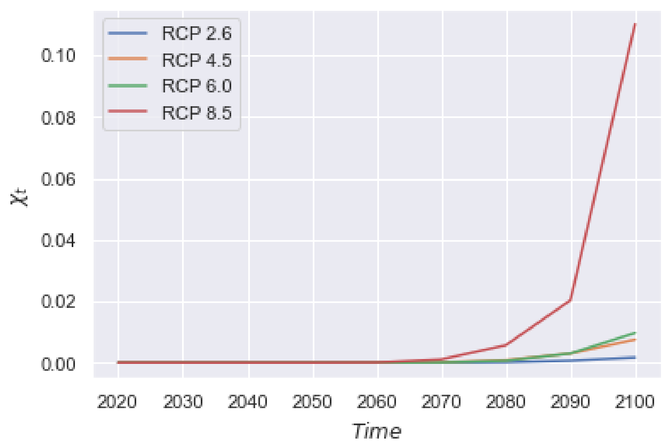

Figure 1: The probability of an 'underwater' mortgage rises with climate risk.

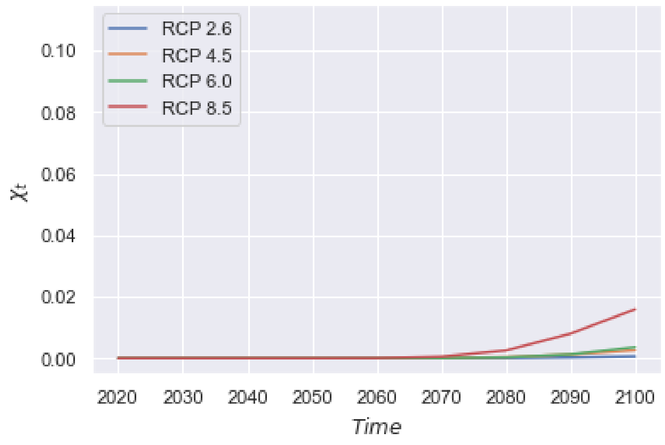

Figure 2: With adaptation, mortgage default risk becomes much lower!

8. Conclusions

The effects of climate change are:

– Heterogeneous across asset classes;
– Intrinsically redistributive!

Adapting to climate change is increasingly harder for those who are financially constrained.

→ **Interested in the role of public intervention?** Come to my presentation of "The Political Economy of Climate Change Adaptation" (joint work with Enrico Perotti, and Rick Van der Ploeg), at the Symposium on **Tuesday, at 14:30**!