

# **Climate change beliefs and savings behavior: a macroeconomic perspective**

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- There is large uncertainty and disagreement surrounding the extent of climate change.
- Savings allow to smooth consumption over transition.
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1. Does concern over climate change affect savings?
2. Does the effect on capital impact the macroeconomy?

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  - Analytical consumption-savings model: idiosyncratic + aggregate risks
  - Responses to dynamic shifts in probability of aggregate shock

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  - Fixed effects: individual, place of residence, exposure

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  - Heterogeneous agent model with aggregate risk, extended with **non-stationary shift** in aggregate process and **dispersed beliefs**
  - Increased capital helps to mitigate output loss from climate change.
  - Mean of beliefs matters for aggregates, variance has small effect.
  - Distributional effects: **Accurate** aggregate beliefs in particular improve welfare of poor.

## Predictions in partial equilibrium

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## Consumption savings problem

Two types of uncertainty:

- Idiosyncratic  $\phi \in \Phi$ : skills and demographics
- Aggregate  $\zeta \in Z = \{\zeta^L, \zeta^H\}$ : productivity

# Consumption savings problem

Two types of uncertainty:

- Idiosyncratic  $\phi \in \Phi$ : skills and demographics
- Aggregate  $\zeta \in Z = \{\zeta^L, \zeta^H\}$ : productivity

An agent  $i$  chooses consumption to maximize expected utility over their life-time

$$\max_{c_{it}} \mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t u(c_{it}) \right]$$

using some (possibly subjective) probability distribution, subject to budget constraint

$$c_{it} + a_{it+1} = y(\zeta_t, \phi_{it}) + R(\zeta_t)a_{it}, \quad a_{it+1} \geq 0.$$

For multiplicative productivity shocks:

$$R(\zeta) = \zeta \bar{r} + 1 - \delta, \quad y(\zeta, \phi) = \zeta \bar{w} e_{\phi}$$

How does consumption respond to a change in the probability of  $\zeta^L$ ?

## First order consumption response

Assume the probability of  $\zeta_L$  is given by  $p_t$ . Applying the implicit function theorem to the Euler equation yields

$$\frac{dc_0}{c_0} = -\varepsilon_0 \sum_{t=0}^{\infty} \left( \sum_{\theta^t} \mathbb{P}^*(\theta^t) \left( \prod_{j=0}^t MPS(\theta^j) \right) \mathcal{D}_t(\theta^t) \right) dp_{t+1}. \quad (1)$$

where

- $MPS = da/dy_0 = 1 - dc/dy_0$  is the marginal propensity to save out ;
- $\varepsilon(c) = -u'(c)/(cu''(c))$  is the elasticity of intertemporal substitution;
- $\mathcal{D}_t$  is the change in expected marginal value of holding an extra unit of assets, given by the difference

$$\mathcal{D}_t = \frac{\mathbb{E}[V'(a_{t+1}, \theta^{t+1}) | \zeta_{t+1} = \zeta^L] - \mathbb{E}[V'(a_{t+1}, \theta^{t+1}) | \zeta_{t+1} = \zeta^H]}{\mathbb{E}[V'(a_{t+1})]};$$

- $\mathbb{P}^*$  is the risk-adjusted probability measure over  $\theta^t$

$$\mathbb{P}^*(\theta^t | \theta^{t-1}) = \mathbb{P}(\theta^t | \theta^{t-1}) \frac{V'(a_t, \theta^t)}{\mathbb{E}[V'(a_t, \theta^t)]}.$$

The consumption response

$$\frac{dc}{c} = -\varepsilon_0 \sum_{t=0}^{\infty} \left( \sum_{\theta^t} \mathbb{P}^*(\theta^t) \left( \prod_{j=0}^t MPS(\theta^j) \right) \mathcal{D}_t(\theta^t) \right) dp_{t+1}.$$

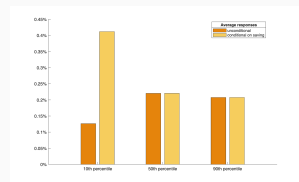
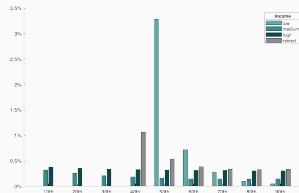
depends on the current idiosyncratic state:

- *MPS* small for borrowing constrained agents
- Difference in marginal value of savings higher for low asset holdings
- $\mathbb{P}^*$  measure puts larger weight on bad states

→ Counteracting channels in state dependence

# Consumption response in the cross section

- Quantitative illustration of  $d \ln c_0 / dp_1$  using calibration from GE model
- No reaction of poor low income households:  $MPS = 0$ .
- Response declines with asset holdings: difference in marginal value of savings between aggregate states decreases
- At longer horizons: Reaction stronger for high incomes
- Conditional on savings: Largest response for low income





## Empirical evidence

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## UK Longitudinal Household Survey, 14 waves (2009-2023)

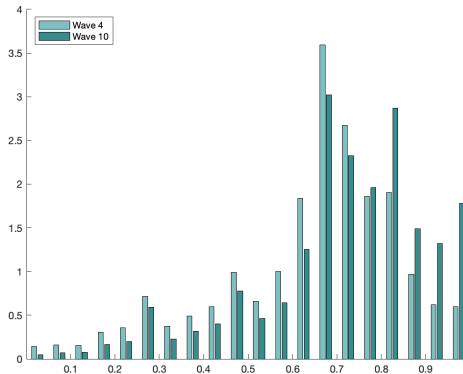
- Waves 4 and 10: Index about climate change concern
  - 5 different questions, e.g.,
    - People in the UK will be affected by climate change in the next 30 years. (y/n)
    - If things continue on their current course, we will soon experience a major environmental disaster. (agree-disagree, 5 steps)
  - Normalized and aggregated to index  $\iota^C \in [0, 1]$ .
- All even waves: Savings variables (binary and amount)
- Demographic indicators
  - education, income, residence (LSOA), age, children

[All questions](#)[Details](#)

## Exposure

- Flood data matched on residence

# Descriptive Statistics: Index



- Autocorrelation  $\rho = 0.52$
- Correlated with higher education

$$s = \beta_0 + \beta_1 \iota^C + \beta_2 X$$

➤ Baseline: OLS

- Binary/restricted variables: logit/tobit transformation

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### Two main concerns

➤ Preferences over risk and time

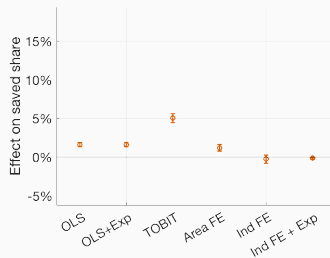
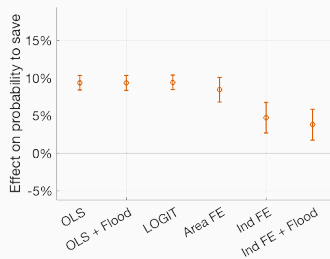
- Correlated with both climate change concern and savings choices
- Controlling for individual fixed effects, assuming preferences constant over time

➤ Idiosyncratic exposure

- Direct and indirect effects (e.g. damages and salience)
- Controlling for previous flooding events

# Empirical results

- Average marginal effect of CC index on savings decision: 9.3% more likely to save.
- Effect of CC index on saving relative to income: 0.9% more of income saved
- Individual FE: smaller effect, but positive and significant on extensive margin
- Restriction to subsamples shows higher effect sizes for lowest compared to highest quintile.



## Key take-aways

- The passthrough of adverse macro risks to savings is non-negative; depends on current idiosyncratic state.
- Empirical evidence shows relationship between climate concern and savings behavior, which cannot be fully attributed to preferences or exposure.

## Open questions

- How does capital accumulation react to changes in disaster risk, allowing for indirect effects through savings adjustments?
- How does disagreement over aggregate risks transmit to the macroeconomy?

→ Dynamic general equilibrium model

## General Equilibrium Model

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Continuum of households of measure 1, working age or retired

- Probability of retiring (dying):  $1 - \theta (1 - \nu)$

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- Working age:
  - are endowed with labor efficiency units  $e_{i,t}$ , following Markov chain;
  - receive labor income and returns on capital holdings;
  - pay social security contributions as percentage of labor income;

$$c_{it} + a_{i,t+1} = (1 - \tau)w_t e_{it} + (1 + r_t)a_t$$

- Retirees
  - receive income from social security and returns on capital

$$c_{it} + a_{i,t+1} = b_t^{SS} + (1 + r_t)a_{it}/\nu$$

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Everyone maximizes expected life-time utility under budget constraint

$$\max_{c_{it}} \mathbb{E} \left[ \sum_t^{\infty} \beta^t u(c_{it}) \right]$$

Incomplete markets: Households can only save in assets  $a_{it} \geq 0$ .

A representative firm

- produces according to a Cobb-Douglas production function

$$F = \zeta_t A K_t^\alpha L_t^{1-\alpha};$$

- demands capital and labor until

$$r_t = F_K - \delta, \quad w_t = F_L;$$

- is subject to aggregate shocks captured by  $\zeta_t$ .

Market clearing:

$$L_t = \int_0^1 e_{i,t} di = \bar{L}, \quad K_t = \int_0^1 a_{i,t} di.$$

## Modeling aggregate risk and disagreement

- Aggregate shocks are transmitted via  $\zeta$ .
- The probability of the low state is given by

$$(\mathbb{P}(\zeta_t = \zeta^L) = p_t = p(T_t) = p^{1-\gamma T_t})$$

where  $T_{t+1} = \mu_T + \nu(T_t - \mu_T)$  for  $t \geq 0$ .

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Beliefs over  $\gamma$

- Two possible states the world:  $\gamma \in \{0, \bar{\gamma}\}$
- Certainty about  $\bar{\gamma}$ , temperature process  $T_t$ , current and past values of  $\zeta$
- Each agent has a subjective belief

$$\mathbb{P}(\gamma = \bar{\gamma}) = \pi_{it}.$$

- Bayesian updating

$$\pi_{it} = \pi_{it-1} \mathcal{P}_{it}, \text{ where } \mathcal{P}_{it}^{-1} = \begin{cases} \pi_{it-1} + (1 - \pi_{it-1}) p^{\bar{\gamma} T_t} & \text{if } \zeta_t = \zeta^L \\ \pi_{it-1} + (1 - \pi_{it-1}) \frac{1-p}{1-p^{1-\bar{\gamma} T_t}} & \text{if } \zeta_t = \zeta^H. \end{cases} \quad (2)$$

Differences in mean and variance, **implicit** level effect.

- The idiosyncratic state consists of the demographic state  $\phi$ , individual assets  $a$  and the current belief  $\pi$ . Let  $\Psi$  denote the distribution over these individual states.
- Key issue of heterogeneous agent models: forecasting prices requires distribution  $\Psi'$ , which is an infinite dimensional state variable.

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- Key issue of heterogeneous agent models: forecasting prices requires distribution  $\Psi'$ , which is an infinite dimensional state variable.
- Standard assumption: Forecast only capital using perceived law of motion (PLM)  $\mathcal{H}(K, \zeta, T; \mathcal{X})$ .
- Two approaches to pin down  $\mathcal{H}(K, \zeta, T; \mathcal{X})$ 
  - Static: Estimate PLM based on simulations.
  - Adaptive: Update PLM throughout transition.



## Definition (Temporary equilibrium)

Taking as given a PLM  $\mathcal{H}(K, \zeta, T; \mathcal{X})$  and current state variables  $\zeta_t$ ,  $\Psi_t$  and  $T_t$ , *temporary equilibrium* is defined as wage  $w_t$ , interest rate  $r_t$  and a choice function of households  $a' = a'(\phi, a, \pi, K, \zeta, T)$  so that:

- (a) The choice function solves the individual household problem;
- (b) The representative firm sets  $r_t = F_K(K_t, L_t; \zeta_t)$ ,  $w_t = F_L(K_t, L_t; \zeta_t)$ ;
- (c) Markets for capital, labor and social benefits clear.

## Definition (Dynamic equilibrium)

For given processes  $\{\zeta_t\}_{t \geq 0}$ ,  $\{T_t\}_{t \geq 0}$ , initial values  $\Psi_0$  and a PLM  $\mathcal{H}(K, \zeta, T; \mathcal{X})$ , the *dynamic equilibrium* of the economy is given by a sequence  $\{\Psi_t\}_{t \geq 0}$  so that:

- (a) Each period, the economy is in temporary equilibrium.
- (b) The distribution evolves consistently with the exogenous law of motion for demographics, Bayes' formula, and the endogenous choice function  $a'$ :

$$\Psi_t(\phi', a', \pi') = \int_{a'(\phi, a, \pi, K_t, \zeta_t, T_t) = a'} \int_{\phi} \int_{\pi(\zeta_t, \pi) = \pi'} \Psi_{t-1}(\phi, a, \pi) M(\phi', \phi)$$

Aggregate shocks: Effect of climate change on UK productivity

- Temperature follows AR(1) process:

$$T_{t+1} = \bar{\mu} + \nu(T_t - \bar{\mu})$$

with  $T_0 = 0$  and convergence towards  $\bar{\mu}$ .

- Meta study Rising et al. (2022) estimates 1.1% 2022, 3.3% by 2050
- Bad states:  $p = 0.15$ ,  $\zeta^L = 0.93$ .  $\mathbb{E}_0(\zeta) = 0.9895$ .

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Earnings and life cycle:

- Idiosyncratic skill process: AR(1)

$$\log(e_{it}) = \rho_e \log(e_{it-1}) + \epsilon_t, \epsilon \sim N(0, \sigma_e^2).$$

- Probability of retiring (dying): 1/40 (1/15).
- Replacement rate of social security: approx 40%.

Variable		Value
Discount factor	$\beta$	0.976
Depreciation rate	$\delta$	0.08
Capital share	$\alpha$	0.36
RRA	$\sigma$	2.0
Skill persistence	$\rho_e$	0.9
Skill variance	$\sigma_e$	0.4
Long run temperature	$\mu_T$	0.5
Temperature persistence	$\nu$	0.9
Damage linking	$\bar{\gamma}$	0.7

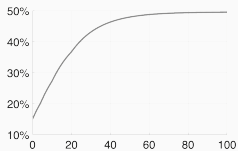
$$p_T = 0.49563, \mathbb{E}_T(\zeta) = 0.96531$$

Initial histogram of Stochastic Steady State for simulations

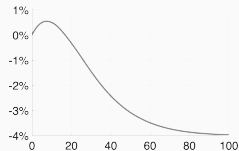
## Results

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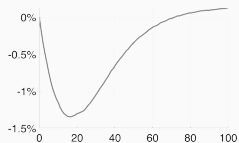
# Dynamic equilibrium under CC with accurate beliefs



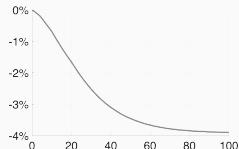
(a) Probability of low state



(b) Aggregate Capital

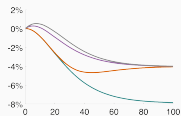


(c) Rate of return

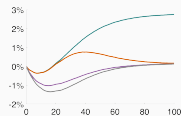


(d) Average wage

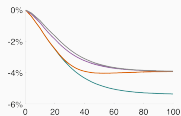
# The impact of inaccurate beliefs



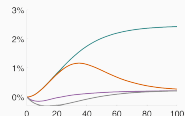
(a) Aggregate capital



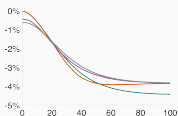
(b) Rate of return



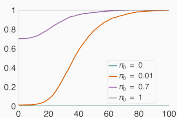
(c) Average wage



(d) Gini

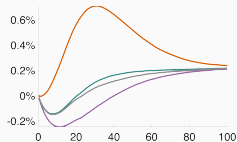
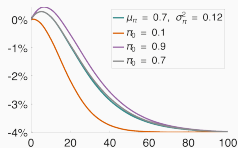


(e) Aggregate Consumption



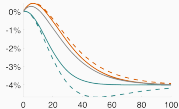
(f) Dynamics of belief  $\pi$

# Implications of disagreement

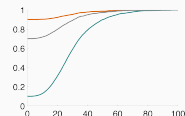


(a) Aggregate Capital

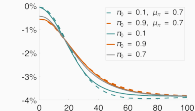
(b) Gini



(c) Capital per prior group



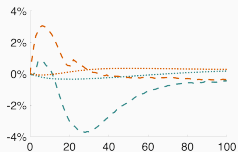
(d) Beliefs



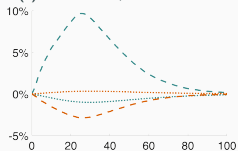
(e) Consumption per prior group



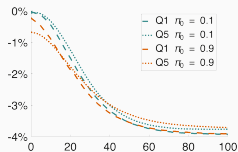
# Distributional impacts



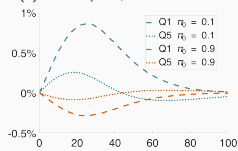
(a) Wealth share, relative to initial



(c) Wealth share, relative to homogenous



(b) Consumption, relative to initial



(d) Consumption, relative to homogenous

- Differences in beliefs lead to different savings choices
- GE effects
  - anticipation increases capital accumulation, decreases damages to income
  - transmitted to welfare through labor income
- Disagreement effects
  - mostly distributional
  - accurate mean beliefs valuable for poor households

- Consumption-savings choice under aggregate uncertainty
  - Relevance of idiosyncratic state to response in shifts in outcomes
- Empirical evidence
  - Correlation between concern for Climate Change and higher savings
  - Robust to variety of specification
- GE model with heterogeneous agents
  - Precautionary behavior consistent with empirical evidence
  - Implications for wealth inequality and polarization

## References

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Rising, J., Dietz, S., Dumas, M., Khurana, R., Kikstra, J., Lenton, T., Linsenmeier, M., Smith, C., Taylor, C. and Ward, B. (2022), What will climate change cost the uk? risks, impacts and mitigation for the net-zero transition, Technical report, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

## Appendix

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- Linear probability model for extensive margin
  - very similar to Logit: concerned are 9.6% more likely to save
- Linear regression for intensive margin
  - marginal effect of concern index: 27 pounds
  - not conditional on positive savings
- Alternative definitions of the index
  - drop some questions/reweighting
  - Extensive margin: between 5.9 – 7%
  - Lower effect on intensive margin: 14 – 24 pounds
- Non-winsorized savings data
  - Large outliers with high savings
  - Bigger effects if not winsorizing

- Long-term vs short-term saving
  - higher concern is more related to long-term savings rather than short-term savings
- Value/responsibility index
  - constructing a new index to measure how responsible respondents feel for CC and include this as control
  - effect of concern index lower, but still positive and significant
- Across income distribution
  - AME on extensive margin is largest for lowest income quintile: 10% vs 5.7% for highest quintile
  - AME on intensive margin similar in absolute terms

## Survey questions: Beliefs concerning climate change

Please select the extent to which you agree or disagree with the following statements.

Response options are: strongly agree (1), tend to agree (2), neither agree nor disagree (3), tend to disagree (4), strongly disagree (5)

Statement	Variable name
My behavior and everyday lifestyle contribute to climate change.	bccc
I would be prepared to pay more for environmentally-friendly products.	pmep
If things continue on their current course, we will soon experience a major environmental disaster.	meds
The so-called 'environmental crisis' facing humanity has been greatly exaggerated.	crex
Climate change is beyond control - it's too late to do anything about it.	tlat
The effects of climate change are too far in the future to really worry me.	nowo
Any changes I make to help the environment need to fit in with my lifestyle.	fitl
It's not worth me doing things to help the environment if others don't do the same.	noot
It's not worth the UK trying to combat climate change, because other countries will just cancel out what we do.	canc

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## Survey questions: Beliefs about extent of CC

Please select whether, on the whole, you personally believe or do not believe each of the following statements.

Response options are: yes (1), no (2)

Statement	Variable name
People in the UK will be affected by climate change in the next 30 years.	scopecl30
People in the UK will be affected by climate change in the next 200 years	scopecl200

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## Survey questions: Savings

Statement	Response options
Do you save any amount of your income, for example by putting something away now and then in a bank, building society, or Post Office account, other than to meet regular bills? Please include share purchase schemes and ISA's.	Yes (1), No (2)
About how much on average do you personally manage to save a month?	numerical value
Would you say your savings are mainly long term savings for the future or mainly short term savings for things you need now and for unexpected events?	Mainly long term (1), mainly short term (2), both equally (3), neither (4)

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## Survey questions: Environmental habits

Now a few questions about the environment.

Could you tell me how often you personally do each of the following things.

Response options are: always (1), very often (2), quite often(3), not very often (4), never (5)

Habit	Variable name
Leave your TV on standby for the night	envhabit1
Switch off lights in rooms that aren't being used	envhabit2
Keep the tap running while you brush your teeth	envhabit3
Put more clothes on when you feel cold rather than putting the heating on or turning it up	envhabit4
Decide not to buy something because you feel it has too much packaging	envhabit5
Buy recycled paper products such as toilet paper or tissues	envhabit6
Take your own shopping bag when shopping	envhabit7
Use public transport (e.g., bus, train) rather than travel by car	envhabit8
Walk or cycle for short journeys less than 2 or 3 miles	envhabit9
Car share with others who need to make a similar journey	envhabit10
Take fewer flights when possible	envhabit11

# Survey questions: Opinions about personal lifestyle in relation to the environment

Question	Variable name	Response options
Which of these best describes how you feel about your current lifestyle and the environment?	ftst	happy with what I do (1), like to do a bit more (2), like to do lots more (3)
Which of these would you say best describes your current lifestyle?	crlf	I don't really do anything (1), do one or two things (2), do quite a few things (3) that are environmentally-friendly, I'm environmentally friendly in most things (4), everything (5) I do
Do you agree or disagree that being green is an alternative lifestyle, it's not for the majority?	grn	agree strongly (1), agree (2), disagree (3), disagree strongly (4)

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- Baseline variables: scope30, scope200, meds, nowo, crex
- Recoding:
  - Binary yes/no questions to 0 and 1
  - Rating-scale questions between 0 and 1, with intermediate responses incremented in steps of 0.25.
  - higher concern corresponds to higher number
- Aggregation: average of recoded indices
- Robustness checks for subsets of variables

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		Q1	Q2	Q3	Q4	Q5
$\mathbb{P}(s_{it} > 0)$	OLS	0.107 (0.021)	0.099 (0.022)	0.066 (0.022)	0.108 (0.022)	0.058 (0.022)
	Logit	0.109 (0.021)	0.100 (0.022)	0.066 (0.022)	0.108 (0.022)	0.057 (0.022)
$s_{it}$	OLS	0.031 (0.008)	0.013 (0.005)	0.014 (0.005)	0.015 (0.005)	0.006 (0.006)
	Tobit	0.143 (0.028)	0.058 (0.014)	0.036 (0.011)	0.041 (0.009)	0.019 (0.009)
Observations		13909	13908	13908	13907	13907

**Table 1:** Marginal effects estimates of concern index on savings variables for subsamples along the income distribution quintiles. Controlling for wave fixed effects, income, exposure, and additional controls.