The Expectations Channel of Climate Change: Implications for Monetary Policy

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Introduction

Emerging consensus: climate change is key challenge for monetary policy

- *"[...] it is vital for monetary policymakers to understand the nature of climate disturbances to the economy, as well as their likely persistence and breadth, in order to respond effectively."* — Lael Brainard - FED, *November 8, 2019*
- *"I want to explore every avenue available in order to combat climate change."* — Christine Lagarde - ECB, *July 8, 2020*

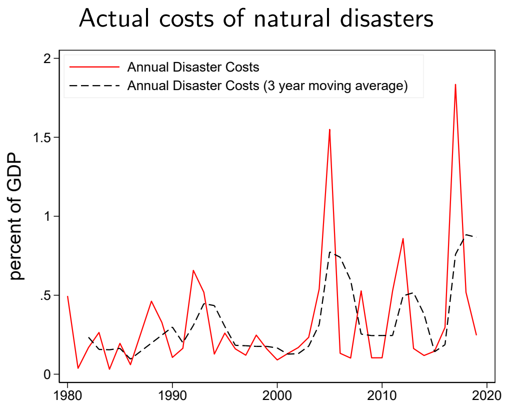
Much debate about **physical** phenomenon of climate change

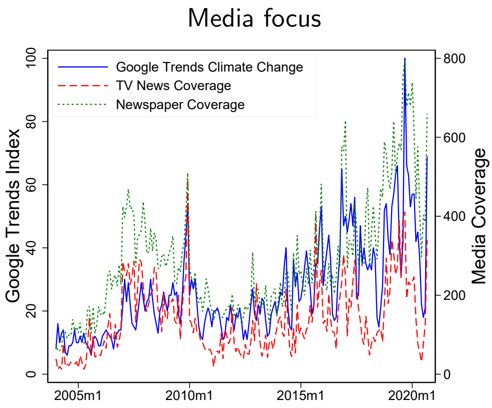
- Climate change hazards may threaten financial stability
- Use monetary policy instruments to combat climate change

This paper: **expectations** of climate change influence economic activity today

- Matters for monetary policy

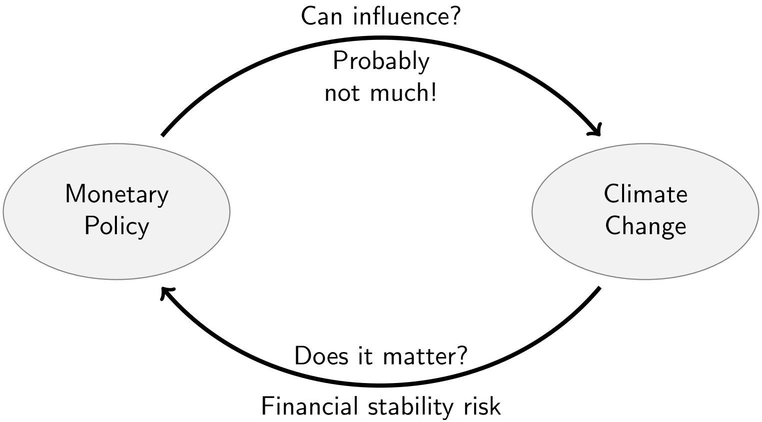
Climate Change Trends



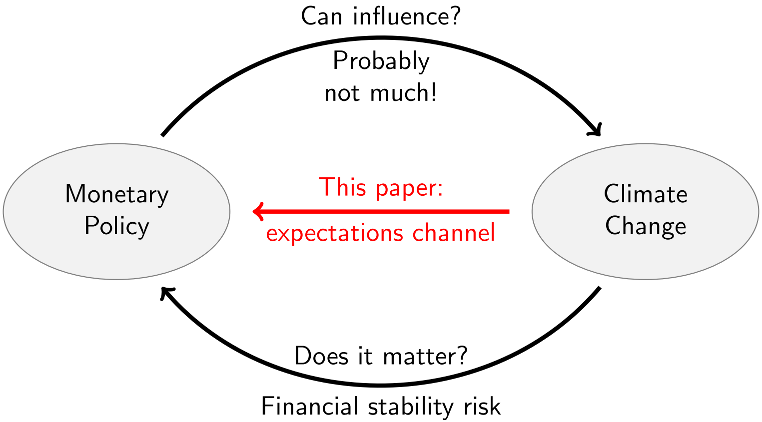


Note: actual costs is sum of natural disaster damages USA (in excess of 1 bn)
Source: National Centres for Environmental Information

Climate Change and Monetary Policy



Climate Change and Monetary Policy



Our Survey

Extension of Federal Reserve Bank of Cleveland's daily tracking survey

- Representative of U.S. consumers, $N = 14{,}162$.
- Survey weights to adjust for sampling inaccuracy.

Includes regular Cleveland Fed questions (demographics, media use) plus additional block of questions on effects of climate change

- distribution of GDP growth, and economic damages due to natural disasters
- tail risk probability of natural disaster
- information treatments
- complementary probability literacy question

Survey Question: Probability of Large Natural Disaster

"As a result of climate change, the risk of natural disasters (such as hurricanes, tropical cyclones, droughts, wildfires, or flooding) is likely to increase. The economic damage of such disasters may be sizeable. Considering the next 12 months, what do you think is the probability of a large disaster causing damage of about 5 percent of GDP?

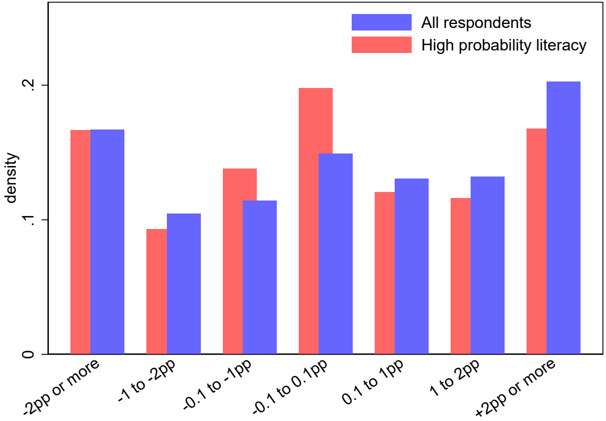
The probability of a large disaster will be ___ percent."

- We also ask about expected GDP growth impact and economic damages over the next 12 months.

Four Information Treatments

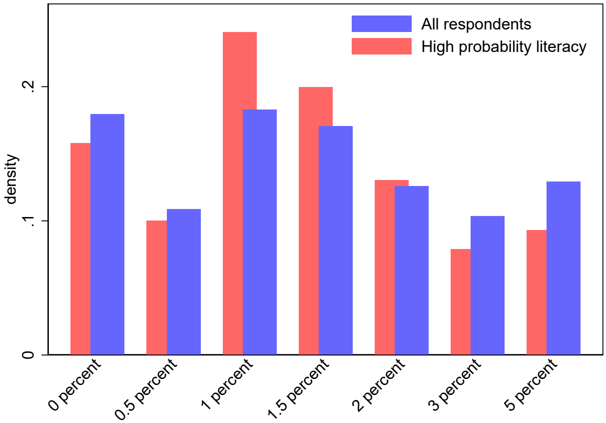
Newspaper treatment (T1)	Extract from an USA Today article summarizing the 2020 hurricane season on the east cost and in the gulf region and the wildfires on the west cost. The article links both developments to global warming.
Historic disaster size (T2)	"Over the past 20 years there have been 197 natural disasters in the United States, but even the largest caused damages of less than 1% of GDP (Source: National Centers for Environmental Information)."
Lagarde treatment (T3)	"I think when it comes to climate change, it's everybody's responsibility. Where I stand, where I sit here as head of the European Central Bank, I want to explore every avenue available in order to combat climate change."
Historic disaster frequency (T4)	"Over the past 20 years there have been 197 natural disasters in the United States. Two of them caused damage of more than 0.5 percent of GDP (Source: National Center for Environmental Information)."

Q1: GDP Growth Impact Over Next 12 Months



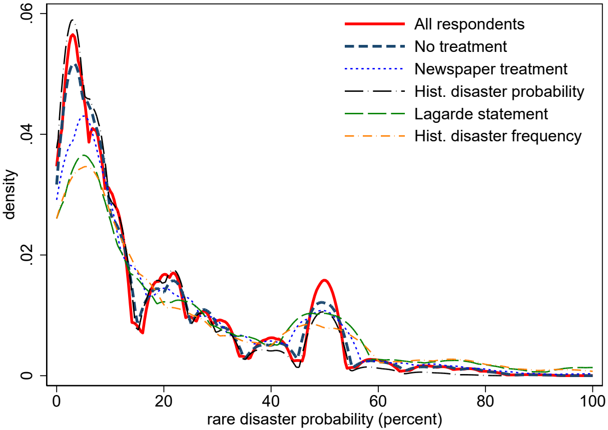
- Average effect of 0.16pp moderate, but sizeable disagreement (std: 1.24pp)

Q2: Economic Damages Over Next 12 Months



- Large expected damages of 1.51% of GDP.
- Heavy tail: more than 10% expect losses of more than 5%

Q3: Probability of Rare Natural Disasters



- Median probability at 12% for large rare disaster
- Large mass to the right: e.g. 10% believe that probability is $> 60\%$

What Is Behind These Responses?

- Likely not measurement error:
  - Similar responses for high probability literacy respondents, and magnitude explanations
  - Meaningful covariance with socio-economic variables and economic behavior
- Salience plays an important role:
  - Personal experience
  - Media usage
  - Policy communication
- Information treatments suggest causality

Info Treatments Shift Disaster Probability

	(1)	(2)	(3)	(4)
Newspaper (T1)	1.612*	0.943	1.837***	1.497**
	(2.36)	(1.20)	(3.75)	(2.75)
Historic Disaster Size (T2)	-1.624*	-1.808*	-0.728	-0.984
	(-2.43)	(-2.32)	(-1.57)	(-1.89)
Lagarde treatment (T3)	2.855***	2.557**	1.620**	1.383*
	(3.92)	(3.09)	(3.13)	(2.44)
Historic Disaster Freq (T4)	0.240		-1.123	
	(0.27)		(-1.95)	
State Fixed Effect	yes	yes	yes	yes
Demographic Controls	yes	yes	yes	yes
Drop largest 25% probabilities	no	no	yes	yes
N	10603	8436	8678	6935
r2	0.0387	0.0992	0.0424	0.0862

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Extra Slides

New Keynesian Model With Rare Disasters

Setup largely follows Fernandez-Villaverde and Levintal (2018)

- Solve simplified version of model analytically
- Calibrate to survey expectations on climate disasters
- Solve full model numerically

Rare disaster $d_t \in \{0, 1\}$:

- Probability of climate-change related natural disaster $Prob_t(d_t = 1) = p_t$
- If $d_t = 1$: Fraction of capital is lost, productivity growth drops

Households

Consume, work, and save via bond or capital stock in order to

$$
\begin{aligned}
\max V_t^{1-\psi} &= U(C_t, N_t)^{1-\psi} + \beta E_t \left(V_{t+1}^{1-\gamma}\right)^{\frac{1-\psi}{1-\gamma}} \\
\text{s.t. } \int_0^1 P_t(i) Y_t(i) di + Q_t B_t &\leq B_{t-1} + W_t N_t + R_t^K K_t + D_t \\
K_t &= \left\{ (1-\delta) K_{t-1} + \left[1 - S\left(\frac{X_t}{X_{t-1}}\right) X_t \right] \right\} e^{d_t \log(1-\mu_t)}
\end{aligned}
$$

- Consumption and investment goods are standard Dixit-Stigliz aggregates
- Rare disaster destroys fraction μ_t of capital with

$$\mu_t = \bar{\mu}^{(1-\rho_\mu)} \mu_{t-1}^{\rho_\mu} e^{\sigma_\mu \epsilon_{\mu,t}},$$

Firms

Firms produce using labor N_t and capital K_t:

$$Y_t(i) = A_t K_t(i)^{\alpha} N_t(i)^{1-\alpha}$$

Productivity growth

$$\frac{A_t}{A_{t-1}} = e^{d_t (1-\alpha) \log(1-\mu_t) + \Lambda}$$

Calvo constraint: set P_t^* to solve

$$\max \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left[P_t^* \left(\frac{P_{t-1+k}}{P_{t-1}} \right)^{\chi} Y_{t+k|t} - \mathcal{C}(Y_{t+k|t}) \right] \right\},$$

Markets clear and monetary policy sets interest rates according to a rule as below.

A Special Case And Some Closed-Form Results

Simplifying assumptions

1. Restrict preferences $(\gamma = \psi)$: households maximize expected utility
2. Investment costs prohibitively high and no depreciation: abstract from capital dynamics
3. Focus exclusively on productivity shock
4. No trend growth in productivity: $\Lambda = 0$
5. Extent of disaster not time-varying: $\mu_t = \bar{\mu}$

Canonical (textbook) representation of the model (Galí, 2015)

$$\begin{aligned} \pi_t &= \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \\ \tilde{y}_t &= E_t \tilde{y}_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - r_t^n) \end{aligned}$$

Natural Rate Drops In Response To Bad News: Intensive and Extensive Margin of Expected Disaster

Given the simplified model, the solution for the natural rate and for potential output is given by:

$$r_t^n = \rho - \Omega(1-\alpha)p\bar{\mu}$$

and

$$y_t^n = \begin{cases} 0, & \textit{if } d_t = 0, \\ \Xi_\mu \bar{\mu}, & \textit{if } d_t = 1, \end{cases}$$

where $\rho = -\log(\beta)$, $\Omega = \frac{\sigma(1+\varphi)}{\sigma(1-\alpha)+\alpha+\varphi} > 0$ *and* $\Xi_\mu = -\frac{\sigma(1-\varphi)(1-\alpha)}{\sigma(1-\alpha)+(\alpha+\varphi)} < 0$.

Monetary Policy Matters for How Disaster Expectation Plays Out

Assume that monetary policy follows the interest-rate feedback rule, i.e.

$$i_t = \phi_r r_t^n + \phi_{\pi,t}\pi_t$$

with $\phi_{\pi,t} > 1$ *if monetary policy is unconstrained or* $\phi_{\pi,t} = 0$ *and* $P(\phi_{\pi,t+1} > 1) = \zeta$ *if the ELB binds.*
In this case, the unique and stable solution for the output gap and inflation depends on monetary policy and is given by:

$$\tilde{y}_t = \begin{cases} 0 \\ \Pi_y r_t^n \\ \Gamma_y r_t^n \end{cases} \qquad \pi_t = \begin{cases} 0, & \text{if } \phi_r = 1 \\ \Pi_\pi r_t^n, & \text{if } \phi_r = 0 \text{ and } \phi_\pi \in (1,\infty) \\ \Gamma_\pi r_t^n, & \text{if } \phi_r = 0 \text{ and } \phi_{\pi,t} = 0; \end{cases}$$

where the natural rate r_t^n *declines with disaster expectations (both along the intensive and the extensive margin), as established in Proposition 1. Also,* $\Pi_y, \Pi_\pi \geq 0$ *and* $\Gamma_y, \Gamma_\pi \geq 0$*. It holds that* $\Gamma_y > \Pi_y$ *and* $\Gamma_\pi > \Pi_{\pi,t}$*. If* $\phi_{\pi,t} \to \infty$*,* $\Pi_y \to 0$ *as well as* $\Pi_\pi \to 0$*.*

Simulation of Full Model

Calibration to annual frequency, follows Fernandez-Villaverde and Levintal (2018) details

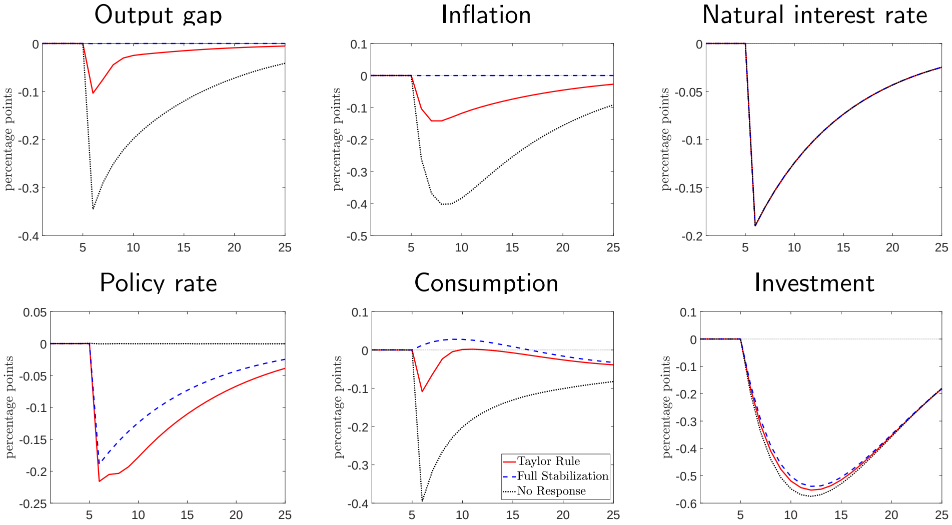
- Monetary policy: conventional Taylor rule
- Set average disaster size to $\bar{\mu} = 0.05$, $p = 0.12$ and $\sigma_p = 0.069$ in line with survey

Risky steady state

	No Disaster	Disaster expectations
Mean disaster size $\bar{\mu}$	0	0.05
Std. of disaster size σ_μ	0	0
Mean disaster prob. $\bar{p}$	0	0.12
Std. of disaster prob. σ_p	0	0.069
Natural rate of interest r^n	1.67%	0.85%
Output gap $\tilde{y}$	-0.01p	-0.17pp
Inflation π	1.94%	1.41%

Impulse Response Functions to a Disaster Probability Shock

- Transitory increase in disaster probability from 12% to 14.2%



Conclusion

Expectations regarding short-run economic impact of climate change

- Positive but small for GDP growth
- Prob(large natural disaster)=12%

New Keynesian model with rare disasters

- Bad news lower natural rate:
  Expected future supply shocks as demand shocks
- Directly relevant for monetary policy

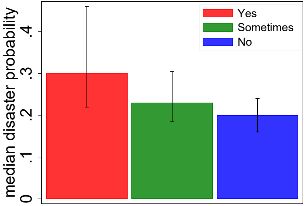
"Paradox of Communication"

- Monetary policy by engaging in the climate change debate may deliver bad news
- Adverse impact on natural rate makes life harder for conventional monetary policy, given low interest-rate environment

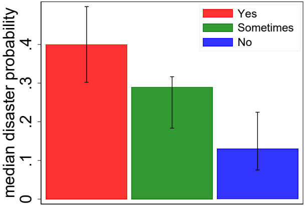
Extra Slides

Extra Slides: Research

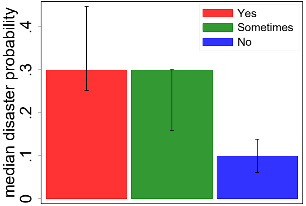
Behavioral Choices and Disaster Probabilities



eat no or less meat
due to climate change
(Yes: 15.7%)
(No: 58.8%)



refrain from flight
travel
(Yes: 22.6%)
(No: 58.4%)



avoid plastic products
due to climate change
(Yes: 27.3%)
(No: 35.1%)

Similar pattern regarding investment divestment or avoidance.

Responses Vary With Socio-Economic Variables In Meaningful Way

	(1) Growth	(2) Growth	(3) Damage	(4) Damage	(5) Disaster Prob.	(6) Disaster Prob.
Female	0.00293	-0.0100	0.121**	0.119**	3.835***	4.005***
	(0.07)	(-0.22)	(3.29)	(3.27)	(4.46)	(4.60)
35 to 44 years	0.0291	0.0473	0.0697	0.0609	2.078	2.581*
	(0.54)	(0.88)	(1.43)	(1.25)	(1.87)	(2.27)
45 to 54 years	0.0116	-0.0211	0.000592	-0.0162	-1.288	-0.993
	(0.18)	(-0.32)	(0.01)	(-0.29)	(-0.97)	(-0.75)
above 55 years	0.219***	0.217***	-0.142***	-0.134**	0.234	0.602
	(4.17)	(4.10)	(-3.39)	(-3.20)	(0.22)	(0.57)
High Educated	-0.0860	-0.0868	0.0196	0.0296	-0.658	-0.631
	(-1.68)	(-1.68)	(0.47)	(0.70)	(-0.70)	(-0.67)
Middle Income	-0.0826	-0.0965	-0.116*	-0.108*	-0.518	-0.838
	(-1.49)	(-1.74)	(-2.53)	(-2.37)	(-0.50)	(-0.80)
High Income	-0.0946	-0.102	-0.0611	-0.0738	0.263	0.0417
	(-1.31)	(-1.43)	(-1.05)	(-1.26)	(0.21)	(0.03)
Republican	-0.0363	-0.0244	-0.131**	-0.128**	-3.779***	-3.591***
	(-0.67)	(-0.45)	(-2.96)	(-2.92)	(-3.83)	(-3.61)
Democrat	0.0368	0.0574	0.209***	0.210***	3.468***	3.756***
	(0.74)	(1.16)	(5.08)	(5.08)	(3.40)	(3.65)
State FE	no	yes	no	yes	no	yes
N	4344	4344	3222	3210	3223	3223
r2	0.00915	0.0388	0.0549	0.0856	0.0322	0.0629

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Salience of Disasters Affects Risk Perception

	(1) Disaster Prob.	(2) Disaster Prob.	(3) Disaster Prob.	(4) Disaster Prob.	(5) Disaster Prob.
County Wildfire Experience	6.505**		3.582*		5.121*
	(2.93)		(2.01)		(2.13)
County Flood Experience	3.429*		4.151***		3.913**
	(2.56)		(3.46)		(2.92)
County Hurricane Experience	0.186		1.175		1.027
	(0.11)		(0.81)		(0.56)
# Hurricane Events in State		0.00368	0.0123		
		(0.51)	(1.24)		
# Flood Events in State		0.00589	0.00842		
		(0.46)	(0.57)		
# Fire Events in State		0.0100	-0.00326		
		(1.23)	(-0.32)		
High Wildfire Risk				8.089***	6.708**
				(3.84)	(3.13)
High Hurricane Risk				-3.520	-3.409
				(-1.61)	(-1.43)
High Flood Risk				-0.625	-0.743
				(-0.38)	(-0.47)
State FE	yes	no	no	yes	yes
Demographic Controls	yes	yes	yes	yes	yes
N	2167	2148	2148	2167	2167
r2	0.138	0.0463	0.0536	0.140	0.148

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Same With Media Usage ...

	(1) Disaster Prob.	(2) Disaster Prob.	(3) Disaster Prob.
no major TV station	-5.185***		
	(-4.43)		
no major Newspaper		-3.348***	
		(-3.69)	
consume major TV station $\times$ no major newspaper			-1.476
			(-1.42)
no major TV station $\times$ consume major newspaper			0.673
			(0.23)
no major TV station $\times$ no major newspaper			-6.880***
			(-5.31)
State FE	yes	yes	yes
Demographic Controls	yes	yes	yes
N	3223	3223	3223
r2	0.0695	0.0684	0.0718

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back to results Back to conclusion