Greening Monetary Policy: Climate Change Expectations and the Natural Rate

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Abstract

Using a representative consumer survey in the U.S., we elicit beliefs about the economic impact of climate change. Respondents perceive a high probability of costly, rare disasters due to climate change, but not much of an impact on GDP growth. Salience of rare disasters through media coverage increases the probability by up to 10 percentage points. Increasing expectations about climate-change related disasters matter for monetary policy because they lower the natural rate of interest. We quantify this effect in a standard New Keynesian model and find that the natural rate drops by about 70 basis points. If monetary policy fails to accommodate this drop, inflation and output decline by about 0.5 percent.

Keywords: Climate change, Disasters, Households Expectations, Survey, Media focus, Monetary policy, Natural rate of interest, Paradox of Communication

JEL-Codes: E43,E52,E58

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"I want to explore every avenue available in order to combat climate change."
— Christine Lagarde - ECB, *July 8, 2020*

"[...] 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*

1 Introduction

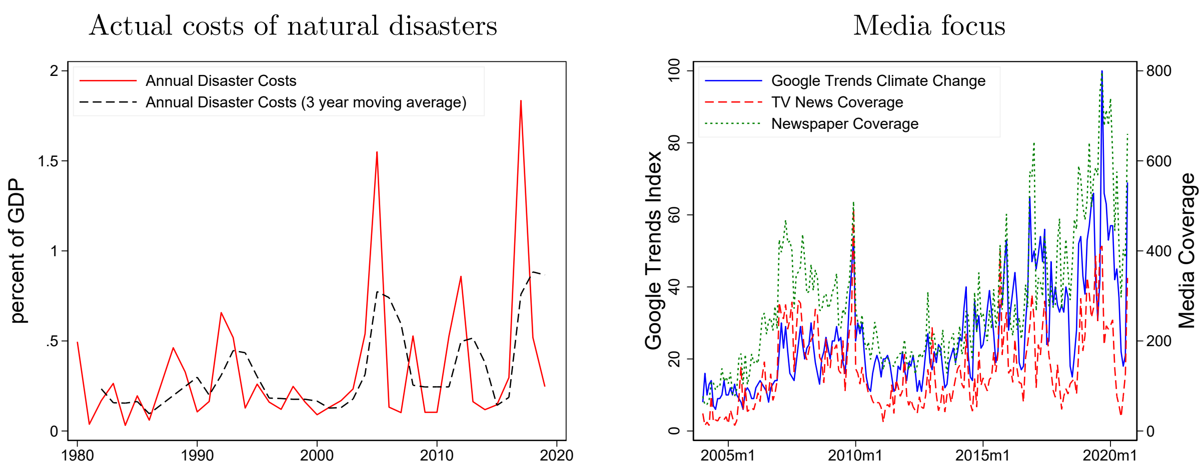
Climate change is a hotly debated topic and as such it presents a rising, complex challenge for policymakers. Even central bankers have recently begun to weigh in on this debate—as the quotes above illustrate. And while some consider an active role in climate policy to be part of central banks' mandates, others argue that by assuming such a role, central banks run the risk of undermining their independence and their ability to maintain price stability (Weidmann, 2020). Still, it is perhaps less controversial that central banks should make every effort to understand "the nature of climate disturbances to the economy." This, however, is a daunting task because the extent of climate change and its immediate consequences are highly uncertain—let alone their implications for, say, price and financial stability.

Against this background we offer a fresh perspective: irrespective of how climate change actually plays out, the debate about climate change influences peoples' expectations and these feed back into economically relevant decisions today. This, in turn, matters for monetary policy. In a nutshell our argument can be summarized as follows: for today's policy it does not matter how climate change plays out; what matters is how people expect it to play out. Figure 1 may help to illustrate the point. The left panel shows how the costs of natural disasters have evolved since the early 1980s. Measured as a fraction of GDP these costs have been very volatile, but it may appear that they are on a rising trajectory. But while these data are suggestive, the debate to what extent natural disasters are caused by climate change has not been settled yet (e.g., Coronese et al., 2019). But ultimately this does not matter, because as the right panel of Figure 1 shows, climate change is on peoples' minds and increasingly so over time: the panel displays time series for TV and newspaper coverage of the topic as well as google trends—all three showing consistently a considerable increase over time.

In the first part of the paper, we make an attempt to measure the expectations of the economic consequences of climate change. To this purpose, we rely on a large, representative consumer survey in the U.S. In the survey we elicit beliefs about climate change and more specifically its likely economic costs. Among other things, we ask respondents whether, going forward, they expect climate change to impact output growth, either adversely, say, because of increased regulation or positively, say, because of technological innovation. We find that on average they do not.[1] We also ask them to assign a probability to natural disasters causing significant economic damage in the near future. Here we find a high probability, much higher than what would seem justified given the historical record.

[1] For the impact of temperature on output and output growth, see Dell et al., (2012) and Burke et al., (2015).

Figure 1: Climate Change makes itself felt



Notes: left panel shows annual damages due to natural disasters in the US between 1980 and 2019 in percent of GDP (red solid line), black line is a three year moving average, Source: NCEI, (2020). In the right panel, the blue solid line shows monthly averages of Google search queries for "climate change" (source: Goolge Trends); the red dashed (green dotted) line shows media coverage of climate change by seven major news stations (five major newspapers), Source: Boykoff et al., (2020).

There are various explanations for this discrepancy. For instance, respondents may think we have been lucky in the past, just like in the case of "peso problems:" in the relatively short sample under consideration, adverse events simply materialized less often than what the objective probability would have implied. Alternatively, natural disasters due to climate change may be much more frequent in the future because the climate may change beyond so-called "tipping points." Yet another possibility is that we are picking up a salient "Greta effect:" people overestimate the risk of natural disasters because of a media focus on climate change, consistent with research that has documented that media focus can be an independent source of business cycle fluctuations (Chahrour et al., 2020). This salience interpretation is also plausible because we find in the survey that respondents that are not exposed to media at all report a significantly lower estimate for the probability of natural disasters. Our focus, however, is how a given change in expectations about climate-change related disasters plays out economically today, rather than in explaining how these expectations come about.

We pursue this issue in the second part of the paper as we study the role of climate change expectations in a New Keynesian model. Extended versions of this model are widely used in various contexts, notably by central banks to study the role of monetary policy in determining business cycle outcomes. In order to keep our analysis as transparent as possible we abstract from various complications and rely on the textbook version of the model (Galí, 2015). We only depart from the basic version of the model in order to account for changing expectations about large natural disasters. Specifically, we use a Markov-switching framework that is simple enough to derive our main results in closed form. We show that as the probability of a natural disaster goes up, the natural rate of interest declines. At the heart of the mechanism which generates this result is a standard asset pricing equation as, for instance, in Barro, (2006).

The natural rate of interest is the interest rate that would prevail if prices were flexible and it serves as an important benchmark for monetary policy (Woodford, 2003). The natural rate is a counterfactual that cannot be observed directly, but serval attempts have been made to estimate it following the seminal work of Laubach and Williams, (2003). Recently, it has become clear that the natural rate is on a declining trajectory (e.g., Holston et al., 2017; Jorda and Taylor, 2019) and a number of important factors that may account for this decline have been identified. The list of suspects includes the slowdown of productivity growth, demographic trends and increase in the convenience yield (e.g., Del Negro et al., 2019). Once we analyze the results of our survey through the lens of our model, we find that expectations of natural disasters caused by climate change can also account for a decline of the natural rate. And the effect is non-trivial: for our baseline calibration we find that the effect is about 70 basis points.

This has important implications for monetary policy today. In fact, there is a case for "greening monetary policy." The argument goes as follows. As expectations of climate-change related losses increase, the natural rate declines. Monetary policy may insulate the economy from the impact of the decline of the natural rate by lowering the policy rate accordingly. But if policy makers fail to respond either because they are not willing or able to, say because they are constrained by the effective lower bound (ELB), the consequences may be severe. We show this result through model simulations. We find that output and inflation may drop by several percentage points.

To the extent that the ELB is a hard constraint, there is little central bankers can do in order to contain the adverse effect of climate change expectations, an effect which operates via the natural rate of interest. What exacerbates the problem is that our analysis points towards a "paradox of communication:" To the extent that central bankers engage in the debate about climate change they may themselves contribute to the media focus on climate change which, in turn, may foster adverse expectations about future climate-change related disasters. In this way, by trying to takle a major global challenge upfront they may actually contribute to making their own life much harder today. How to resolve this trade-off is a question beyond the scope of this paper.

Our paper relates to recent studies which study and measure the impact of climate change risk via financial markets (Bansal et al., 2019; Bauer and Rudebusch, 2020). Conceptually related to our study is Batten et al., (2020) as they disentangle distinct channels through which climate-change related physical risks impact both aggregate demand—via increased uncertainty—and as well as aggregate supply through actual damages. Fried et al., (2019), in turn, study the impact of uncertainty about future climate policy, that is, possible carbon taxes in the U.S. There is also important work on how climate change and the macroeconomy interact, including the influential work by Nordhaus, (1994), Mendelsohn et al., (1994) and Nordhaus, (2006), see also Hassler and Krusell, (2018) for a review of the "macroeconomics and climate" literature. Lastly, Golosov et al., (2014) study the optimal tax response to an externality from fossil energy.

The remainder of this paper is organized as follows. We introduce our survey in the next section. Section 3 introduces the New Keynesian model and presents result. For these we map the results of the survey into the model and conclude with a final section.

2 The Survey

In what follows we first provide some basic information regarding the nature of the survey. We subsequently present the main survey results.

2.1 Survey Design

Our data come from a larger, nationally representative daily survey of consumers sponsored by the Federal Reserve Bank of Cleveland which has been running since March 11, 2020. The survey is described in detail in Dietrich et al. (2020) and Knotek et al (2020). We add three questions on climate change to the survey, complementing the regular survey questions on consumers' demographic characteristics, their expectations, and consumers' perceptions surrounding COVID-19 and its impact on their behavior. The Appendix contains a detailed list of questions.

The survey is administered by Qualtrics Research Services, which representatively draws respondents from several actively managed, double-opt-in market research panels, complemented using social media (Qualtrics 2019). The survey includes filters to eliminate respondents who write in gibberish for at least one response, or who complete the survey in less (more) than five (30) minutes. Our analysis uses a raking scheme to compute respondent weights ensuring that our sample is representative of the U.S. population by gender, age, income, ethnicity, and Census region.

Table 1: Survey Respondent Characteristics

	pct.	(Target)		pct.	(Target)
Age			**Race**		
18-34	33.61%	(33.3%)	non-Hispanic white	70.55%	(66%)
35-55	33.61%	(33.3%)	non-Hispanic black	12.03%	(12%)
older than 55	32.78%	(33.3%)	Hispanic	7.69%	(12%)
			Asian or other	9.73%	(12%)
Gender					
female	49.38%	(50%)	**Household Income**		
male	50.21%	(50%)	less than 50k$	46.23%	(30%)
other	0.41%	(-%)	50k$ - 100k$	29.08%	(35%)
			more than 100k$	24.69%	(30%)
Region					
Midwest	19.48%	(20%)	**Education**		
Northeast	20.03%	(20%)	some college or less	48.83%	(50%)
South	40.74%	(40%)	bachelors degree or more	51.17%	(50%)
West	19.75%	(20%)			
					N=4542

Notes: This table presents data on the characteristics of participants in the survey administered by Qualtrics.

Table 1 provides a detailed breakdown of our sample. It shows that our sample even before weighting is approximately representative of the U.S. population according to the sampling criteria such as age, gender and race. But it is also representative from a geographical point of view, as well as in terms of income and education.

Our first question on climate change elicits consumer beliefs about the overall impact of climate change on economic growth over the next 12 months, as follows:

"The average growth rate of real GDP in the US between 2009 and 2019 has been about 2 percent. Climate change might influence future growth rates positively, say, because it triggers technological innovation or negatively because of regulation and taxes.
What do you think is the overall impact of climate change on economic growth over the next 12 months? Please assign probabilities to each scenario listed below:
Due to climate change, economic growth, compared to what it would be otherwise, will be

- *2 percentage points higher or more (say, more than 4 percent rather than 2)*
- *1 - 2 percentage points higher (say, between 3 and 4 percent rather than 2)*
- *0.1 - 1 percentage points higher (say, between 2.1 and 3 percent rather than 2)*
- *different by -0.1 to 0.1 percentage points.*
- *0.1 - 1 percentage points lower (say, between 1 and 1.9 percent rather than 2)*
- *1 - 2 percentage points lower (say, between 0 and 1 percent rather than 2)*
- *2 percentage points lower or more (say, less than 0 percent rather than 2)"*

The second question on climate change elicits consumer beliefs about the economic damage due to natural disasters also over the next 12 months, as follows:

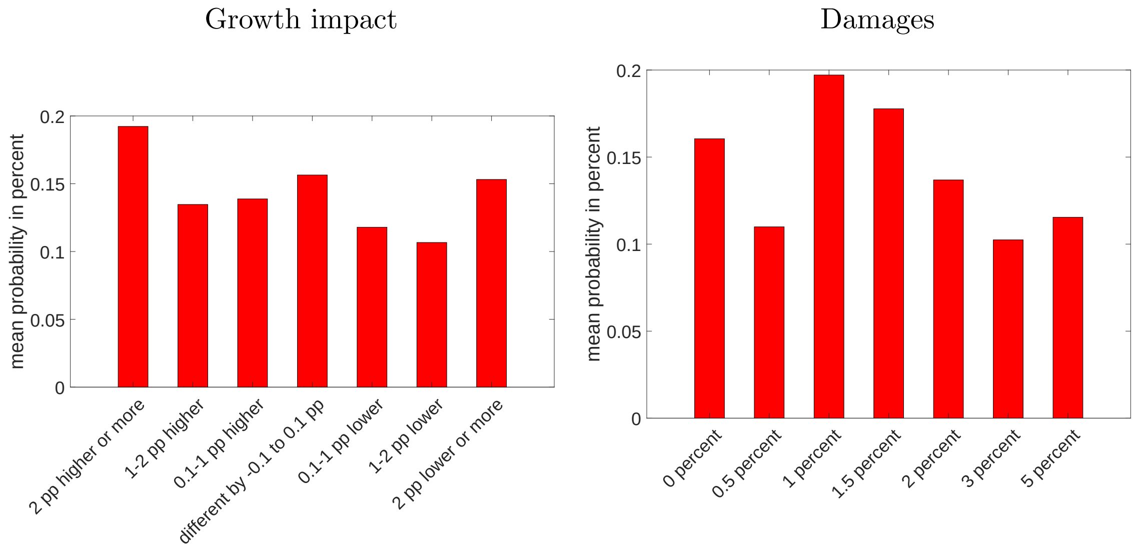
"Recently, the economic damage due to natural disasters amounted to about 1% of GDP per year (Source: National Center for Environmental Information). In your view, will these damages be larger or smaller because of climate change? Please assign probabilities to each scenario listed below:
Specifically, what would you say is the percent chance that, over the next 12 month there will be . . .

- *no damage.*
- *less damage then in the past. (say, around 0.5% of GDP)*
- *the same as in the past. (say, 1% of GDP)*
- *more damage than in the past. (say, 1.5% of GDP)*
- *considerably more than in the past (say, 2% of GDP)*
- *much more than in the past (say, 3% of GDP)*
- *extremely rare disasters, with damage on an order of 5% of GDP."*

Our third question asks respondents about their perceptions of natural disaster risks. Specifically, we ask them about a large disaster causing damage of about 5 percent of GDP. Half of respondents receive an information treatment—given in bold below—before receiving the question, which is meant to gauge the extent to which official estimates of damages can affect responses. The info treatment and question are as follows:

"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).
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."

Figure 2: Climate Change Expectations: Survey results



Notes: the left panel shows mean probability assigned to each scenario for Question 1, the right panel the mean probability assigned to each scenario for Question 2.

2.2 Survey Results

We find that respondents hold widely dispersed beliefs about the effects of climate change on economic growth and damages. Also, respondents believe that disasters causing large damages carry substantial probability.

First, on average, respondents expect a slightly positive impact of climate change on economic growth with an average increase of GDP growth by 0.17 percentage points over the next 12 months. However, there is a lot of mass in the distribution on both positive and negative effects. For example, nearly 20% of respondents expect a growth increase of more than 2 percentage points over then next 12 months while nearly 15% expect a growth decrease of more than 2 percentage points. The standard deviation is 1.92 percentage points. The first line of Table 2 and the left panel of Figure 2 summarize and illustrate these results.

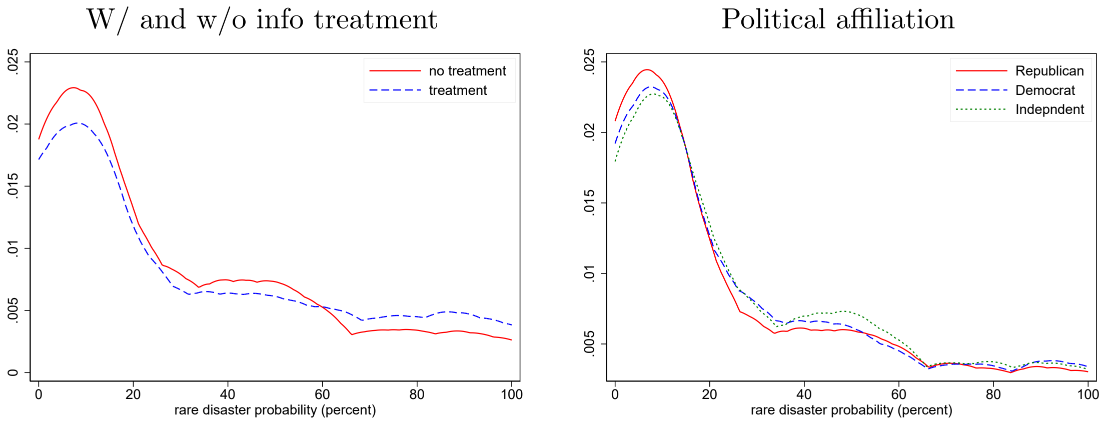
Table 2: Survey Summary Statistics

	Mean	Median	Std. Dev.	N
Growth Impact (Question 1)	0.15pp	0.00pp	1.54pp	3382
Disaster Costs (Question 2)	1.67%	1.50%	1.15%	2266
Disaster Probability (Question 3)	28.36%	15.00%	29.36%	2167
no treatment	27.38%	15.00%	28.73%	1100
treatment	29.44%	15.00%	31.04%	1057

Notes: This table presents summary statistics for the survey questions on Climate Change. All reported statistics are weighted using survey weights.

Second, respondents also expect substantial economic damages, amounting to 1.67% of GDP on average over the next 12 months. Again, expectations are widely dispersed over loss scenarios. For example, approximately 15% of respondents expect 0 losses, while 20% expect

Figure 3: Expected probability of rare natural disaster



Notes: The Figure shows the distribution of expected probabilites of a rare disaster with damage of 5% of GDP within the next 12 months.

losses equal to 1% and more than 10% expect losses equal to more than 5% of GDP. The standard deviation of expected losses is at 1.47%. The second line of Table 2 and the right panel of Figure 2 summarize and illustrate these results.

When we ask respondents about the probability of a natural disaster with damage of 5% of GDP within the next 12 months, we again uncover a wide distribution. The mean probability for such a rare disaster is at 29.86% while the median is at 15%. In fact, as the high median probability suggests, there is a substantial mass of respondents that assign large probabilities to such an event. For example, almost 15% of respondents believe that such a rare disaster can occur with more than 60% probability. The left panel of Figure 3 shows a kernel estimate of the probability distribution, both for the case without information treatment (red solid line) and for the with information treatment (dashed line). We also summarize the answers to the third question at the bottom of Table 2.

The information treatment has a surprising effect in that it leaves the mode of respondents unchanged at 10%, but shifts mass to the right. Now, 23% of respondents believe that a high-cost natural disaster can occur with more than 60% probability. This is even though the information we provide makes clear that high-cost natural disasters have been very rare in the past. While we cannot rule out that respondents may lack the ability to compute the frequencies with which rare events happened in the past, other explanations are also possible. For instance, as discussed in the introduction above, participants may expect a strong increase of high-cost natural disasters because they expect climate to change beyond relevant tipping points.

Finally, we estimate regressions that relate either disaster loss, the growth impact, or large, rare disaster risks to respondent characteristics and control for state fixed effects. Table 3 reports the results. In the case of disaster loss expectations, we find a large negative significant coefficient for republican voters expecting less losses. The effect of income is also large and negative. Highly educated respondents expect the losses to increase due to climate change in the future and the effect of being female is similarly large and positive. The effect of age is non-linear: Relative to the youngest age group, those below age 35, those age 35 to 44 expect

Table 3: Cross Section Regressions

	(1) Growth	(2) Growth	(3) Damage	(4) Damage	(5) Disaster Prob.	(6) Disaster Prob.
Female	-0.0322	-0.0469	0.148***	0.153***	4.111***	3.625***
	(-0.65)	(-0.95)	(3.57)	(3.74)	(3.72)	(3.31)
35_to_44_years	-0.00676	0.0258	0.148**	0.128*	0.814	0.299
	(-0.12)	(0.44)	(2.70)	(2.38)	(0.63)	(0.22)
45_to_54_years	0.00483	-0.00754	0.00452	0.0129	0.177	-0.0463
	(0.07)	(-0.11)	(0.07)	(0.20)	(0.11)	(-0.03)
above_55_years	0.209***	0.216***	-0.102*	-0.0915	-2.630*	-3.213*
	(3.63)	(3.73)	(-2.16)	(-1.93)	(-2.15)	(-2.51)
High_Educated	-0.0460	-0.0558	0.129**	0.142**	-1.629	-2.412
	(-0.80)	(-0.95)	(2.87)	(3.18)	(-1.30)	(-1.92)
Middle_Income	-0.165**	-0.178**	-0.152**	-0.172***	1.218	1.466
	(-2.75)	(-2.90)	(-2.94)	(-3.32)	(0.95)	(1.11)
High_Income	-0.172*	-0.170*	-0.200**	-0.215***	0.847	0.968
	(-2.05)	(-2.02)	(-3.25)	(-3.51)	(0.51)	(0.58)
White	-0.0624	-0.0691	-0.173*	-0.134	7.609***	8.123***
	(-0.56)	(-0.62)	(-1.97)	(-1.58)	(4.47)	(4.75)
Black	-0.143	-0.141	-0.151	-0.129	3.345	3.229
	(-1.10)	(-1.09)	(-1.41)	(-1.23)	(1.53)	(1.47)
Asian	-0.00914	-0.0204	-0.387***	-0.338**	1.251	2.619
	(-0.06)	(-0.14)	(-3.42)	(-2.99)	(0.50)	(1.10)
Hispanic	-0.105	-0.160	-0.312**	-0.244*	4.009	3.719
	(-0.75)	(-1.14)	(-2.87)	(-2.35)	(1.56)	(1.43)
Republican	-0.0408	-0.0217	-0.115*	-0.0956*	-3.704**	-3.409**
	(-0.70)	(-0.37)	(-2.41)	(-2.02)	(-3.05)	(-2.67)
Democrat	0.0410	0.0534	0.208***	0.209***	-1.119	-1.331
	(0.74)	(0.97)	(4.45)	(4.52)	(-0.90)	(-1.07)
Treatment					0.382	0.471
					(0.39)	(0.47)
Constant	0.330**	0.816***	1.637***	1.615***	14.73***	4.475
	(2.73)	(3.60)	(17.88)	(7.24)	(7.59)	(1.34)
State FE	no	yes	no	yes	no	yes
N	3382	3381	2250	2244	2167	2167
r2	0.0112	0.0458	0.0701	0.109	0.0300	0.120

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents cross section regression results on the impact of demographics on the climate change expectations. We use weighted regressions with robust standard errors. Weights used are the product of survey weights and calculated Huber robust weights.

a significantly higher damage. Those age 45 to 54 show no differential effect while those age 55 and above expect significantly lower damages. In the case of the growth impact, age also has a non-linear effect with significantly higher growth expectations for those age 55 and above. Those in the median and high income categories have similarly lower growth expectations. Other variables do not have a significant relationship with growth expectations.

When we survey respondents about disaster probabilities, three results emerge: First, by far the largest effect is given for those who identify as ethnically white. Respondents in this category believe that a very large rare disaster is 8.12% more likely. Respondents age 55 or higher also show a large effect. They believe very large rare disasters are 3.21% less likely than the youngest age group. Republicans, all else equal, also believe that a very large rare disaster is less likely, by 3.41%, compared to independent voters. Our treatment in question 3 does not change the probability in a significant way.

2.3 Media Usage and Expected Disaster Probability

We also find an important role of media—TV and newspapers—for the perception of disaster risks. In particular, we survey participants' answers on media usage, both for TV stations and newspapers, by asking them about their preferred TV stations and newspapers. We then regress disaster risk probabilities on the same demographic and socioeconomic explanatory variables as before but additionally allow for media use in specifications of varying degrees of detail.

Table 4 shows the results. Our main result is the following: Respondents who consume news from neither a major TV Station nor a major newspaper exhibit approximately 10 percentage points lower rare disaster expectations. Respondents who watch multiple news stations have nearly 9 percentage point higher disaster expectations. There is some evidence for individual TV Station/Newspaper impacts on the disaster probability of respondents, even though impacts as well as differences between different stations seem to be less clear here. Overall, this evidence strongly suggests that salience of disasters communicated (or not) in the news has strong effects on perceptions.

Table 4: Media Usage Regressions

	(1) Disaster Prob.	(2) Disaster Prob.	(3) Disaster Prob.	(4) Disaster Prob.	(5) Disaster Prob.	(6) Disaster Prob.
no_major_TV_Station	-7.847***					
	(-5.34)					
no_major_Newspaper		-2.847*				
		(-2.55)				
TV_None=0 × News_None=1			0.0709			
			(0.06)			
TV_None=1 × News_None=0			-1.764			
			(-0.57)			
TV_None=1 × News_None=1			-9.543***			
			(-5.86)			
Multiple_News_Stations				8.968***		7.590***
				(5.56)		(4.30)
Fox				3.975*		4.459*
				(2.12)		(2.28)
CNN				8.133***		9.625***
				(3.37)		(3.85)
ABC				7.587**		8.310***
				(3.22)		(3.30)
MSNBC				5.602		5.791
				(1.74)		(1.69)
PBS				7.599		8.302
				(1.82)		(1.94)
NBC				11.05***		11.58***
				(3.64)		(3.83)
CBS				7.468*		8.722**
				(2.48)		(2.81)
Multiple_Newspapers					5.525***	3.445*
					(4.16)	(2.36)
New_York_Times					-1.369	-3.985*
					(-0.73)	(-2.01)
Washington_Post					1.461	-0.573
					(0.54)	(-0.20)
Wall_Street_Journal					-4.248*	-6.321**
					(-2.00)	(-2.88)
USA_Today					3.571	1.639
					(1.66)	(0.75)
Los_Angeles_Times					-1.494	-3.578
					(-0.44)	(-1.02)
Constant	6.300	5.356	6.566	-0.615	2.023	-1.435
	(1.85)	(1.58)	(1.91)	(-0.18)	(0.59)	(-0.41)
State FE	yes	yes	yes	yes	yes	yes
N	2167	2167	2166	2167	2167	2167
r2	0.130	0.123	0.133	0.131	0.129	0.139

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents regression results on the impact of media usage on the expected disaster probability. We use weighted regressions with robust standard errors. Weights used are the product of survey weights and calculated Huber robust weights.

2.4 Disaster Risk, Past Experience and Disaster Probability

Next, we investigate if expectations over future natural disaster probabilities are affected by either past local natural disaster experiences or local risk for future disasters. We use official data for natural disaster declarations on a county level provided by the Federal Emergency Management Agency (FEMA) for the last 10 years (Federal Emergency Management Agency, 2020). Within our sample 16.8% of respondents live in a county with a wildfire related disaster over the last 10 years, 42.99% wit a hurricane, tornado, or typhoon event and 40.64% with a flood in the past. From the same datasource, we also construct data for the total number of events (fire, flood and hurricane, etc.) within a state in the given timespan. To measure the risk of future natural disasters in a county, we use the US Natural Hazards Index, provided by the National Center for Disaster Preparedness of Columbia University (NCDP, 2020). For each county, the index categorizes the risk of a given type of natural disaster as either "None", "Low", "Medium" of "High". Table 5 displays the results.

Three findings stand out: First, respondents within counties with a past record of natural disasters tend to expect higher disaster probabilities than respondents without a disaster experience. Second, concerning future risk, especially the increased possibility of wildfires drives up expectations for a future large disaster. Third, when including the total number of disasters of a type for a given state - which shoud be a good proxy for how common a disaster type is within the state, both in the past experience and for future risk - it is still local experiences which drive the results.

Table 5: Disaster Risk and Experience Regressions

	(1) Disaster Prob.	(2) Disaster Prob.	(3) Disaster Prob.	(4) Disaster Prob.	(5) Disaster Prob.
Fire_experience	6.505**		3.582*		5.121*
	(2.93)		(2.01)		(2.13)
Flood_experience	3.429*		4.151***		3.913**
	(2.56)		(3.46)		(2.92)
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_landslide_risk				1.941	2.072
				(0.88)	(0.94)
High_earthquake_risk				-5.257	-7.628*
				(-1.61)	(-2.24)
High_hurricane_risk				-3.520	-3.409
				(-1.61)	(-1.43)
High_flood_risk				-0.625	-0.743
				(-0.38)	(-0.47)
Constant	5.993	15.97***	13.10***	7.861*	7.730*
	(1.69)	(7.33)	(5.35)	(2.11)	(2.03)
State FE	yes	no	no	yes	yes
N	2167	2148	2148	2167	2167
r2	0.138	0.0463	0.0536	0.140	0.148

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents regression results on the impact of past disaster experience and estimated future risk on the expected disaster probability. We use weighted regressions with robust standard errors. Weights used are the product of survey weights and calculated Huber robust weights.

3 Model

We now turn to a formal analysis of our survey results within a New Keynesian framework. Section 3.1 will outline our basic model and introduce the Markov structure assumed to possible natural disasters. Section 3.2 will derive three analytical results highlighting the interdependence between economic outcomes due to households' disaster expectations and monetary policy. Section 3.3 will calibrate the model with our survey results.

3.1 Model outline

In order to assess the macroeconomic impact of climate change we feed private sector expectations as solicited in the survey into a standard New Keynesian model. In what follows we outline a simple extension of the textbook model following chapter 3 of (Galí, 2015).

A representative **household** has preferences over private consumption, C_t^i, and labor,

N_t^i, given by

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{1}$$

In the expression above E_0 is the expectation operator, $\beta \in (0,1)$ is the discount factor, σ is the degree of relative risk aversion, and φ is the inverse of the Frisch elasticity of labor supply. Aggregate consumption is a bundle of varieties $C_t(i)$ with $i \in [0,1]$:

$$C_t \equiv \left[\int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} . \tag{2}$$

In the expression above $\epsilon > 1$ is the elasticity of substitution across varieties. The household chooses consumption in order to maximize (1), (2) and a flow budget constraint:

$$\int_0^1 P_t(i) C_t(i) di + Q_t B_t \leq B_{t-1} + W_t N_t + D_t, \tag{3}$$

as well as a solvency constraint. Here $P_t(i)$ is the price index of good i, B_t is a nominally riskless discount bond which trades at price Q_t, W_t are wages and D_t is the household's dividend income.

The households supplies labor and saves via the riskless bond in order to satisfy the following optimality conditions

$$\frac{W_t}{P_t} = C_t^{\sigma} N_t^{\varphi} \tag{4}$$

$$Q_t = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \tag{5}$$

The optimal intertemporal allocation of consumption expenditures implies the demand function for a generic good i:

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} C_t \tag{6}$$

where $P_t \equiv \left[\int_0^1 P_t(i)^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}$ is the consumption price index.

There is a continuum of **firms**, indexed by $i \in [0,1]$; each firm produces a differentiated good operating under monopolistic competition. The production function of a generic firm i is given by

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

where $Y_t(i)$ is the firm's output, $N_t(i)$ is labor employed by firm i, A_t is productivity. It is common across firms and determined exogenously. $\alpha \in [0,1)$ is a parameter.

Firms are constrained in their ability to adjust prices. In each period a fraction $\theta \in [0,1]$ is unable to adjust its price. Under this assumption the price level evolves as follows:

$$P_t = \left[\theta (P_{t-1})^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} , \tag{7}$$

where P_t^* is the optimal price set by firms that are randomly selected to be able to adjust their price. Since they face an identical decision problem, they chose the same price. Specifically, P_t^* solves

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

where $Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k}$ is demand in period $t+k$, given prices set in period t and $Q_{t,t+k} \equiv \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+k}}\right)$. Here this assumption is that firms are ready to produce any amount demanded at the posted prices. The optimal price satisfies:

$$\sum_{t=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left(P_t^* - \mathcal{M} \Psi_{t+k|t} \right) \right\} = 0,$$

where $\Psi_{t+k|t} = \mathcal{C}'_{t+k}(Y_{t+k|t})$ denotes marginal costs and $\mathcal{M} \equiv \frac{\epsilon}{\epsilon-1}$ is the markup in steady state.

If prices are completely flexible ($\theta = 0$), the optimal price implies a constant markup over marginal costs:

$$P_t^* = \mathcal{M} \Psi_{t|t}.$$

Market clearing requires for each variety i:

$$Y_t(i) = C_t(i) + X_t(i).$$

$X_t(i) = \psi_t Y_t(i)$ gives output that is lost due to natural disasters. ψ_t gives the fraction of output lost in period t. For analytical simplicity, we assume the fraction lost to be symmetric across all varieties. Further, defining aggregate output $Y_t \equiv \left(\int_0^1 Y_t(i)^{1-\frac{1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$, we also have

$$(1 - \psi_t) Y_t = C_t. \tag{8}$$

Labor market clearing implies

$$N_t = \int_0^1 N_t(i) di = \left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}} di.$$

The riskless bond B_t is zero net supply.

We can express the log linearized model outlined above in the canonical representation:

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \frac{1}{\sigma}(i_t - E_t \tilde{\pi}_{t+1} - r_t^n) \tag{9}$$

$$\tilde{\pi}_t = \beta E_t \tilde{\pi}_{t+1} + \kappa \tilde{y}_t \tag{10}$$

$$r_t^n = \rho + \gamma_{ya} E_t \Delta a_{t+1} - \gamma_{y\psi} E_t \Delta \psi_{t+1} \tag{11}$$

With $\rho = -\log(\beta)$, $\kappa = \lambda(\sigma + \frac{\varphi+\alpha}{1-\alpha})$, $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\alpha}{1-\alpha+\alpha\epsilon}$ and $\gamma_{ya} = \frac{\sigma(1+\varphi)}{\sigma(1-\alpha)+\alpha+\varphi}$ as well as $\gamma_{y\psi} = \frac{\sigma(\alpha+\varphi)}{\sigma(1-\alpha)+\alpha+\varphi}$. The model now features two state variables: the level of technology as well as the current fraction of output lost to natural disasters. Note that the natural rate is an increasing function of expected changes in technology $E_t \Delta a_{t+1}$ and a decreasing function in expected changes to the fraction of output lost due to natural disasters, $E_t \Delta \psi_{t+1}$.

From equations (9) to (11) it is obvious to see that expectations about the change in the output fraction lost are the core variable of interest when studying households' climate change induced natural disaster expectations.

$$E_t \Delta \psi_{t+1} = E_t \psi_{t+1} - \psi_t$$

While $\psi_t \in [0,1]$ is a random state variable to our model , results are driven by the difference between the former and households expectations about the very same variable in the next period. We assume that expectations on future losses $E_t \psi_{t+1}$ follow the same Markov structure in every period. This may be formalized by:

$$E_t \psi_{t+1} = E_t \left(\psi_{t+1} | \psi_t = \Psi_i \right) = \sum_{j=1}^{n} \mathbf{P}_{ij} \Psi_j \tag{12}$$

Ψ_{t+1} is a $(n \times 1)$ vector of possible realizations of natural disaster related output losses ("states"). $\mathbf{P}$ gives the $(n \times n)$ transition matrix, with element $\mathbf{P}_{ij}$ giving the probability to move to state j when currently in state i. Since every realization of ψ is independent of past values, we assume that all n rows of $\mathbf{P}$ are identical, giving the expected probabilities for each element of Ψ to be realized next period. This means that the probability of a disaster realization in the next period is independent of the current state. The first equality of (12) now formalizes that the expectation over next periods disaster losses is independent of past realizations of the same variable. The second equality gives that the expectation is equal to the probability weighted sum of all n possible realizations.
Section 3.3 will take up this formally defined Markov structure again and take it to our survey question results.

3.2 Monetary Policy and Model Solution

We will now close the model by postulateing a rule for monetary policy. Thereby, we can show how cental banks - by defining their monetary policy reaction - can forge the economy's reaction to expectations about future losses caused by climate change.

The first possibility we consider is that monetary policy tracks the natural rate, as given by (11). The central bank will then follow the rule:

$$i_t = r_t^n + \phi_\pi \pi_t. \tag{13}$$

In this case, monetary policy stabilizes the economy at its natural level and, in fact, accomodates all possible output loss expectations. The following proposition states this result formally.

Proposition 1 *Consider the model, as represented by equations* (9) *and* (10)*, and assume that monetary policy tracks the natural rate of interest in line with rule* (13)*. In this case, the unique and stable solution is given by:*

$$\pi_t = \tilde{y}_t = 0,$$

that is, producer price inflation is zero and the output gap is closed at all times and in all regimes.

The solution for potential output and the natural rate differs across policy regimes. It is given by:

$$y_t^n = \begin{cases} \Xi_\psi \psi_t, \\ \Xi_\psi \psi_t, \\ \Xi_\psi \psi_t, \end{cases} \qquad r_t^n = \begin{cases} -\gamma_{y\psi} E_t \Delta\psi_{t+1} < 0 & \text{if } E_t\Delta\psi_{t+1} > 0, \\ 0 & \text{if } E_t\Delta\psi_{t+1} = 0 \\ -\gamma_{y\psi} E_t \Delta\psi_{t+1} > 0 & \text{if } E_t\Delta\psi_{t+1} < 0, \end{cases}$$

where $\Xi_\psi = \frac{\sigma(1-\alpha)}{\sigma(1-\alpha)+(\alpha+\varphi)} > 0$ *as well as* $\gamma_{y\psi} > 0$. ***Proof.*** *See Appendix A.1.* ■

Proposition 1 shows the reaction of potential output y_t^n to any realization of disaster losses: As a fraction of output ψ_t is lost, fewer resources are available for consumption by households. Following their intra-temporal optimization, households decide to make up for some of the decline in consumption by increasing their labor input and thus boosting potential output. Natural disasters may thus cause output available for consumption to decline, but at the same time increase potential output, due to increased labor effort by households. Note that y_t^n is only dependent on the actual realization of the state variable, but independent of expectations about the future.

The natural rate of interest, on the other hand, now depends on expectations about future output losses, relative to today's losses: As agents expect to be worse off in the future, i.e. to have fewer resources left for consumption, because climate change drives up natural disaster losses, $E_t\Delta\psi_{t+1} > 0$, the natural rate of interest decreases. Inter-temporal optimization requires households to save today, in order to smooth out consumption between the two periods. With bonds in zero net supply, interest rates have to decline so that savings demand equals supply again.

Monetary policy may now stabilize the economy by tracking the natural rate. This result may be derived formally by placing equation (13) into the system of (9) to (11). If the nominal interest rate is set according to the natural rate, any incentive to increase savings by the households' consumption smoothing motive is offset.

However, tracking the natural rate, as implied by rule (13), is a demanding policy, not least because the natural rate is not directly observable. Next, we consider a less demanding rule, given by the following equation:

$$i_t = \phi_\pi \pi_t. \tag{14}$$

This rule merely requires monetary policy to adjust interest rates in response to producer price inflation. However, as a result, monetary policy fails to stabilize the economy at full potential as the next proposition establishes formally.

Proposition 2 *Consider the model, as represented by equations* (9) *and* (10)*, and assume that monetary policy follows the interest-rate feedback rule given by* (14)*. In this case, the unique and stable solution for the output gap and inflation differs across policy regimes. It is given by:*

$$\tilde{y}_t = \begin{cases} \Pi_y r_t^n, \\ 0, \end{cases} \qquad \pi_t = \begin{cases} \Pi_\pi r_t^n, & \text{if } E_t\Delta\psi_{t+1} \neq 0 \\ 0, & \text{if } E_t\Delta\psi_{t+1} = 0, \end{cases}$$

where $\Pi_y \geq 0$ *as well as* $\Pi_\pi \geq 0$. *Note that, if* $\phi_\pi \to \infty$, *we obtain full stabilization just like in* Proposition 1, *that is,* $\Pi_y \to 0$ *as well as* $\Pi_\pi \to 0$. ***Proof.*** *See Appendix A.2.* ■

Proposition 2 discusses the case that the central bank follows a Taylor rule and does thus implicitly only partly accommodate the natural disaster expectations of households. In this case, expectations of increasing disaster losses, that is $E_t\Delta\psi_{t+1} > 0$ will cause a negative output gap as well as deflation. As monetary policy does not cut the nominal interest strong enough, the real interest rate exceeds the natural rate, which incentivizes consumption tomorrow, relative to today. Declining consumption demand today lets the inflation rate decline and thus the output gap turn negative: Less is produced than it would be in a flexible price equilibrium (where the real rate would always be equal to the natural rate), since the reduction of consumption today requires households also to cut back labor supply, following intra-temporal optimization.
For the borderline case of $\phi_\pi \to \infty$, central banks can achieve the same results as with natural rate tracking: Any deflationary pressure would cut nominal rates that much that in euqilibrium, real interest rates and natural rate of interest would be aligned back again, stabilizing the economy and replicating the flexible price equilibrium.

Assume now, as a third case, that monetary policy is at the zero lower bound or unwilling to react to output loss expectations:

$$i_t = 0. \tag{15}$$

Proposition 3 *Consider the model, as represented by equations* (9) *and* (10)*, and assume that monetary policy follows the interest-rate feedback rule given by* (15)*. In this case, the unique and stable solution for the output gap and inflation differs across policy regimes. It is given by:*

$$\tilde{y}_t = \Gamma_y^U r_t^n, \qquad \pi_t = \Gamma_\pi^U r_t^n.$$

Where $\Gamma_y^U, \Gamma_\pi^U \geq 0$*. In addition, the following holds:*

$$\Gamma_y^U > \Pi_y, \quad \Gamma_\pi^U > \Pi_\pi.$$

Proof. *See Appendix A.3.* ■
As shown in proposition 3, if monetary policy does not react to expectations about future output losses at all, both the output gap and inflation deviation are maximized. Since the nominal interest rate remains unchanged, the gap between real interest rate and natural rate is maximized. The mechanism causing the outcome to the economy is then in principle the same as discussed above.

3.3 Survey Calibrated Model Solution

We now calibrate the model using our survey results from section 2. Table 3.3 gives the calibration of the models' structural parameters, which follow Galí, (2015). We bring the Markov structure to the data, using first our results to the expected output damage of natural disasters (question 2) and then for the rare disaster probability (question 3). For the first exercise, there are $n = 7$ states in the economy, each corresponding to one of the possible answer bins we asked respondents to assign probabilities to. As we anchored the disaster costs for this year at roughly 1% of GDP p.a., we set $\psi_t = 1.0\%$ in the calibration. Table 3.3 gives results. We find that

Table 6: Constant parameter values

Discount factor	β	0.96	steady state real interest rate of 4%
Inter-temporal elasticity of substitution	σ	1	Baseline case with log utility
Inverse elasticity of labor supply	φ	5	Frisch elasticity of labor supply of 0.2
Labor Share in production	α	1/4	
Elasticity of substitution	ϵ	9	Steady State markup of 12.5%
Calvo price setting parameter	θ	3/4	
Taylor Rule parameter	ϕ_π	1.5	

Notes: This table gives constant parameter values for our model. Values set according to Galí, (2015), chapter 3, except for the discount factor, which is adjusted to match the annual timing of our model.

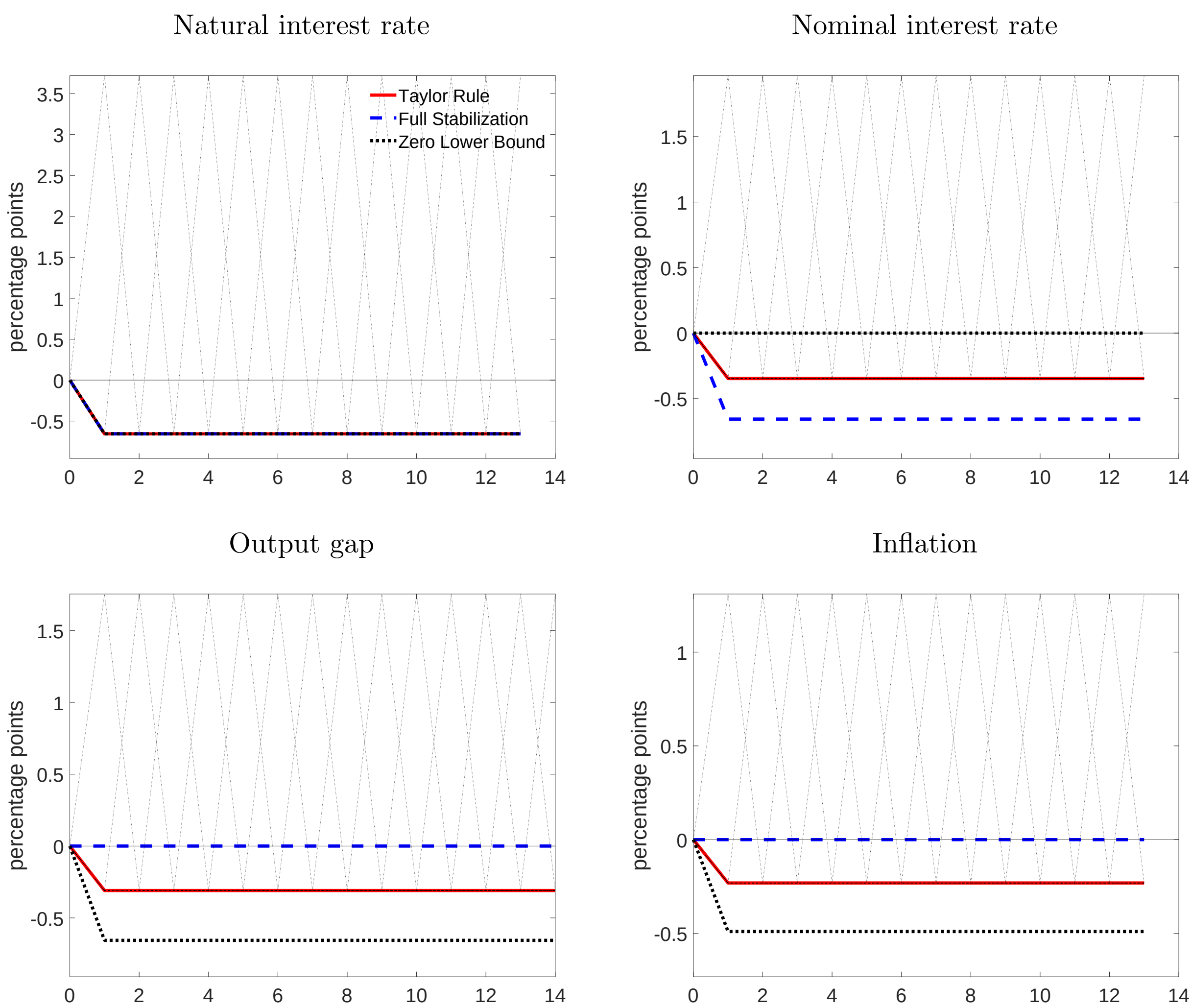
Table 7: Model Results

Expected Damages (Q 2)		
$E_t\psi_{t+1} = 1.6\%$, $\psi_t = 1.0\%$		
σ	1	4
$E_t\Delta\psi_{t+1}$	0.70pp	0.70pp
r_t^n	-0.61pp	-1.78pp
$\tilde{y}_t$	-0.29pp	-0.32pp
π_t	-0.21pp	-0.33pp
Expected prob. of rare disaster (Q 3)		
$Prob$(Disaster=1) = 15%($median$)		
σ	1	4
$E_t\Delta\psi_{t+1}$	0.75pp	0.75pp
r_t^n	-0.66pp	-1.91pp
$\tilde{y}_t$	-0.31pp	-0.34pp
π_t	-0.23pp	-0.25pp

Notes: This table gives results for our model given the expectations from survey respondents.

expectations depress the natural rate of interest by 70 basis points, resulting in a output gap of -0.29pp and -0.21pp lower inflation rates - given our standard Taylor rule inflation response. For the second exercise, we use the median probability given by respondents when asked about the probability of a rare natural disaster exceeding 5% of GDP in damages over the next 12 months. Hee, we assume that the economy has only two states ($n = 2$), either there is no large disaster and $\psi = 0$ or a large disaster takes place $\psi = 5\%$. For our exercise we assume that we are currently in the former state, with no large disaster present. As table 3.3 shows, results are in a similar range as for question 2: the natural rate drops by 75 basis points.

Figure 4: Increase in disaster probability



Notes: The figure shows impulse responses for the natural rate of interest, nominal interest rate, output gap and inflation following a permanent increase in the probability of a 5% damage rare disaster by 15% in $t = 1$ as our results from question 3 show. The bold lines give the outcome under different monetary policy regimes for the scenario that the disaster does not materialize in a given period, but expectations remain set. The red solid line gives the solution if the central bank follows a Taylor rule, the blue dashed line given full stabilization and the dashed black line when the economy is constraiend at the zero lower bound. Small dashed lines give the outcome under a Taylor rule in each period, given that the disaster materializes.

4 Conclusion

Using a representative consumer survey in the U.S., we elicit beliefs about the economic impact of climate change. We find that respondents perceive a high probability of costly, rare disasters due to climate change, but not much of an impact on GDP growth. Salience of rare disasters through media coverage increases the probability by up to 10 percentage points.

Increasing expectations about climate-change related disasters matter for monetary policy because they lower the natural rate of interest. We quantify this importance of the expectational channel in a standard New Keynesian model and find that the natural rate drops by about 70 basis points. If monetary policy fails to accommodate this drop, inflation and output decline by about 0.5 percent.

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A Proofs

A.1 Natural Level of Output (Proposition 1)

We can derive the natural level of output, similar as in Galí, (2015) by:

$$\begin{aligned}\frac{1}{\epsilon-1} &= -(w_t - p_t) + a_t - \alpha n_t + log(1-\alpha) \\ &= -(\sigma c_t + \varphi n_t) + a_t - \alpha n_t + log(1-\alpha) \\ &= -(\sigma y_t + \varphi n_t) + a_t - \alpha n_t + log(1-\alpha) + \sigma \psi_t\end{aligned}$$

where we use in the third step that $y_t = c_t + \psi_t$. Note that $\frac{1}{\epsilon-1}$ gives the markup under flexible prices, i.e. the desired mark up of firms. We may solve to:

$$\hat{y}_t^n = -\Xi_a a_t - \Xi_\psi \psi_t + \Lambda$$

where $\Xi_a = \frac{1+\varphi}{\sigma(1-\alpha)+(\alpha+\varphi)} > 0$ and $\Xi_\psi = \frac{\sigma(1-\alpha)}{\sigma(1-\alpha)+(\alpha+\varphi)} > 0$ as well as $\Lambda = \frac{(1-\alpha)(\mu-log(1-\alpha)}{\sigma(1-\alpha)+(\alpha+\varphi))} > 0$. We can now use the linearized euler equation:

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t \tilde{\pi}_{t+1}\rho) - E_t \Delta \psi_{t+1}$$

and our solution for the natural output to solve for the cannonical IS equation (9) as well as the natural rate of interest:

$$r_t^N = \rho + \gamma_{ya} E_t \Delta a_{t+1} - \gamma_{y\psi} E_t \Delta \psi_{t+1}$$

where $\gamma_{ya} = \frac{1+\varphi}{\sigma(1-\alpha)+\alpha+\varphi} > 0$ and$\gamma_{y\psi} = \frac{\alpha+\varphi}{\sigma(1-\alpha)+\alpha+\varphi} > 0$. The natural rate of interest thus declines if households expect damages to rise within the next period $E_t \Delta \psi_{t+1} > 0$. Given the equations (9) and (10) and monetary policy follwing an optimal interest rate rule as given in (13), the only solution is for all regimes that $\tilde{y}_t = 0$ and $\pi_t = 0$. This follows trivially by inserting the interest rate rule into the equations.

A.2 Taylor Rate Rule (Proposition 2)

If the economy follows a Taylor rule, it holds that the response of output and inflation is given as:

$$\tilde{y}_t = \Pi_y r_t^n \tag{16}$$

$$\pi_t = \Pi_\pi r_t^n \tag{17}$$

with $\Pi_y = \frac{1}{\sigma+\kappa\phi_\pi} > 0$ for the output gap and $\Pi_\pi = \frac{\kappa}{\sigma+\kappa\phi_\pi} > 0$ for PPI inflation.

A.3 Zero Lower Bound (Proposition 3)

Assuming that we stay at the zero lower bound with probability μ, the solution is given by:

$$\tilde{y}_t = \Gamma_y^U r_t^n \tag{18}$$

$$\pi_{H,t} = \Gamma_\pi^U r_t^n \tag{19}$$

With

$$\Gamma_y^U = \frac{(1-\beta\mu)}{(1-\mu)(1-\beta\mu)\sigma - \kappa\mu} \tag{20}$$

and

$$\Gamma_\pi^U = \frac{\kappa}{(1-\mu)(1-\beta\mu)\sigma - \kappa\mu} \tag{21}$$

Follwoing Woodford, (2003) it can be shown that the solution is determinate as long as $(1-\mu)(1-\beta\mu)\sigma - \kappa\mu > 0$. It can also be shown that

$$\Gamma_y^U > \Pi_y \tag{22}$$

as long as $\kappa\phi_\pi > -\mu\sigma(1-\beta\mu) - \kappa\mu$ which holds for common parameter values and that

$$\Gamma_\pi^U > \Pi_\pi \tag{23}$$

as long as $\kappa(\phi_\pi - \mu) > \sigma\mu(\beta(\mu-1)-1))$ which is true if $\mu < 1$ and $\phi_\pi > 1$.

B Survey Appendix

B.1 Demographic Questions

First, we ask all respondents the following demographic questions:

D1: Please enter your age.

D2 Please indicate your gender.

- *Male*
- *Female*
- *Other*

D3: How would you identify your ethnicity? Please select all that apply.

- *Asian/Asian American*
- *Black/African American*
- *White/Caucasian*
- *Other*
- *Prefer not to say*

D4: Do you consider yourself of Hispanic, Latino or Spanish origin?

- *Yes*
- *No*

D5: Please indicate the range of your yearly net disposable income.

- *Less than $10,000*
- *$10,000 - $19,999*
- *$20,000 - $34,999*
- *$35,000 - $49,999*
- *$50,000 - $99,999*
- *$100,000 - $199,999*
- *More than $200,000*

D6: In which state do you currently reside?

D7: What is the postal (zip) code for the address of your permanent residence?

D8: What is the highest level of school you have completed, or the highest degree you have achieved?

- *Less than high school*
- *High school diploma or equivalent*
- *Some college, but no degree*
- *Bachelor's degree*
- *Master's degree*
- *Doctorate or Professional Degree*

D9: How many children do you have?

D10: What is the percent chance that you will leave any inheritance?

B.2 Questions on climate change

Q1: The average growth rate of real GDP in the US between 2009 and 2019 has been about 2 percent. Climate change might influence future growth rates positively, say, because it triggers technological innovation or negatively because of regulation and taxes.
What do you think is the overall impact of climate change on economic growth over the next 12 months? Please assign probabilities to each scenario listed below:
Due to climate change, economic growth, compared to what it would be otherwise, will be

- *2 percentage points higher or more (say, more than 4 percent rather than 2)*
- *1 - 2 percentage points higher (say, between 3 and 4 percent rather than 2)*
- *0.1 - 1 percentage points higher (say, between 2.1 and 3 percent rather than 2)*
- *different by -0.1 to 0.1 percentage points.*
- *0.1 - 1 percentage points lower (say, between 1 and 1.9 percent rather than 2)*
- *1 - 2 percentage points lower (say, between 0 and 1 percent rather than 2)*
- *2 percentage points lower or more (say, less than 0 percent rather than 2)*

Q2: Recently, the economic damage due to natural disasters amounted to about 1% of GDP per year (Source: National Center for Environmental Information). In your view, will these damages be larger or smaller because of climate change? Please assign probabilities to each scenario listed below:
Specifically, what would you say is the percent chance that, over the next 12 month there will be . . .

- *no damage.*
- *less damage then in the past. (say, around 0.5% of GDP)*
- *the same as in the past. (say, 1% of GDP)*
- *more damage than in the past. (say, 1.5% of GDP)*
- *considerably more than in the past (say, 2% of GDP)*
- *much more than in the past (say, 3% of GDP)*
- *extremely rare disasters, with damage in an order of 5% of GDP.*

Q3: ***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).***
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.
Half the respondents were given the treatment (in bold letters) before the question.

B.3 Questions on Media Usage and Political Affiliation

Some respondents were additionally given the following questions:

P1: What would you say is your political affiliation?

- *Democrat*
- *Independent*
- *Republican*
- *Other*

P2: Please select your preferred news station from the list below: (you might pick more than one answer)

- *ABC*
- *CBS*
- *CNN*
- *Fox*
- *MSNBC*
- *NBC*
- *PBS*
- *Other*
- *I do not watch any of these TV/news stations.*

P3: Please select your preferred newspaper (print or online) from the list below: (you might pick more than one answer)

- *Washington Post*
- *Wall Street Journal*
- *New York Times*
- *USA Today*
- *Los Angeles Times*
- *Other*
- *I do not read any of those newspapers.*