Journal of Behavioral and Experimental Finance 37 (2023) 100710

Contents lists available at ScienceDirect

Journal of Behavioral and Experimental Finance

journal homepage: www.elsevier.com/locate/jbef

Full length article

Extreme local temperatures lower expressed sentiment about U.S. economic conditions with implications for the stock returns of local firms

Christos A. Makridis [a], Jason D. Schloetzer [b,*,1]

[a] Stanford University, Stanford Digital Economy Lab, Stanford, CA 94305, USA
[b] Georgetown University, McDonough School of Business, Washington, DC 20057, USA

ARTICLE INFO

Article history:
Received 14 March 2022
Received in revised form 29 June 2022
Accepted 1 July 2022
Available online 8 July 2022

JEL classification:
G12
G14
G41
M41
D91
Q54

Keywords:
Economic sentiment
Climate
Limited attention
Investor psychology
Capital markets
Asset prices

ABSTRACT

We draw from research that finds local weather conditions affect individuals' belief-formation process and asset prices to investigate whether "extreme" local temperatures impact individuals' beliefs about U.S. economic conditions (i.e., economic sentiment) and the stock returns of local firms. We combine Gallup's U.S. Daily Poll, which provides the daily-level economic sentiment of a population-representative random sample of 1.5 million individuals, with daily weather conditions based on survey respondent location. We document that extreme local temperatures decrease individuals' sentiment about the U.S. economy and that this decrease relates to declines in the stock returns of local firms. Further tests distinguish this extreme local temperature–sentiment effect from the effect of perceived life satisfaction on individuals' economic sentiment, suggesting that the potential effect of extreme temperatures on individuals' moods is not driving our results. We conclude that extreme local temperatures affect individuals' sentiment about economic activity beyond the potential effect of temperature on firm- or local-level economic variables, with implications for stock returns.

1. Introduction

Scholars across economics and finance, among other disciplines, are naturally interested in individuals' views about economic activity and their potential impact on real economic outcomes. For instance, studies find that investors' beliefs about future cash flows and investment risks are a strong negative predictor of asset prices, suggesting that such sentiment is a behavioral factor associated with asset prices that diverge from their fundamental values (DeLong et al., 1990; Shefrin, 2005). The consequences of individuals' views about economic activity relate to other economic outcomes, such as influencing managers' disclosure choices and analysts' earnings forecasts (Bergman and Roychowdhury, 2008; Seybert and Yang, 2012; Brown et al., 2012; Bochkay and Dimitrov, 2015; Jiang et al., 2019). The underlying reasoning for such consequences is that individuals throughout the economy are affected by behavioral factors that cause them to form overly optimistic or pessimistic beliefs about the future (e.g., Shleifer (2000)). Despite the important implications of individuals' views about economic activity, relatively less is known about how individuals *form* such beliefs.

This paper extends our understanding of the economic implications of sentiment by investigating how individuals form beliefs about U.S. economic conditions and linking these beliefs to stock returns. We broadly define the notion of economic sentiment as reflecting a belief about the state of the U.S. economy that is not justified by the available facts (hereafter, *economic sentiment*). We situate our work in the broader literature on how individuals incorporate information about local shocks in their belief formation process (Johnson and Tversky, 1983; Arkes et al., 1988; Saunders,

* Corresponding author.
E-mail addresses: cmakridi@stanford.edu (C.A. Makridis), jds99@georgetown.edu (J.D. Schloetzer).

[1] We thank Lint Barrage, Tatyana Deryugina, Lisa Kramer, Howard Kunreuther, Charles Lee, Elena Simintzi, Uri Simonsohn, and Ayung Tseng for helpful suggestions. We are grateful to David Hirshleifer for a series of insightful conversations, Nick Obradovich for generously sharing the PRISM data, and Yi-Lin Tsai (United Nations Data Pulse project) for helpful discussions. We appreciate assistance from Kris Hodgins (Gallup) and Ron Nakao (Stanford) to organize the Gallup-Sharecare Well Being Index and Gallup for its academic partnership. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

https://doi.org/10.1016/j.jbef.2022.100710
2214-6350/

1993; Hirshleifer and Shumway, 2003; Cao and Wei, 2005) and how personal experiences impact beliefs (Malmendier and Nagel, 2016; Bailey et al., 2018). We then draw on studies linking local weather conditions with individuals' psychological states to investigate whether a behavioral factor–namely, perceived life satisfaction–contributes to the formation of economic sentiment and, in turn, influences stock returns. As a result, we conjecture that individuals' psychological states impact the formation of economic sentiment with implications for asset prices, leveraging variation in local weather conditions to develop our identification strategy.

We use data from Gallup's U.S. Daily Poll to test our framework. The U.S. Daily Poll measures individuals' economic sentiment and well-being from a population-representative randomly sampled group of 1,000 U.S. citizens per day. This high-frequency data has at least two features that make it well-suited for our analyses. First, Gallup's infrastructure and expertise enable it to conduct large-scale, well-organized surveys using similar questions over long periods. Second, the survey collects respondents' geographic information, enabling us to study the formation of economic sentiment after accounting for local labor and housing market shocks that likely relate to individuals' sentiment about U.S. economic conditions. We link the U.S. Daily Poll data with daily county-level temperatures from 2008 to 2018, yielding a sample of 1.5 million respondent-days. This empirical design allows us to use plausibly exogenous variation in local temperature to study the formation of economic sentiment and its implications for daily asset prices. Furthermore, we can use respondents' self-reported well-being data to investigate a potential behavioral factor through which these results occur.

The analysis proceeds in three steps. We first use the Gallup data to study the relationship between local temperature and individuals' economic sentiment. Consistent with an interplay between weather and individuals' economic sentiment, our tests reveal that an additional degree increase in what we label as "extreme" temperatures (below 15 degrees or above 85 degrees Fahrenheit) is associated with a 0.2-0.4pp decline in individuals' sentiment about the strength of the U.S. economy, particularly individuals' sentiment towards future economic conditions.[2] Hence, extreme local temperatures reduce individuals' perceptions of U.S. economic conditions, particularly perceptions of future economic activity.

Next, we use the Gallup data to examine a potential mechanism through which these results manifest–individuals' perceived life satisfaction. Our results indicate that increases in perceived life satisfaction relate to increases in economic sentiment, which is compatible with models in which behavioral factors affect projections about the future independent of available information (Loewenstein et al., 2000; Mehra and Sah, 2002). Of particular interest, we show that the temperature–sentiment effect cannot be explained by the life satisfaction–sentiment effect, suggesting that, while individuals' psychological states extend to their sentiment regarding economic activity, they do not explain the temperature–sentiment relationship. Therefore, we document that the effect of extreme local temperatures on assessments of U.S. economic conditions forms separately from the relationship between perceived life satisfaction and sentiment, suggestive of the strength of the effect of extreme local temperatures on economic sentiment.

Given the evidence of an interrelation between local daily temperature and economic sentiment, the third step in our analysis establishes economic implications by investigating the relation between temperature, economic sentiment, and asset prices. We link daily county-level temperatures with the daily stock returns of local firms using corporate headquarters to proxy for location—we take this assumption from the literature on investor "home bias" (Coval and Moskowitz, 1999). Our baseline specification exploits daily temperature fluctuations within-county and is conditional on a rich set of individuals' demographic and income characteristics and local labor and housing market conditions. The results show that an additional degree increase at extreme temperatures is associated with a 0.2-0.3pp decline in the stock returns of local firms; the result persists after accounting for the potential contemporaneous effect of temperature on firm- and local-level productivity. To strengthen the interpretation of an economic sentiment effect, we document a positive association between economic sentiment and the monthly stock returns of local firms. Overall, our evidence highlights how extreme temperatures affect the process through which individuals form beliefs about economic activity, with implications for stock returns.

Our paper extends the literature on the capital market implications of individuals' beliefs about economic activity. Focusing on the sentiment of capital market participants, Baker and Wurgler (2006), Baker and Wurgler (2007), Yu and Yuan (2011), Baker et al. (2012), Stambaugh et al. (2012), and Huang et al. (2015), among others, provide evidence of return predictability with stock market-based investor sentiment measures. Other work examines the potential implications of such sentiment on manager and analyst outcomes. For example, managers reduce the frequency of long-term earnings forecasts and are more likely to disclose pro forma earnings when sentiment is high (Bergman and Roychowdhury (2008), Brown et al. (2012)), while Hribar and McInnis (2012) find that analysts' earnings forecasts are more optimistic for difficult-to-value firms in periods of high investor sentiment. Related work focuses on the measurement of sentiment (Arif and Lee, 2014; Jiang et al., 2019; Gregory, 2021). Our paper contributes to this literature by shifting attention to how individuals *form* their sentiment about economic activity. We examine the formation of individuals' sentiment about U.S. economic conditions and establish that extreme local temperatures help explain variation in economic sentiment *beyond* the effect of temperature on firm- or local-level economic variables. Moreover, our evidence indicates that life satisfaction is unlikely to be the driving force behind this temperature–economic sentiment relationship. We note this result is not in conflict with research on how mood affects abstract and cognitively-intensive judgment (Schwarz and Clore, 1983; Forgas, 1995); we indeed find strong empirical evidence that decreases (increases) in perceived life satisfaction relate to decreases (increases) in individuals' economic sentiment. Instead, our findings point out that extreme local temperatures do not impact this behavioral factor (i.e., life satisfaction). We conclude that, while individuals' psychological states extend to their sentiment regarding economic activity through perceptions of life satisfaction, our findings on decreases in individuals' economic sentiment from extreme local temperatures are not driven by temperature-induced decreases in perceived life satisfaction. This finding provides new insights into our understanding of the hypothesized link between emotions and assessments of future prospects (Johnson and Tversky, 1983; Arkes et al., 1988). We then show that the extreme local temperature–sentiment effect impacts the stock returns of local firms.

Finally, our results raise the possibility of future research along several broad themes. For example, our evidence regarding the impact of temperature on economic sentiment suggests the interesting potential for scholars to uncover whether changing local temperatures contribute to the formation of managers' firm-specific sentiment (i.e., the formation of manager sentiment;

[2] We follow the environmental economics literature (e.g., Deschenes and Greenstone (2011)) to define the temperature bins we use throughout our study: below 15 degrees Fahrenheit, 16–30, 31–53, 54–59, 60–70, 71–84, and above 85 degrees Fahrenheit.

see Jiang et al. (2019) for more about the capital market implications of manager sentiment). Furthermore, our findings suggest climate-related impacts might influence managerial decisions internal to the firm that require assessments of the future, such as forecasting, target setting, and capital investment decisions. More generally, given the development of asset pricing models seeking to quantify the economic effects of climate change (Giglio et al., 2015; Bansal et al., 2016), studies of the mechanisms through which climate affects the sentiment of economic agents and economic activity is of increasing interest. Our evidence of a null relationship between extreme local temperatures and individuals' perceived life satisfaction contributes to the discussion of how climate factors such as temperature influence behavioral factors that ultimately contribute to the sentiment of economic agents.

The remainder of the paper proceeds as follows. Section 2 reviews related literature and develops our hypotheses. Section 3 describes the sample and provides descriptive statistics. Section 4 presents our results, and Section 5 concludes.

2. Previous literature and hypotheses development

Our study relates to three prominent streams of literature, which examine whether sentiment affects stock prices and the activities of capital market participants (e.g., managers, analysts), the micro-foundations of sentiment formation and their impact on various economic outcomes, and the role of climate in influencing individuals' beliefs and economic outcomes. The key innovation of our study is leveraging research on how climate factors affect psychological states to examine how individuals form beliefs about U.S. economic conditions and their implications for stock returns within a unified framework. Taking this approach, we present evidence that extreme local temperatures help explain variation in economic sentiment beyond the effect of temperature on firm- or local-level economic variables. We then show that individuals' perceived life satisfaction is unlikely to be the driving force behind this temperature–economic sentiment relationship. Lastly, we offer evidence that this extreme local temperature–economic sentiment effect impacts stock returns.

At least as early as Keynes (1936), researchers have investigated whether sentiment about economic activity affects economic outcomes. The notion that underlies these studies is that individuals with high (low) sentiment tend to make overly optimistic (pessimistic) judgments and choices. One large area of sentiment research deals with investor sentiment, with studies such as DeLong et al. (1990), Shleifer and Vishny (1997), and Shleifer (2000) laying out the foundations regarding investors being subject to sentiment. These foundations were extended by studies examining the association between various measures of investor and, more recently, manager sentiment and important economic outcomes. For instance, Baker and Wurgler (2006), Baker and Wurgler (2007), Yu and Yuan (2011), Baker et al. (2012), Stambaugh et al. (2012) and many others provide evidence of return predictability with stock market-based investor sentiment measures. Other work focuses on different approaches to measuring investor sentiment (Arif and Lee, 2014; Huang et al., 2015).[3] Research also examines the implications of investor sentiment for economic activity other than stock returns, including managers' disclosure behavior and analysts' forecasts (e.g., Bergman and Roychowdhury (2008), Brown et al. (2012), and Hribar and McInnis (2012)). Taken together, studies demonstrate that the sentiment of individuals about an important aspect of the broader economy (i.e., capital markets) affects asset prices and the activities of economic actors (e.g., managers, analysts).

A related but largely parallel literature focuses on the micro-foundations of sentiment, seeking to understand the broader notion of sentiment formation and its implications across a wide array of non-economic and economic outcomes. Within this literature, studies often appeal to psychological foundations, such that uncertainty means that the effect of overconfidence, representitiveness, and conservatism is more pronounced (Daniel et al., 1988; Barberis et al., 1998; Shleifer, 2000). On the importance of personal experience, macroeconomic theory models have long emphasized the presence of learning from experience (Bray, 1982; Marcet and Sargent, 1983; Sargent, 1993). Agents in these models use adaptive-learning algorithms as heuristics to avoid cognitive and computational constraints associated with devoting attention to and processing every piece of information. Recent empirical work demonstrates the role of personal experience in shaping beliefs about inflation (Malmendier and Nagel, 2016) and housing price growth (Kuchler and Zafar, 2019), while other work investigates the relationship between learning about climate and assessments of rare disaster risk (Gillman et al., 2015; Lu and Siemer, 2016). Overall, this line of research finds that behavioral factors serve as micro-foundations of sentiment formation, with implications for important non-economic and economic activity.

Within these two streams of literature, an emerging set of studies investigates how climate factors (e.g., pollution, lack of sunshine) impact individuals' beliefs and behaviors and how such climate factors affect economic outcomes. Studies generally find that climate factors impact individual beliefs and behaviors. For example, Baylis (2020) and Baylis et al. (2018) analyze social media posts to show that temperature influences individuals' underlying hedonic states. Deryugina (2013) uses environmental polling data to study how temperature affects beliefs about the probability of climate change, finding evidence that long-run shocks to temperature indeed have an effect. Herrnstadt and Muehlegger (2014) examine Google search data and find that hotter temperatures raise the frequency that people search for the terms "global warming" or "climate change" during winter and summer months. Anderson et al. (2013) find that individuals generally create reasonable forecasts about future energy prices, but considerable heterogeneity mirrors the variation in the valuation of energy efficiency programs. Moreover, there is a general recognition that weather affects macroeconomic activity (Gallup et al., 1999; Dell et al., 2012), with recent empirical evidence pointing to the non-linear effects (Burke et al., 2015) and persistent effects (Hsiang and Jina, 2014) of climate factors on economic growth.[4]

There is also growing evidence of the microeconomic effects of weather events on human behavior. For example, Obradovich and Fowler (2017) find that temperature increases may lead to a net increase in recreational activity. However, Obradovich et al. (2018) document an important consequence: short-term exposure to extreme weather events can lead to declines in mental health. These papers are consistent with evidence on the adverse effects of temperature on student test scores (Park et al., 2020; Park, 2019) and pollution on subjective well-being (Zheng et al., 2019). Other work builds from an extensive psychology literature that shows how mood influences abstract and cognitively-intensive judgment, especially in the absence of concrete and full information (Schwarz and Clore, 1983; Forgas, 1995), and how emotions affect assessments of future prospects (Johnson and Tversky, 1983; Arkes et al., 1988), to show, for instance, that a lack of sunshine not only increases the likelihood of depression (Eagles, 1994) and suicide (Tietjen and Kripke, 1994), but also decreases stock returns (Saunders, 1993; Hirshleifer

[3] See, for example, Zhou [2018] for a review of how studies measure investor sentiment.

[4] See Diaz and Moore (2017) for a survey of the literature and current systems modeling approaches.

Table 1
Main Gallup U.S. daily poll survey questions.

Variable	Survey question	Rating
Life satisfaction	Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?	0–10 scale
Expected future life satisfaction	On which step do you think you will stand about five years from now?	0–10 scale
Perception of current economic activity	How would you rate economic conditions in this country today: as excellent, good, only fair, or poor?	1–4 scale
Perception of future economic activity	Right now, do you think that economic conditions in this country, as a whole, are getting better, staying the same, or getting worse?	1–3 scale

Notes.- The table reports the survey questions and associated rating index used by Gallup when speaking with respondents.

and Shumway, 2003; Cao and Wei, 2005).[5] Weather conditions influence even financially sophisticated investors. For example, Goetzmann et al. (2015) show that cloud cover influences perceptions of market mispricing among institutional investors, and Goetzmann and Zhu (2005) show that cloud cover influences retail investor propensities to buy and sell. In this sense, the fact that climate factors influence sophisticated investors is consistent with the view that "mood betas" help explain security prices (Hirshleifer et al., 2018). However, such studies do not explicitly incorporate tests of whether behavioral factors indeed drive the observed relations between weather conditions and economic outcomes.

In summary, our study examines how individuals form beliefs about U.S. economic conditions and their implication for stock returns through the following three predictions. First, extending studies that find weather events affect the formation of individuals' beliefs and human behavior, we expect that extreme local temperatures will be negatively associated with individuals' sentiment about U.S. economic conditions. Second, we anticipate that temperature-induced changes to behavioral factors will be a mechanism through which temperature influences economic sentiment. Finally, consistent with studies that link sentiment about economic activity with stock returns, we expect that these temperature-induced effects on economic sentiment will be negatively associated with stock returns. Overall, we complement and extend our understanding of the link between how individuals form beliefs about economic activity and the relation between these beliefs and real economic outcomes by quantifying how extreme local temperatures influence individuals' economic sentiment and its implications for asset prices.

3. Sample and descriptive statistics

Our primary data source consists of licensed data from Gallup's U.S. Daily Poll, which surveys 1,000 population-representative randomly sampled individuals per day on various political, economic, and well-being topics.[6] To construct the U.S. Daily Poll, approximately 200 Gallup interviewers conduct computer-assisted telephone interviews with respondents aged 18 and over from all 50 states and the District of Columbia. Gallup's polling procedures are methodical; they use live rather than automated interviews administered in English or Spanish, dual-frame sampling, including random-digit-dial, of landline and wireless phone numbers, and a three-call design to reach respondents who do not answer the original attempt.

The sampling frame (2008 through 2018) reaches each of the more than 3000 U.S. counties, with over 1000 counties having at least 300 respondents. Half of the respondents receive the "well-being track" version of the survey (with a nine percent survey response rate), while the other half receives the "politics and economy track" version (with a 12 percent survey response rate). The two surveys contain different topical questions, but both have identical identifying demographic information. Gallup combines the survey responses with detailed location data, including the ZIP Code and metro area, and is available with corresponding sample weights. While Gallup modified a subset of survey questions in 2014, the main variables we require are available from 2008 to 2018 without modification. Table 1 presents survey questions about economic sentiment and well-being, which Gallup labels as life satisfaction.

We then obtain weather data by matching the U.S. Daily Poll data to daily county average temperature and precipitation data from PRISM Climate Group's AN81d gridded weather data set. The data set provides measurements at approximately 4 × 4 kilometer grid cells for the U.S. using the Parameter-elevation Relationships on Independent Slopes Model (PRISM). PRISM interpolates measurements from over 10,000 weather stations and corrects terms based on a regression that accounts for altitude and other influences on local weather that a distance-based interpolation method may fail to capture (Daly et al., 2002). Like others have noted (e.g., Baylis (2020)), we use the forward value on maximum daily temperature and precipitation because PRISM days are defined using a "day-end naming" standard.[7] We aggregate the gridded data to a county × day frequency to coincide with the frequency of Gallup data in our sample.

To investigate the relationship between how individuals form beliefs about the economy and asset prices, we use daily returns net of dividends from CRSP. We then match these daily data to annual data from Compustat to obtain the ZIP Code of the headquarters and firm financial information (e.g., employment, revenues, capital expenditures). We cross-walk ZIP Codes into counties and use the location of the headquarters to proxy for local investment in the corresponding stock based on the result that local investors display a bias towards holding local stocks (Coval and Moskowitz, 1999).[8] Although linking counties to firms

[5] A related literature focuses on seasonal affective disorder as a source behind changes in the marginal investor's risk aversion and, therefore, helps account for the seasonality displayed in stock returns (Kamstra et al., 2003). Although there has been some dispute (e.g., Kelly and Meschke (2010)), but Kamstra et al. (2012) reconcile the perceived differences.

[6] These data have been used by Kahneman and Deaton (2010) to study the relation between well-being and income, and by Deaton (2012) to study well-being during the Great Recession.

[7] For further discussion, see "Yesterday's maximum temperature is...today's maximum temperature?" available here: http://www.g-feed.com/2017/07/yesterdays-maximum-temperature-is.html.

[8] Reasons for this behavior include investors have better information about local firms (Bernile et al., 2015) or place greater weight on personal experience (e.g., direct interactions with the firm). See Hirshleifer (2015) for a broad survey of the reasons behind behavioral inconsistencies among investors.

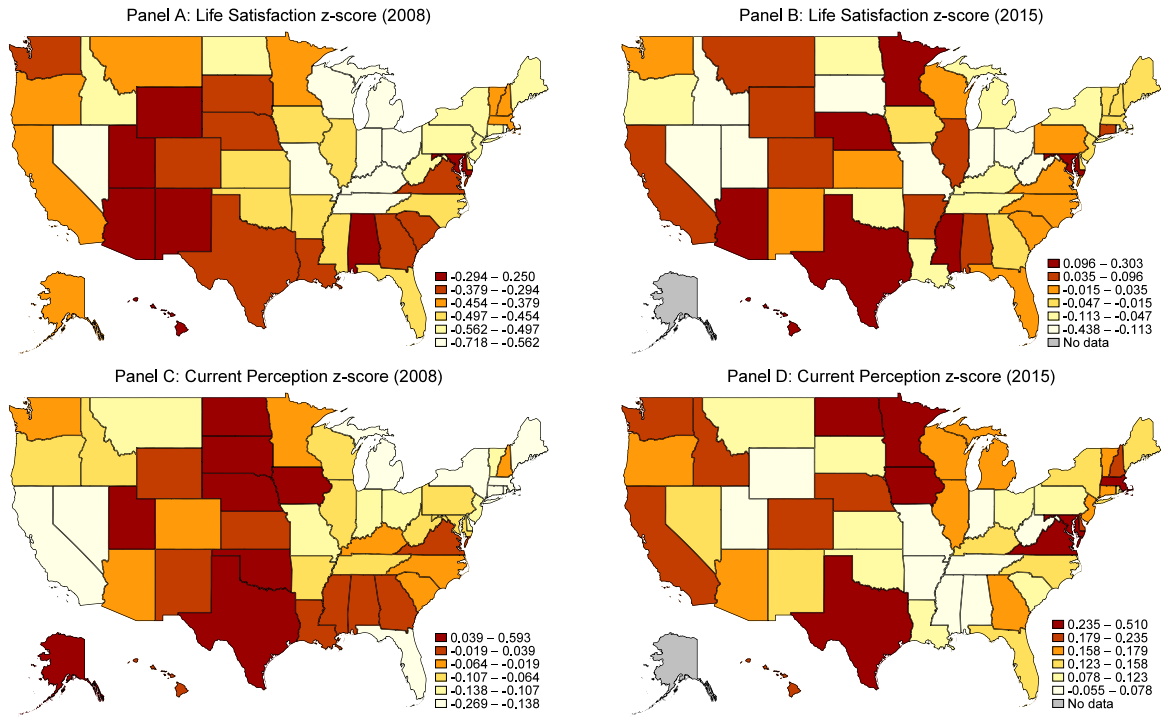

Fig. 1. Variation in Life Satisfaction and Economic Sentiment Across Time. *Notes*.-The figures plots the spatial variation across states for two sets of questions. For Panels A and B, the question asks participants: Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time? For Panels C and D, the question asks participants: How would you rate economic conditions in this country today: as excellent, good, only fair, or poor? We subsequently compute the z-score of the one to four index coded such that higher values represent more favorable responses. Sample weights are used to produce the state averages in the different years.

based on headquarters location introduces measurement error, it is a common approach within the literature (e.g., see Bernile et al. (2015) and Tuzel and Zhang (2017) for recent applications) and will only serve to attenuate any results that are present.[9]

Table 2 presents descriptive statistics regarding the resulting data set. Of note, the demographic information is comparable to other nationally representative data sets.[10] We report descriptive statistics in three time periods to mitigate concerns about a shifting composition of survey respondents over time. The typical respondent is 48 years old, 48 percent are male, 67–72 percent are Caucasian, 32 percent have a college degree, 51–54 percent are married, has approximately one child, and 59–63 percent are employed depending on the year. The data set has a strong representation throughout the income distribution. Although many of the individuals earning less than $1,500 in monthly income are unemployed or out of the labor force, roughly 49 percent of the sample is considered at least middle class (i.e., earning at least $3,500 per month).

We also document meaningful variation in economic sentiment. For instance, while between 2008 and 2010, only 27 percent of the sample reports that the economy will improve, this proportion increased to 42 percent by 2014–2017. Similarly, the share of individuals reporting that the current economy is in a good state nearly doubles from 13 percent to 24 percent between the 2008–2010 and 2014–2017 sample periods. To provide a visual characterization of spatial variation, Fig. 1 plots perceived life satisfaction and economic sentiment measures across all U.S. states in 2008 and 2017. Panels A and B reveal significant heterogeneity in the average z-score of current life satisfaction across states. Panels C and D plot the average z-score of perceptions about the current state of the economy, revealing significant heterogeneity in the average z-score of current economic sentiment.

Finally, we note evidence of significant variation in temperature across the sample period, with the lower and upper parts of the temperature distribution appearing in the data set (i.e., below 15 degrees and above 85 degrees, respectively).[11] Fig. 2 plots distributions of daily average temperature across four years—2008 compared with 2010 (Panel A), and 2014 compared with 2017 (Panel B). Because the identifying variation in the analyses will arise from fluctuations in average daily temperature, these plots highlight the wide array of variation available across space and time. Even though "extreme" temperatures (below 15 degrees Fahrenheit or above 85 degrees Fahrenheit) are, by construction, uncommon, Fig. 2 shows that there is still variation in the data. Specifically, roughly 2.9 percent of the sample experiences days less than 15 degrees Fahrenheit and 2.4 percent of the sample experiences days over 85 degrees Fahrenheit (untabulated).

4. Analysis

This section first examines individuals' economic sentiment formation using temperature as a plausibly exogenous identification strategy. We then investigate a potential channel through which individuals' psychological states impact economic sentiment formation–namely, perceived life satisfaction. Finally, we

[9] For example, Bernile et al. (2015) study the relation between the geographical dispersion of a firm's economic activities and investor portfolio decisions by linking firm activities to the states mentioned in the firm's Form 10-K.

[10] Gallup designs its polling methods to ensure such comparability. For details, see https://www.gallup.com/178685/methodology-center.aspx.

[11] As noted previously, we follow the environmental economics literature (e.g., Deschenes and Greenstone (2011)) to define the temperature bins we use throughout our study: below 15 degrees Fahrenheit, 16–30, 31–53, 54–59, 60–70, 71–84, and above 85 degrees Fahrenheit.

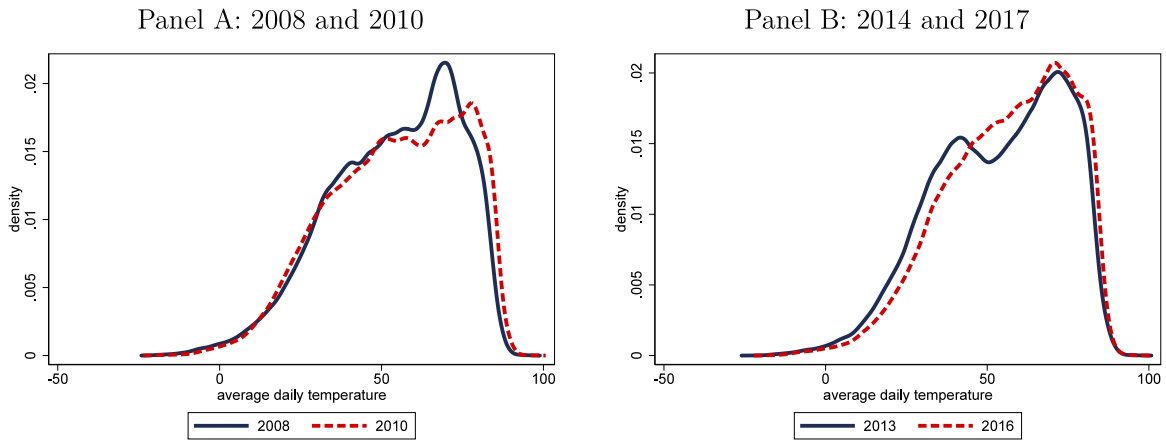

Fig. 2. Variation in Daily Temperatures Across Time. *Notes.*-The figure plots the distribution of daily temperatures in degrees Fahrenheit across counties for the respective year.

Table 2
Descriptive statistics.

	2008–2010		2011–2013		2014–2017	
	mean	sd	mean	sd	mean	sd
demographics						
College	0.32	0.47	0.32	0.47	0.32	0.47
Male	0.48	0.50	0.49	0.50	0.49	0.50
White	0.72	0.45	0.69	0.46	0.67	0.47
Age	48.4	18.1	47.7	18.8	48.1	19.1
Number of children	0.9	3.7	0.9	4.2	0.9	4.8
Married	0.54	0.50	0.52	0.50	0.51	0.50
Employed	0.59	0.49	0.62	0.48	0.63	0.48
income/sentiment						
Monthly income, <1500	0.26	0.44	0.25	0.43	0.22	0.41
Monthly income, 1500–2500	0.14	0.35	0.14	0.35	0.13	0.34
Monthly income, 2500–3500	0.12	0.32	0.12	0.32	0.11	0.31
Monthly income, 3500–5500	0.10	0.30	0.11	0.31	0.10	0.30
Monthly income, 5500–6500	0.17	0.38	0.17	0.38	0.17	0.38
Monthly income, 6500–8500	0.08	0.26	0.07	0.26	0.09	0.29
Monthly income, >8500	0.14	0.35	0.14	0.34	0.17	0.38
Good economy	0.13	0.33	0.15	0.36	0.24	0.43
Economy improving	0.27	0.45	0.40	0.49	0.42	0.49
Feeling good	0.62	0.48	0.65	0.48	0.67	0.47
temperature						
Below 15 F	0.02	0.13	0.01	0.11	0.02	0.15
16–30 F	0.08	0.27	0.06	0.24	0.07	0.25
31–53 F	0.32	0.47	0.33	0.47	0.29	0.45
54–59 F	0.11	0.32	0.11	0.31	0.11	0.31
60–70 F	0.20	0.40	0.20	0.40	0.21	0.40
71–84 F	0.24	0.43	0.26	0.44	0.28	0.45
above 85 F	0.03	0.17	0.03	0.18	0.03	0.17
Observations	802952		822104		823541	

Notes.- The table reports individual demographic, income, economic sentiment, and county weather information. College, male, race, married, employed, good economy (reporting a current state of the economy index of 3 or 4), getting better (reporting a future of the economy index of 3), feeling good (life ladder is at least a 7 out of 10 index), income brackets and temperature bins are all measured as percentages. Age and number of children are measured as continuous variables. Sample weights are used.

examine the implications of these relations on daily and monthly stock returns to provide evidence of the economic implications of the results.

4.1. Formation of economic sentiment

We estimate the following model using daily variation in county-level temperature across time among observationally-equivalent individuals to conduct our analysis:

$$s_{icdt} = \psi^k T_{cdt} + \beta^k X_{it} + \eta^k_{ct} + \lambda^k_{dt} + \epsilon^k_{icdt}, \quad \forall k \tag{1}$$

where s, denotes the measure of economic sentiment from the U.S. Daily Poll, i indexes individuals, c indexes counties, d indexes the day of the year, t indexes the year-month, T is the temperature associated with the kth temperature bin, X is a vector of individual and weather covariates, and η and λ denote fixed effects on county and day of the year, respectively. We partition daily county temperature in degrees Fahrenheit into bins to allow for heterogeneous treatment effects across the temperature distribution. This empirical approach follows related work with one difference–to retain day-to-day variation in temperature, T denotes daily temperature instead of the number of days in a year between a particular temperature threshold. We cluster standard errors by county to allow for arbitrary degrees of autocorrelation within the same geography across time (Bertrand et al., 2004) and use population-representative sample weights.

The individual and weather covariates include common demographic characteristics and weather covariates motivated by prior research. For the demographic characteristics, Eq. (1) includes respondents' employment status, marital status, a quadratic in age, education fixed effects (less than high school, technical, some college, college, and more than college), and race fixed effects (White, non-White). For the weather covariates, we include historical county temperature as suggested by Simonsohn (2010), and precipitation, cloud cover, and rain to control for potentially spurious factors jointly correlated with temperature and economic sentiment. We also explore specifications that include county × year × month fixed effects to control for seasonal shocks that may affect a county, and the day-of-the-year fixed effects to control for aggregate shocks.

Fig. 3 plots the outcome from Eq. (1) using two measures of economic sentiment. Panel A measures national economic sentiment with a one to four index of perceptions about current economic conditions (Excellent, Good, Only Fair, Poor), and Panel B measures economic sentiment with an indicator for perceptions about whether economic activity will improve (Getting Better, Staying the Same, Getting Worse). Our specification allows the coefficients to vary across the temperature distribution. The panels show an inverse-U shape for both perceptions about current and future economic conditions, with the gradients for perceptions about the future economy reaching statistical significance. In particular, Panel B shows that an additional degree increase on days of extreme temperatures is associated with a 0.2-0.4pp decline in the probability that an individual reports the national economy will improve (p- value < 0.10 for the below 15 degrees temperature bin and p- value < 0.00 for the above 85 degrees temperature bin), whereas Panel A depicts a similar inverted U-shaped distribution on perceptions about the current

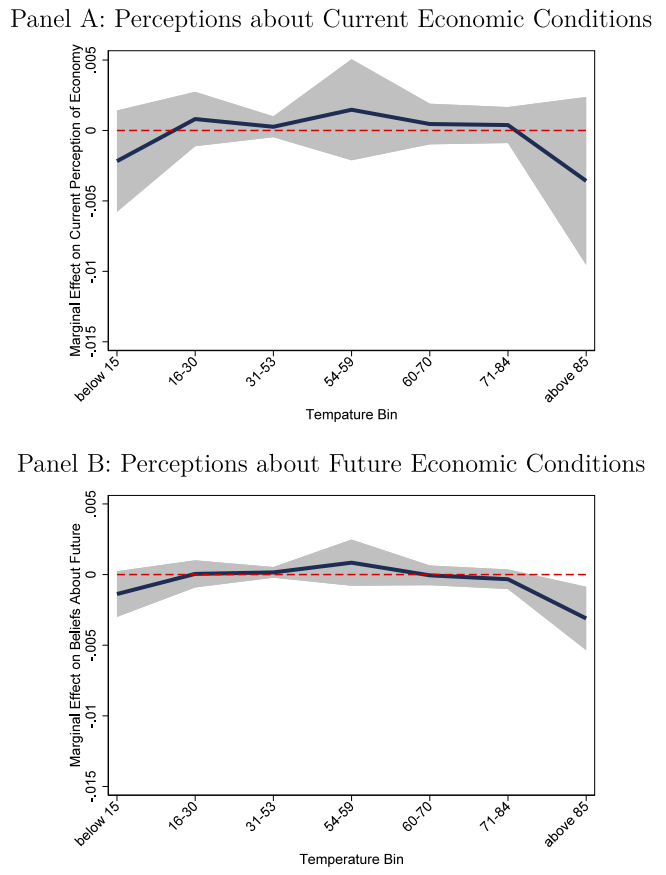

Fig. 3. Temperature and Economic Sentiment. *Notes.*-The figure plots the coefficients associated with regressions of the z-score of perceptions about current economic conditions (one to four index) and an indicator for the perception that future economic conditions will improve on average daily temperature interacted with bins on the temperature range (below 0, 0–15, 16–30, 31–53, 54–59, 60–70, 71–84, and above 85 degrees Fahrenheit), individual controls, conditional on county historical temperature and precipitation, individual demographics, and county and day-of-the-year fixed effects. Individual controls: an indicator for whether the individual is employed, marital status, a quadratic in age, male, education fixed effects (less than high school, technical, some college, college, and more than college), and race (White/non-White). Standard errors are clustered at the county-level and sample weights are used.

state of the economy, but the extreme local temperature bins do not reach conventional levels of statistical significance (p-value > 0.10). Hence, the results establish that extreme local temperatures reduce individuals' economic sentiment, particularly sentiment about future economic conditions.

Next, we explore these results in more detail by presenting a series of estimates obtained by regressing an indicator for individuals' perceptions about future economic conditions on a series of temperature measurements and interactions. This analysis is important because Deryugina (2013) emphasizes that both long-run temperature changes and temperature volatility influence individuals' beliefs about the future. Given that Fig. 3 illustrates that perceptions about the future, more so than the current, economic conditions are most sensitive to extreme local temperatures, it is important to examine whether the baseline result relates to long-run temperature changes and temperature volatility. Failing to find such a relation would call into question the drivers of the baseline result.

Column 1 in Table 3 confirms that the baseline result persists—a one degree increase in temperature is associated with a 0.024pp decline in the probability that an individual reports the national economy will improve. Motivated by the non-linearities in Fig. 3, column 2 interacts daily temperature with an indicator for extreme temperatures on that day. As column 2 reports, extreme temperatures are associated with an incremental 0.012pp decline in economic sentiment. Column 3 interacts daily temperature with an indicator for whether the individual is at least 65 years old, capturing the fact that older individuals may be more heat-sensitive.[12] Column 3 reports that the gradient of 0.036pp on this interaction term is roughly twice as large as the direct effect of 0.017pp, consistent with the view that heat-sensitive individuals will adjust their expectations more elastically.

Regarding alternative temperature measurements, column 4 shows that a 1pp rise in the five-year temperature growth rate is associated with a sizable 6.011pp decrease in the probability that individuals report that economic conditions will improve. The fact that the gradient is so large compared to transient daily temperature fluctuations is consistent with the evidence in Deryugina (2013) that long-run shifts in temperature are most salient to individuals. Column 5 subsequently shows that increases in temperature dispersion also cause declines in economic sentiment, consistent with studies that show individuals prefer more stable climates (Albouy et al., 2015). Finally, column 6 provides robustness by showing that the main results persist when using logged daily temperature–a one percent increase in temperature is associated with a 0.501pp decrease in the probability that individuals perceive that economic conditions will improve. Of note, all coefficients are identified from within-county variation after controlling for real economic activity (i.e., quarterly county employment, housing price growth) and the set of demographic and weather covariates previously discussed (employment status, marital status, a quadratic in age, education fixed effects, race fixed effects, historical county temperature, precipitation, cloud cover, and rain). Collectively, these results are consistent with our first prediction–local temperature, particularly extreme local temperatures, is negatively associated with individuals' sentiment about the U.S. economy.

We discuss two potential concerns with these results before concluding this subsection. Wilson (2019) suggests that weather predicts changes in employment, potentially due to its effect on the timing and magnitude of non-durables consumption. In Eq. (1), if day-to-day temperature changes influence real economic factors, the variation in economic sentiment could arise indirectly due to the county-level economic consequences of temperature fluctuations (e.g., lower employment) rather than temperature per se. To assuage such concerns, note that our results are robust to the inclusion of county × year × month fixed effects, which removes variation from any potential real economic factors. Moreover, our results persist when we include quarterly county-level employment and county-level growth in housing prices as additional controls (untabulated). Second, temperature fluctuations might affect the composition of survey respondents across time. We examine this potential concern by replacing the dependent variable in Eq. (1) with an indicator for college attainment. We find no evidence of differential selection–the gradient on daily temperature is 0.00045 (p- value = 0.431, untabulated) for the coldest temperature bin and 0.00055 (p- value = 0.603, untabulated) for the warmest temperature bin. Thus, it is unlikely that temperature fluctuations unduly impact the composition of survey respondents. Overall, our results are robust to these potential concerns, indicating support for our first prediction.

[12] For further discussion, see "Heat and older adults" available here: https://www.cdc.gov/disasters/extremeheat/older-adults-heat.html.

Table 3
Temperature and economic sentiment.

Dep. var. =	1[future state of the economy is improving]					
	(1)	(2)	(3)	(4)	(5)	(6)
daily temperature	−.00024***	−.00023***	−.00017***			
	[.00006]	[.00006]	[.00006]			
×1[extreme temp.]		−.00012*				
		[.00007]				
5-year temperature growth				−.06011***		
				[.00523]		
×1[age > 65]			−.00036***			
			[.00006]			
sd(daily temperature)					−.00080***	
					[.00030]	
ln(daily temperature)						−.00501***
						[.00190]
R-squared	.09	.09	.09	.09	.09	.09
Sample Size	1536762	1540661	1536762	1361805	1536762	1533201
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes.- The table reports the coefficients associated with regressions of the z-score of perceptions about the current state of the economy (one to four index) and an indicator for the perception that the future state of the economy will improve on different measures of average daily temperature (in Fahrenheit), conditional on year-to-year county employment and housing price growth, daily precipitation and historical county average, county and day-of-the-year fixed effects, and the following individual controls: day of the week fixed effects, an indicator for whether the individual is employed, marital status, a quadratic in age, male, education fixed effects (less than high school, technical, some college, college, and more than college), and race (White/non-White). The different measures of temperature are: daily average temperature, its interaction with an indicator for whether that particular day has extreme temperatures (below 15 or above 85 degrees Fahrenheit), an interaction for whether the individual is in a sensitive age group (defined as over age 65), the five-year growth rate in monthly temperature, the standard deviation of temperature over the year, and logged daily temperature. Standard errors are clustered at the county-level and sample weights are used.

4.2. Evidence on potential mechanisms

One potential reason that extreme local temperatures affect beliefs about economic sentiment is that extreme temperatures adversely influence behavioral factors that, in turn, explain the temperature–sentiment relationship. We explore this potential by drawing on the Gallup U.S. Daily Poll data regarding individuals' perceived life satisfaction to investigate the interplay between economic sentiment and perceived life satisfaction through regressions of the form:

$$s_{it} = \xi l_{it} + \omega w_{it} + \beta X_{it} + \eta_c + \lambda_t + \epsilon_{ict} \quad (2)$$

where l denotes a standardized z-score of an individual's self-reported life satisfaction (one to ten scale), w denotes individual monthly income bins, X is the vector of individual and weather covariates discussed previously (employment status, marital status, a quadratic in age, education fixed effects, race fixed effects, historical county temperature, precipitation, cloud cover, and rain), and η and λ denote fixed effects on county and day of the year, respectively. The identifying assumption is that unobserved shocks to individuals' economic sentiment are uncorrelated with their self-reported life satisfaction.

Table 4 reports the results. We find that a standard deviation increase in perceived life satisfaction is associated with a 0.18sd increase (column 1) in perceptions about the current state of the economy and a 0.047pp increase (column 4) in the probability that an individual reports the economy will improve. Of note, these estimates are robust to specifications containing both industry and income fixed effects as controls (columns 2–3 and 5–6). In this sense, while we cannot control fully for selection effects, the invariance of these estimates to including detailed controls suggests that the relationship is meaningful. Hence, we find that a behavioral factor–perceived life satisfaction–influences individuals' economic sentiment.

Next, we examine whether this life satisfaction–sentiment relationship explains the temperature–sentiment relationship documented previously. We explore this by estimating analogous regressions to Eq. (1), but using life satisfaction instead of economic sentiment as the dependent variable. Fig. 4 plots the outcome from Eq. (1) using two measures of perceived life satisfaction–a z-score of perceived current life satisfaction and an indicator for whether an individual is thriving, defined by Gallup as incorporating both current and expected future life satisfaction. Again, our specification allows the coefficients to vary across the temperature distribution. The panels fail to show a strong inverse-U shape for both perceptions about current life satisfaction (Panel A) and whether an individual is thriving (Panel B). Hence, the null associations and large confidence intervals suggest that life satisfaction is unlikely to be the driving force behind the temperature–economic sentiment relationship documented previously. That is not to disagree with prior research on how mood affects abstract and cognitively-intensive judgment (Schwarz and Clore, 1983; Forgas, 1995), but instead to point out that extreme local temperatures do not impact this behavioral factor. We conclude that, while individuals' psychological states extend to their sentiment regarding economic activity through perceptions of life satisfaction, our evidence on decreases in individuals' economic sentiment from extreme temperatures is not due to temperature-induced decreases in perceived life satisfaction.

4.3. Economic sentiment and asset prices

The evidence presented in the preceding subsections links extreme local temperatures to the formation of economic sentiment. Motivated by this evidence, we examine their real economic implications for firm-level stock returns using the following specification:

$$r_{jcdt} = \psi^k T_{cdt} + \eta_j^k + \Phi_{ct}^k + \lambda_{dt}^k + \epsilon_{jcdt}^k, \quad \forall k \quad (3)$$

where r denotes the stock return net of dividends, j indexes firms, c indexes counties, d indexes the day of the year, t indexes year-month, η and λ denote firm and year / month fixed effects, and k denotes the temperature bin (below 15 degrees Fahrenheit, 16–30, 31–53, 54–59, 60–70, 71–84, and above 85 degrees Fahrenheit). We again cluster standard errors at the county-level

Table 4
Perceived life satisfaction and economic sentiment.

Dep. var. =	State of the Economy (z-score)			Believes Economy is Improving		
	(1)	(2)	(3)	(4)	(5)	(6)
Life Satisfaction (z-score)	.180***	.191***	.190***	.047***	.049***	.049***
	[.001]	[.002]	[.002]	[.001]	[.001]	[.001]
R-squared	.12	.11	.12	.10	.12	.12
Sample Size	1643323	785430	679085	1620427	776215	671994
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Income FE	No	No	Yes	No	No	Yes

Notes.- The table reports the coefficients associated with regressions of standardized (z-score) perceptions about current economic conditions (one to four index) and an indicator for beliefs that economic conditions will improve on standardized current life satisfaction (zero to ten index), conditional on county historical temperature and precipitation, individual demographics, and county and day-of-the-year fixed effects. Individual controls: an indicator for whether the individual is employed, marital status, a quadratic in age, male, education fixed effects (less than high school, technical, some college, college, and more than college, and race (White/non-White). Industry fixed effects include: professional services (e.g., lawyer), manager or executive, business owner, clerical or office, sales, service, construction or mining, transportation, installation or repair worker, farming/fishing/forestry, or other. Income fixed effects include: under $720, $720–5,999, 6,00–11,999, $12,00–23,999, $24,000–35,999, $36,00–47,999, $48,000–59,999, $60,000–89,999, $90,000–119,999 and over $120,000. Standard errors are clustered at the county-level and sample weights are used.

and use sample weights. To generate spatial variation in stock returns, we proxy the location of each firm by the county that their headquarters resides in based on the insight from Coval and Moskowitz (1999) that investors display a strong preference for investing close to home, as discussed previously.

The coefficient of interest, ψ, is identified by within-county fluctuations in daily temperature. The inclusion of firm and year / month fixed effects removes time-invariant heterogeneity across firms that might be driven by seasonality; for example, firms with goods in higher demand during the winter are also more productive. We note that including other firm-level controls (i.e., total employment, total assets) and location-level controls (i.e., local employment and growth in housing prices) do not alter the results. We omit these controls due to the potential concern that endogeneity between stock prices and firm fundamentals may bias the estimated marginal effect on temperature; we include them to assess robustness because temperature could have direct productivity effects that, in turn, affect individuals' economic sentiment through an income effect or productivity channel. The identifying assumption in Eq. (3) is that unobserved shocks to the stock returns of local firms are uncorrelated with fluctuations in daily temperature within the same firm over time.

We begin the analyses using an ordinary least squares approach before presenting semi-parametric results. Recognizing the confounding role of time-invariant factors across location and time, we regress daily stock returns on daily average temperature, conditional on year, month, and firm fixed effects. The results show that an additional degree increase in temperature is associated with a 0.0236pp decline in the stock returns of local firms (p- value < 0.00; untabulated). Next, we examine the non-linearities that are present in the data. Fig. 5 plots the gradients associated with different temperature bins over the temperature distribution. We find that an additional degree increase at extreme temperatures relates to a 0.2-0.3pp decrease in daily (county-firm) stock returns (p- value < 0.00 for the below 15 degrees temperature bin and p- value < 0.10 for the above 85 degrees temperature bin).[13] In addition, the figure shows the relation between temperature and daily returns is insignificant from zero in all other parts of the temperature distribution. To strengthen the evidence on temperature-induced impacts to the returns of local firms, we examine whether the effects are driven by the potential for real effects of temperature on productivity via local risk factors (Tuzel and Zhang, 2017). If temperature fluctuations impact certain industries (e.g., energy) more than others, then counties with, for instance, more energy firm headquarters might drive the observed effects. We test this possibility by augmenting Eq. (3) with an indicator for whether the firm is in the energy sector and its interaction with daily temperature. Untabulated tests reveal a statistically insignificant interaction term, suggesting it is unlikely that the inverse-U relation in Fig. 5 is driven by the real effects of temperature on productivity.

Having confirmed and extended results on the relation between temperature and stock returns, we next complete the analysis by documenting the impact of economic sentiment on stock returns. Using the Gallup data, Fig. 6 produces a monthly panel across counties and plots the share of individuals who report that the economy will improve with monthly stock returns. In addition to a strong raw correlation—a 1pp increase in the share of individuals reporting that the economy will improve is associated with a 0.37pp increase in a local firm's stock return—the correlation is robust to the inclusion of year, month, and firm fixed effects—a 1pp increase in the share of individuals reporting that economic conditions will improve is associated with a 0.19pp increase in a local firm's stock return (untabulated). Collectively, this evidence indicates that economic sentiment and stock returns are highly correlated within a county. Hence, consistent with our third prediction, we find that extreme local temperature-induced decreases in economic sentiment relate to declines in the stock returns of local firms. Overall, the evidence complements and extends our understanding of the link between how individuals form beliefs about economic activity and the relation between these beliefs and real economic outcomes by quantifying how climate factors influence individuals' economic sentiment, with implications for stock returns.

[13] While we identify these gradients using short-run temperature variations, it is useful to put them in context of the broader debate. For example, the 10th and 90th percentiles of day-to-day temperature changes are −7.6 and 6.5 degrees Fahrenheit, respectively, meaning that marginal effects could be approximately seven times as large when evaluated at the tails. Moreover, given the importance of compounding, the evidence has cumulative consequences. For instance, Hassan and Mertens (2015) and Hassan and Mertens (2017) show that even if individual manager forecasts contain a small but common error, the resulting resource misallocation can be substantial.

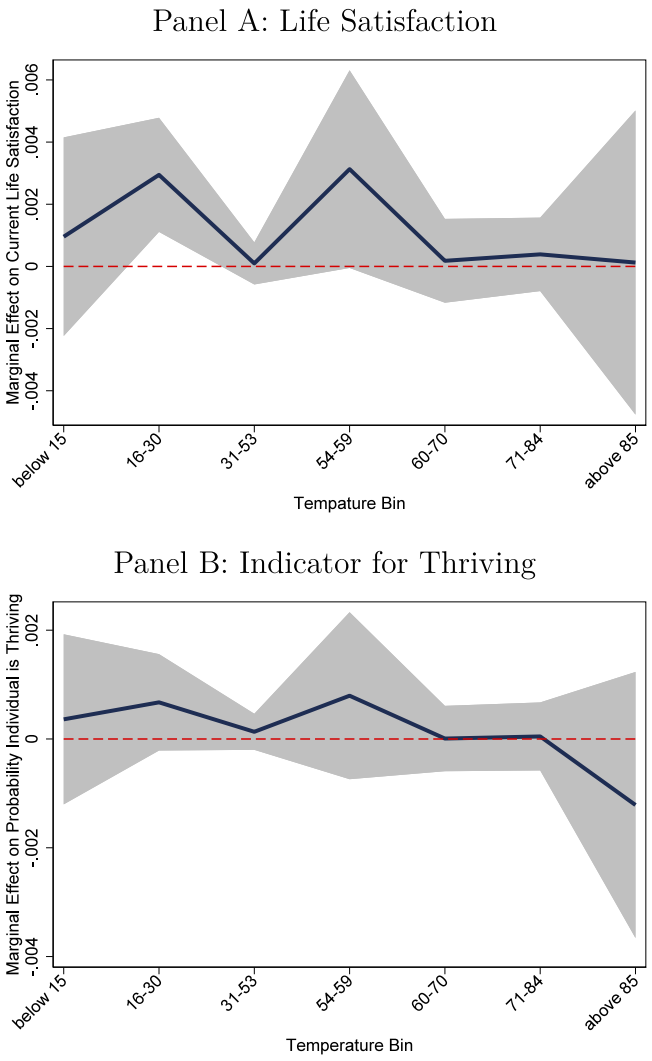

Fig. 4. Temperature and Perceived Life Satisfaction. *Notes.* -The figure plots the coefficients associated with regressions of the z-score of current life satisfaction (on a zero to ten index) and an indicator for whether the individual is thriving on average daily temperature interacted with bins on the temperature range (below 0, 0–15, 16–30, 31–53, 54–59, 60–70, 71–84, and above 85 degrees Fahrenheit), conditional on county historical temperature and precipitation, individual demographics, and county and day-of-the-year fixed effects. We classify individuals as thriving if they report at least a 7 out of 10 on current life satisfaction and at least an 8 out of 10 on expected future life satisfaction. Individual controls: an indicator for whether the individual is employed, marital status, a quadratic in age, male, education fixed effects (less than high school, technical, some college, college, and more than college, and race (White/non-White). Standard errors are clustered at the county-level and sample weights are used.

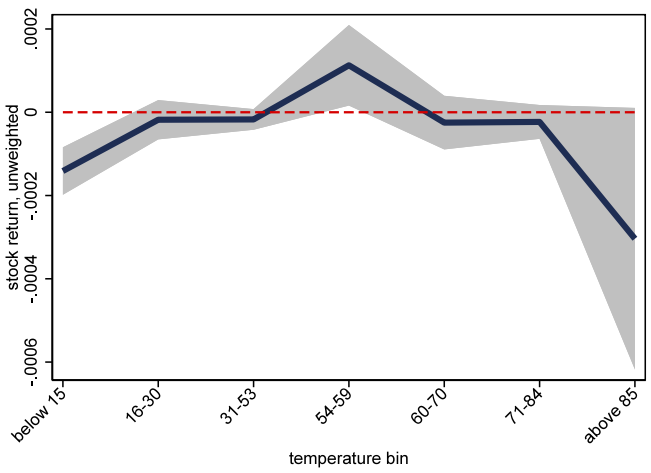

Fig. 5. Temperature and the Stock Returns of Local Firms. *Notes.*-The figure plots the coefficients associated with regressions of the stock return net of dividends on average daily temperature separately across seven temperature bins (below 0, 0–15, 16–30, 31–53, 54–59, 60–70, 71–84, and 85+), county, year, and month fixed effects and daily county precipitation. Stock returns for each firm are conditional the county location of their headquarters based on the result from Coval and Moskowitz (1999) that investors tend to invest more heavily in local stocks. Standard errors are clustered at the county-level and observations are unweighted.

5. Conclusion

Scholars across various disciplines are interested in individuals' views of economic activity and their potential impact on real economic outcomes, and a series of studies reveal how sentiments held by different economic agents (e.g., investors, managers, individuals) impact a wide variety of outcomes (e.g., return predictability, managers' disclosure choices, inflation expectations). The fundamental reasoning that guides these studies is that individuals throughout the economy are affected by behavioral factors that cause them to form overly optimistic or pessimistic beliefs about the future. Despite the importance of this sentiment formation process, we know comparatively less about how individuals form beliefs about economic activity. Understanding how individuals form such beliefs is important because they ultimately affect how individuals optimize and make decisions under bounded rationality (Simon, 1955).

This paper extends studies of the economic implications of individuals' sentiment by investigating how individuals form beliefs about U.S. economic conditions (i.e., *economic sentiment*) and examining its implication for asset prices. We use individual-level data from Gallup's U.S. Daily Poll on economic sentiment and link it with daily county-level temperatures across time. This empirical design enables us to use plausibly exogenous variation in temperature to study the formation of economic sentiment and its impact on daily asset prices without taking sentiment as exogenous. Furthermore, we can use survey respondents' self-reported well-being data to investigate a potential behavioral factor through which these results may occur.

We find that an additional degree increase at extreme local temperatures (below 15 degrees Fahrenheit or above 85 degrees Fahrenheit) is associated with a significant decline in individuals' economic sentiment, particularly their sentiment about future economic activity. We then provide fresh evidence that these decreases in individuals' economic sentiment are not due to temperature-induced decreases in perceived life satisfaction. We complete the analysis by providing evidence of a negative relation between extreme temperatures and stock returns, indicating that local temperatures are an important contributing force behind this negative relation.

Overall, the results suggest that extreme local temperatures impact individuals' beliefs about the economy *beyond* the effect of temperature on firm- or local-level economic variables. Moreover, our evidence regarding the importance of perceived life satisfaction in explaining variation in economic sentiment while having little role in explaining the temperature–sentiment link provides new insights into our understanding of the connections between climate factors, behavioral factors, and assessments of future prospects (Johnson and Tversky, 1983; Arkes et al., 1988). More generally, given the development of asset pricing models seeking to quantify the economic effects of climate change (Giglio et al., 2015; Bansal et al., 2016), studies of the mechanisms through

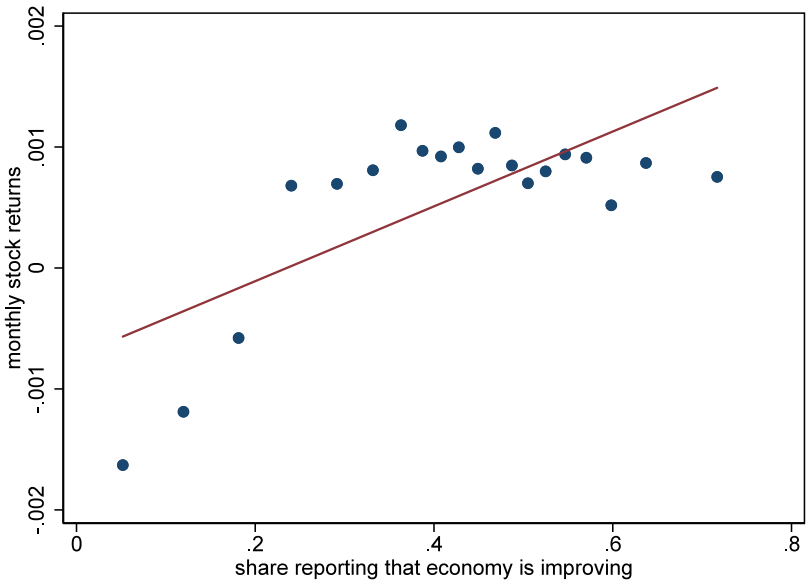

Fig. 6. Economic Sentiment and the Stock Returns of Local Firms. *Notes*.-The figure plots a bin-scatterplot of the share of individuals in a county month reporting that economic conditions will improve with the monthly stock return for a firm restricted to the sample of county-month pairs with at least 10 respondents.

which climate factors, including extreme local temperatures, influence the sentiment of economic agents and economic activity is of increasing interest.

CRediT authorship contribution statement

Christos A. Makridis: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft. **Jason D. Schloetzer:** Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Albouy, D., Kellogg, R., Graf, W., Wolff, H., 2015. Extreme temperature, climate change and the American quality of life. J. Assoc. Environ. Resour. Econ.

Anderson, S.T., Kellogg, R., Sallee, J.M., 2013. What do consumers believe about future gasoline prices? J. Environ. Econ. Manag. 66, 383–403.

Arif, S., Lee, C.M.C., 2014. Aggregate investment and investor sentiment. Rev. Financ. Stud. 27 (11), 3241–3279.

Arkes, H., Herren, L.T., Isen, A.M., 1988. The role of potential loss in the influence of affect on risk-taking behavior. Organ. Behav. Hum. Decis. Mak. Process. 42, 181–193.

Bailey, M., Cao, R., Kuchler, T., Stroebel, J., 2018. The economic effects of social networks: evidence from the housing market. J. Polit. Econ. 126 (6), 2224–2276.

Baker, M., Wurgler, J., 2006. Investor sentiment and the cross-section of stock returns. J. Finance 61 (4), 1645–1680.

Baker, M., Wurgler, J., 2007. Investor sentiment in the stock market. J. Econ. Perspect. 21 (2), 129–151.

Baker, M., Wurgler, J., Yuan, Y., 2012. Global, local, and contagious investor sentiment. J. Financ. Econ. 104, 272–287.

Bansal, R., Ochoa, M., Kiku, D., 2016. Climate Change and Growth Risks. NBER Working Paper.

Barberis, N., Shleifer, A., Vishny, R., 1998. A model of investor sentiment. J. Financ. Econ. 49 (3), 307–343.

Baylis, P., 2020. Temperature and temperament: evidence from Twitter. J. Publ. Econ. 184.

Baylis, P., Obradovich, N., Kryvasheyeu, Y., Chen, H., Coviello, L., Moro, E., Cebrian, M., Fowler, J.H., 2018. Weather impacts expressed sentiment. PLoS One 13 (4).

Bergman, N.K., Roychowdhury, S., 2008. Investor sentiment and corporate disclosure. J. Account. Res. 46 (5), 1057–1083.

Bernile, G., Kumar, A., Sulaeman, J., 2015. Home away from home: Geography of information and local investors. Rev. Financ. Stud. 28 (7), 2009–2049.

Bertrand, M., Duflo, E., Mullainathan, S., 2004. How much should we trust differences-in-differences estimates? Q. J. Econ. 119 (1), 249–275.

Bochkay, K., Dimitrov, V., 2015. Qualitative Management Disclosures and Market Sentiment. SSRN Working Paper.

Bray, M., 1982. Learning, estimation and the stability of rational expectations equilibria. J. Econom. Theory 26, 318–339.

Brown, N.C., Christensen, T.E., Elliot, W.B., Mergenthaler, R.D., 2012. Investor sentiment and pro forma earnings disclosures. J. Account. Res. 50 (1), 1–40.

Burke, M., Hsiang, S.M., Miguel, E., 2015. Global non-linear effect of temperature on economic production. Nature 527, 235–239.

Cao, M., Wei, J., 2005. Stock market returns: A note on temperature anomaly. J. Bank. Financ. 29 (6), 1559–1573.

Coval, J.D., Moskowitz, T.J., 1999. Home bias at home: Local equity preference in domestic portfolios. J. Finance 54 (6), 2045–2073.

Daly, C., Gibson, W.P., Taylor, G.H., Johnson, G.L., Pasteris, P., 2002. A knowledge-based approach to the statistical mapping of climate. Clim. Res. 22 (2), 99–113.

Daniel, K., Hirshleifer, D., Subrahmanyam, A., 1988. Investor psychology and security market under- and overreactions. J. Finance 53 (6), 1839–1885.

Deaton, A., 2012. The financial crisis and the well-being of Americans. Oxf. Econ. Pap. 64 (1), 1–26.

Dell, M., Jones, B.F., Olken, B., 2012. Temperature shocks and economic growth: Evidence from the last half century. Am. Econ. J. Macroecon. 4 (3), 66–95.

DeLong, J.B., Shleifer, A., Summers, L.H., Waldmann, R.J., 1990. Noise trader risk in financial markets. J. Polit. Econ. 98 (4), 703–738.

Deryugina, T., 2013. How do people update? The effects of local weather fluctuations on beliefs about global warming. Clim. Change 118 (2), 397–416.

Deschenes, O., Greenstone, M., 2011. Climate change, mortality and adaptation: Evidence from annual fluctuations in weather in the US. Am. Econ. J. Appl. Econ. 3, 152–185.

Diaz, D., Moore, F., 2017. Quantifying the economic risks of climate change. Nature Clim. Change 7, 774–782.

Eagles, J.M., 1994. The relationship between mood and daily hours of sunlight in rapid cycling bipolar illness. Biol. Psychiat. 36, 422–424.

Forgas, J.P., 1995. Mood and judgment. Psychol. Bull. 117, 39–66.

Gallup, J.L., Sachs, J.D., Mellinger, A.D., 1999. Geography and economic development. Int. Reg. Sci. Rev. 22 (2), 179–232.

Giglio, S., Maggiori, M., Stroebel, J., Weber, A., 2015. Climate change and long-run discount rates: Evidence from real estate. J. Political Econ. R R.

Gillman, M., Kejak, M., Pakos, M., 2015. Learning about rare disasters: Implications for consumption and asset prices. Rev. Finance 19 (3), 1053–1104.

Goetzmann, W.N., Kim, D., Kumar, A., Wang, Q., 2015. Weather-induced mood, institutional investors, and stock returns. Rev. Financ. Stud. 28 (1), 73–111.

Goetzmann, W.N., Zhu, N., 2005. Rain or shine: Where is the weather effect? Eur. Financial Manag. 11 (5), 559–578.

Gregory, R.P., 2021. What determines manager and investor sentiment? J. Behav. Exp. Finance 30.
Hassan, T.A., Mertens, T.M., 2015. Information aggregation in a dynamic stochastic general equilibrium model. NBER Macroecon. Annu. 29, 159–207.
Hassan, T.A., Mertens, T.M., 2017. The social cost of near-rational investment. Amer. Econ. Rev. 107 (4), 1059–1103.
Herrnstadt, E., Muehlegger, E., 2014. Weather, salience of climate change and congressional voting. J. Environ. Econ. Manag. 68, 435–448.
Hirshleifer, D., 2015. Behavioral finance. Ann. Rev. Financ. Econ. 7, 133–159.
Hirshleifer, D., Jiang, D., Meng, Y., 2018. Mood Betas and Seasonalities in Stock Returns. NBER Working Paper.
Hirshleifer, D., Shumway, T., 2003. Good day sunshine: Stock returns and the weather. J. Finance 58 (3), 1009–1032.
Hribar, P., McInnis, J., 2012. Investor sentiment and analysts' earnings forecast errors. Manage. Sci. 58 (2), 293–307.
Hsiang, S.M., Jina, A.S., 2014. The Causal Effect of Environmental Catastrophe on Long Run Economic Growth: Evidence from 6, 700 Cyclones. NBER Working Paper.
Huang, D., Jiang, F., Tu, J., Zhou, G., 2015. Investor sentiment aligned: A powerful predictor of stock returns. Rev. Financ. Stud. 28 (3), 791–837.
Jiang, F., Lee, J., Martin, X., Zhou, G., 2019. Manager sentiment and stock returns. J. Financ. Econ. 132, 126–149.
Johnson, E.J., Tversky, A., 1983. Affect, generalization, and the perception of risk. J. Personal. Soc. Psychol. 45, 20–31.
Kahneman, D., Deaton, A., 2010. High income improves evaluation of life but not emotional well-being. Proc. Natl. Acad. Sci. 107 (38), 16489–16493.
Kamstra, M.J., Kramer, L.A., Levi, M.D., 2003. Winter blues: A SAD stock market cycle. Amer. Econ. Rev. 93 (1), 324–343.
Kamstra, M.J., Kramer, L.A., Levi, M.D., 2012. A careful re-examination of seasonality in international stock markets: Comment on sentiment and stock returns. J. Bank. Financ. 36, 934–956.
Kelly, P.J., Meschke, F., 2010. Sentiment and stock returns: The SAD anomaly revisited. J. Bank. Financ. 34, 1308–1326.
Keynes, J.M., 1936. The General Theory of Employment, Interest and Money. Palgrave Macmillan.
Kuchler, T., Zafar, B., 2019. Personal experiences and expectations about aggregate outcomes. J. Finance 74 (5), 2491–2542.
Loewenstein, G., O'Donoghue, T., Rabin, M., 2000. Projection Bias in Predicting Future Utility. Working Paper, University of California Berkeley.
Lu, Y.K., Siemer, M., 2016. Learning, Rare Disasters, and Asset Prices. Working Paper.
Malmendier, U., Nagel, S., 2016. Learning from inflation experiences. Q. J. Econ. 131 (1), 53–87.
Marcet, A., Sargent, T.J., 1983. Convergence of least squares learning mechanisms in self-referential linear stochastic models. J. Econom. Theory 48, 337–368.
Mehra, R., Sah, R., 2002. Mood, projection bias and equity market volatility. J. Econom. Dynam. Control 26, 869–887.
Obradovich, N., Fowler, J.H., 2017. Climate change may alter human physical activity patterns. Nat. Hum. Behav. 1, 1–17.
Obradovich, N., Migliorini, R., Pauus, M.P., Rahwan, I., 2018. Empirical evidence of mental health risks posed by climate change. Proc. Natl. Acad. Sci. 115 (43), 10953–10958.
Park, R.J., 2019. Hot temperature and high stakes cognitive performance. J. Hum. Resourc. R R.
Park, R.J., Goodman, J., Hurwitz, M., Smith, J., 2020. Heat and learning. Am. Econ. J.: Econ. Policy 12 (2), 306–339. http://dx.doi.org/10.1257/pol.20180612.
Sargent, T.J., 1993. Bounded Rationality in Macroeconomics. Clarendon Press, Oxford.
Saunders, E.M.J., 1993. Stock prices and Wall street weather. Amer. Econ. Rev. 83, 1337–1345.
Schwarz, N., Clore, G., 1983. Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. J. Personal. Soc. Psychol. 45 (3), 513–523.
Seybert, N., Yang, H., 2012. The party's over: the role of earnings guidance in resolving sentiment-driven overvaluation. Manage. Sci. 58, 308–319.
Shefrin, H., 2005. A Behavioral Approach to Asset Pricing. Elsevier Academic Press.
Shleifer, A., 2000. Inefficient Markets. Oxford University Press.
Shleifer, A., Vishny, R., 1997. The limits of arbitrage. J. Finance 52 (1), 35–55.
Simon, H., 1955. A behavioral model of rational choice. Q. J. Econ. 69 (1), 99–118.
Simonsohn, U., 2010. Weather to go to college. Econom. J. 120 (543), 270–280.
Stambaugh, R., Yu, J., Yuan, Y., 2012. The short of it: investor sentiment and anomalies. J. Financ. Econ. 104, 288–302.
Tietjen, G.H., Kripke, D.F., 1994. Suicides in California (1968–1977)–absence of seasonality in Los Angeles and Sacramento Counties. Psychiatr. Res. 53, 161–172.
Tuzel, S., Zhang, M.B., 2017. Local risk, local factors, and asset prices. J. Finance 72 (1), 325–370.
Wilson, D., 2019. Clearing the fog: the predictive power of weather for employment reports and their asset price responses. In: American Economic Review: Insights.
Yu, J., Yuan, Y., 2011. Investor sentiment and the mean-variance relation. J. Financ. Econ. 100, 367–381.
Zheng, S., Wang, J., Sun, C., Zhang, X., Kahn, M.E., 2019. Air pollution lowers Chinese urbanites' expressed happiness on social media. Nat. Hum. Behav. 3, 237–243.