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Split personalities? Behavioral effects of temperature on financial decision-making

Despina Gavresi[1] | Anastasia Litina[2] | Christos A. Makridis[3,4]

[1]Faculty of Law, Economics, and Finance, Department of Economics and Management, University of Luxembourg, Campus Kirchberg, Luxembourg City, Luxembourg

[2]University of Macedonia, Thessaloniki, Greece

[3]University of Nicosia, Nicosia, Cyprus

[4]Stanford University, Stanford, California, USA

Correspondence
Anastasia Litina, University of Macedonia, Thessaloniki, Greece.
Email: anastasia.litina@uom.edu.gr

Abstract

The fact that environmental factors have a broader effect on financial decision-making has been lengthily explored, but there is a gap in understanding how personality traits might mediate the effects of temperature on individual decision-making. Using plausibly exogenous variation of individuals' exposure to changes in national temperature between 2004 and 2018 across NUTS 1 regions in 29 European countries, we estimate the causal effect of a marginal change in temperature on financial investments and its interaction with the trait of optimism/pessimism using Survey of Health, Ageing and Retirement in Europe (SHARE) data. A 10% increase in temperature is associated with a 0.03 percentage point (pp) rise in the probability that an optimist invests in bonds and a 0.024 pp decline in the probability for investment in stocks. However, among pessimists, we find null effects. The results are comparable on the intensive margin. In sum, our results highlight the potentially heterogeneous ways that environmental factors shape individual decision-making.

1 | INTRODUCTION

The interplay between environmental factors and individual psychological traits in shaping financial decisions represents a frontier in behavioral finance research. Traditional models have often considered financial decision-making through the prism of rationality and uniform information processing. However, a large body of literature in the field of psychology suggests that individual differences, particularly traits such as optimism and pessimism, can significantly alter how information is processed and acted upon. This paper draws on the psychological theory of affect, which suggests that mood and environmental factors, such as temperature, can influence cognitive function and decision-making processes (Isen, 2000; Schwarz & Clore, 1983). Specifically, we posit that temperature acts as an external mood regulator, potentially amplifying the innate optimism or pessimism within individuals, thereby affecting their financial decisions.

Optimists, characterized by a general disposition of expecting positive outcomes, may become more inclined towards risk taking under warmer conditions, a hypothesis supported by evidence linking warm temperatures to increased mood and risk propensity (Kahneman & Tversky, 1979; Lerner & Keltner, 2000). Conversely, the impact on pessimists, who are generally more risk averse, might become apathetic or even inverse. This theoretical motivation seeks to bridge the gap in the literature by providing a clear rationale for the empirical exploration of how temperature variations interact with personality traits to influence financial behavior.

There is a large body of empirical evidence pointing towards the role of behavioral factors in financial decision-making (Beshears et al., 2018). Leading theories of behavioral finance have emphasized the role of attention for asset prices (Bordalo et al., 2012; DellaVigna & Pollet, 2009) and financial decision-making (Stango & Zinman, 2009, 2014). Salience behaves as a mediating force (Bordalo et al., 2013). Expectations have emerged as a leading explanation for why and how individuals undertake different financial investments (Bordalo et al., 2018), such as whether to participate in the stock market (Barber & Odean, 2001) or whether to allocate more of their portfolio to stocks over bonds (Grinblatt & Keloharju, 2000). However, much less emphasis has been placed on the interplay between personality characteristics and environmental factors, i.e., exploring how shocks interact with behavioral factors that may influence financial decision-making. We focus on optimism, which influences how an individual processes information, affecting behaviors such as working and saving habits (Coval et al., 2005; Gervais & Goldstein, 2007; Puri & Robinson, 2007). Additionally, evidence points towards the impact of climate on individual decisions and attitudes (Makridis & Schloetzer, 2023; Park, 2020).

Why is it important to study optimism/pessimism? A common alternative to rational expectation models is rational inattention whereby investors focus on more salient information. Our focus on optimism is even broader because it influences not only the set of information but also the way that information is perceived and processed, leading to different economic decisions. In a rapidly changing world that triggers positive or negative emotions to individuals, understanding the role of personality in classical economic decisions is essential.

The exploration of optimism and pessimism within economic theory challenges the conventional assumption of universal rationality and uniform information processing. Traditional economic models often overlook the various ways in which individual personality traits can alter the interpretation and response to information, thereby influencing decision-making processes. This simplification fails to capture the complex reality that individuals, each shaped by unique perspectives influenced by optimism or pessimism, process the same information differently. This leads to a varied spectrum of economic behaviors and choices, underscoring the necessity to delve into how these personality traits impact economic decisions. Emotional triggers, processed through the prism of an individual's personality, can significantly sway economic behaviors, ranging from spending and saving to investing and assessing risk. The intersection of psychology and economics, particularly through the lens of optimism and pessimism, can lead us to models and findings that can account for the diversity of human behavior and offer a more accurate reflection of how individuals navigate economic choices amidst uncertainty and change, highlighting the critical role of psychological factors in shaping economic outcomes.

Empirically, understanding the role of environmental factors and their interaction with personality characteristics is challenging. For example, because individuals sort into different labor market arrangements based on their underlying preferences and abilities, fluctuations in income are endogenously related with their underlying characteristics and financial decision-making. Similarly, macroeconomic conditions might influence risk taking and financial decision-making, but these conditions are potentially related with other unobserved factors that affect financial behavior.

Our paper delves into how temperature influences investment behavior and examines whether personality traits—specifically optimism versus pessimism—modulate this effect. Using data spanning 2004 to 2018 across 53 sub-regions of 17 European countries, we exploit annual temperature variation as a quasi-exogenous factor affecting individual investment decisions. By implementing country and year fixed effects, we mitigate biases arising from constant regional attributes like institutional quality or cultural factors, alongside individual-level controls to isolate the unique impact of temperature fluctuations on investment behavior. This identification strategy allows us to discern the differential effects of temperature on the financial choices of optimists and pessimists, offering a clearer understanding of environmental and psychological interplay in economic activities.

We introduce a stylized theoretical model to illustrate the mechanisms at play (see the Appendix S1 for details), positing that optimism not only induces a positive outlook on future possibilities but also heightens an individual's responsiveness to external stimuli, leading to an increased cognitive load. Furthermore, our model explains how fluctuations in temperature have a more pronounced effect on individuals with an optimistic disposition, intensifying the cognitive effort required for navigating complex decisions. This emphasis on the influence of optimism draws from a robust body of literature that underscores the critical role of anticipatory beliefs in shaping both individual behavior and broader economic outcomes (Adam et al., 2017; Adelino et al., 2018; Kaplan et al., 2020). Through this model, we aim to provide an understanding of how environmental factors and psychological traits interlace to influence economic decision-making, offering valuable insights into the dynamics of financial behavior.

Our empirical approach draws on the Survey of Health, Ageing and Retirement in Europe (SHARE) between 2004 and 2018 matched with the average annual temperature in each country. We measure the average annual temperature within country, rather than high-frequency fluctuations, because we are studying a longer run phenomenon, namely, investment activity over the life cycle. We find that a 10% rise in temperature is associated with a 0.03 percentage point (pp) rise in the probability an optimist invests in bonds and a 0.024 pp decline in the probability an optimist invests in stocks. We find null effects for pessimists. Put together, these results suggest that higher temperatures lead to a reallocation towards (away from) safer (risky) assets for optimists but no effect for pessimists. In this sense, we provide new microeconomic evidence on how idiosyncratic factors not only affect financial behavior but also interact with personality characteristics to generate movements in asset prices. While we recognize that temperature fluctuations are not a first-order determinant of asset prices, we view them as a useful window and source of variation to learn more about how people respond to external stimuli.

Furthermore, we investigate these phenomena on the intensive margin and find similar results. We show that a 10% rise in temperature is associated with a 0.012 pp decline in investment in bonds and a 0.006 pp decline in investment in stocks for optimists. However, there are no such effects for pessimists. Given that optimism is a function of beliefs about people and risk, among other factors, we subsequently decompose the determinants to understand more about the mechanism underlying these results. In particular, we find that variation in optimism is driven more heavily by attitudes about taking risk (as in Coval & Shumway, 2005), rather than attitudes about trust. This result is important because it helps us disentangle between different types behavioral biases that moderate the effects of shocks on financial decision-making (Hirshleifer, 2020).

Our results remain robust to a number of alternative tests and specifications i.e., accounting for seasonal or even monthly variations in temperature where the results on stocks are more systematic compared with bonds, the use of the maximum and minimum temperature as well as heatwaves. We are also accounting for the dependence in past investments, as well as other personality traits such as happiness. In most cases, our results remain qualitatively similar to those of our benchmark specification.

Last, we highlight the role of risk taking as a mechanism behind these results, focusing on the differential risk of between stocks and bonds. Specifically, the estimates for stock investments are more pronounced, suggesting that temperature influences are likely to impact risk-taking behaviors associated with stock market investments more systematically. This distinction is crucial, as it highlights the differential response of investment types to environmental stimuli, further emphasizing the intricate interplay between personality traits and the perception of risk. These insights not only contribute to our understanding of financial decision-making under varying environmental conditions but also underscore the importance of considering both asset-specific characteristics and individual differences in assessing the broader implications of climate on economic activities.

1.1 | Related literature

Our paper is related to a large behavioral finance literature on the relationship between personality characteristics and financial decision-making, including stock market participation. For example, Grinblatt et al. (2011) show that stock market participation is monotonically related with IQ even after controlling for a wide array of demographic and income characteristics. Barber and Odean (2001) show similar results for males, as well as Addoum et al. (2017) by height and weight. We are the first to focus primarily on the role of optimism as a moderator for attention for personality traits.[1] In the presence of a lot of noise, optimists might be more likely to pay attention to their surroundings because they have greater expectations and hope for the future, whereas pessimists might "accept their fate" and tune out external stimuli. Other personality traits, particularly across different cultures, also matter. For example, Hirshleifer et al. (2016) show how superstitious attitudes about "lucky numbers" play a role in explaining abnormally high returns about firms that undergo an initial public offering with a "lucky" listing code. Besides time-invariant personality characteristics, investor moods also shape the fluctuations and growth in stock returns (Hirshleifer et al., 2020), which can also be influenced by environmental factors, like weather (Makridis & Schloetzer, 2023), in addition to seasonal patterns. Others have demonstrated how personal experiences can exert substantial effects on investment behavior. For example, Andersen et al. (2019) show that those who personally lost from investing in banks during the 2007-2009 financial crisis led to greater future risk aversion. Similarly, Malmandier and Nagel (2011) also show how history, including exposure to the Great Depression, affects future risk taking. Our findings hint to the fact that optimism alters how temperature is associated with investment decisions, highlighting the conditional nature of the temperature-investment relationship.

Our paper also contributes to a literature on climate and financial decision-making. Motivated by a large literature on the determinants of cross-country growth, geography and climate have emerged as one potential factor (Bloom & Sachs, 1998). Although there is generally a recognition that climate does not affect economic growth directly but through indirect channels, it can impact the evolution of institutions and culture (Rodrik et al., 2004; Robinson & Acemoglu, 2012). Another novelty of our research lies in the fact that it provides such a mechanism: Hotter climates can discourage risk taking (e.g., participation in the stock market), particularly among those most likely to become entrepreneurs (e.g., optimists). These results also build on research within psychology, including Sanders and Brizzolara (1982) who show that weather has a direct effect on human behavior, health, emotion, and mood. Others have explored the effect of sunshine on returns (Hirshleifer & Shumway, 2003; Goetzmann & Zhu, 2005; Goetzmann et al., 2014) and the effect of temperature on mood and economic sentiment (Baylis, 2020; Makridis & Schloetzer, 2023). Moreover, our paper complements research that finds a close connection between personality and stock market investment (Puri & Robinson, 2007). Some research showed that investors' personality is correlated to stock market investment (Durand et al., 2008; Donnelly et al., 2012). Others have found a similar relationship between economic behavior and personality traits (Becker et al., 2011; Giglio et al., 2021).

Policy wise, our study sheds light on the significant influence of psychological factors and environmental changes on economic behaviors, emphasizing the critical role of mental health, targeted support for vulnerable groups, and sustainable investment in policy development. It advocates for incorporating mental health into economic policies, particularly to counteract the psychological and financial impacts of extreme weather, thereby

[1]See Caplan (2016) for a review of the literature on attention in behavioral finance.

promoting economic resilience that includes mental well-being. Additionally, recognizing the varied responses to temperature based on optimism, there is a pressing need for policies that specifically assist populations at greater risk from environmental changes. Providing these groups with enhanced resources and education aimed at improving financial literacy and psychological resilience is essential for better preparation against climate change's uncertainties

The structure of the paper is organized as follows. Section 2 introduces the data and measurement strategy. Section 3 lays out the empirical specification and identification strategy. Section 4 presents the main results. Section 5 discusses heterogeneity, and Section 6 presents the robustness exercises. Section 7 concludes.

2 | DATA AND MEASUREMENT

2.1 | Individual investment data

Our primary data comes from six waves (i.e., wave combination 1-2-4-5-6-7) of the SHARE (2004–2018), an individual panel across 17 European countries. SHARE gathers detailed information on important areas of respondents' lives, ranging from partners and children over housing and employment history to more detailed questions on economic decisions, social attitudes, expectations, demographic, and health status. The fully fledged SHARE dataset comprises individual-level micro data, including 140,000 individuals aged 50 or older who currently reside in 28 European countries and Israel, including Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Germany, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia, Spain, Switzerland, and Israel. SHARE data collection is based on computer-assisted personal interviewing (CAPI) and provides a common generic questionnaire that is translated into the national language of each country.

We use two alternative dependent variables, i.e., investments in (i) bonds and (ii) stocks. Respondents are given the question “Do you currently have invested in bonds or stocks? Yes or No.” The value 1 means that individual has invested, and 0 means he or she has no investments, i.e., it captures the extensive margin of investment. Moreover, SHARE provides us with information about the individuals' gender, age, health status across multiple dimensions, NUTS 1 region of residence, and year that the interview took place.

The SHARE data provide variation at the wave level, i.e, we only know whether the individual has invested or not this particular year on bonds/stocks (and how much). However, we do not know if this investment took place at a particular point of the year or at the timing of the interview. It is thus not possible to associate investment decisions with temperature data at the monthly or at the daily level. It is only possible to associate each individual with the mean temperature in his NUTS 1 region of stay at the timing of the interview, and it is thus only the yearly variation in temperature and investment variables that we can exploit. Our data contains individuals over the age of 50, which importantly reflects the ages when individuals are making more notable investment decisions.

We focus on the role of hope about the future, or optimism, as our primary measure of personality. For example, Puri and Robinson (2007) and Angelini and Cavapozzi (2017) discuss dispositional optimism as generalized positive expectations about future events. Individuals respond to the question “What are your hopes for the future? Please note only whether hopes are mentioned or not.” We classify an individual as an optimist if he/she replies with hopes about the future, and zero otherwise. We also focus on optimism due to its role in fluctuations in asset prices (Coval & Shumway, 2005; Frazzini, 2006; Goetzmann et al., 2014).

SHARE also provides us with additional personality variables, including happiness. Happiness is measured in response to “Have you feel enjoyment recently?.” We use this additional trait in the robustness section to show our heterogeneous effects are especially concentrated over the distinction between optimists versus pessimists and not a general phenomenon.

2.2 | Regional weather and demographic data

We extract the data for weather from the ERA5 climatic reanalysis data. ERA5 contains time series that have hourly, daily, and monthly frequency that are aggregated with the Nomenclature of Territorial Units for Statistics (NUTS) levels of classification. This dataset belongs to the European Centre for Medium-Range Weather Forecasts (ECMWF) which is an independent intergovernmental organization supported by 34 states. ECMWF produces global numerical weather predictions and offers one of the largest meteorological data archives in the world. ERA5 climatic reanalysis data cover the majority of European countries from 1950 to present. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset, using the laws of physics and produces data that goes several decades back in time, providing an accurate description of climate conditions of the past. ERA5 combines vast amounts of historical observations into global estimates using advanced modeling and data assimilation systems.

We restrict the geographical sample from 2004 to 2018, covering NUTS 1 regions within the European countries according to SHARE dataset. Weather data comes from reanalysis, which offers some improvements in regions with sparse data. Our approach follows that frequently used by economists in constructing and using weather data (Dell et al., 2014). We use the mean annual temperature measured in Celsius, constructed as the average of mean monthly temperature. We do so at the NUTS 1 regional level, providing variation within the same country. We also measure mean annual precipitation, calculated as the sum of the mean monthly precipitation, measured in millimeters, from the ERA5 dataset too. Finally, in our empirical analysis, we account for various demographic characteristics in order to examine whether our main hypothesis; the effect of temperature on investment behavior and their differential effect remains robust. More specifically, we control for additional time-varying country characteristics from the World Bank, including GDP per capita growth rate, annual population growth, value of services, and agriculture as percentages of GDP.

One of the main reasons for using SHARE is precisely that it allows us to exploit NUTS 1 variation and adopt such a strict specification compared with the rest of the associated literature. Another advantage is the fact that SHARE is considered the largest pan-European social science panel study providing internationally comparable longitudinal micro data which allow insights in the fields of public health and socio-economic living conditions of European individuals. Furthermore, for a panel study like SHARE, its value is strongly determined by the long-term participation of panel members over waves. In fact, there is the attrition bias as individuals who participate in SHARE are older than 50 years; thus, they are more prone to natural mortality. Accordingly, 6,310 individuals are repeated in two waves, 18,383 individuals participate in three waves, 22,721 in four waves, 7,430 individuals take place in five waves, and 6,940 in six waves.

We merge our data and use the whole sample from 2004 to 2018, ending up now with 53 NUTS 1 regions within 17 European countries including Austria, Germany, Sweden, the Netherlands, Spain, Italy, France, Denmark, Belgium, Czech Republic, Poland, Luxembourg, Hungary, Portugal, Slovenia, Estonia, and Croatia as we lose some countries from SHARE that are not contained to the ERA5 climatic reanalysis data and some others that are not included in all the questions of SHARE. The panel consists of 61,784 individuals, following them on a wave/year basis. We find each individual in more than two and less than six rounds of answers. All the interviews are conducted in several dates, without giving to individuals the opportunity to choose when they would like to answer. The cross-section part contains 89,684 individuals who participate in only one or in more rounds of interviews.

2.3 | Descriptive statistics

Table 1 documents the descriptive statistics for the pooled sample. However, in our empirical analysis, we take into account the panel of SHARE for optimists. We see that only 2.8% of individuals invest in bonds and 6.8% invest in stocks. We also see substantial differences in investment behavior among optimists versus pessimists.

TABLE 1 Descriptive statistics, 2004–2018.

	Pooled sample		Optimists		Pessimists	
	Mean	SD	Mean	SD	Mean	SD
Financial investments						
Investments in bonds	0.03	0.17	0.03	0.18	0.01	0.11
Investments in stocks	0.1	0.3	0.1	0.3	0.0	0.1
Amounts in financial investments						
Amount invested in bonds	45,782.88	72,706.86	46,535.57	73,585.56	35,230.61	58,153.96
Amount invested in stocks	41,259.4	87,189.9	41,642.2	87,850.4	33,327.8	71,812.6
Personality						
Optimism	0.86	0.35	1.00	0.00	0.00	0.00
Happiness	0.8	0.4	0.9	0.3	0.7	0.5
Trust others	6.9	2.4	7.0	2.3	6.2	2.5
Risk aversion	0.81	0.39	0.80	0.40	0.90	0.30
Health quality	0.6	0.5	0.6	0.5	0.3	0.5
Demographics						
Male	0.44	0.50	0.45	0.50	0.42	0.49
Age at interview	67.0	9.8	66.5	9.6	69.9	10.6
Property value	202,428.03	188,408.07	211,036.02	190,386.94	138,327.99	158,932.25
Country sentiment						
GDP per capita growth	1.68	2.04	1.55	1.96	2.47	2.30
Population growth	0.32	0.57	0.34	0.57	0.23	0.56
Services value	62.96	5.03	63.14	5.01	61.89	5.02
Total agriculture value	1.84	0.88	1.78	0.86	2.21	0.89
Weather						
Temperature	10.36	3.87	10.36	3.89	10.38	3.75
Precipitation	12.01	2.82	12.01	2.81	11.98	2.86
Observations	148,751		127,375		21,376	

Note: The table reports financial investments, amounts invested in financial derivatives, personality traits, region weather information, individual basic demographic, and country sentiment descriptive statistics. Financial investments are binary variables taking 0 or 1 and show if the respondents have invested or not in financial derivatives. Real amounts invested in bonds and stocks are continuous variables, presenting the amounts that the respondent has invested in bonds and stocks. The personality traits are binary variables taking 0 or 1 and indicate if the respondents have felt optimism and happiness, recently. Other personality traits such as the levels of trust, risk aversion, and health status as determinants of optimism. Risk aversion and health quality are binary variables whereas trust takes values from 0 to 10 related to a higher level of trust. Temperature is measure in degrees of Celsius and precipitation in millimeters. Male indicates the gender of each respondent, taking the value 1 for males and 0 for females. Age is measured as continuous variable. Property value is a continuous variable, expressed in real terms and it is used as an indicator of wealth. GDP per capita growth rate, population growth, services value, and total agriculture are all measured as percentages of GDP. Sample weights are not used.
Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

For example, the share of optimist individuals invest in stocks is 8% whereas the share of pessimists is 2.2%. These raw averages reflect stark differences between optimistic and pessimistic individuals that cannot be explained by demographics.

Turning towards the remaining variables, we see that the average temperature is 10°C. Roughly 44% of the sample is male and the average age is 67, showing that our sample skews towards those in retirement. Optimists tend to be slightly younger at age 66 on average, whereas pessimists are nearly 70. Finally, we see notable differences in country-level characteristics among pessimists and optimists, reflecting the correlation between happiness and income per capita (Deaton, 2008). For example, per capita GDP is \$37,462 among optimists and \$28,058—a difference of nearly \$10,000. We also see that optimists reside in countries with higher population growth, a higher services employment share, and a lower agricultural employment share.

3 | EMPIRICAL STRATEGY

We apply a least squares with fixed effects regression model to examine how environmental factors influence financial decision-making and interact with behavioral characteristics, relating measures of financial behavior, either at the intensive or extensive margins, with the logged annual NUTS 1 level temperature and measures of personality through regressions of the form:

$$y_{ijt} = \gamma TEMP_{jt} + \phi c_{ijt} + \xi(TEMP_{jt} \times c_{ijt}) + \eta_c + \lambda_t + \epsilon_{ijt}, \tag{1}$$

where y_{ijt} denotes two different measures of investments that are employed: (i) investment in bonds and stocks for each individual i residing in region j at year t, $TEMP$ denotes the average logged annual temperature, c denotes the personality characteristic indicator (e.g., optimist versus pessimist), and η and λ denote fixed effects on country and year, respectively. We cluster standard errors at the individual level. We use annual, rather than monthly, temperature to focus on larger fluctuations in temperature that are more likely to affect the extensive margin of investment.

Traditional survey data would make it challenging to estimate Equation (1). For example, repeated cross-sectional data could be contaminated by changes in composition over time. Even controlling for composition effects that could be correlated with changes in temperature, repeated cross-sectional data would not allow for the identification of life cycle effects on investment behavior in the presence of heterogeneous preferences or abilities. Instead, we use panel data to trace out the average treatment effect of changes in temperature over time on investment behavior.

To identify a causal effect of temperature on investment activity in Equation (1), we exploit plausibly exogenous variation in the exposure of observationally equivalent individuals in the same within-country region to different temperatures over time. The inclusion of country fixed effects purges variation in country-specific factors, such as geographic and institutions, that are correlated with both financial decision-making and environmental factors. The inclusion of year fixed effects purges aggregate fluctuations in financial decision-making, such as general trends towards greater financial literacy and business cycle patterns.

One concern, however, is that there are omitted variables that are correlated with both personality and financial decision-making. Although we are controlling for age, and other standard demographic characteristics, we may have an upwards biased estimate on our indicator for optimism (and consequently the interaction). In particular, more optimistic individuals also take more risks, thereby leading to a higher probability of investing in the stock market and lower probability of investing in bonds. To address this concern, we further restrict our identifying variation by also introducing person fixed effects, which exploit the exposure of the same person to fluctuations in temperature in the same NUTS 1 region over time (note that in our sample people do not move across NUTS regions). In this sense, we do not compare optimistic and pessimistic individuals but rather trace out the response of optimistic and pessimistic individuals separately to changes in temperature over the span of 14 years.

Another concern is that the temperature alters an individual's mood. For example, using variation in individuals' exposure to different daily temperatures, Makridis and Schloetzer (2023) show that individuals become more pessimistic about the state of the national economy and their expectations over the future state at very cold and hot temperatures. To the extent that an individual's pessimism or optimism is a function of temperature, then we will have additional variation in our right-hand-side variable that is more reflective of the environmental conditions than their underlying personality characteristics, producing attenuation bias. We nonetheless examine this possibility in more detail by regressing an indicator for optimism on temperature. While there is a negative correlation in the cross-section, after we add country and year fixed effects, the coefficient becomes positive and economically small in magnitude. Furthermore, with country × year and individual fixed effects, the correlation becomes statistically insignificant. In this sense, we interpret optimism as more of a person characteristic that is not directly affected by temperature.

A final concern is that there are other time-varying unobserved country-specific characteristics, like macroeconomic shocks, that are correlated with both temperature and financial behavior. For example, Dell et al. (2012) show how economic growth is correlated with temperature. While Makridis and Ransom (2020) show that temperature is uncorrelated with real wages, income, and GDP over the short and medium run, we nonetheless introduce country × year fixed effects to focus on changes in financial behavior for a given individual after controlling for all shocks that are common within the same country and year. This exploits variation at the regional level within each country for each individual, thereby purging macroeconomic conditions or other country-specific policy factors that also influence financial decision-making.

4 | MAIN RESULTS

Table 2 documents the results associated with Equation (1) when the outcome variable is the indicator for whether an individual invests in bonds.[2] We present our results sequentially, starting from the less demanding specification and gradually moving to the most demanding one, in order to assess the evolution of our results and of the coefficient to the introduction of each additional control. Starting with the conditional correlation in column 1, we see that a 10% rise in temperature is associated with a 0.283 pp decline in the probability that a pessimistic individual invests in bonds but a nearly null response among optimists. The interaction effect fully offsets the direct effect of temperature on investment, suggesting that optimism is an important dimension of heterogeneity. We also see that optimists are 0.54 pp less likely to invest in bonds (and more likely to invest in stocks), conditional on controls.

However, these conditional correlations could reflect differences in unobserved heterogeneity across individuals who live in countries that also have better macroeconomic conditions and institutions. While we have already controlled for time-varying country-specific factors, such as the GDP per capita growth rate, column 2 now introduces country and year fixed effects. The coefficients remain qualitatively similar, but lower in economic significance: A 10% rise in temperature is now associated with a 0.081 pp decline in the probability of investing in bonds among pessimists.

Yet another concern is that there are time-varying shocks to a country's macroeconomic or policy conditions that correlate with financial decision-making. Column 3 controls for a more demanding specification, i.e., we introduce country × year fixed effects. While the direct effect of temperature becomes statistically insignificant, the coefficient on the interaction remains positive and significant. Now, a 10% rise in temperature is associated with a 0.127 pp rise in the probability that an optimist invests in bonds but a null effect for pessimists. The invariance of these estimates to different specifications that omitted variables is an unlikely culprit for our results.

To address concerns about unobserved individual-specific heterogeneity, column 4 subsequently introduces person and year fixed effects, exploiting variation within the same person to fluctuations in temperature over time,

[2] For the sake of transparency, Table A.1 reported in Appendix S1 illustrates the benchmark analysis without using the control variables.

TABLE 2 Benchmark results: Temperature, optimism, and the extensive margin of investment.

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Optimist	−.0539***	−.0139*	−.0293***	−.0009	−.0256**	−.0531***	.0098	−.0134	.0600***	.0345**
	[.0084]	[.0083]	[.0082]	[.0128]	[.0085]	[.0146]	[.0144]	[.0147]	[.0172]	[.0090]
Log temperature	−.0283***	−.0081**	−.0003	−.0036	−.0070	−.0353***	−.0116**	−.0032	.0066	.0097
	[.0027]	[.0035]	[.0044]	[.0052]	[.0073]	[.0047]	[.0056]	[.0070]	[.0065]	[.0057]
× Optimist	.0228***	.0073**	.0130***	.0008	.0100**	.0304***	.0015	.0101*	−.0216***	−.0121**
	[.0032]	[.0031]	[.0031]	[.0048]	[.0033]	[.0056]	[.0055]	[.0056]	[.0066]	[.0039]
R^2	.02	.03	.04	.55	.55	.05	.12	.12	.71	.71
Sample	89,684	89,684	89,684	61,784	61,784	89,715	89,715	89,715	61,803	61,803
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No	Yes	No	No	No
Year FE	No	Yes	No	Yes	No	No	Yes	No	Yes	No
Person FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Country ∗ Year FE	No	No	Yes	No	Yes	No	No	Yes	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for investment in bonds and stocks on an indicator for whether the individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, a vector of precipitation and individual demographic characteristics, which include age, gender, and health status. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

*$p < .10$, **$p < .05$, and ***$p < .01$.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

TABLE 3 Benchmark analysis: Temperature, optimism, and the intensive margin of investment.

	Amounts in bonds					Amounts in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Optimist	−.1551**	−.0018	−.0207	.0044	−.0207*	−.1006**	.0064	−.0156	.0554***	.0370**
	[.0635]	[.0133]	[.0127]	[.0157]	[.0093]	[.0448]	[.0149]	[.0153]	[.0178]	[.0095]
Log temperature	−.0672***	−.0045	.0017	−.0036	−.0088	−.0430***	−.0198***	−.0061	−.0036	.0117
	[.0226]	[.0055]	[.0066]	[.0069]	[.0090]	[.0157]	[.0060]	[.0075]	[.0072]	[.0057]
× Optimist	.0654***	.0029	.0100**	−.0016	.0076	.0543***	.0027	.0110*	−.0195***	−.0123**
	[.0235]	[.0050]	[.0048]	[.0062]	[.0039]	[.0167]	[.0057]	[.0059]	[.0068]	[.0039]
R^2	.01	.88	.88	.94	.94	.02	.82	.83	.93	.93
Sample	89,922	89,922	89,922	62,005	62,004	90,071	90,071	90,071	62,149	62,149
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No	Yes	No	No	No
Year FE	No	Yes	No	Yes	No	No	Yes	No	Yes	No
Person FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Country ∗ Year FE	No	No	Yes	No	Yes	No	No	Yes	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for logged real amounts invested in bonds and stocks on an indicator for whether individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

$^{*}p < .10$, $^{**}p < .05$, and $^{***}p < .01$.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

which reduces the statistical significance. Column 5 introduces both person and country × year fixed effects, isolating variation in the same person after controlling for all shocks in the country-year across sub-regions. Now, we find that a 10% rise in temperature is associated with a 0.03 pp rise in the probability of investing in bonds for optimists, but a null effect for pessimists. These results are consistent with our previous specifications.

Columns 6–10 replicate the same analysis as in columns 1–5, using stocks instead of bonds. Focusing on our preferred specification that contains both person and country × year fixed effects (column 10), we also identify other noteworthy patterns. For example, we find that a 10% rise in temperature is associated with a 0.024 pp decline in the probability that an optimist invests in stocks but a null effect for pessimists.[3]

Finally, we examine the intensive margin effects of temperature on financial investments, moderated by optimism. We replace our outcome variable with the logged amount of investment in each category, treating individuals who do not invest as having zero expenditures. Table 3 documents these results. We find similar results. Under our strictest specification with person fixed effects, a 10% rise in temperature is now associated with a 0.012 pp decline in investment in bonds and a 0.006 pp decline in investment in stocks for optimism. However, we find null effects again for pessimists. The similarity of our results on the intensive and extensive margins is significant: Behavioral changes from external stimuli are not just singular in nature but ongoing. To put these coefficients in perspective, it is important to remember how they can contribute to large *cumulative* changes in savings and investment activity *over time*.

5 | DISCUSSION

5.1 | Sources of optimism

The benchmark results in Table 2 point out an important moderating effect of personality, in particular the degree of optimism, on financial market participation. However, are these differences in optimism driven more by underlying levels of trust, risk aversion, or some other determinant, such as health status or gender? We now consider regressions of an indicator for whether the individual is an optimist on an indicator for whether they have trust in others, whether they are risk averse, health quality, age, and gender. We proxy risk aversion by the response to the question "What amount of financial risk are you willing to take when you save or make investments?." The possible answers are: "The individual is not willing to take any financial risks" or "takes above average financial risks expecting to earn above average returns."

Table 4 documents these results. Age is negatively correlated with optimism, showing that people tend to become more pessimistic as they grow older. More importantly, we find that this is a strong association between optimism and trust, risk aversion, and health. For example, those who tend to trust others have a 0.083 pp higher probability of being an optimist under our preferred specification in column 4, which controls for country × year fixed effects.

We also see that those in good health have a 0.056 pp higher probability of being an optimist, consistent with empirical evidence arguing that health shapes the way that people process their environment (Finkelstein et al., 2013). Not surprisingly, risk aversion is also negatively correlated with optimism: Risk-averse individuals are 0.147 pp less likely to be optimists. Importantly, the coefficient on risk aversion is twice as large as the coefficient on trust, suggesting that attitudes related to risk more heavily driven expectations and hope for the future, relative to overall trust in others.

[3]Tables A.2 and A.3 in Appendix S1 also present results using temperature, rather than the log temperature and the results remain robust. Tables A.4 and A.5 in Appendix S1 present results using temperature measured in Fahrenheit.

TABLE 4 Discussion: Determinants of optimism.

	Optimist		
	(1)	(2)	(3)
Trust others	.0133***	.0086***	.0083***
	[.0005]	[.0005]	[.0005]
Risk aversion	−.0306***	−.0156***	−.0147***
	[.0025]	[.0025]	[.0025]
Health status	.0704***	.0568***	.0563***
	[.0026]	[.0025]	[.0025]
Age at interview (in years)	−.0012***	−.0022***	−.0021***
	[.0001]	[.0001]	[.0001]
Male	−.0017	.0010	.0010
	[.0024]	[.0022]	[.0022]
Constant	0.9083***	6.2369***	0.8990***
	[.0191]	[.3166]	[.0211]
R^2	.09	.21	.21
Sample	66,417	66,417	66,417
Controls	Yes	Yes	Yes
Country FE	No	Yes	No
Year FE	No	Yes	No
Country ∗ Year FE	No	No	Yes

Note: The table reports the coefficients of determinants of optimism such as the levels of trust, risk aversion and health quality, annual temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.
***$p < .01$.
Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

5.2 | Sources of heterogeneity

In our heterogeneity analysis, we examine the impacts of temperature on investment behaviors within the frameworks of NUTS 1 regions within "High vs Low Trust Countries" and "Eastern vs Western Countries" to capture the differential effects of cultural and institutional variations on economic decision-making. This segmentation is grounded in literature that highlights significant differences in trust levels and economic behaviors across different cultural and institutional contexts.

For regions in "High vs Low Trust Countries," our analysis is inspired by the body of research suggesting that trust in institutions and societal norms significantly influences financial decisions, including risk tolerance and investment strategies (Guiso et al., 2004, 2008; Rieger et al., 2021; Wang et al., 2016; Zak & Knack, 2001). Countries with higher levels of trust are posited to exhibit distinct investment behaviors due to the greater confidence in financial markets and institutions, potentially affecting how temperature variations impact financial decisions.

Similarly, the distinction among regions in "Eastern vs Western Countries" is premised on the historical, economic, and cultural divergences that have been shown to influence economic outcomes and behaviors (Alesina & Fuchs-Schündeln, 2007; Hofstede, 1980; Jenkins et al., 2005; Roland, 2004). This categorization allows us to explore how geographical and cultural differences might modulate the relationship between environmental factors and economic decision-making, considering the varying levels of economic development, market maturity, and societal norms across these regions.

By analyzing these sub-samples, our study not only contributes to the understanding of how temperature affects investment decisions but also enriches the discourse on the role of trust and cultural-economic contexts in shaping these effects. This approach facilitates a deeper exploration into the interplay between environmental conditions, psychological traits, and the broader cultural and institutional environment, offering comprehensive insights into the heterogeneous impacts of temperature on financial behavior.

5.2.1 | Regions in Eastern versus Western countries

The results in Table 5 further explores the cultural division between East and West by splitting the sample into these two groups and replicating the results for each group separately. Qualitatively our results are similar across the two specifications. Quantitatively though, the results are stronger for the Eastern countries as opposed to Western countries. This effect is even further stronger for the case of stocks, which is the more risky asset.

5.2.2 | Regions in high versus low trust countries

Using data from Rieger et al. (2021) that distinguishes between time preferences and time across 117 countries, we partition the sample into countries that rank above and below the median.

Table 6 documents the results for high and low trust countries. In our preferred specifications containing person and country × year fixed effects (columns 5 and 10), we find that the treatment effects for temperature and its interaction with personality are concentrated among the high trust countries. In particular, we find no statistically or economically significant effects in the low trust countries. Because we expect that trust amplifies salience, and it is a complement to investments, this is consistent with our hypothesis. Moreover, in low trust countries, we would expect that personality and temperature matter less in general because trust is such a crucial ingredient. Indeed, columns 5 and 10 do not even show a statistically significant association between optimism and financial decision-making and the weaker specifications in columns 1–4 and 6–9 showing less statistically significant associations as well. This is comforting because we would expect that low trust dwarfs every other factor, especially ones like temperature.

We also explore heterogeneity in the rate of time preference but find no statistically distinguishable results. This suggests to use that the primary mechanism at work is through a channel related to trust: Optimism about life is connected with social capital and personal relationships.

5.3 | Alternative outcome variables and specifications

In the benchmark analysis, we explore the relation between temperature, optimism, and their moderating effect on financial investments. More specifically, we find that hotter temperatures reduce optimists' appetite for risk by declining their demand for stocks and increasing their demand for safer assets, such as bonds. Moreover, we try to explore the relation between temperature, optimism, and economic behavior, according to Puri and Robinson (2007). For that reason, in Table 7, we investigate the relation between temperature, optimism and different economic choices like retirement timing and work ethic (self-employment status and job satisfaction). Both optimism and risk tolerance affect the willingness of individuals to become entrepreneurs. This is consistent with the theoretical predictions of Gervais and Goldstein (2007) who argue that optimists overestimate the marginal product of their labor, working harder and taking more risks.

TABLE 5 Discussion: Eastern versus Western countries.

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A. East										
Optimist	−.0330***	−.0340***	−.0322***	−.0382***	−.0295*	.0067	.0115	.0115	.0429**	.0441**
	[.0095]	[.0091]	[.0087]	[.0132]	[.0110]	[.0144]	[.0142]	[.0142]	[.0169]	[.0133]
Log temperature	−.0138***	.0017	.0045	.0007	−.0044	−.0170***	.0076	.0238**	.0187**	.0285**
	[.0031]	[.0065]	[.0099]	[.0084]	[.0098]	[.0046]	[.0080]	[.0116]	[.0092]	[.0070]
× Optimist	.0146***	.0156***	.0145***	.0156***	.0117**	.0012	−.0011	−.0014	−.0150**	−.0158*
	[.0038]	[.0036]	[.0035]	[.0054]	[.0039]	[.0056]	[.0056]	[.0056]	[.0068]	[.0061]
R^2	.04	.04	.05	.55	.55	.04	.04	.04	.69	.69
Sample	31,936	31,936	31,936	21,897	21,897	31,966	31,966	31,966	21,920	21,920

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel B. West										
Optimist	−.0454**	−.0377*	−.0366*	−.0232	−.0207*	.0761**	.0048	−.0129	.0070	.0109
	[.0206]	[.0209]	[.0215]	[.0320]	[.0076]	[.0352]	[.0351]	[.0363]	[.0434]	[.0312]
Log temperature	−.0199***	−.0210***	−.0052	−.0177	−.0072	.0208*	−.0223*	−.0056	−.0220	−.0009
	[.0070]	[.0076]	[.0081]	[.0117]	[.0077]	[.0123]	[.0128]	[.0136]	[.0158]	[.0107]
× Optimist	.0190***	.0161**	.0155**	.0095	.0082**	−.0133	.0046	.0108	−.0016	−.0034
	[.0073]	[.0074]	[.0076]	[.0115]	[.0029]	[.0129]	[.0128]	[.0133]	[.0158]	[.0115]

TABLE 5 (Continued)

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
R^2	.01	.03	.03	.55	.55	.05	.13	.13	.71	.71
Sample	57,748	57,748	57,748	39,887	39,887	57,749	57,749	57,749	39,883	39,883
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No	Yes	No	No	No
Year FE	No	Yes	No	Yes	No	No	Yes	No	Yes	No
Person FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Country ∗ Year FE	No	No	Yes	No	Yes	No	No	Yes	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for investment in bonds and stocks on an indicator for whether the individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status splitting the sample in Eastern (Panel A.) and Western (Panel B.) European countries. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

$^*p < .10$, $^{**}p < .05$, and $^{***}p < .01$.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

TABLE 6 Discussion: High versus low trust level countries.

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A. High										
Optimist	−.0524***	−.0109	−.0253***	−.0068	−.0290*	−.0498***	.0205	−.0044	.0673***	.0374**
	[.0093]	[.0092]	[.0090]	[.0141]	[.0109]	[.0164]	[.0161]	[.0164]	[.0193]	[.0131]
Log temperature	−.0297***	−.0082**	.0004	−.0064	−.0067	−.0364***	−.0097	−.0022	.0090	.0112
	[.0030]	[.0038]	[.0048]	[.0058]	[.0078]	[.0053]	[.0063]	[.0079]	[.0073]	[.0099]
× Optimist	.0225***	.0062*	.0117***	.0034	.0118**	.0298***	−.0025	.0068	−.0241***	−.0129*
	[.0035]	[.0034]	[.0034]	[.0054]	[.0042]	[.0062]	[.0061]	[.0063]	[.0074]	[.0056]
R^2	.02	.03	.04	.55	.55	.05	.12	.13	.72	.72
Sample	77,305	77,305	77,305	51,365	51,365	77,331	77,331	77,331	51,373	51,373
	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel B. Low										
Optimist	−.0484**	−.0399**	−.0482**	−.0412	−.0179	−.0523**	−.0615**	−.0571**	.0847	.0292
	[.0204]	[.0193]	[.0203]	[.0645]	[.0623]	[.0264]	[.0266]	[.0276]	[.0987]	[.0545]
Log temperature	−.0169**	−.0060	−.0061	−.0274	−.0116	−.0319***	−.0161	−.0090	.0198	−.0054
	[.0071]	[.0083]	[.0108]	[.0337]	[.0391]	[.0078]	[.0104]	[.0132]	[.0381]	[.0507]
× Optimist	.0194**	.0163**	.0190**	.0114	−.0004	.0251**	.0269***	.0250**	−.0275	−.0045
	[.0079]	[.0075]	[.0078]	[.0301]	[.0254]	[.0101]	[.0103]	[.0107]	[.0399]	[.0270]

TABLE 6 (Continued)

	Investment in bonds					Investment in stocks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
R^2	.01	.02	.03	.57	.58	.03	.06	.06	.61	.62
Sample	12,379	12,379	12,377	1542	1538	12,384	12,384	12,382	1544	1540
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No	Yes	No	No	No
Year FE	No	Yes	No	Yes	No	No	Yes	No	Yes	No
Person FE	No	No	No	Yes	Yes	No	No	No	Yes	Yes
Country * Year FE	No	No	Yes	No	Yes	No	No	Yes	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for investment in bonds and stocks on an indicator for whether the individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status splitting the sample taking into consideration the levels of trust (high and low trust levels). Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

$^*p < .10$, $^{**}p < .05$, and $^{***}p < .01$.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

TABLE 7 Discussion: Alternative outcome variables, temperature, optimism, and economic behavior.

	Self-employed					Satisfied with job		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Optimist	.2376**	−.0697	−.2063*	−.2325*	−.3826***	−.1059	−.2550**	−.1754
	[.1130]	[.1136]	[.1161]	[.1401]	[.0738]	[.1196]	[.1205]	[.1224]
Log temperature	.2295***	.1337***	−.0264	.0237	−.1614***	.0490	−.0908*	−.0071
	[.0418]	[.0454]	[.0522]	[.0527]	[.0315]	[.0446]	[.0491]	[.0557]
× Optimist	−.0904**	.0320	.0858*	.0792	.1380**	.0009	.0672	.0381
	[.0434]	[.0437]	[.0447]	[.0528]	[.0328]	[.0464]	[.0468]	[.0476]
R^2	.04	.05	.06	.80	.81	.04	.06	.06
Sample	36,291	36,291	36,291	22,872	22,872	23,892	23,892	23,892
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	No	No	No	Yes	No
Year FE	No	Yes	No	Yes	No	No	Yes	No
Person FE	No	No	No	Yes	Yes	No	No	No
Country ∗ Year FE	No	No	Yes	No	Yes	No	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for working attitudes such as self-employment, satisfaction with job, plans for early retirement and an indicator for whether the individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

*p < .10, **p < .05, and ***p < .01.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

TABLE 7 (Continued)

	Satisfied with job		Look for early retirement				
	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Optimist	−.4355**	−.3058*	−.0129	1.3769***	1.1627***	.8628*	.5378
	[.2062]	[.1108]	[.3397]	[.3361]	[.3440]	[.4912]	[.3087]
Log temperature	−.2143***	−.1101	−.5737***	.4175***	.4259***	.3829**	.3123*
	[.0825]	[.0833]	[.1248]	[.1307]	[.1456]	[.1875]	[.1290]
× Optimist	.1667**	.1190*	.1123	−.4886***	−.4061***	−.3363*	−.2125
	[.0791]	[.0446]	[.1293]	[.1278]	[.1308]	[.1857]	[.1225]
R^2	.59	.60	.04	.10	.10	.65	.65
Sample	11,285	11,285	32,655	32,655	32,655	20,005	20,005
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	Yes	No	No	No
Year FE	Yes	No	No	Yes	No	Yes	No
Person FE	Yes	Yes	No	No	No	Yes	Yes
Country ∗ Year FE	No	Yes	No	No	Yes	No	Yes

Note: The table reports the coefficients associated with regressions of an indicator for working attitudes such as self-employment, satisfaction with job, plans for early retirement and an indicator for whether the individual is optimistic, annual logged temperature for the NUTS 1 region (within a country), their interaction, and a vector of precipitation and individual demographic characteristics, which include age, gender, and health status. Additional country-level controls are used such as GDP per capita growth rate, population growth, services, and agriculture value as a percentage of GDP. Standard errors are robust and clustered at the individual level. Observations are unweighted.

*p < .10, **p < .05, and ***p < .01.

Source: Survey of Health, Ageing and Retirement (SHARE) in Europe (2004–2018).

Similarly, more optimistic people feel more satisfied with their work (Dawson, 2017) and are more likely to report that they will work forever. Thus, not only do they work more currently, but they intend to continue doing so indefinitely. This fact works against the possibility that increased optimism leads to false beliefs about early retirement. Furthermore, risk-tolerant and higher net worth individuals are more likely to continue working indefinitely (Puri & Robinson, 2007). Our findings are in accordance with the existing literature.

Although we have explored alternative specifications (e.g., quadratic), we can be even more flexible in our specification to explore the potential for mis-specification. We follow Lind and Mehlum (2007) by non-parametrically testing for further non-linearity. We obtain a *p* value of .187, which means we can reject the null that there is not a non-linear and possibly U-like relationship between temperature and investment behavior (see Table A.6 in Appendix S1).

6 | ROBUSTNESS EXERCISES

In the robustness section, we test the robustness of our analysis on a wide range of alternative assumptions, measures, and underlying mechanisms.

6.1 | Does temperature operate via optimism?

First, to mitigate identification concerns, we test whether there is a direct effect of temperature on optimism. Specifically, we regress our measure of optimism on the measure of temperature (see Table A.7 of Appendix S1). To remain consistent with our analysis, we use the exact same specification as in our benchmark analysis, illustrated in Table 2 of the paper. Once we introduce our most demanding specification, i.e., the one with individual fixed effects, we find that the effect of temperature on optimism become insignificant, mitigating our concerns, that in our benchmark specification, temperature operates via affecting the level of optimism.

6.2 | Wealth effects

One concern is that we are capturing other unobserved shocks to an individual's financial portfolio, i.e., an income effect. For example, an individual might experience a decline in their overall net worth, thereby affecting their willingness to invest in different financial assets. Although we do not have comprehensive measures of wealth, and we do not think this is likely because our variation in temperature is plausibly exogenous with no direct effect on income, we have their self-reported property value, which we use as a proxy for household wealth because property is one of the most significant contributors to household wealth (Flavin & Yamashita, 2011). Table A.8 in Appendix S1 documents these results. While there is a strong positive correlation between temperature and property values in the cross-section (column 1), these effects disappear when we control for country and year fixed effects (column 2). We subsequently layer additional fixed effects on NUTS and person (columns 3–5). The fact that we find no statistically significant association suggests that income effects are not at play.

6.3 | Happiness

Another potential concern is that we are simply detecting another omitted person-specific characteristic that also varies with temperature. Table A.9 in Appendix S1 presents similar results when we use happiness as an additional control variable. However, the benchmark results remain robust and significant.

In addition, Table A.10 in Appendix S1 presents the benchmark specification using as an additional control variable the interaction term between happiness and temperature. The baseline results remain qualitatively and quantitatively robust.

6.4 | Extreme temperatures, seasonal effects, and the aspect of risk taking

6.4.1 | Extreme temperatures

Tables A.11 and A.12 in Appendix S1 conduct robustness checks using the minimum and the maximum values of the temperature index correspondingly. Instead of using the mean value for each NUTS at the yearly level, we use instead the logged minimum temperature throughout the year and the logged maximum temperature. Additionally, Table A.13 in Appendix S1 also conducts a robustness check using the logged maximum value of temperature during heatwaves for each NUTS 1 region at the yearly level. These produce qualitatively similar results, although they are slightly less significant when we include person and country × time fixed effects on investments in stocks. This is what we would expect if averaging across days and months tends to mitigate measurement error or if people respond more to the average temperature than other parts of the distribution.

Moreover, Tables A.14–A.16 in Appendix S1 present the effect of minimum temperature, maximum temperature, and the maximum value of temperature during heatwaves on optimism, respectively.

6.4.2 | Temperature variation

Table A.17 in Appendix S1 establishes the robustness of the benchmark specification to the use of an additional control variable, i.e., the yearly regional temperature variation measured as the difference between maximum and minimum temperature in NUTS 1 regions. Furthermore, Table A.18 in Appendix S1 incorporates an interaction term between this control variable and optimism in order to explore potential relationships more deeply.

6.4.3 | Seasonal effects

Though the SHARE data are not ideal in studying high-frequency changes in temperature, mostly due to the fact that we do not have high-frequency changes in investments being reported in the sample, yet we replicate our analysis using a more seasonal measure of temperature.

Table A.19 in Appendix S1 replicates the benchmark specification using the average seasonal temperatures in NUTS 1 regions. Specifically, we take into account the average seasonal three month temperature variation as we already know which month each individual has been interviewed. Similarly, in Table A.20 in Appendix S1, we replicate the baseline analysis using the average seasonal six month temperature variation in NUTS 1 regions categorizing the month each individual answered in two seasons, summer and winter. The findings are qualitatively similar with the benchmark results; however, they are not significant on investments in bonds, but they are continually significant on investments in stocks.

Table A.21 in Appendix S1 replicates the benchmark specification considering the average monthly temperatures in NUTS 1 regions. The findings are significant when we introduce country × time fixed effects on investments in stocks.

6.5 | Past investment decisions

In Table A.22 in Appendix S1, we replicate the benchmark specification controlling for the lagged investments in bonds and stocks, respectively. In Table A.23 in Appendix S1, we control for the lagged investments in bonds and stocks and we additionally control for the interaction between lagged investments and temperature. The results remain similar and robust. In both specifications the results remain similar and robust.

6.6 | Selection on observables and unobservables

Last, to further mitigate identification concerns and to assess the significance of unobserved heterogeneity, we have conducted the coefficient stability test as proposed by Oster (2019). The δ statistic in Oster's test is a measure used to evaluate the robustness of empirical findings to omitted variable bias. Our δ values are calculated based on the most restrictive assumption, i.e., that the maximum R^2 value is equal to one. To interpret the value of δ, Oster (2019) suggests that a δ statistic larger than one provides evidence of robustness to unobserved confounders. As reported in Table A.24 (see Appendix S1), the δ values are much higher than this conventional threshold in both cases, for example, investments in bonds and stocks. Analytically, the δ statistic is 12.36 for investments in bonds and 14.33 when investments in stocks is the dependent variable. We thus infer that the effect of the independent variable on the dependent variable is strong and stable enough that it would not be easily nullified by the inclusion of additional, unmeasured variables in the analysis.

7 | CONCLUSIONS

Despite the large and growing empirical evidence that points towards the role of behavioral biases that affect asset prices and the real economy, there is little understanding about the interaction between personality characteristics for an individual investor and external stimuli. That is, how do personality characteristics moderate or mediate the effects of shocks on financial decision-making? Exploiting year-to-year variation in the exposure to different temperatures across NUTS 1 regions for over a decade, we identify the causal effect of temperature on both the intensive and extensive margin of financial investments, ranging from bonds to stocks, and the moderating role of optimism. Our identification comes from within-person variation, also controlling for country $\times$ year fixed effects.

Our primary result is that hotter temperatures reduce optimists' appetite for risk by depressing their demand for stocks and boosting their demand for safe assets, such as bonds. However, we find no such effects for pessimists. Given a large body of empirical literature from psychology that has documented differences between optimists and pessimists, especially with regards to their responsiveness to external stimuli, these results show how different types of investors may respond to external stimuli. In this sense, the fluctuations that are observed in stock returns reflects a change in not only underlying fundamentals but also the composition of investors. We show that these results are driven by optimism as the personality characteristic, rather than general interests or mental well-being. Furthermore, we find that attitudes about risk are a major determinant of the differences in optimism that we observe in the cross-section.

One limitation of our research is that our sample consists of primarily older individuals. While we still believe these results are important and applicable to behavioral finance, especially because younger individuals are less likely to participate in the stock market anyways, it would be interesting to see whether these results hold on a more representative sample and at a higher frequency. For example, is it climate (i.e., longer run changes) or weather (i.e., shorter run changes) that affects financial decision-making? However, we believe that what we capture is the lower bound of our results given that older people tend to become more pessimistic. Similarly, how do personality characteristics moderate other external stimuli? We have focused on temperature because of its ability to clearly identify causal effects, but there are many other external shocks that are even more interesting for understanding fluctuations in asset prices as a result of investor behavior.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Despina Gavresi https://orcid.org/0000-0002-5194-8286
Anastasia Litina https://orcid.org/0000-0001-9575-5489
Christos A. Makridis https://orcid.org/0000-0002-6547-5897

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