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Climate Change, Firm Performance, and Investor Surprises

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Abstract. We link records of firm performance, equity analyst forecast errors, and stock returns around companies' earnings announcements to firm-specific measures of heat exposure for more than 17,000 firms in 93 countries from 1995 to 2019. We find that increased exposure to extremely high temperatures reduces firms' revenues and operating income. A one-standard-deviation increase in the number of hot days decreases revenues (operating income) by 0.6% (1.8%) of the average quarterly revenue (operating income). Moreover, we provide evidence that increased heat exposure impacts negatively on firm financial performance relative to analyst predictions and on earnings announcement returns. These findings indicate that capital market participants do not fully anticipate the economic consequences of heat as a first order physical climate risk.

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1. Introduction

According to the Task Force on Climate-Related Financial Disclosures (2017, p. 3),[1] climate change is "one of the most significant, and perhaps most misunderstood, risks that organizations face today." In particular, central banks and international financial institutions express concerns that investors might not anticipate the effects of climate change and this could endanger financial stability (Bank for International Settlements 2018, Bank of England 2019, Board of Governors of the Federal Reserve System 2021, European Central Bank 2021, International Monetary Fund 2021). In corporate finance and investments, these concerns are reflected in two fundamental questions: First, do past records indicate that physical climate risk affects the financial performance of listed firms? Second, if so, do investors anticipate that the physical risks of climate change affect firms' earnings?

In this paper, we investigate these questions in the context of high temperatures for a global sample of more than 17,000 firms in 93 countries from 1995 to 2019. Understanding the financial effect of heat is particularly important as the Intergovernmental Panel on Climate Change (2013, 2021) (IPCC) projects high temperatures to become much more frequent. Whereas major change has yet to occur, the new millennium has given a preview of what these projections entail as it has so far recorded 19 of the 20 hottest years since 1850 (NASA 2021).

To address the question of whether temperatures affect the financial performance of listed firms, we estimate the past sensitivity of earnings to extremely high temperatures. We causally identify the net effect of extremely high temperatures using year-to-year variation in firms' exposure to days of extreme temperatures. This variation is exogenous and randomly distributed conditional on spatial and temporal fixed effects and, therefore, resembles an ongoing natural experiment (see Auffhammer et al. 2013, Dell et al. 2014 for discussions of the econometric approach). We find that high temperatures negatively affect both revenues and operating income. Subsequently, we test whether analysts and investors anticipate these effects on performance.

To measure heat exposure, we use within-location and -season variation in the number of days per financial quarter on which firms are exposed to heat. To classify days as hot, we use two different approaches: First, physiologic studies indicate that task performance falls substantially when temperatures exceed 30°C (Pilcher et al. 2002, Seppänen et al. 2006). As worker performance constitutes one important channel through which temperatures could affect firm performance, we use 30°C as the first temperature threshold. Second, whether temperatures cause economic repercussions could be contingent on local levels of adaptation driven by historical temperature conditions. Therefore, our second measure defines days as hot when temperatures exceed both 30°C and the 90th percentile of the location- and season-specific temperature distribution.[2] We derive both measures from spatially and temporally granular information on daily maximum temperatures from a global temperature reanalysis data set, ERA5.[3] To link financials and temperatures, we determine the coordinates of firms' addresses and spatially match them with the ERA5 grid. Further, we measure performance through revenues and operating income, obtain analysts' revenue and income estimates as a proxy for investor expectations of financial performance, and calculate daily abnormal returns around public earnings announcements.

Our study connects to the microeconomic and macroeconomic evidence that heat decreases the supply of inputs[4] as well as studies illustrating a negative relation between heat stress and the productivity of unlisted firms (e.g., Traore and Foltz 2017, Xie 2017, Zhang et al. 2018, Li et al. 2021, Somanathan et al. 2021), household incomes, and aggregate economic output.[5] Earlier studies stress a persistent negative effect on workers' cognitive and physical performance (see Pilcher et al. 2002, Seppänen et al. 2006, Xiang et al. 2014 for reviews) and on the quantity of hours worked (Graff-Zivin and Neidell 2014). In addition, some studies argue that the employee-related effects compound to economically relevant magnitudes that could explain the observed performance sensitivity at the firm level (e.g., Zhang et al. 2018, Somanathan et al. 2021).

Building on these studies, we investigate if the negative effect of heat also manifests itself at the level of individual listed firms. Whereas the International Energy Agency (2018) reports that air conditioning (AC) rates outside of the United States are low, firms could adjust to high temperatures in other ways in the absence of AC, for instance, by adapting the combination of inputs used or by rescheduling operations around temperature peaks. These efforts to adapt could be substantial, and the general economic logic indicates that firms adapt to the extent that the marginal benefits of additional measures equal the marginal costs. With our identification strategy, we capture firms' remaining sensitivity to heat net of all realized adaptation. Implicitly, we adopt the null hypothesis that, if firms have already invested in adaptation to an extent that makes them resilient to fluctuations in extreme temperatures, we should not observe a relation between exogenous variation in high temperature exposure and firm performance.

We find that, on average, an additional day of heat exposure significantly reduces both revenues and operating income: assuming that every day of the financial quarter is equally important in generating quarterly revenues (income), each additional day of heat yields a loss of about 8.4% (26.1%) of an average day's worth of revenues (operating income) normalized by assets.[6] These estimates are economically significant and reject our null hypothesis. Relative to firms' performance over the financial quarter, a one-standard-deviation increase in the number of hot days results in a decrease in revenues (operating income) of 0.3%–0.6% (1.3%–1.8%). Compared with the mean total assets of the firms in our sample, the decrease in operating income corresponds to an absolute quarterly decrease of up to 655,202 U.S. dollars per financial quarter.[7]

To better understand the economic channels behind this effect, we conduct a series of additional tests. First, we find increases in the costs of goods sold (COGS) as well as selling, general, and administrative (SGA) expenses when firms experience more days of heat, which could in part be driven by increased costs of cooling. Second, we find that firms' total wages increase after two financial quarters. This lagged effect is consistent with the temporal structure we observe for the effects of heat on firm performance and is in line with the idea that firms increase labor inputs in later quarters to compensate for earlier decreases in performance. In addition, the wage response is consistent with physiologic and microeconomic studies indicating that heat's effect on workers is an important channel through which heat exposure affects the economy. Third, we observe that the performance reduction is attenuated when firms have large shares of foreign customers not subject to the periods of heat themselves. However, the results differ depending on how we measure the share of foreign sales, and in line with the recent literature (Pankratz and Schiller 2021, Custodio et al. 2022), it appears plausible that both demand and supply shocks are at play.[8] Fourth, whereas we find that firms across a large, diverse, and international sample are, on average, adversely affected, some firms might benefit from high temperatures, and we find insignificant effects on financial performance of firms in colder areas of the world.

Subsequent to the cross-sectional tests, we investigate whether financial markets anticipate the net physical effect of high temperatures on firms through all potential economic channels. Given that firms' revenues and income prove to be heat-sensitive, do investors and analysts anticipate the net performance repercussions of extreme temperatures at the firm level? Whereas financial theory argues that asset prices quickly adjust to and reflect all publicly available information, recent debates by central banks, regulators, and the investment community raise doubts about the extent to which the market absorbs information on climate change. With regard to mitigating climate change and the transition to a low-carbon economy, financial assessment is often complicated by policy and climate uncertainty.[9] The case of extremely high temperatures as a physical risk, in contrast, provides a clean setting to test investors' anticipation for two reasons: First, information on heat exposure is widely and publicly available, particularly as analysts and investors can acquire information on a firm-by-firm basis.[10] Second, extreme temperatures cannot be influenced externally, and that enables an objective study of whether participants in financial markets anticipate the performance repercussions.

To learn whether investors anticipate the effect of heat on financial performance to date, we conduct two tests. First, we use analysts' forecasts of revenue and operating income as a proxy for investors' expectations and test if analyst surprises about firm performance are negatively related to randomly distributed deviations in corporate exposure to heat above average conditions. If extremely high-temperature days are financially material and analysts do not anticipate this effect, their forecasts of revenue and operating income should be systematically too high in periods when firms are affected by more extremely warm days than usual. Hence, deviations in the forecasts from the actual performance should become more negative with increasing heat exposure unless analysts correctly assess and sufficiently incorporate information on high temperatures. To ensure that information on location-specific exposure is available, we use revenue and income forecasts that could have been updated after the heat exposure of the firm was realized but before earnings were announced.

Despite the fact that this test ensures that analysts have sufficient time to update their expectations, we find that surprises about revenue and operating income become more negative with increased corporate exposure to heat. The finding that the financial effect of heat is not fully anticipated is surprising in light of the efficient-market hypothesis. Particularly, as the firms in our sample have some degree of geographic concentration, the exposure to extreme weather conditions is more straightforward to assess than in the case of firms with global, complex production networks. At the same time, analysts might not have the capacity to follow the firms closely enough to respond to local, environmental conditions even if these conditions are performance-relevant.[11]

We conduct a second test to confirm that our findings are predictive of investors' capacity to assess the performance repercussions of heat in general that are not solely attributable to analysts' inertia in reassessing small and midcaps. In this test, we study earnings-announcement returns to investigate if investors are surprised by firms' financial sensitivity to heat. Again, we hypothesize that exogenous year-to-year changes in firms' heat exposure should not be systematically related to announcement returns if investors incorporate information on temperatures in their expectations on performance prior to the announcement. However, we find that announcement returns become more negative when firms are exposed to more days with extremely high temperatures. Hence, our results indicate that not only analysts, but also investors do not fully anticipate the effect of heat on firm performance.

The first part of our study adds to the growing economic literature on heat exposure and firm productivity as well as the financial literature on the impact of climate hazards on firm performance and financing decisions. Firm-level research on temperatures initially focused on unlisted firms in developing countries and predominantly studies economic measures of productivity: Somanathan et al. (2021) analyze the effect of heat on the productivity and attendance of workers in India and find a sizeable negative effect. Li et al. (2021) show that temperature shocks reduce Chinese firms' export quantities. Zhang et al. (2018) similarly find that heat reduces the productivity of a large sample of Chinese production facilities. Traore and Foltz (2017) study a detailed data set of firms in the Ivory Coast and find a negative link between high temperatures and performance. Xie (2017) shows that thermal stress drives exit probabilities of Indonesian firms. Consistent with these studies, we find that heat significantly affects revenues and profitability. We extend this literature by studying the effect of heat exposure on firms through a capital-market lens by testing whether analysts and investors anticipate the financial repercussions of heat at the firm level. Instead of analyzing productivity, we focus on financial measures of interest to investors and analysts, which we can compare with analysts' forecasts and investors' surprises.

In a concurrent study, Addoum et al. (2020) investigate the effect of abnormal temperatures on establishment sales and productivity in the United States. Apart from a positive impact of low temperature on sales in the energy sector and a marginally positive impact on healthcare firms, they find no significant effects of abnormally high or low temperatures on firm sales. This result could indicate that firms located in more developed countries build capacity to withstand extreme weather although our results point to a significant negative effect of heat across a wide range of developed countries outside the United States.

Further, this study closely relates to research on corporate finance and other environmental hazards. Barrot and Sauvagnat (2016) study the effect of natural disasters on sales growth and find that disasters negatively affect both the sales growth of directly exposed firms and their largest customers. Adopting a behavioral perspective, Dessaint and Matray (2017) provide evidence that corporate managers overreact to nearby hurricane strikes that do not increase real firm risk: firms neighboring areas that experience a natural disaster—but are not affected by it—increase cash holdings following the disaster. Studying cold spells and the use of credit, Brown et al. (2021) find that extreme cold represents a shock to firms' cash holdings. In contrast to Brown et al. (2021), we focus on high-temperature extremes because high temperatures, in particular, could become much more frequent in economically important areas.[12]

Beyond the literature on the performance implications of environmental conditions, the second part of this study extends the literature on investor reactions to physical climate risks. Recent studies find that exposure to sea-level rise affects property values, municipal-bond yields, and underwriter fees (Bernstein et al. 2019, Baldauf et al. 2020). Moreover, Anttila-Hughes (2016) finds that NASA announcements of temperature records and collapsing ice shelves affect the returns of energy companies. Further, the literature shows that investors may overreact or underreact to climate- and weather-related phenomena.[13] For example, Alok et al. (2020) find that U.S. mutual-fund managers who experience a major natural disaster subsequently underweight disaster-zone stocks. Huynh and Xia (2021) provide evidence that U.S. firms exhibit higher future stock and bond returns after a natural disaster strikes. Choi et al. (2020) find that people increase attention to global warming after experiencing extreme temperatures locally, and this attention affects returns on local "emission-minus-clean" stock portfolios. Hong et al. (2019) conclude that investors underreact to the effects of drought on the profitability of food-sector companies as firms located in countries with severe drought trends experience not only weaker profit growth, but also lower abnormal stock returns. Evidence from surveys of investors, policymakers, and academics further supports the view that markets underestimate climate risk (Krueger et al. 2020, Stroebel and Wurgler 2021).[14] Our results extend Hong et al. (2019) by showing that heat exposure affects firm performance beyond the food and agricultural sectors and this temperature effect contributes to investors' surprises about firms' earnings. These results also contribute to debates about the efficient pricing of climate risk raised in recent studies (Hong et al. 2020).

Moreover, our results connect to studies on the financial materiality of environmental information. Considerable research in this area investigates how firms' impact on the environment is reflected in realized and expected stock returns (i.e., Flammer 2013, Krüger 2015, Bolton and Kacperczyk 2021), spreads on bank loans (Chava 2014), and corporate-bond spreads (Seltzer et al. 2020). In addition, Huynh and Xia (2021) find that corporate bonds have lower future returns when they offer greater potential to hedge against climate risk news, and Delis et al. (2019) associate fossil fuel reserves with higher bank-loan rates. Beyond equity and bond markets, Ilhan et al. (2021) document that uncertainty about climate policy is priced in the option market. In contrast to these studies, which primarily associate corporate environmental impacts with financially relevant policy and regulatory risks, we focus on the effect of the environment on firms.[15]

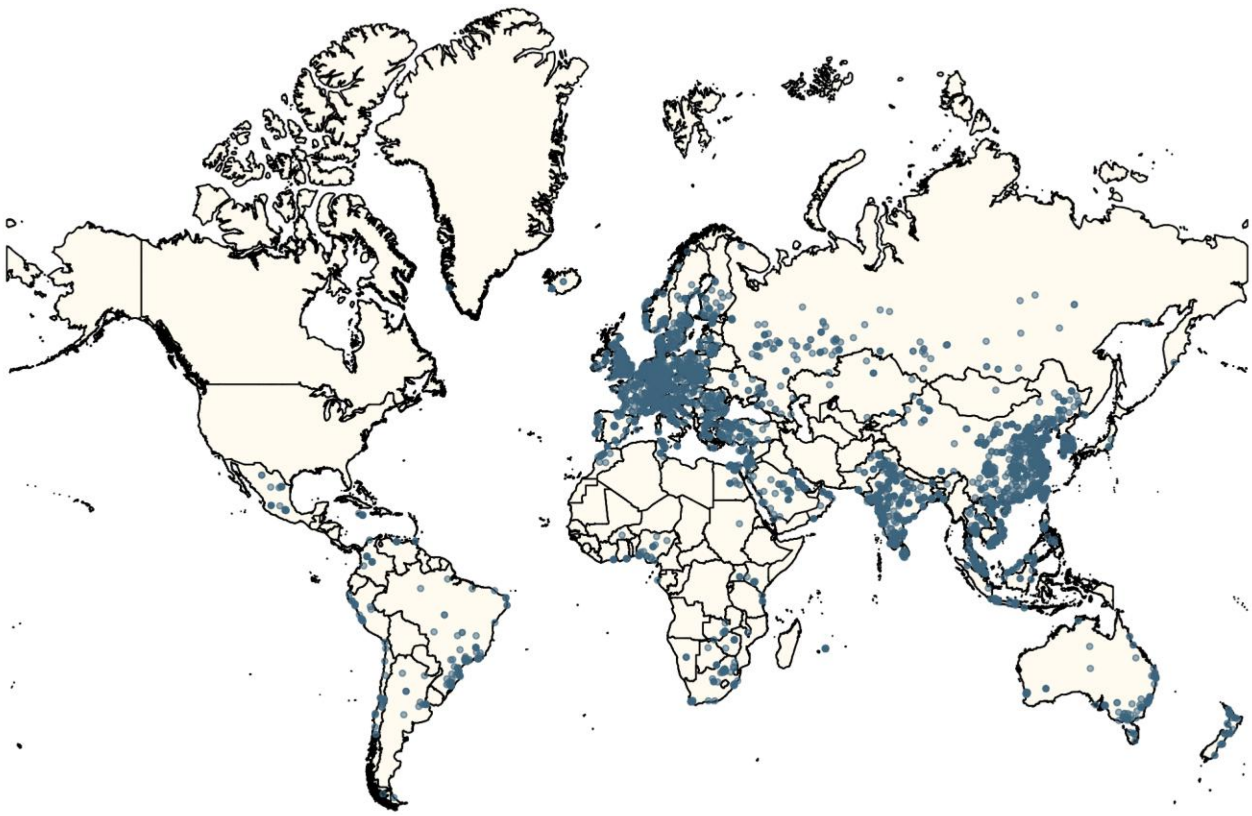
Among other international financial institutions, the Bank for International Settlements (2018), European Central Bank (2021), International Monetary Fund (2021), and the Board of Governors of the Federal Reserve System (2021) voice growing concern with regard to the threat climate change poses to financial stability. In addition, legislators in France[16] and the European Union[17] have recently integrated climate risk into corporate and financial disclosure requirements. To provide guidance, the European Bank of Development and Reconstruction (2018) proposes specific climate-risk metrics, including an assessment of the financial effect of heat exposure as one of six first order physical risks. Our study closely connects to the policy debates on climate change–related disclosure and global warming as a financial risk.

2. Financial Data and Temperatures

2.1. Firms' Locations

For our analyses, we use the universe of firms in Standard & Poor's Compustat Global Database. As information on establishments and firm activities by establishment is scarce in a global context, we link records of firm performance with firms' exposure to temperatures based on headquarters location. For this purpose, we obtain firm locations from Factset Fundamentals and cross-check whether the countries match with Compustat Global records. Subsequently, we geocode street-level addresses using the Bing Maps API and match firms and ERA5 grid nodes by minimizing the respective distance. Clearly, headquarter locations may not represent locations with significant firm operations. To limit the potential distortions caused by such mismatches, we obtain a measure of firms' geographic concentration of assets from Factset's international segment records. In many jurisdictions, publicly listed firms are required to disclose information on their activities by geographic segments in their interim financial reports by adding information on all segments representing more than 10% of total assets, sales, or income. The granularity of the reported segments differs across firms and ranges from state to continental levels. We limit our sample to firms that report segments on a country-by-country basis and obtain information on the concentration of assets in firms' home countries. Ex ante, it is unclear which threshold is adequate to eliminate firms with mismatched temperature data from our sample without imposing unnecessary constraints on the sample and validity of the findings. In a similar setting, Barrot and Sauvagnat (2016) focus on firms with more than 10% of their employees based at headquarter locations to match firms with data on natural disasters. We follow this choice and exclude firms that hold less than 10% of their total assets in their home country.[18] Despite this adjustment, we cannot prevent that firms' exposure to heat is measured with error. However, it is reasonable to expect that the measurement error is randomly

Figure 1. (Color online) Geographic Distribution of the Sample



Notes. This figure shows the geographic distribution of the firms in the sample. To determine a firm-specific measure of heat exposure, we use the location of firms' headquarters combined with information on asset concentration from FactSet Revere records on geographic segments. We exclude firms from the sample that hold less than 10% of their assets in their home country.

distributed and, therefore, likely to attenuate our estimates. The firms in the sample are mapped in Figure 1.

2.2. Financial Performance

We collect financial- and accounting-performance records from Compustat Global. To measure financial performance, we focus on quarterly revenues and operating income. Both revenue and operating income are narrowly defined metrics at the top of the income statement and, therefore, should be relatively less distorted by accounting choices as compared with metrics further down the income statement. We trim the measures below the 1st and above the 99th percentile.[19] Table 1, panel A, shows descriptive statistics. The total asset values in this sample lie between 44 and 581 million U.S. dollars between the 25th and the 75th percentile with a median of 154 million U.S. dollars in firms' total assets.[20]

2.3. Temperatures and Temperature Thresholds

To calculate a firm-specific measure of heat exposure, we obtain global records of daily maximum temperatures from the European Center for Medium-Term Weather Forecasts. The ERA5 reanalysis data of the atmosphere provides continuous daily coverage of a 0.3° × 0.3° grid dating back to 1979. Hersbach et al. (2020) provides a detailed description of the data set. For robustness tests, we also calculate country-level averages of daily maximum temperatures based on ERA5 and obtain the output of the ERA5 data set with daily coverage of a 0.75° × 0.75° grid. We observe firms' financial performance on a quarterly basis and obtain a matching measure of heat exposure by counting the number of days per financial quarter on which firms were exposed to heat. In constructing this measure, we carefully accommodate firms' individual reporting schedules and account for different calendar dates of the fiscal year end. In our main tests, we use two different approaches to classify days as hot as there are economic arguments for the use of absolute thresholds as well as other reasons to rely on place- and time-contingent thresholds. First, physiologic studies demonstrate absolute temperatures above which workers have to reallocate energy from task performance to physical cooling functions. Specifically, Seppänen et al. (2003) document that individual productivity begins to drop at 25°C (Tanabe et al. 2013) and falls with an increasing rate beyond 30°C. As worker performance constitutes one important channel through which temperatures could affect firm performance, we choose 30°C as our first temperature

Table 1. Summary Statistics

Panel A: Firm performance

	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Total assets mUSD	599,347	1,704.92	10,879.70	43.60	153.79	581.37
Revenues mUSD p.q.	592,281	158.29	432.92	7.04	26.20	99.31
Operating income (bef. depr.) mUSD p.q.	587,994	21.04	63.64	0.26	2.27	11.12
Revenues mUSD p.a.	590,359	366.88	1,018.64	14.67	57.05	225.07
Operating income (bef. depr.) mUSD p.a.	586,321	50.07	150.67	0.76	5.45	26.45
Revenues (t)/assets ($t-1$) p.q. (%)	599,347	24.23	18.90	10.93	19.96	32.32
Operating Income (t)/Assets ($t-1$) p.q., %	599,347	2.10	3.50	0.53	2.03	3.80
Labor/total expenses, %	290,665	26.39	19.89	11.06	21.38	35.86

Panel B: Heat exposure

	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Days > 30°C. p.q	599,347	22.47	30.42	0.00	3.00	41.00
Days > 30°C. & 90 Pct. p.q	599,347	7.53	10.88	0.00	2.00	12.00
Days > 30°C. p.q (firm fixed effects)	599,347	0.06	5.36	−1.06	0.00	1.00
Days > 30°C. & 90 Pct. p.q (firm fixed effects)	599,347	0.10	6.31	−1.57	0.00	0.75
Average temperature at firm location	599,347	21.91	8.70	16.24	23.35	29.49

Panel C: Heat exposure and performance of firms with data on analyst forecasts available

Variables	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Days > 30°C. p.q	55,927	16.83	26.71	0	1	24
Days > 30°C. & 90 Pct. p.q	55,927	6.51	10.26	0	0	10
ERA5 average temperature at firm headquarters	55,927	19.87	9.27	12.15	21.54	27.37
Quarterly revenues over assets ($t-1$), %	55,927	26.08	16.65	14.63	22.52	33.31
Quarterly operating income over assets ($t-1$), %	55,781	3.42	2.79	1.81	3.10	4.76
Total Assets mUSD	55,927	4,004.39	7,989.02	301.79	1,025.60	3,495.47

Panel D: Analyst forecast errors—revenues

Variables	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Quarterly revenues mean surprise/assets	55,927	−0.15	2.13	−0.79	0	0.58
Quarterly revenues median surprise/assets	55,890	−0.14	2.10	−0.75	0	0.56

Panel E: Analyst forecast errors—pretax income

Variables	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Quarterly pretax income mean surprise/assets	40,590	−0.15	0.90	−0.44	−0.01	0.24
Quarterly pretax income median surprise/assets	40,573	−0.15	0.89	−0.44	−0.01	0.23

Panel F: Revenue forecast changes before the earnings announcement date

Variables	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Revenue forecast changes for window (a)	53,003	0.64	1.27	0	0	1
Revenue forecast changes for window (b)	55,563	2.51	4.20	0	1	3
Revenue forecast changes for window (c)	55,897	3.57	6.12	0	1	4

Panel G: Income forecast changes before the earnings announcement date

Variables	(1) N	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Pretax income forecast changes for window (a)	38,174	0.62	1.19	0	0	1
Pretax income forecast changes for window (b)	40,277	2.50	3.88	0	1	3
Pretax income forecast changes for window (c)	40,568	3.58	5.67	0	2	4

Table 1. (Continued)

Panel H: Heat exposure of firms with available data on earnings-announcement returns

Variables	(1) *N*	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Days > 30°C. p.q	40,210	18.84	28.08	0	1	31
Days > 30°C. & 90 Pct. p.q	40,210	7.05	10.61	0	1	11
Average temperature at firm location	40,210	20.39	9.40	13.45	21.77	28.17
Revenues (t)/assets ($t-1$) p.q.	38,913	25.94	16.88	14.38	22.24	33.04
Operating income (t)/assets ($t-1$) p.q.	38,843	3.39	2.74	1.81	3.08	4.69
Total assets mUSD	40,210	7,375.78	26,486.08	321.70	1,136.22	4,165.60

Panel I: Announcement returns

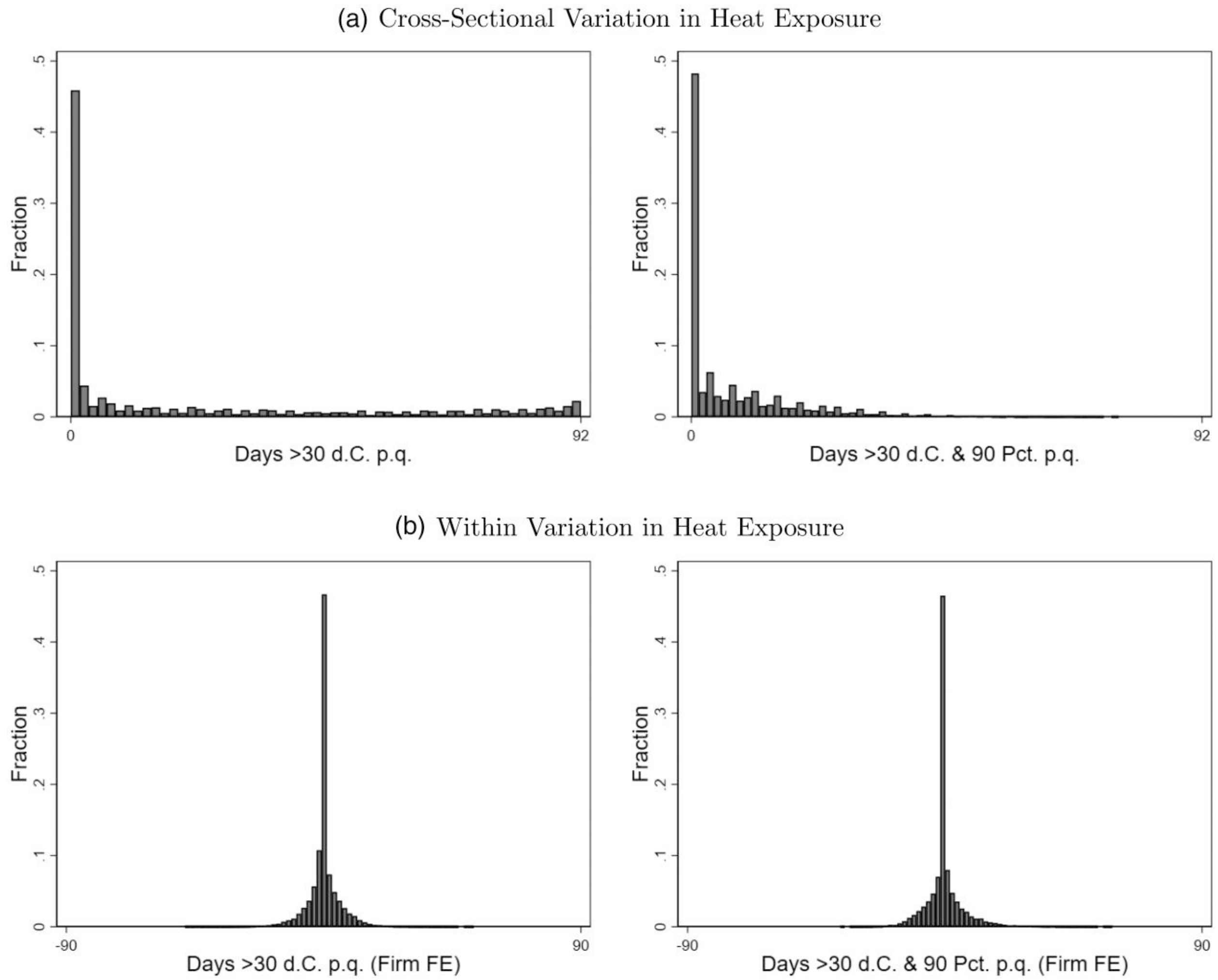
Variables	(1) *N*	(2) Mean	(3) Standard deviation	(4) p25	(5) p50	(6) p75
Cum. return, 3 days	40,210	−0.11	4.78	−2.77	−0.20	2.47
Cum. benchmark-adj. return (EW), 3 days	40,210	0.01	4.60	−2.59	−0.11	2.49
Cum. abnormal return (MM, EW), 3 days	40,210	0	4.63	−2.61	−0.10	2.49
Cum. return, 5 days	40,210	−0.17	5.84	−3.45	−0.28	3.03
Cum. benchmark-adj. return (EW), 5 days	40,210	−0.01	5.56	−3.15	−0.15	3.03
Cum. abnormal return (MM, EW), 5 days	40,210	−0.02	5.60	−3.19	−0.16	3.05
Cum. return, 7 days	40,210	−0.23	6.58	−3.95	−0.31	3.44
Cum. benchmark-adj. return (EW), 7 days	40,210	−0.01	6.25	−3.58	−0.15	3.45
Cum. abnormal return (MM, EW), 7 days	40,210	−0.03	6.30	−3.59	−0.17	3.44
Cum. return, 11 days	40,210	−0.36	7.76	−4.73	−0.37	4.05
Cum. benchmark-adj. return (EW), 11 days	40,210	−0.01	7.34	−4.24	−0.10	4.12
Cum. abnormal return (MM, EW), 11 days	40,210	−0.04	7.40	−4.30	−0.13	4.13

Notes. Panel A shows descriptive statistics on firm performance. Reported are the mean; standard deviation; and the 25th, 50th, and 75th percentiles (p25, p50, p75) for, respectively, current quarter (t) revenue (operating income) as a percentage of one-year-lagged ($t-1$) total assets and for total assets, revenues, and operating income before depreciation (in millions of U.S. dollars). All variables in panel A are obtained from Compustat Global and trimmed at the 1st and 99th percentiles to remove outliers. Panel B shows statistics on firms' heat exposure based on two alternative measures of the number of days a firm's headquarters location experiences heat. To determine a firm-specific measure of heat exposure, we use the location of firms' headquarters combined with information on asset concentration from FactSet Revere records on geographic segments. We exclude firms from the sample that hold less than 10% of their assets in their home country. The first measure of heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C (Days > 30°C. p.q). The second measure is based on the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the historic (1980–1999) distribution of temperatures that occurred at the firm's location on the same day as well as the five preceding and subsequent days (Days > 30°C & 90th Pct. p.q.). Firm fixed effects indicates that the respective variable has been demeaned with the firm-specific average across the sample period. Reported is also the average temperature observed at the firm's locations. *N* refers to firm quarters. Panel C shows summary statistics on the two alternative measures of firms' heat exposure based on the sample firms used in analysis of analysts' forecast errors along with the average temperature observed at the firms' locations. Panel D presents summary statistics on the measures of analysts' revenue-forecast errors, whereas panel E shows statistics on errors in analysts' forecasts of pretax income. The quarterly error in forecast of a firm's revenue (pretax income) is computed by deducting either the mean or the median of forecasts (that analysts in the IBES universe reported for the firm) from the actual revenue (pretax income) and then scaling this difference by total assets lagged by four financial quarters. All variables in panels D and E are obtained from IBES and trimmed at the 1st and 99th percentiles to remove outliers. *N* refers to firm quarters. Panels F and G show how often analysts update forecasts. The tables correspond to the windows shown in Figure A.5. The variables show the number of changes in revenue (panel F) and income (panel G) forecasts. All variables from IBES. *N* refers to firm quarters. Panel H shows summary statistics on the two alternative measures of firms' heat exposure based on the sample firms used in analysis of quarterly earnings-announcement returns along with the average temperature observed at the firms' locations. Panel I presents summary statistics on the accumulated daily stock returns firm experiences during the 3 (5, 7, 11) days surrounding the earnings-announcement date (Cum. return, 3 days), statistics on earnings-announcement returns relative to a benchmark return, and statistics on abnormal returns derived from estimating firms' equity betas in market models (MM) of their stock returns. The benchmark used in computation of benchmark-adjusted and abnormal returns is an equal-weighted (EW) average of all firms in the global sample. Stock returns from Compustat Global Security Daily, converted to U.S. dollars, and trimmed at the 1st and 99th percentiles.

threshold. At the same time, individuals and organizations are likely to adapt to typical weather conditions. Whether temperatures cause economic repercussions could, therefore, be contingent on the local level of adaptation driven by historical temperature conditions. To test if temperatures are particularly damaging when they are unusual given the place and time of the year, our second threshold combines the absolute threshold of 30°C with a location-specific indicator of whether temperatures are extreme compared with past temperature distributions. To construct this indicator, we first derive historical temperature distributions by day of the year and location by aggregating temperatures from 1980 to 1999 on the day (e.g., July 15) itself as well as the previous and subsequent five days (generating an estimation window from July 10 to July 20). Next, we determine the historical 90th percentile threshold of the resulting distribution for every location and day of the year. We classify days as hot when the daily maximum temperature during the sample period exceeds the historical 90th percentile threshold.[21]

Table 1, panel B, shows the summary statistics of the measures of heat exposure for the firms in the sample from 1995 to 2019. Because we estimate all empirical tests based on within-firm variation, we show both the cross-sectional and within variation in the number of high-temperature days. The median temperature per financial quarter in this sample is 23.4°C with 16.2°C at the 25th percentile and 29.5° at the 75th percentile. On average, firms are exposed to 22.5 days per financial quarter on which temperatures exceed 30°C. The exposure varies strongly between firms (25th percentile: 0 days, 75th percentile: 41 days). As Figure 2 shows, the choice of the absolute thresholds in isolation leads to a setting in which some firms are "always treated" with temperatures exceeding 30°C on every day of the respective financial quarter. However, when firms are classified as exposed to heat based on both the absolute and the relative percentile thresholds, more firm financial quarters are subject to within variation. The standard deviation in the number of days exposed to temperatures above 30°C deviating from the location-specific average is 5.4 days per quarter and 6.3 days under the combined 30°C and 90th percentile threshold.

Figure 2. Identifying Variation



Notes. (a) Cross-sectional variation in heat exposure. (b) Within variation in heat exposure. Panel (a) shows the cross-sectional variation in quarterly heat exposure. When using absolute temperature thresholds to classify days as extremely warm (above 30°C at a firm's location), some firms are either never or always "treated" (see image on the left). In other words, they are located in climate zones in which the thresholds are always or never crossed. The image on the right shows the distribution of quarterly heat exposure measured by days on which temperatures exceed not only 30°C, but also the 90th percentile of the historic (1980–1999) distribution of temperatures that the firm experienced on the same day as well as on the five preceding and subsequent days. Panel (b) shows *within variation* in quarterly heat exposure. This variation is the number of days in a fiscal quarter on which firms experienced extreme temperatures minus the average number of days of heat exposure in the same quarter over the years in the sample period.

3. Heat Exposure and Financial Performance

In our first analysis, we test whether firm performance is sensitive to short-term changes in exposure to extreme temperatures. In contrast to Zhang et al. (2018) and Somanathan et al. (2021), we focus specifically on the capital-market lens. Therefore, we chose revenues and operating income over assets as our outcome variables instead of economic concepts that measure productivity. These outcomes are of particular interest to analysts and investors and allow us to align the tests for the sensitivity of firm performance to extreme temperatures with analyses of investor and analyst expectations later in the paper. Our identification strategy accounts for long-term corporate decision making that frequently involves the climate. For instance, production decisions might be based on the average climate exposure in a given location, or entrepreneurs might choose to establish businesses in places that provide optimal operational conditions. If firms with particular observable or unobservable characteristics choose to locate (produce) in a specific place (certain products or use particular technologies), these characteristics could be correlated with both the climate and observed financial performance. In contrast, year-to-year differences in the realized weather cannot be influenced by the firms' decisions or predicted with a high level of accuracy in the long run. Therefore, we can causally identify the impact of heat exposure on firm performance—net of all short-term adaptation potential that firms realize—based on the variation in the number of realized hot days over time. Compared with the location- and season-specific average temperature conditions, the realization in any given year is randomly distributed and exogenously determined conditional on spatial and temporal fixed effects (see Auffhammer et al. 2013, Dell et al. 2014 for a discussion of the approach). Figure 2(b) illustrates this variation and shows that the number of days when firms are exposed to heat in a given financial quarter compared with the average number of days of exposure varies substantially by firm.

To isolate this variation, we use pooled ordinary least squares (OLS) regressions with firm–season fixed effects. Instead of simple firm fixed effects, we rely on firm–season fixed effects to avoid pronounced and potentially confounding firm-specific seasonality. For instance, if firms in certain industries face either particularly low or high returns in the warmest quarter of the year, lower temperatures would, by construction, be associated with lower firm performance. Addressing this seasonality with separate firm and quarter fixed effects does not adequately address this concern as seasonality may vary by firm depending on the firm's operations and location. Equations (1) and (2) outline the OLS specification:

$$\frac{revenues_{ist}}{assets_{ist-1}} = \sum_{t=-3}^{0} \beta\, Heat\ Exposure_{ist} + \mu_{is} + \gamma_{mt} + \delta\, Trend_{ct} + \epsilon_{ist}, \tag{1}$$

$$\frac{operating\ income_{ist}}{assets_{ist-1}} = \sum_{t=-3}^{0} \beta\, Heat\ Exposure_{ist} + \mu_{is} + \gamma_{mt} + \delta\, Trend_{ct} + \epsilon_{ist}, \tag{2}$$

where i stands for the firm, s stands for the fiscal quarter of the year ($s = 1, \ldots, 4$) based on each firm's financial reporting schedule, and t stands for the observed year. To ensure that our results are not confounded by potential heat shocks on assets, we lag assets by one year in $\frac{revenues_{ist}}{assets_{ist-1}}$ and $\frac{operating\ income_{ist}}{assets_{ist-1}}$. The firm–financial quarter fixed effect, μ_{is}, absorbs the firm location– and firm season–specific heat-exposure levels. γ_{mt}, an industry–year fixed effect, absorbs the variation in financial performance resulting from technological change or industry-specific economic trends with m as an index for M industries determined by i. $\delta Trend_{ct}$ indicates country linear trends with c as an index for C countries determined by the location of i. $Heat\ Exposure_i$ is the number of days in a quarter firm i is exposed to heat. It is ex ante unclear when the financial effects of heat become apparent, so we include three lags in our main tests. To ensure that our results are driven by heat and not by changes at the other extreme end of temperature distributions, we also present results for specifications that control for the number of cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. We cluster standard errors two ways at the country and year–quarter levels.[22]

As location-specific variation in heat exposure over time cannot be actively influenced by the firm's choices, no firm-specific characteristics should drive both the outcome and the measure of heat exposure. Hence, we do not include controls for time-varying firm-level characteristics in the baseline analysis to avoid bad-control problems[23] at the expense of potentially unnecessarily high residual variance (Dell et al. 2014). However, as we focus on common financial ratios with revenues and operating income scaled by assets, we implicitly account for variation in firm size over time.

Table 2 and Figure 3 show the estimates of the effect of extreme temperatures on financial performance in the current as well as the three subsequent financial quarters. In addition to the main regression model, columns (2), (4), (6), and (8) in Table 2 are augmented with controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Columns (1)–(4) refer to

Table 2. Heat Exposure and Firm Performance

	Revenues/assets				Op. income/assets			
	30°C		30°C/90thP		30°C		30°C/90thP	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat exp. (q)	−0.0005	−0.0004	−0.0031	−0.0027	−0.0004	−0.0005	−0.0013**	−0.0013*
	(0.0048)	(0.0050)	(0.0035)	(0.0039)	(0.0010)	(0.0011)	(0.0006)	(0.0007)
Heat exp. ($q-1$)	−0.0087	−0.0089	−0.0104	−0.0102	−0.0030***	−0.0030***	−0.0028***	−0.0028**
	(0.0065)	(0.0063)	(0.0082)	(0.0080)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Heat exp. ($q-2$)	−0.0031	−0.0046	−0.0061**	−0.0071**	−0.0008	−0.0011	−0.0014	−0.0016
	(0.0035)	(0.0032)	(0.0030)	(0.0033)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Heat exp. ($q-3$)	0.0025	0.0015	−0.0022	−0.0027	−0.0004	−0.0006	−0.0004	−0.0004
	(0.0036)	(0.0033)	(0.0037)	(0.0038)	(0.0008)	(0.0008)	(0.0007)	(0.0007)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	No	Yes	No	Yes	No	Yes	No	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\sum$ heat exposure	−0.0098	−0.0123	−0.0219	−0.0227*	−0.0047**	−0.0051**	−0.0059***	−0.0061***
Joint p-value	(0.38)	(0.25)	(0.10)	(0.09)	(0.03)	(0.01)	(0.00)	(0.00)
R^2	0.7511	0.7512	0.7511	0.7512	0.5780	0.5782	0.5781	0.5782
Mean dep. variable	24.23	24.23	24.23	24.23	2.10	2.10	2.10	2.10
Number of observations	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347
Number of firms	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591
Number of countries	93	93	93	93	93	93	93	93

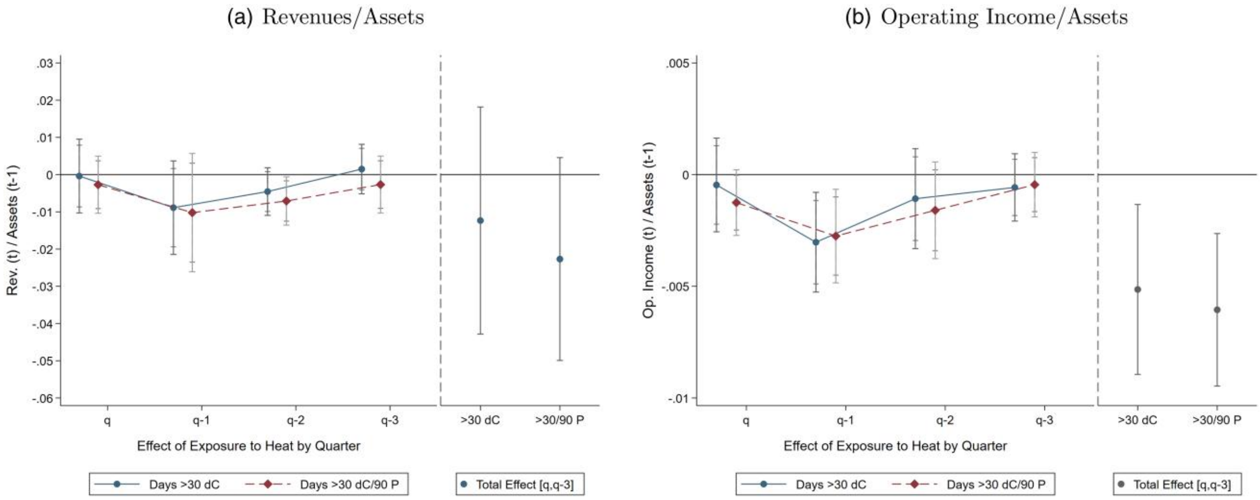
Notes. This table reports the effects of high temperatures on quarterly revenues as a percentage of assets (Revenues/assets, columns (1)–(4)) and operating income as a percentage of total assets (Op. income/assets, columns (5)–(8)); see specifications in Equations (1) and (2). Heat exposure refers to the number of days in a quarter on which the firm experiences a temperature exceeding a threshold level based on headquarters location. To determine a firm-specific measure of heat exposure, we match firms and temperatures based on headquarters location, but require firms to hold at least 10% of their assets in their home country. In columns (1), (2), (5), and (6), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C. In columns (3), (4), (7), and (8), heat exposure is the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days (30°C/90thP). All specifications include heat exposure augmented with three lagged quarterly exposures (q, $q-3$), firm–financial quarter fixed effects, industry–year fixed effects, and country linear trends. Columns (2), (4), (6), and (8) additionally include controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. In addition, the sum of coefficients on the four quarterly heat exposures (q, $q-3$) are presented along with p values for tests of their joint significance (joint p-value). The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

revenues, columns (5)–(8) to operating income over assets. We find that both quarterly revenues and income over assets decrease with the number of hot days. The effects on firms' income are more pronounced: temperatures above 30°C have a statistically significant effect on operating income regardless of whether the temperatures are unusual (columns (7) and (8) of Table 2) or not (columns (5) and (6)). As Figure 3 shows, the effects on revenues and income set in with a lag of one to two financial quarters. Observing such a lagged effect is plausible if extreme temperatures delay or distort operations in ways that only materialize when products are sold in subsequent financial periods. Moreover, observing lagged effects after environmental shocks is consistent with the related literature (e.g., Barrot and Sauvagnat 2016).

To understand the overall magnitude of the effect, we calculate the cumulative effects of heat over the directly affected and three lagged financial quarters. The size of the effect is both plausible and economically meaningful. First, with regard to the plausibility of the magnitude, we compare the estimates to the effects documented in the context of heat exposure and individual performance. Based on column (4) of Table 2, we estimate that, relative to the average revenue over assets in the sample divided by the days in the respective financial period (the quarterly ratio of 24.2% divided by 90 days), an additional day above 30°C and the 90th percentile reduces firms' (daily equivalent of) revenue by 8.4%. In addition, based on column (6) (column (8)), we estimate that an additional day of temperatures above 30°C (30°C and the 90th percentile) corresponds to a reduction of about 21.9% (26.1%) in daily equivalent operating income given a mean quarterly operating income over assets of 2.1%. Thereby, the relative response of operating income is not only statistically stronger, but also larger in magnitude compared with the effect of one additional day of high temperatures on revenues. The difference in the magnitude of the effects on revenues and income could indicate that there are both detrimental effects on revenues and expenses, which we investigate in the next section. According to Seppänen et al. (2003), worker exposure to temperatures above 25°C in the office environment

Figure 3. (Color online) Heat Exposure and Firm Performance



Notes. (a) Revenues/assets. (b) Operating income/assets. This figure reports the effects of high temperatures on quarterly revenues as a percentage of assets and on operating income as percentage of total assets; see specifications (1) and (2). Heat exposure refers to the number of days in a quarter on which the firm experiences a temperature that exceeds the threshold level indicated by the legend of the figure. We match firms and temperatures based on headquarters location but require firms to hold at least 10% of their assets in their home country. The specifications include heat exposure in the directly affected quarter (q) as well as exposures in three lagged quarters ($q-1$, $q-2$, $q-3$), firm–financial quarter fixed effects, industry–year fixed effects, and country linear trends and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Two-way standard errors clustered at the country and year–quarter level. Small bars indicate 90% and 95% confidence intervals.

decreases their task performance by 2% per additional degree; a daily temperature increase to 30°C would, hence, correspond to an expected output loss of 10%. The effects on revenues fall into a similar range.[24] In addition, the effect size is similar to the estimates of Zhang et al. (2018). The authors study a large sample of firms in China and find that an additional day above 90°F (32.2°C) per year decreases annual output by 0.45%. Relative to the quarterly operating income over assets, we document a reduction of 0.24 (0.29) per additional day above 30°C (30°C/90th percentile).

Second, the estimated effect is relevant in economic terms given that firms exert effort to optimize operational performance. A one-standard-deviation increase in the number of hot days (5.4 days above 30°C, 6.3 days above 30°C and above the 90th percentile) compared with the average conditions results in a 0.028 (0.0051×5.4, column (6), >30°C) to 0.038 (0.0061×6.3, column (8), >30°C/90th percentile) percentage point reduction in operating income over assets over four financial quarters.[25] Relative to the average quarterly operating income over assets, a one-standard-deviation increase in days above 30°C (30°C and the 90th percentile) compared with average local conditions reduces operating income over assets by 1.3% (1.8%),[26] leading to an absolute decrease of 469,536 (655,202) U.S. dollars for an individual firm given the mean total assets of the firms in our sample.

3.1. Robustness Tests

We conduct a series of robustness tests. First, we compare our estimates to alternative regressions with different sets of fixed effects in Table A.2. We find very similar results when we replace the combined firm–quarter with simple firm fixed effects and test continent–year–quarter fixed effects as alternatives to country-linear trends. Second, to test if the results could be driven by spurious correlations and to provide alternative p values, we conduct a permutation test in Figure A.1. Following Hsiang and Jina (2014) and Fishman et al. (2019), we randomly reassign heat exposures in three ways: (a) unconditionally, (b) between firms and preserving the ordering of years, and (c) within firms but reshuffling observations over time. Approach (b) maintains the time structure within the data and helps to test if regional trends generate spurious correlations. Approach (c) only affects the time structure of the observed heat exposure to test if time-invariant cross-sectional patterns impose spurious correlations. Based on the random reassignment, we reestimate the model in Equation (1) 5,000 times. In support of the statistical model, we find in Figure A.1 that the average effects with randomly assigned heat exposures are centered around zero. Only for the distribution of the coefficients of the effect of heat on revenues in panel (b), we obtain a mean slightly larger but close to zero (0.005). Further, we obtain p-values by calculating the share of estimations that yield coefficient sizes equal to or larger than the actual estimate. Most values are smaller than 0.01 with the exception of the left-hand side of panel (c) with a p-value of 0.011. Therefore, it is unlikely that our findings are an outcome of chance or driven by errors in the research design. Third, we test if the results could be confounded by the financial crisis as aggregate financial shocks could have coincided with particularly high temperatures. Table A.3 shows that the magnitude of the estimates slightly increases after we exclude the years of 2008–2009 (2008–2010). Fourth, we estimate our results with ERA-Interim (ERAi) as well as country-level ERA5 average temperatures in Figure A.7. ERA5 and ERAi produce similar estimates although the results are stronger in magnitude and significance when we use ERAi: for instance, we find that both revenues and operating income decrease significantly and over two instead of only one financial quarter. In contrast, country-level averages yield wider confidence intervals compared with the estimates of the effects of more local temperature records. Fifth, we replace the temperature thresholds to define days as hot with a series of alternatives in Table A.4.[27] Across all alternative thresholds, we find a negative sign. For revenues, days above 25°C and the 90th percentile threshold (column (2)) and 30°C and the 90th percentile (column (5)) lead to significant decreases (10% level). For operating income, we find significant decreases for days with temperatures above 25°C/90th percentile, 25°C/95th percentile, 30°C, 30°C/90th percentile, and 30°C/95th percentile.

We also estimate the effects of temperatures on firm performance using a bin specification. The coefficients are plotted in Figure A.2. We find that, for the average firm, operating income over assets peak between 20°C and 25°C. Further, the main effects of days with temperatures above 30°C are not solely driven by the most extreme days as the effects of temperatures from 30°C to 35°C and above 35°C are similar in magnitude and significance. In line with Brown et al. (2021) and Zhang et al. (2018), we find that not only high, but also low temperatures can reduce revenues and operating income. However, low temperatures occur much less frequently: the average firm experiences temperatures below –5°C (–5°C to 0°C) on 2.6 (5.3) days over four financial quarters and temperatures between 30°C and 35°C (above 35°C) on 78.4 (15.9) days.[28]

In addition, we test if firms compensate for the short-run performance shocks in later time periods or whether the shocks persist beyond the horizon of one fiscal year. Figure A.3 plots the effects of firms' heat exposure on annual revenues and operating income. The results are of a slightly larger magnitude and materialize after a longer lag compared with the main tests. We find neither evidence for the persistence of an effect beyond four financial quarters nor a pronounced reversal in the long run. However, the individual effects are not statistically significant.[29]

Moreover, we estimate the results for different levels of asset concentration in the firm's home country. If our estimates indeed capture the financial repercussions of heat, we might expect that the strength of the results increases with the quality of the match, which could increase with firms' concentration of assets. At the same time, different levels of asset concentration may be correlated with other covariates, such as firm size, profitability, and financial constraints, which could all directly influence the estimated magnitude. For firm performance (Figure A.4(a)), we find the most negative, partly insignificant, estimates for firms with 75%–100% of assets in the home country.

3.2. Firm Expenses

Our results so far indicate that firm performance is negatively affected by heat exposure. To better understand firms' responses, we investigate if heat exposure also affects expenses. For instance, the additional electricity consumption for cooling could increase utility bills. At the same time, heat-related hazard pay could increase per-hour wages, and a short-term increase in labor inputs to meet contractual obligations could affect total wage bills. We observe outcomes in three different variables related to these considerations: firms' COGS, SGA expenses, and wages. Standard & Poor's defines COGS as "all expenses directly allocated by the company to production, such as material, labor, and overhead." SGA include "all commercial expenses of operation (such as, expenses not directly related to product production) incurred in the regular course of business" (Standard & Poor's 2004, p. 48). Both wages and electricity costs can, in principle, be attributed to the COGS or SGA. However, attribution of utility costs to SGA is common (Robinson 2020).

Table 3 shows the results for the effects of temperature on expenses, and the coefficients are plotted in Figure 4. Whereas we find evidence for transitory increases in expenses in terms of individual lags, the significance of the cumulative effects of heat across four quarters is limited: the only significant cumulative impact of temperatures above 30°C affects the logarithm of wages (column (3), coefficient 0.0023, significant at the 5% level). Potentially, the insignificant cumulative effects could indicate that firms experience temporary increases and respond with measures to cut cost in later time periods. In terms of transitory effects, the log of the COGS increases when temperatures exceed 30°C (column (1), coefficient 0.0006, significant at the 5% level). When 30°C is unusual relative to the place- and season-specific distribution of temperatures, we find a small positive effect on the logs of COGS (column (4), coefficient 0.0004, significant at the 10% level) and SGA (column (5), coefficient 0.0005, significant at the 1% level). To put the magnitude of this transitory response into context, we have to make a series of assumptions. An immediate increase of 0.05% in SGA expenses corresponds to an increase of 1,854 U.S. dollars per additional hot day (above both 30°C and the 90th percentile) at the median quarterly SGA expense of 3.708 million U.S. dollars. According to the U.S. Energy Information Administration (2012), the average annual electricity costs of a sample of 2,391,000 fully cooled commercial

Table 3. Heat Exposure and Firm Expenses

	Ln(COGS)	Ln(SGA) 30°C	Ln(Wages)	Ln(COGS)	Ln(SGA) 30°C/90thP	Ln(Wages)
	(1)	(2)	(3)	(4)	(5)	(6)
Heat exp. (q)	0.0006**	0.0003	0.0005	0.0004*	0.0005***	0.0005
	(0.0003)	(0.0004)	(0.0007)	(0.0003)	(0.0002)	(0.0007)
Heat exp. ($q-1$)	0.0000	−0.0002	0.0005	−0.0003	−0.0004	−0.0001
	(0.0004)	(0.0007)	(0.0003)	(0.0005)	(0.0007)	(0.0004)
Heat exp. ($q-2$)	0.0001	0.0000	0.0010***	0.0003	0.0001	0.0010*
	(0.0003)	(0.0004)	(0.0003)	(0.0002)	(0.0003)	(0.0006)
Heat exp. ($q-3$)	0.0003	0.0005	0.0003	−0.0001	0.0005	0.0002
	(0.0004)	(0.0006)	(0.0004)	(0.0003)	(0.0005)	(0.0004)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes
$\sum$ heat exposure	0.0011	0.0006	0.0023**	0.0003	0.0008	0.0016
Joint p-value	(0.28)	(0.64)	(0.03)	(0.71)	(0.31)	(0.17)
R^2	0.9190	0.9369	0.9119	0.9190	0.9370	0.9119
Mean dep. variable	7.44	6.06	5.86	7.44	6.06	5.86
Number of observations	532,598	532,598	291,870	532,598	532,598	291,870
Number of firms	16,896	16,896	10,182	16,896	16,896	10,182
Number of countries	92	92	92	92	92	92

Notes. This table reports the effects of high temperatures on different measures of firm expense: SGA, COGS, and wages. The dependent variables refer to the natural logarithm of U.S. dollar-denominated expenses. Heat exposure refers to the number of days in a quarter that the firm experiences a temperature that exceeds a threshold level based on headquarters location. We match firms and temperatures based on headquarters location but require firms to hold at least 10% of their assets in their home country. In columns (1)–(3), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C. In columns (4)–(6), heat exposure is the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days (30°C/90thP). All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$); firm–financial quarter fixed effects; industry–year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. In addition, the sum of coefficients on the four quarterly heat exposures (q, $q-3$) are presented along with p-values for tests of their joint significance (Joint p-value). The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

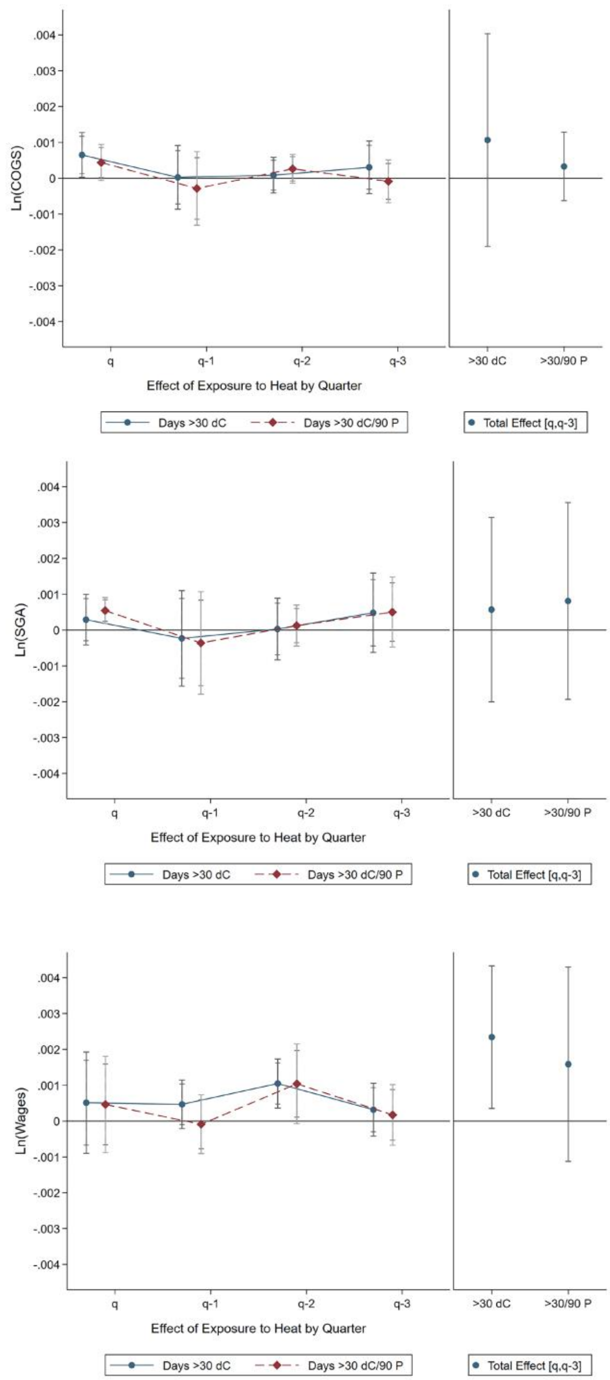
buildings with an average of 15,757 square feet (1,464 meters squared) is 27,162 U.S. dollars. Not taking different sources of electricity costs and usage into account, this number corresponds to a daily cost of cooling of 74 U.S. dollars per building. We do not have information on the facilities of the firms in our sample at hand. If the increase in SGA were exclusively attributable to electricity, the estimate for the increase in SGA under one additional day of 30°C would be equivalent to the daily costs of cooling 25 buildings. At a median number of 936 employees per firm, this number appears rather large for increased costs to be attributable to electricity use only.

As for wages, columns (3) and (6) indicate an increase after two financial quarters rather than an immediate effect. In principle, one could expect that heat-related hazard pay influences wages in the quarter in which workers are directly affected by heat. However, an increase after two quarters could arise with intertemporal substitution, for example, when firms increase labor inputs to compensate for an earlier decrease in performance. Apart from that, the lagged effect is consistent with the finding that heat affects revenues and income beyond the current financial quarter as well as with the estimates of related studies on firm performance and environmental shocks (e.g. Barrot and Sauvagnat 2016). Depending on inventories or turnover times in production, it is possible that the performance shortfalls only become visible later in the financial year and delay firms' responses.[30] In terms of the magnitude of the effect on wages, we find that one additional day of 30°C increases wages by 0.1% after two quarters. To put this result into context, the increase corresponds to additional costs of 3,460 U.S. dollars at the median value of quarterly wages of 3.46 million U.S. dollars per firm in our sample. At the 2019 U.S. median hourly wage of 19.33 U.S. dollars (Economic Policy Institute 2020), this effect corresponds to a loss of 179 worker hours and a decrease in the time worked of 11.5 minutes per worker at the median number of 936 employees from Factset Fundamentals.

3.3. Economic Channels and Heterogeneity

As these analyses show, the detrimental effects of heat are not solely driven by cost channels: The estimates are of mixed significance and do not match the magnitude of the decrease in operating income. Unrelated to costs, two different forces could affect firm performance: heat

Figure 4. (Color online) Heat Exposure and Firm Expenses



Notes. This figure shows the effect of high temperatures on log expenses. We observe three different outcomes related to these considerations: Firms' COGS, SGA, and wages. Standard & Poor's defines the COGS as "all expenses directly allocated by the company to production, such as material, labor, and overhead." SGA are "all commercial expenses of operation (such as, expenses not directly related to product production) incurred in the regular course of business." Heat exposure refers to the number of days in a quarter on which the firm experiences a temperature above the threshold level indicated by the legend of the figure. We match firms and temperatures based on headquarters location but require firms to hold at least 10% of their assets in their home country. The specifications include heat exposure in the directly affected quarter (q) as well as exposures in three lagged quarters ($q-1$, $q-2$, $q-3$), firm–financial quarter fixed effects, industry–year fixed effects, and country linear trends and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Two-way standard errors clustered at the country and year–quarter level. Small bars indicate 90% and 95% confidence intervals.

exposure could delay or compromise firms' operations, or the decreases in performance could be demand-driven if firms' customers are simultaneously affected by heat. In Table 4, we use information on the geographic separation of firms' assets and sales and interact heat exposure with an indicator of whether firms' top geographic revenue segment is a foreign country. We find that shocks of heat are attenuated (positive and significant interaction terms in columns (1), (3), (5), and (7)) when the largest geographic segment of corporate customers is not exposed to the same temperature shocks as the firm itself. However, the interaction term is insignificant and has an inconsistent sign when we measure the dependence on domestic demand with an indicator of whether less than 30% of firm sales are realized in the home country. In line with this mixed evidence, recent literature indicates that both supply and demand shocks may be relevant.[31] The distinction has important managerial implications: if firms are subject to demand shocks through heat exposure, firm-level investment in adaptation can only partially mitigate the negative effects. In contrast, the differentiation is less focal in capital markets: analysts and investors must assess the total effect of heat on firm performance and are less concerned with the decomposition of the effect by channel.

If the observed decrease in financial performance is at least partially supply-related, the magnitude of the effect might vary with firms' operational sensitivity to heat. In Table 5, we test several hypotheses related to this idea.[32] First, the literature argues that reduced labor supply (e.g., Graff-Zivin and Neidell 2014) and productivity may be an important economic channel through which extreme temperatures affect economic output. Therefore, we interact heat exposure with several measures of firms' vulnerability to temperatures: we calculate the share of labor expenses over total expenses and lag labor and total expenses by one year to preempt confounding direct heat shocks to the share of labor costs.[33] Consistent with the hypothesis that labor may be an important mechanism, we find a negative and significant coefficient for this interaction term for both revenues and operating income (columns (1) and (8), significant at the 10% and 1% levels). Moreover, we use a proxy of firm-level average wages per

Table 4. Heat Exposure and Firm Performance—Geographic Sales-Assets-Separation

	Revenues/assets				Op. income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
∑ heat exp. > 30°C	−0.0083**	−0.0023			−0.0027***	−0.0014***		
	(0.0041)	(0.0030)			(0.0006)	(0.0005)		
∑ heat exp. > 30°C & 90thPctl			−0.0102**	−0.0054			−0.0025***	−0.0015***
			(0.0043)	(0.0034)			(0.0006)	(0.0005)
∑ heat exp. > 30°C × #1 revenue abroad	0.0098**				0.0024***			
	(0.0044)				(0.0009)			
∑ heat exp. > 30°C × < 30% domestic sales		−0.0053				0.0003		
		(0.0063)				(0.0011)		
∑ heat exp. > 30°C & 90thPctl × #1 revenue abroad			0.0077*				0.0015*	
			(0.0042)				(0.0008)	
∑ heat exp. > 30°C & 90thPctl × < 30% domestic sales				−0.0031				−0.0003
				(0.0044)				(0.0008)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test difference (p-value)	(0.67)	(0.20)	(0.52)	(0.12)	(0.67)	(0.37)	(0.14)	(0.07)
R^2	0.7489	0.7489	0.7489	0.7489	0.5676	0.5676	0.5676	0.5676
Mean dep. variable	24.49	24.49	24.49	24.49	2.18	2.18	2.18	2.18
Number of observations	588,974	588,974	588,974	588,974	588,974	588,974	588,974	588,974
Number of firms	17,048	17,048	17,048	17,048	17,048	17,048	17,048	17,048
Number of countries	92	92	92	92	92	92	92	92

Notes. This table reports the effects of high temperatures on revenues as a percentage of assets (Revenues/assets, columns (1)–(4)) and operating income as a percentage of total assets (Op. income/assets, columns (5)–(8)) in interaction with indicators of revenue earned abroad. Reported are the sum of coefficients on the four quarterly heat exposures (q, $q-3$) along with standard errors. In columns (1), (2), (5), and (6), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C (Heat exp. > 30°C). In columns (3), (4), (7), and (8), heat exposure is the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days (Heat exp. > 30°C. & 90thPctl). #1 revenue abroad indicates that the firm's top-ranked revenue country is not the headquarters country. The indicator < 30% domestic sales is a dummy variable that indicates less than 30% is sales occurred in the firm's home country. Test difference indicates the joint significance of the coefficients on heat exposure and the interaction variable. All specifications additionally include firm–financial quarter fixed effects; industry–year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

Table 5. Heat Exposure and Firm Heterogeneity

	Revenues/assets							Op. income/assets						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
∑ heat exp. > 30°C & 90thPctl	−0.0026	−0.0221***	−0.0029	−0.0056	−0.0055	−0.0064*	−0.0059*	−0.0000	−0.0033***	−0.0013	−0.0013***	−0.0016***	−0.0016***	−0.0016***
	(0.0049)	(0.0059)	(0.0091)	(0.0037)	(0.0034)	(0.0035)	(0.0034)	(0.0008)	(0.0010)	(0.0009)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Labor/total expenses $_{it}$	−0.0031							−0.0000						
	(0.0033)							(0.0002)						
∑ heat exp. > 30°C & 90thPctl × labor/total expenses $_{it}$	−0.0002*							−0.0000***						
	(0.0001)							(0.0000)						
∑ heat exp. > 30°C & 90thPctl × wages/employees		0.0007***							0.0000					
		(0.0002)							(0.0001)					
∑ heat exp. > 30°C & 90thPctl × pct outdoors			−0.0178							−0.0023				
			(0.0372)							(0.0040)				
∑ heat exp. > 30°C & 90thPctl × OSHA definition				−0.0016							−0.0012*			
				(0.0055)							(0.0007)			
∑ heat exp. > 30°C & 90thPctl × food					−0.0112							0.0042		
					(0.0232)							(0.0026)		
∑ heat exp. > 30°C & 90thPctl × agriculture					−0.0083							−0.0029		
					(0.0093)							(0.0019)		
∑ heat exp. > 30°C & 90thPctl × utilities						0.0194							0.0001	
						(0.0144)							(0.0014)	
∑ heat exp. > 30°C & 90thPctl × Scandinavia							0.1285							0.0684
							(0.1104)							(0.0552)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Joint p-value				(0.16)		(0.35)	(0.26)				(0.00)		(0.28)	(0.23)
R^2	0.7855	0.8179	0.7647	0.7512	0.7512	0.7512	0.7512	0.6441	0.6745	0.5955	0.5782	0.5782	0.5782	0.5782
Mean dep. variable	24.23	24.23	24.23	24.23	24.23	24.23	24.23	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Number of observations	295,750	161,889	322,619	599,347	599,347	599,347	599,347	295,750	161,889	322,619	599,347	599,347	599,347	599,347
Number of firms	9,167	4,502	9,511	17,591	17,591	17,591	17,591	9,167	4,502	9,511	17,591	17,591	17,591	17,591
Number of countries	90	87	85	93	93	93	93	90	87	85	93	93	93	93

Notes. This table reports the effects of heat exposure on revenues as a percentage of assets and operating income as a percentage of total assets in interaction with, respectively, the firm-level average share of labor expenses relative to total expenses, the average wage per employee, the ratio of labor to total expenses lagged by one year, the percentage of time spent outdoors by industry, an indicator of heat sensitive industries derived from OSHA, a dummy variable indicating firms from agricultural industries, and a dummy variable that identifies utilities. Reported are the sum of coefficients on the four quarterly heat exposures (q, $q-3$) and their interaction effects. Heat exposure measured by the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days (Heat exp. > 30°C. & 90thPct). For indicator variables, the joint significance of the coefficient on heat exposure and the interaction variable appear below the table (Joint p-value). All specifications additionally include firm–financial quarter fixed effects; industry–year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

worker as the total wage bill divided by the number of employees. In line with the idea that highly skilled workers may be less exposed to outdoor conditions, we find a positive interaction effect for revenues but not for operating income (column (2), 0.008, significant at the 1% level). In addition, we use data from ONET on the percentage of time spent outdoors by industry, and following guidance of the Occupational Safety and Health Administration (OSHA) on occupational heat exposure, we classify firms in the agriculture, mining, construction, and transportation industries as particularly sensitive. The interactions of heat exposure with both measures take a negative sign. However, only the interaction on heat exposure and sensitive firms as defined by OSHA is statistically significant (column (11), significant at the 10% level).

Another common view is that extreme temperatures could be economically harmful mainly through sectors in which output is a direct function of temperature. For instance, agricultural returns are directly related to heat through the effects of temperatures on crop yields. Hong et al. (2019) illustrate this relation using financial returns in the food industry. To test if the agricultural and food industries are major drivers of the observed effects, we interact heat exposure with an indicator for firms in agricultural and food industries. For revenues, the interaction effects are negative but insignificant (column (5)). The estimate of the effect on operating income is robust (column (12), –0.0016, significant at the 1% level) and consistent with the studies showing that extreme temperatures negatively affect agricultural and nonagricultural economic activities (Hsiang 2010, Burke et al. 2015).

In addition, we might expect that some industries benefit from extreme temperatures. For instance, firms in the utility sector could benefit from an increase in the number of high temperature days as cooling increases the demand for electricity. We interact heat exposure with an indicator of utilities firms in columns (6) and (12). The interaction terms are positive and insignificant. Joint tests of the coefficients indicate the overall effect of hot days on firm performance in the utility sector is indistinguishable from zero (p-values between 0.35 and 0.38).[34]

3.4. Geographic Heterogeneity

Further, we investigate differences in the estimates by average temperatures and economic development. On the one hand, hot days may be more disruptive when they are unusual compared with local climate conditions. On the other hand, hotter countries tend to be less developed, and firms in those countries may face more fragile infrastructure and constraints to adaptation. We plot average marginal effects by average temperature at firms' headquarters and gross domestic product (GDP) per capita in Figure 5.[35] Consistent with the idea that firms in less-developed countries may be more vulnerable to climate risk, we find that the negative effects on firms become significant with average temperatures above 25°C at their headquarters. For revenues, the effects are insignificant across the temperature distribution. Concerning GDP, we find negative and significant average marginal effects on revenues (operating income) for firms in the lowest two (three) quintiles. This observation is consistent with studies on heat, firm productivity, and the nonlinear effects of temperatures on economic output (Dell et al. 2012, Burke et al. 2015, Zhang et al. 2018).[36]

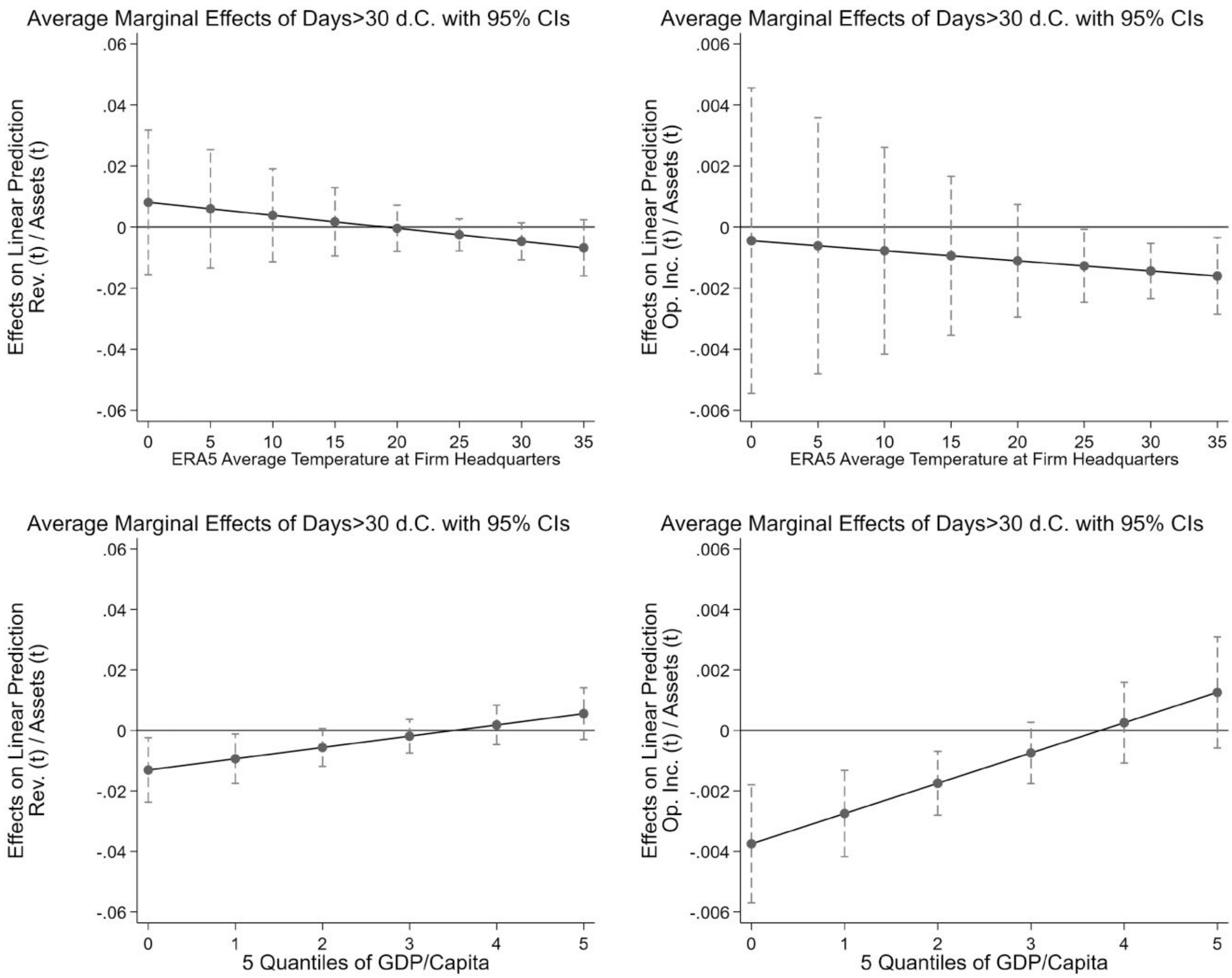
4. Heat Exposure and Analyst Forecast Accuracy

The results of the first part of the analysis indicate that heat exposure reduces revenue and operating income. Hence, information on extreme-temperature days is relevant for financial projections of firm performance. At the same time, policymakers voice concerns that investors and financial analysts might not be prepared to consider climate-related information when pricing securities. We empirically test this policy assumption in the context of temperatures.

To do so, we collect I/B/E/S data on analyst forecasts and stock-return data from Compustat Global Security Daily. Both databases cover subsamples of the universe of firms in Compustat Global Fundamentals, which results in important differences in their composition. Out of the full sample, we obtain analyst forecasts (returns) for 8.1% (9.7%) of the firms. For a geographic comparison, we map the difference between the sample in Figure 6, panels (a) (analysts) and (b) (returns). The maps visualize that both subsamples comprise fewer firms in southern areas, leading to an increased share of firms in cold areas (Scandinavia: 18.2%/18.4% versus 4.1% in the full sample; lowest temperature quintile: 27.8%/25.2% versus 19.9%). The average temperature at firm locations is 19.9°C (Table 1, panel C). Further, the subsamples cover fewer countries (64/61 compared with 93). In terms of industry composition, the share of utilities, which may be subject to positive performance shocks, is relatively similar across all samples and ranges from 4.1% to 4.5%. Moreover, firms covered by analysts and with return data available appear to be more profitable. The mean operating income over assets is 3.4% versus 2.1% in the full sample. The mean revenue over assets is 26.1% versus 24.2%. If heat exposure is less detrimental in colder areas and if more profitable firms face reduced financial constraints to adapt, these differences could attenuate the subsequent results.

Analogous to the first analysis, we use the randomly distributed and exogenous variation in the number of extreme temperature days around the average number of days at the firm's location to identify the effect of heat exposure on the accuracy of analyst forecasts.[37] In this test, we aim to understand whether analysts

Figure 5. Heat Exposure and Regional Heterogeneity



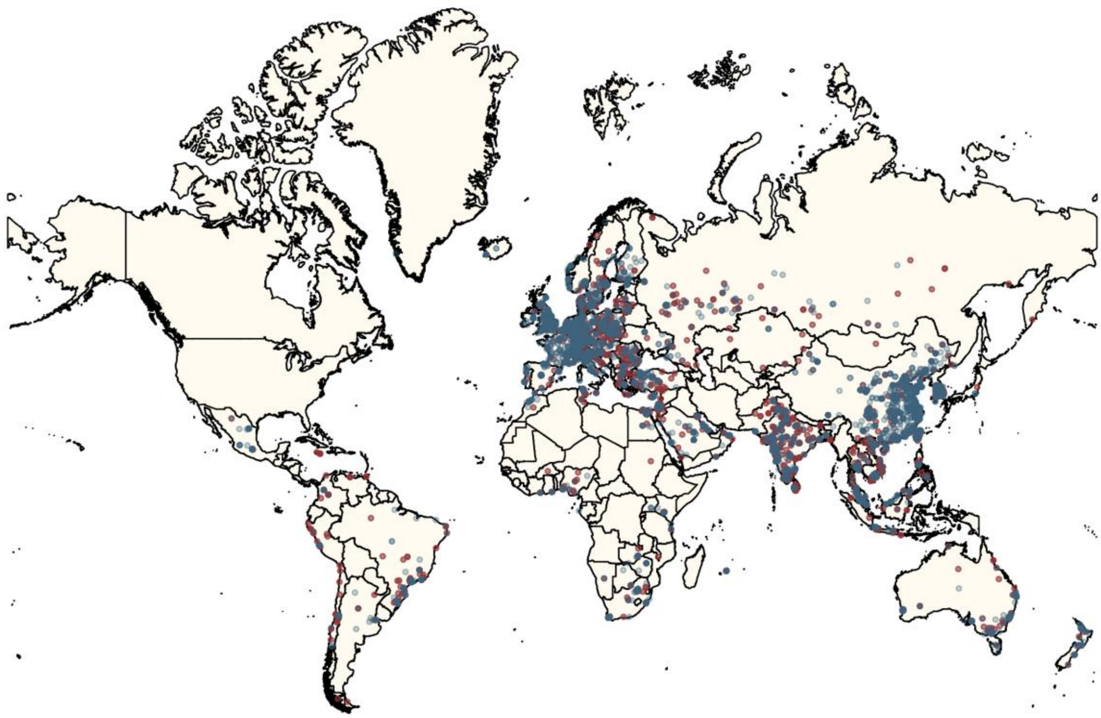
Notes. This figure shows the average marginal effects of high temperatures on revenues and operating income by average temperatures and GDP per capita. *Heat Exposure* refers to the number of days in a quarter on which the firm experiences a temperature above the threshold level indicated by the legend of the figure. We match firms and temperatures based on headquarter location but require firms to hold at least 10% of their assets in their home country. The specifications include heat exposure in the directly affected quarter as well as exposures in three lagged quarters, firm–financial quarter fixed effects, industry-year fixed effects, and country linear trends and controls for days below 0°C. Two-way standard errors are clustered at the country and year-quarter level, and 90% and 95% confidence intervals are indicated by small bars.

understand the financial repercussions of heat for firm performance. The null hypothesis is that analysts respond to available information on firms' exposure to heat and no systematic changes to forecast errors occur when firms are exposed to more days of high temperatures. However, if analysts do not sufficiently incorporate information on the realized heat exposure in their predictions, then surprises in financial performance should become systematically more negative in periods when firms experience heat-driven repercussions. Hence, we focus on deviations of forecasts from the actual performance. To align the tests with the previous analyses, we focus on analysts' projections of revenues and income. We obtain these projections from I/B/E/S and scale both forecast types by the firms' total assets. Because I/B/E/S includes few forecasts on operating income, we substitute them with forecasts of pretax income.[38]

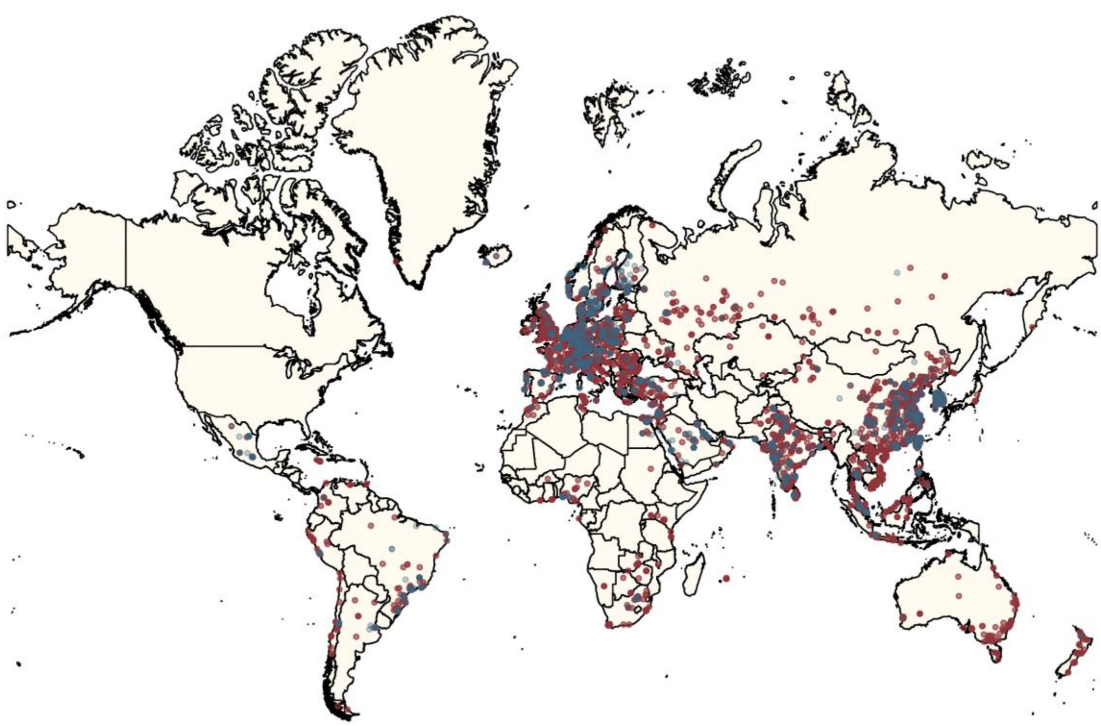
Instead of understanding the cumulative effect of heat over time, we focus on the magnitude of the deviation of expectations and realizations per financial quarter in this set of tests. This difference is important: investors might take corrective actions quarter by quarter and errors could net out if investors (incorrectly) adjust their expectations after a negative surprise, such as by assuming that a performance shock persists longer than it actually does. Further, we construct the tests to ensure quarter by quarter that information on heat exposure is publicly available and to allow us to assume that analysts have sufficient time to incorporate this information into their projections. Figure A.5 illustrates this timing. Analysts forecast the performance of firms for any given financial quarter, and

Figure 6. (Color online) Comparison of Samples

(a) Geographic Distribution—Firm Performance and Analyst Forecasts



(b) Geographic Distribution—Firm Performance and Announcement Returns



Notes. (a) Geographic distribution—firm performance and analyst forecasts. (b) Geographic distribution—firm performance and announcement returns. Panel (a) (Panel (b)) shows the geographic distribution of firms with data available on analyst forecasts (announcement returns). Firms shown as dark (blue) dots appear in both the analyst (return) sample and the firm-performance sample; firms only included in the firm performance sample and not in subsequent analyses are shown in lighter color (red).

the quarter the forecast refers to is labeled *Affected Fiscal Period*(t) in the figure. During this period, the firm is exposed to a certain number of hot days, labeled *Heat Exposure*(t). The financial performance of the firm is then announced at the *Announcement Date*, which follows the affected financial quarter with a certain time lag. Precisely, this time lag gives analysts time to update their projections toward the end or after the closing of the fiscal period when the realized number of days of heat exposure is known. Moreover, lagged effects over several quarters give analysts additional time to update their forecasts. If heat exposure affects firms particularly with a lag of one to two quarters, analysts have time until the announcement of the earnings of the fiscal quarter $t+2$. At the same time, the lag of the effect might make it harder for analysts to discern that firms are negatively affected by heat. Table 1, panels F and G, documents how often analysts update forecasts in this time frame. Per firm- and financial quarter–specific revenue (income) forecast, analysts change their forecast 0.64 (0.62) times after the close of the financial period and before the announcement date (panel (a) in Figure A.5). Between the affected financial quarter and the time when the effects of heat materialize, analysts update revenue and income forecasts 3.6 times on average. Equation (3) shows the regression specification:

$$\begin{aligned}&\textit{Performance Surprise}_{iskt}\\&=\sum_{t=-3}^{0}\beta\,\textit{Heat Exposure}_{ist}+\kappa_{is}+\theta_{mt}+\delta\textit{Trend}_{ct}+\epsilon_{ist},\end{aligned}\qquad(3)$$

where i stands for the firm, s stands for the season based on each firm's financial reporting schedule $(s=1,\ldots,4)$, and κ_{is} represents the firm- × financial-quarter fixed effect to absorb firm location– and firm season–specific levels of heat exposure. m stands for the firm's industry, t for the observed time period, and θ_{mt} for industry–time fixed effects to absorb the average forecast errors that analysts make systematically because of industry-specific economic dynamics. $\delta\textit{Trend}_{ct}$ indicates country linear trends with c as an index for C countries determined by the location of i. k stands for the forecast measure, either revenues or pretax income. We calculate the $\textit{Performance Surprise}_{it}$ by deducting the expected from the actual revenue or pretax income (k) and scale the difference by firms' total assets. *Heat Exposure* refers to the number of hot days, which we count during the affected financial period. Earnings are announced with some delay at the point in time labeled t. The timing of the test is illustrated in Figure A.5. To ensure that our results are driven by heat and not by changes at other extreme temperatures, we include controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. We cluster standard errors two ways by country and year-quarter.

The analyses have three objectives. First, we estimate the effect of heat on revenues (operating income) to test if the main result holds for this subsample of firms. Second, we test whether analyst forecast errors become more negative with firms' exposure to heat, which we would expect if analysts do not anticipate the effects on firm performance. Third, we examine to what extent analyst forecasts respond to heat events by formally comparing the magnitudes of shocks to firm performance with analysts' surprises (*Actual-Surprise*). If analysts do not respond altogether, the magnitude of the increase in surprises should correspond to the magnitude of the repercussions caused by high temperatures.

In line with the three objectives, the main results in Table 6 and Figure 7 are threefold. We focus on analysts' responses after two and three quarters in particular as the previous analysis shows that heat reduces operating income significantly in these time periods. First, we find that the effects of heat on firm performance hold for this subset of firms. We find similar magnitudes although some of the effects decrease in significance.[39] Second, we turn to the potential deviation of analysts' expectations and actual financial performance. For the most pronounced heat-related repercussions after two quarters, the negative coefficients (columns (3), (4), (7), and (8)) indicate that increases in firms' heat exposure indeed come with more negative revenue and income surprises.[40] Surprisingly, we also find a positive and significant coefficient for the effect of heat on analysts' forecast errors after three quarters. In principle, this effect could occur when analysts are negatively surprised in the period in which the shock occurs $(q-2)$ and extrapolate the weak financial results to the next period $(q-3)$.

Third, we contrast the effects on firm performance and the size of the surprises to interpret the observed magnitude with formal tests of the difference of the coefficients in the rows between the coefficients of the lags of heat exposure. If analysts do not respond altogether, the magnitude of the increase in surprises should correspond to the repercussions caused by high temperatures. Consistent with this view, the joint tests indicate that the most pronounced effects after two quarters are not statistically different for revenues. In contrast, there is a statistical difference between the effect of heat exposure on income and analyst errors after two quarters (column (7), significant at the 10% level) and after three quarters.

This gap could indicate that some analysts adjust their forecast in response to firms' exposure or that analysts generally do so but to an insufficient extent. We test if increased exposure to heat leads to more updates or adjusted estimates. As Figure 8(a) shows, we do not find that forecast updates increase with firms' exposure to heat. Further, mean analyst estimates are not systematically adjusted downward (Figure 8(b)).

Taken together, we find that heat exposure leads to more negative earnings responses, whereas the

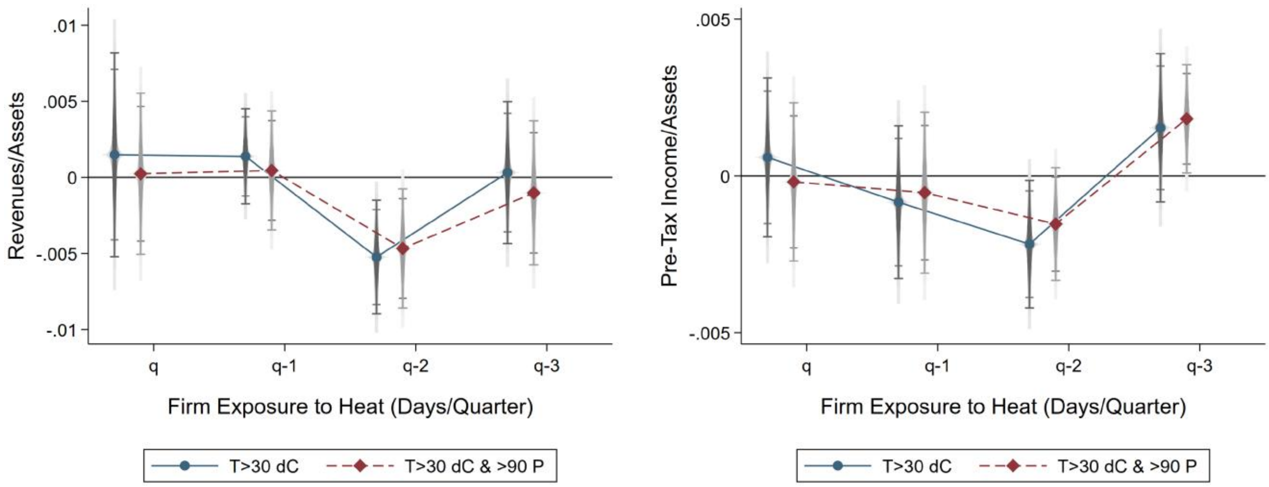
Table 6. Heat Exposure and Analyst Forecast Errors: Formal Comparison

	Revenues/assets			
	Actual effect		Mean surprise	
	30°C	30°C/90thP	30°C	30°C/90thP
	(1)	(2)	(3)	(4)
Heat exp. (q)	0.0048	0.0007	0.0015	0.0002
	(0.0140)	(0.0133)	(0.0034)	(0.0026)
Actual – surprise			0.0033	0.0004
p-value			0.8013	0.9702
Heat exp. [$q-1$]	0.0055	0.0006	0.0014	0.0005
	(0.0094)	(0.0096)	(0.0016)	(0.0020)
Actual – surprise			0.0042	0.0002
p-value			0.6483	0.9827
Heat exp. ($q-2$)	−0.0074	−0.0124	−0.0052***	−0.0047**
	(0.0080)	(0.0090)	(0.0019)	(0.0020)
Actual – surprise			−0.0021	−0.0077
p-value			0.7638	0.3415
Heat exp. ($q-3$)	0.0086	0.0010	0.0003	−0.0010
	(0.0060)	(0.0059)	(0.0023)	(0.0024)
Actual – surprise			0.0083	0.0021
p-value			0.2426	0.7442
R^2	0.8662	0.8662	0.2648	0.2648
Number of observations	55,927	55,927	55,927	55,927
Number of firms	1,122	1,122	1,122	1,122
Number of countries	64	64	64	64
Mean dependent variable	26.1345	26.1345	−0.162	−0.162
Firm-qtr fixed effects	Yes	Yes	Yes	Yes
Ind-year-qtr fixed effects	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes
Cold controls	Yes	Yes	Yes	Yes
	Pretax income/assets			
	Actual effect		Mean surprise	
	30°C	30°C/90thP	30°C	30°C/90thP
	(5)	(6)	(7)	(8)
Heat exp. (q)	−0.0010	−0.0013	0.0006	−0.0002
	(0.0021)	(0.0029)	(0.0013)	(0.0013)
Actual – surprise			−0.0016	−0.0011
p-value			0.4902	0.6466
Heat exp. ($q-1$)	−0.0014	−0.0011	−0.0008	−0.0005
	(0.0024)	(0.0027)	(0.0012)	(0.0013)
Actual – surprise			−0.0005	−0.0006
p-value			0.7941	0.8222
Heat exp. ($q-2$)	−0.0055**	−0.0033	−0.0022**	−0.0015*
	(0.0021)	(0.0025)	(0.0010)	(0.0009)
Actual – surprise			−0.0034*	−0.0018
p-value			0.0946	0.4666
Heat exp. ($q-3$)	−0.0038***	−0.0017	0.0015	0.0018**
	(0.0014)	(0.0011)	(0.0012)	(0.0009)
Actual – surprise			−0.0053***	−0.0035***
p-value			0.0004	0.0086
R^2	0.7144	0.7143	0.2995	0.2995
Number of observations	40,590	40,590	40,590	40,590
Number of firms	737	737	737	737
Number of countries	52	52	52	52
Mean dependent variable	3.4463	3.4463	-0.1573	-0.1573
Firm-qtr fixed effects	Yes	Yes	Yes	Yes
Ind-year-qtr fixed effects	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes
Cold controls	Yes	Yes	Yes	Yes

Notes. This table compares the effect of heat exposure on firms' revenue and income over assets based on the sample of firms that receive analyst forecasts with the effects of heat exposure on errors in analyst forecasts. The forecast error in columns (3) and (4) is the difference between the actual revenue and the mean forecast revenue from IBES scaled by lagged total assets. In columns (1) and (3) ((2) and (4)), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C (30°C and > 90th percentile of place- and time-specific temperature distribution). For each of lags of *Heat Exposure*, the effect on revenues (income) over assets is compared with their effect on forecast errors (Actual − surprise) together with a test of the significance of the difference (p-value). The separate panels show the results for revenue and pretax income forecasts as indicated by the table headers. All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$), firm-financial quarter fixed effects, industry-year fixed effects, and country linear trends, and a control for the number of days when temperatures were below 0°C (cold controls). The number of observations refers to firm-quarters. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Figure 7. (Color online) Heat Exposure and Analyst Forecast Errors



Notes. Shown are the effects of heat exposure on the error in the mean analyst forecasts of revenues scaled by assets (left) and on the mean analyst forecast of pretax income scaled by assets (right). The first measure of heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C ($T > 30$°C). The second measure is based on the number of days on which temperatures exceeded not only 30°C but also the 90th percentile of the historic (1980–1999) distribution of temperatures that occurred at the firm's location on the same day as well as the five preceding and subsequent days ($T > 30$°C and 90th percentile). The specifications include heat exposure in the directly affected quarter (q) as well as exposures in three lagged quarters ($q - 1$, $q - 2$, $q - 3$), firm–financial quarter fixed effects, industry-year fixed effects, and country linear trends and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C; 90% and 95% confidence intervals are indicated by small bars.

difference between the actual shock and the change in the forecast error is at times positive and significant. This finding is consistent with the idea that analysts do not sufficiently take heat into account. However, the interpretation is complicated by the much smaller sample and the less precisely estimated results.

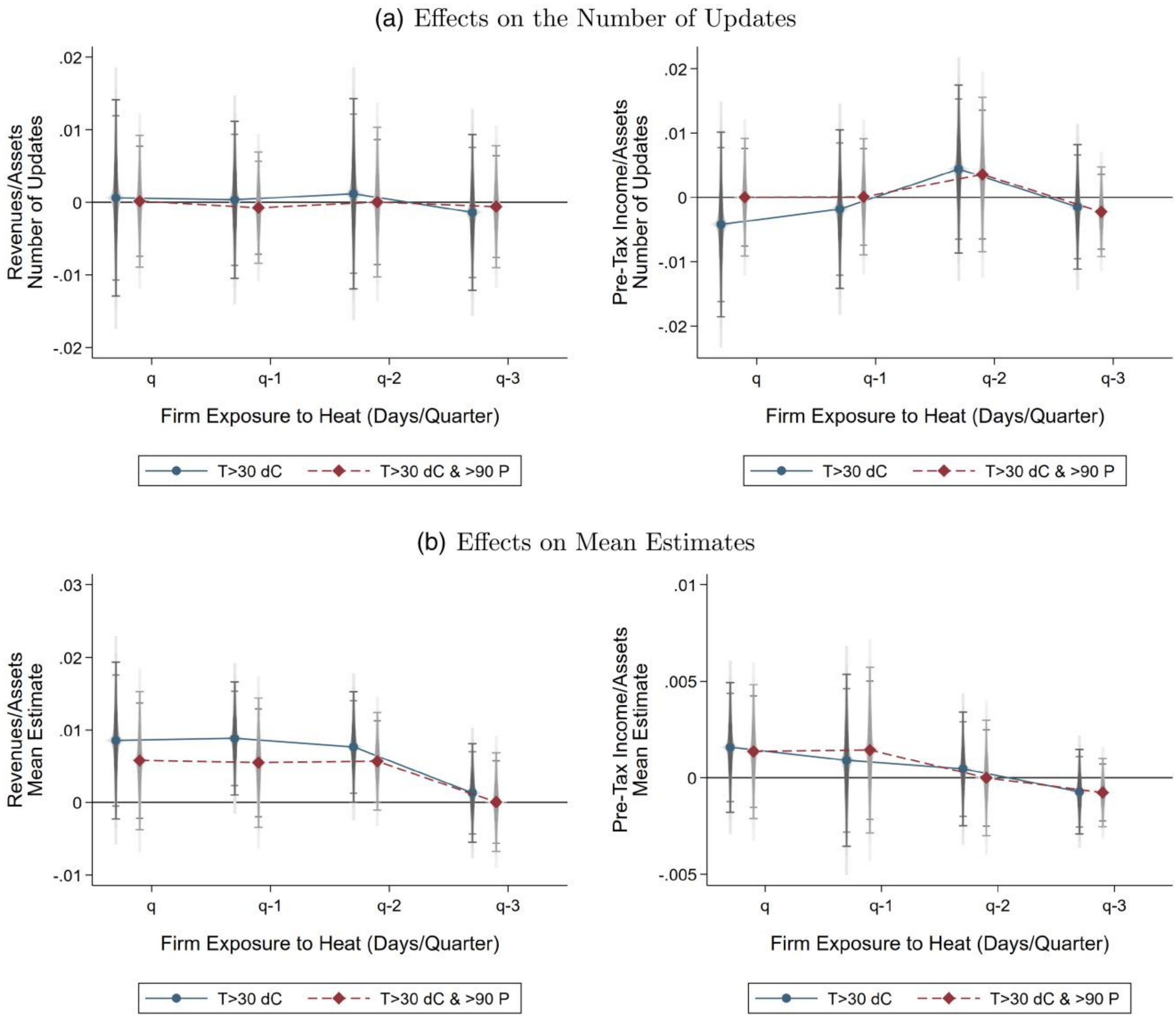
4.1. Robustness Tests

Mirroring the analysis on heat exposure and firm performance, we conduct a series of robustness tests. First, we test whether the results could be confounded by the financial crisis. However, Table A.7 shows that the results remain similar after excluding the crisis years. Second, we compare our estimates using ERA5 temperature data with estimates based on ERAi as well as country-level average temperatures in Figure A.8. ERA5 and ERAi data produce similar results. Based on both temperature-data sources, we find that errors in revenue (income) over assets forecasts are significantly affected by the number of days above 30°C in $q - 2$ (quarters $q - 3$ and $q - 3$). However, the results are different for country-level averages: for revenues, column (3) shows that forecast errors are significantly affected by days above 30°C in both the current and preceding two quarters. For operating-income forecasts, we find no significant effects of days of heat derived from country-level average temperatures. The deviation between country-level and downscaled temperatures is notable and much more pronounced than the difference estimates of the effects of heat on firm performance for the full sample. Third, we replace the temperature thresholds to define days as hot with a series of alternatives in Table A.8. We find that a wide range of alternative thresholds produces similar results (significant effects on revenues: 25°C, 25°C/90th percentile, 25°C/95th percentile, 30°C, 30°C/90th percentile, 30°C/95th percentile, 35°C). Fourth, in line with our robustness tests on performance, Figure A.4(b) shows the effects of heat exposure on pretax income forecast errors after two quarters by asset concentration. The effect of heat after two quarters is more negative and significant for firms that have most assets in their home country (75%–100%) compared with firms that have the least domestic concentration (0%–25%). Whereas this difference is consistent with the idea that improved spatial matching of assets and temperatures better captures the effect of heat on unanticipated revenues and profits, we do not see the magnitude of coefficients increase significance monotonically across the samples with different ranges of asset concentration.

5. Heat Exposure and Announcement Returns

The attention that analysts can devote to assessing the performance of each individual firm is likely to be limited. Therefore, we test whether the conclusion that market participants do not fully anticipate the repercussions of heat for performance holds beyond the case of analysts. As another common (see, e.g., La Porta et al. 1997, Core et al. 2006, Edmans 2011) and more general test on market surprises, we study whether investors

Figure 8. (Color online) Heat Exposure and Analyst Forecasts: Additional Tests



Notes. (a) Effects on the number of updates. (b) Effects on mean estimates. In this figure, panel (a) shows the effect of heat exposure on the number of updates of analyst forecasts of revenues (left) and pretax income (right). Panel (b) reports the effects of heat exposure on analysts' mean estimates of revenues (left) and pretax income (right); 90% and 95% confidence intervals are indicated by small bars. The first measure of heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C ($T > 30$°C). The second measure is based on the number of days on which temperatures exceeded not only 30°C but also the 90th percentile of the historic (1980–1999) distribution of temperatures that occurred at the firm's location on the same day as well as the five preceding and subsequent days ($T > 30$°C and 90th percentile). The specifications include heat exposure in the directly affected quarter (q) as well as exposures in three lagged quarters ($q-1$, $q-2$, $q-3$), firm–financial quarter fixed effects, industry-year fixed effects, and country linear trends and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C; 90% and 95% confidence intervals are indicated by small bars.

react more negatively to earnings announcements in periods when firms have been exposed to heat.

Once again, we construct the test as illustrated in Figure A.5 and use the quasi-random variation in the number of heat days at firms' locations for identification. If investors lower their expectation of firm profitability in response to observable firm-level heat shocks sufficiently before these effects become apparent as earnings surprises at earnings-announcement dates, the negative effects of heat exposure on firm profit should not lead to negative abnormal returns. In contrast, when market participants do not immediately and adequately factor heat exposure effects into stock prices based on publicly available information on firms' heat exposure, we expect valuation adjustments to occur on dates when investors learn about their incorrect expectations of profits, not having taken the full repercussions of heat into account.

For this test, we obtain daily share prices from Compustat Global, convert the time series to U.S. dollars, and calculate daily returns.[41] We implement the tests with raw (*cr*) and abnormal returns (*car*). As a proxy for expected returns and the benchmark for the market model, we calculate equal (market capitalization–weighted) returns of all firms in the sample.[42] Apart from that, we obtain factor returns to estimate expected returns based on three- and four-factor models (French 2021) and calculate 3-, 5-, 7-, and 11-day announcement returns for the announcement date subsequent to the affected fiscal period. The summary statistics are shown in Table 1, panels H and I.[43] Equation (4) shows the regression specification:

$$c(a)r_{ist_{-d,+d}} = \sum_{t=-3}^{0} \beta\, Heat\ Exposure_{ist} + \gamma_{mt} + \kappa_{is} + \delta\, Trend_{ct} + \epsilon_{ist}, \quad (4)$$

where i stands for the firm, and s stands for the season for each firm based on its reporting schedule ($S = 1, \ldots, 4$). t stands for the announcement date, κ_{is} for firm–season fixed effects, γ_{mt} for industry–year fixed effects, and $\delta Trend_{ct}$ for country linear trends. d indicates the length of the window over which we calculate announcement returns *cr*. The timing of the test and the matching of fiscal periods and *Heat Exposure* are analogous to the second analysis as illustrated in Figure A.5. To ensure that our results are driven by heat and not by changes at the other extreme end of temperature distributions, we also present results for specifications that control the number of cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Standard errors are clustered two ways at the country and year-quarter levels.

Table 7 shows the main result for this test based on the raw and abnormal returns (market model, equal-weighted returns) for the 11-day event window.[44] In line with the previous analyses on analyst forecasts, we focus on the magnitude of earnings surprises quarter by quarter and find a negative relation between increases in hot days during the financial period and announcement returns at the respective announcement date. As Figure 9 shows, the effects are most pronounced after two quarters ($q-2$). This lag structure matches the previous tests as well as the estimations of the effects of heat on operating income for this subsample in particular (see Figure A.6, top left corner). For every additional day with temperatures exceeding 30°C, the raw announcement returns become 0.0358 percentage points more negative over the 11-day window around the announcement date (column (2), significant at the 5% level). The effect is slightly weaker in significance when we focus on abnormal returns over an equal-weighted benchmark (coefficient –0.0361, column (6), significant at the 10% level). We do not find larger magnitudes when the realized temperatures are unusual given the place- and time-specific temperature distributions (e.g., columns (4) and (8)).

Given the standard deviation in the number of days per quarter by which heat exposure varies over time (5.4 days for the 30°C threshold), the effect of a one-standard-deviation increase in heat exposure would induce a 0.1976 percentage point more negative announcement return. We compare this magnitude to two related studies. First, Edmans (2011) investigates a portfolio composed of firms on America's Best Companies to Work For (BC) list. The study finds that BC firms generate more positive earnings surprises and the three-day abnormal returns of BC firms are, on average, 0.28 higher compared with non-BC firms. Whereas the event in Edmans (2011) is different in nature from ours, the interpretation is related: the findings indicate that employee satisfaction contributes to firm performance through increased worker performance but the market does not fully understand this relation until the effects become visible in earnings announcements. Given that the literature associates heat with lower worker performance, the potential mechanism behind our finding that high temperatures lead to lower earnings-announcement returns is similar. In comparison, we estimate that a one-standard-deviation change in hot days leads to earnings-announcement returns of about –0.17 percentage point ($q-2$, 6.3 days × 0.0277, Table 7, column (4)). Second, Barrot and Sauvagnat (2016) study how firms' and their suppliers' revenues and returns are affected by natural disasters. The authors report that the returns of the directly affected supplier firms decrease by –0.5 percentage point over 10 days after the event. Considering that Barrot and Sauvagnat (2016) find these effects for large-scale natural disasters, our estimates for heat are sizeable.

5.1. Robustness Tests

We test the robustness of the results to alternative calculations of abnormal returns. First, Figure A.6(a) shows that the results remain similar when we convert stock prices using contemporaneous instead of lagged exchange rates. The effects after two quarters are marginally significant with stronger effects visible after three quarters compared with the main test. Second, we test six different approaches to calculating abnormal returns. The results hold when we use returns adjusted by equal-weighted average market returns (Figure A.6(b)) and returns adjusted using a benchmark derived from the market model with equal- and market capitalization–weighted returns (Figure A.6(c)). Further, we estimate tests using three- and four-factor returns (Figure A.6(a)) using Fama–French international research returns of developed countries excluding the United States (French 2021).[45] The results slightly increase in magnitude. Only for market capitalization–weighted average market returns and days that exceed both 30°C and the historical benchmark, the effect after two quarters becomes insignificant (Figure A.6(b)).

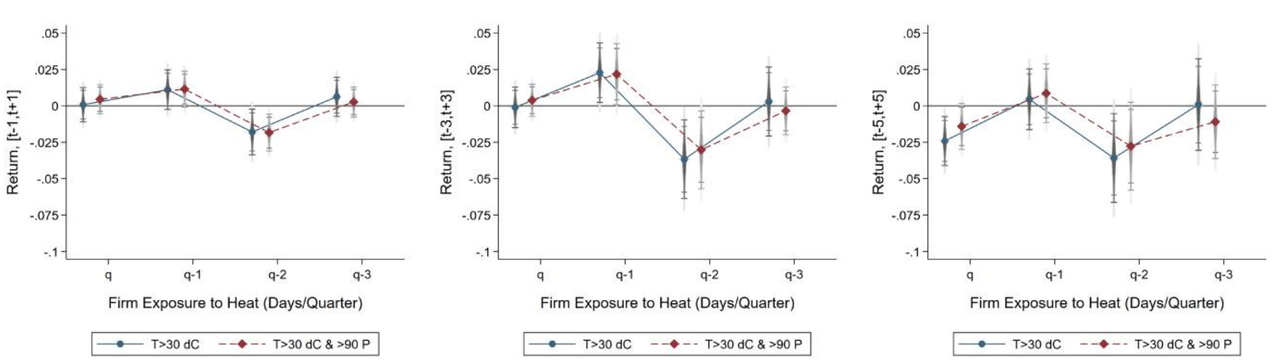
Table 7. Heat Exposure and Earnings Announcement Returns

	Return ($t-5$, $t+5$)				Return MM/EW ($t-5$, $t+5$)			
	30°C		30°C/90thP		30°C		30°C/90thP	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat Exp. (q)	−0.0259***	−0.0241***	−0.0162**	−0.0141*	−0.0097	−0.0078	−0.0029	−0.0008
	(0.0078)	(0.0084)	(0.0069)	(0.0079)	(0.0106)	(0.0103)	(0.0046)	(0.0055)
Heat Exp. ($q-1$)	0.0059	0.0045	0.0095	0.0086	−0.0020	−0.0028	−0.0024	−0.0028
	(0.0108)	(0.0104)	(0.0093)	(0.0101)	(0.0109)	(0.0106)	(0.0062)	(0.0072)
Heat Exp. ($q-2$)	−0.0331**	−0.0358**	−0.0259	−0.0277*	−0.0345*	−0.0361*	−0.0296	−0.0306
	(0.0161)	(0.0152)	(0.0159)	(0.0151)	(0.0204)	(0.0204)	(0.0196)	(0.0194)
Heat Exp. ($q-3$)	0.0019	0.0008	−0.0107	−0.0109	0.0151	0.0144	0.0044	0.0042
	(0.0157)	(0.0157)	(0.0124)	(0.0126)	(0.0136)	(0.0132)	(0.0121)	(0.0120)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	No	Yes	No	Yes	No	Yes	No	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2474	0.2524	0.2473	0.2523	0.2447	0.2468	0.2446	0.2467
Number of observations	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209
Number of firms	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075
Number of countries	64	64	64	64	64	64	64	64

Notes. This table reports the effects of high temperatures on quarterly earnings announcement returns. The first (last) four columns pertain to cumulative stock returns (abnormal returns relative to the market model using equal weighted returns as the market portfolio) over 11 days surrounding the earnings announcement date (−5, +5 days). In results columns (1), (2), (5), and (6), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C. In columns (3), (4), (7), and (), heat exposure is the number of days on which temperatures exceeded not only 30°C but also the 90th percentile of the historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days (30°C/90thP). All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$), firm-financial quarter fixed effects, industry-year fixed effects, and country linear trends. Columns (2), (4), (6), and (8) additionally include controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm-quarters. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.
Significance at the *10%, **5%, ***1% levels.

Further, we test whether the results could be confounded by the financial crisis as in the previous analyses. Again, Table A.9 shows that the results do not change substantially when we exclude the crisis years. We also compare our estimates using ERA5, ERAi, and country-level average temperatures in Figure A.9. ERA5 and ERAi estimates both indicate a significantly negative effect of heat in the current and following two quarters (q and $q-2$) on the five-day earnings-announcement return. For the three-day announcement returns, only the results based on ERA5 are significant in contrast to the results of the firm-performance tests, for which we find stronger

Figure 9. (Color online) Heat Exposure and Earnings Announcement Returns



Notes. Reported are the effects of high temperatures on quarterly earnings announcement returns. Announcement returns are measured over either 3 (left), 7 (middle), or 11 (right) days surrounding the announcement date. Heat exposure indicated by $T > 30$°C is measured by the number of days in a financial quarter on which temperatures exceeded 30°C. Heat exposure indicated by $T > 30$°C and > 90th percentile is the number of days on which temperatures exceeded not only 30°C but also the 90th percentile of the historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days. The specifications include heat exposure in the directly affected quarter (q) as well as exposures in three lagged quarters ($q-1$, $q-2$, $q-3$), firm–financial quarter fixed effects, industry-year fixed effects, and country linear trends and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Two-way standard errors are clustered at the country and year-quarter level; 90% and 95% confidence intervals are indicated by small bars.

results using ERAi. As with the analysis of analyst forecasts, we only find insignificant or counterintuitive positive and significant results using country-level averages. Next, we replace the temperature thresholds to define hot days as in Table A.10 and find that a wide range of alternative thresholds produces similar results. In addition, we estimate the effects of heat on the five-day return around earnings announcements for different levels of asset concentration, analogous to previous tests in Sections 3.1 and 4.1. As Figure A.4(c) shows, the estimated coefficients on our measures of heat exposure are close to zero for firms with the lowest fraction of assets (0%–25%) concentrated in their home country but more negative based on samples of firms with greater domestic asset concentration. However, neither the point estimates nor the standard errors consistently change from one asset-concentration range to another.

6. Conclusion

In this study, we use an international sample of more than 17,000 listed firms with regionally concentrated assets in 93 countries in the period from 1995 to 2019 to test if heat exposure has a negative effect on financial performance and if analysts and investors anticipate this effect.

We find that quasi-random increases in the number of extremely hot days per financial quarter at firms' locations decreases revenues and operating income. Further, more days of heat increase firms' cost of goods sold and selling, general, and administrative expenses. Total wages per firm increase with a lag of two quarters, consistent with the idea that heat decreases worker performance and that firms compensate for losses by increasing labor inputs in later periods. Based on the observed effects of heat on firm performance, we conduct two tests to understand whether analysts and investors anticipate this negative financial effect: if extremely high-temperature days are financially material but not anticipated, expectations on revenue and operating income should be too high in periods when firms are exposed to more extremely warm days than usual. Moreover, expectations on firm performance should similarly be systematically higher than the actual performance and lead to negative announcement returns. Indeed, we find that both revenue and operating income surprises and announcement returns become more negative with increasing heat exposure at the firms' locations. This finding indicates that analysts and investors do not fully take into account information on high temperatures.

An open question relates to the timing of the observed effects. For the full sample, we find that the detrimental consequences on firm performance are most visible after one quarter. For the subset of firms with information on earnings surprises and announcement returns available, the effects are strongest after two financial quarters. Further, we find increases in wage expenses after two quarters, as well as immediate responses in two broader expense categories. These differences in timing could be explained by heterogeneity in firms' production processes: depending on turnover times and inventories, performance shocks could materialize at different points in time. Dissecting these dynamics is an important area for future research as the timelines over which these effects play out are crucial both for managers concerned with adaptation to rising temperatures and investors who want to assess these shocks to firm performance.

Further, our findings raise a question: why do firms remain sensitive to costly temperature shocks? In principle, firms' observed sensitivity to temperature fluctuations does not imply a divergence from profit maximization or a lack of awareness of the problem. As long as the average conditions allow the firm to maximize the value of its production or services, firms might find not investing in adaptation to be optimal, accepting that some years are more productive than others depending on environmental conditions. However, once temperature distributions shift persistently because of climate change, firms' production and adaptation might no longer be optimally matched to the new average exposure to heat. Still, such a shift in temperatures would have to be large enough to financially incentivize firms to make adjustments. For instance, these investments could require firms to consistently use cooling technology and potentially require substantial renovations of plant, property, and equipment. To what extent temperature changes going forward will be apparent enough to justify such investment is an empirical question left open by our study.

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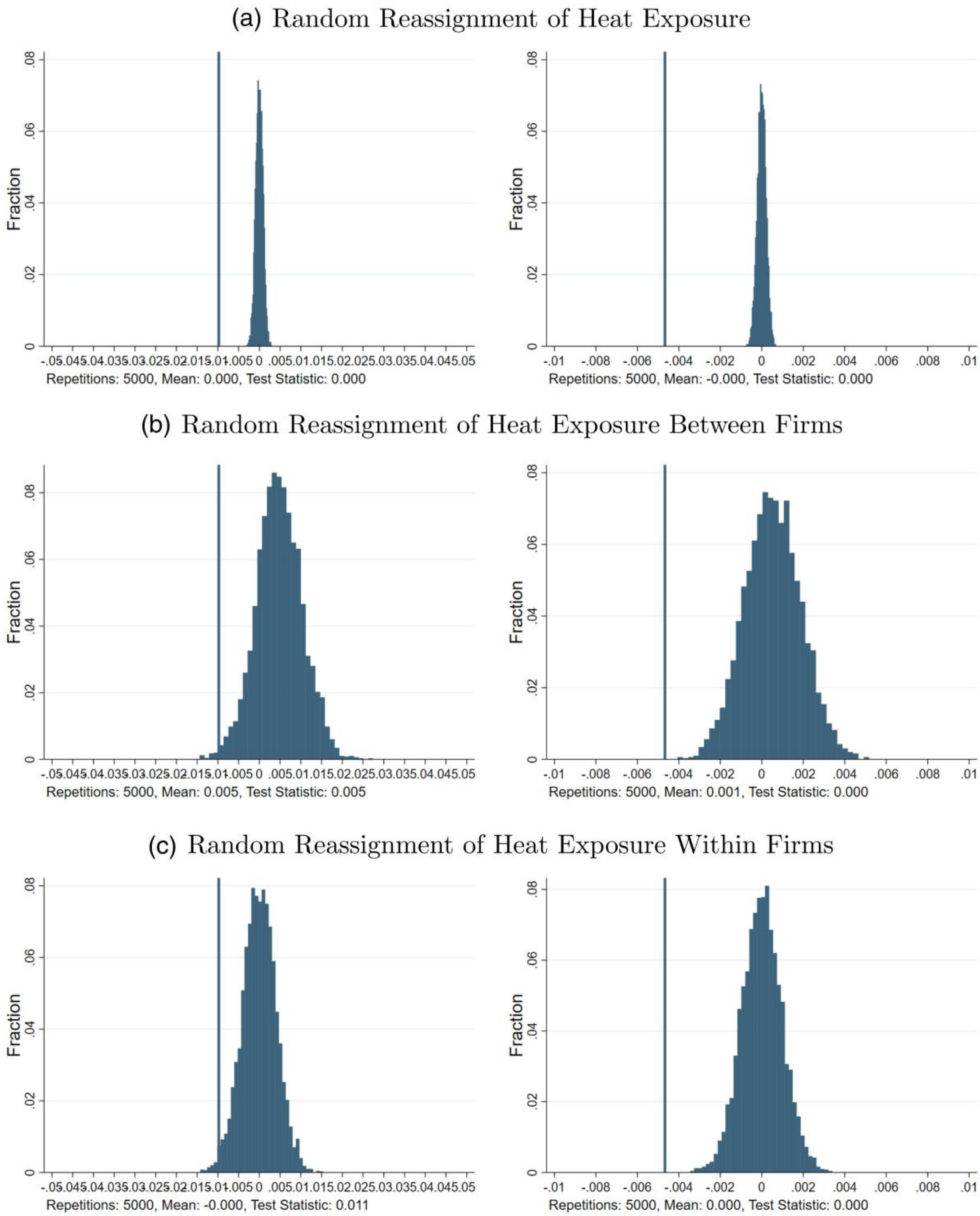
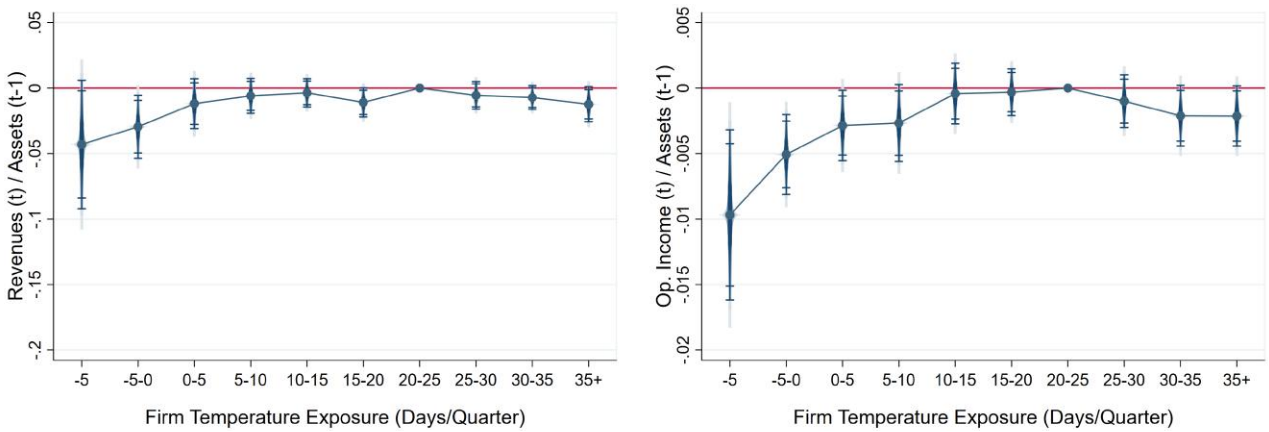
Appendix

Figure A.1. (Color online) Temperatures and Firm Performance: Permutation Test



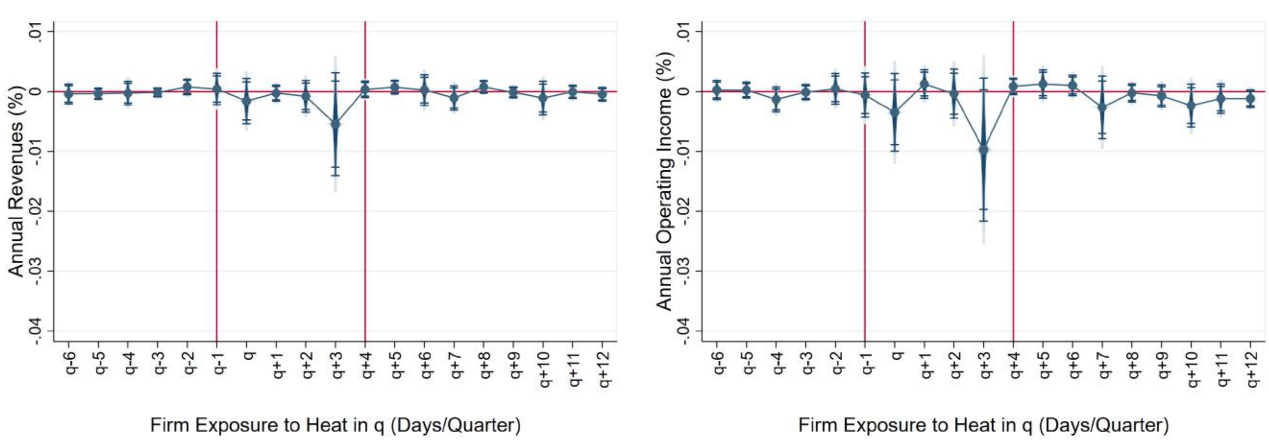
Notes. (a) Random reassignment of heat exposure. (b) Random reassignment of heat exposure between firms. (c) Random reassignment of heat exposure within firms. As a falsification test, this figure reports distributions of point estimates of the effect of heat on revenues and operating income obtained by reestimating Equation (1) on randomized placebo data sets. Each histogram shows the distribution of the effects on revenues (left) and operating income (right) for one of three different randomization schemes (panels) in which we reassign heat exposure unconditionally (a), between firms (b), and within firms over time (c). Based on this reassignment, we reestimate Equation (1) 5,000 times. The actual coefficient estimates are blue vertical lines. *P*-values (test statistic) are calculated as the fraction of coefficients from randomized regressions that exceed the actual estimate. Heat exposure is defined as the number of days on which temperatures exceed 30°C. The specifications include firm–financial quarter fixed effects, industry–year fixed effects, and country linear trends.

Figure A.2. (Color online) Temperatures and Firm Performance: Bin Specification



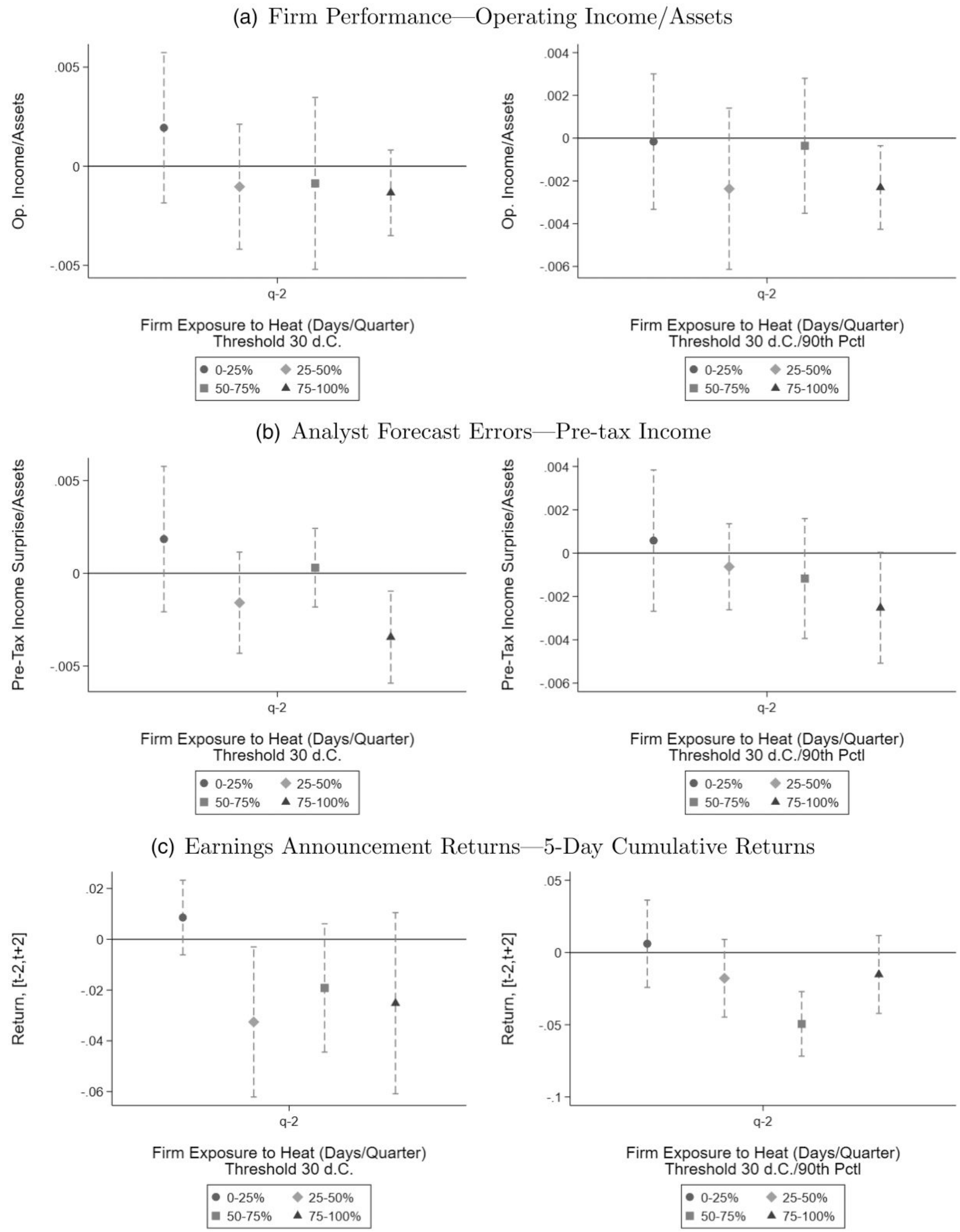
Notes. This figure reports the effects of temperature bins on quarterly revenues as a percentage of one-year lagged assets (revenues/assets, left) and operating income as a percentage of lagged assets (op. income/assets, right). Each temperature bin variable represents a temperature range and counts the number of days on which a firm experienced a temperature within that range. As the baseline, the temperature bin of 20°C–25°C is omitted. The graph presents coefficients on the temperature bin variables along with 90% and 95% confidence intervals. All specifications include firm–financial quarter fixed effects, industry–year fixed effects, and country linear trends.

Figure A.3. (Color online) Temperatures and Firm Performance: Lags



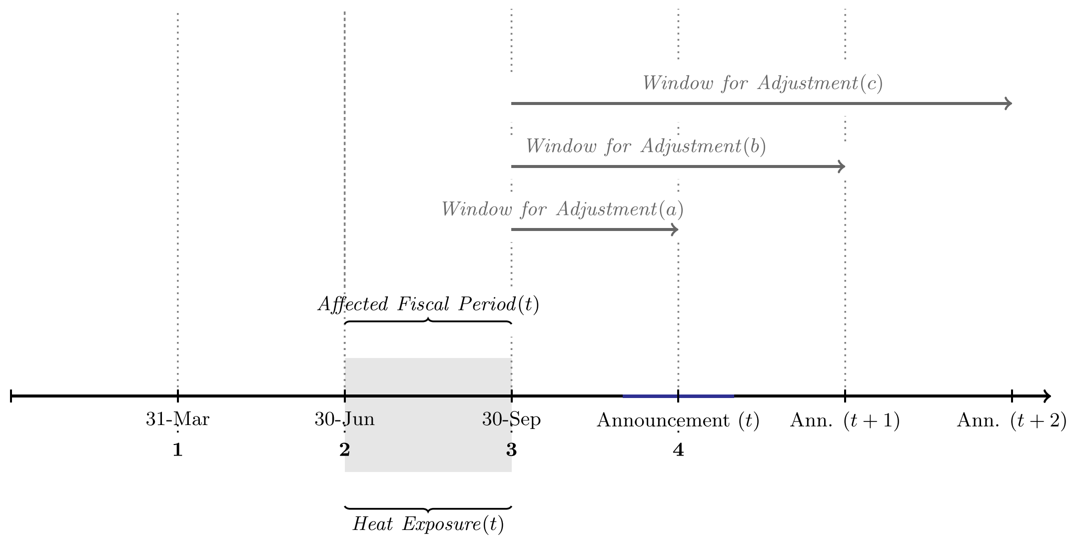
Notes. This figure reports the effects of heat exposure on percentage changes in annual revenues and operating income. The effects are estimated based on Equations (1) and (2) but augmented with lags to encompass one financial year before and two financial years after firms' exposure to heat. Exposure to heat refers to the number of days with temperatures above 30°C. Two-way standard errors clustered at the country and year-quarter levels. The graphs present coefficients on the effects of lagged heat exposure along with 90% and 95% confidence intervals. All specifications include firm–financial quarter fixed effects, industry–year fixed effects, controls for cold days below 0°C, and country linear trends.

Figure A.4. Sensitivity of the Results to Different Asset Concentration Thresholds



Notes. (a) Firm performance—operating income/assets. (b) Analyst forecast errors—pretax income. (c) Earnings announcement returns—five-day cumulative returns. This figure reports the estimated effects of heat exposure on operating income scaled by one-year lagged assets (Equation (2)), on errors in analysts' forecasts of pretax income (Equation (3)), and on five-day earnings announcement returns (Equation (4)) after restricting the sample to firms that are within a specific percentage range of asset concentration: 0%–25%, 25%–50%, 50%–75%, and 75%–100%. The graphs plot the coefficients by asset concentration for the effects of temperatures lagged by two quarters. Specifications include heat exposure augmented with three lagged quarterly exposures (q, $q-3$), firm–financial quarter fixed effects, industry–year fixed effects, country linear trends, and the number of days when temperatures were below 0°C.

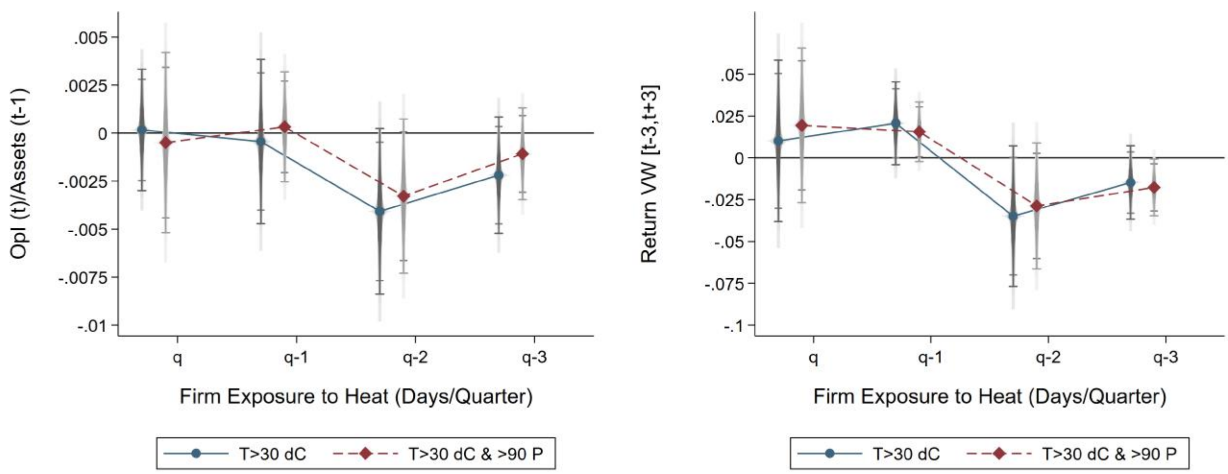
Figure A.5. (Color online) Construction of the Analyst Forecast and Announcement Returns Test



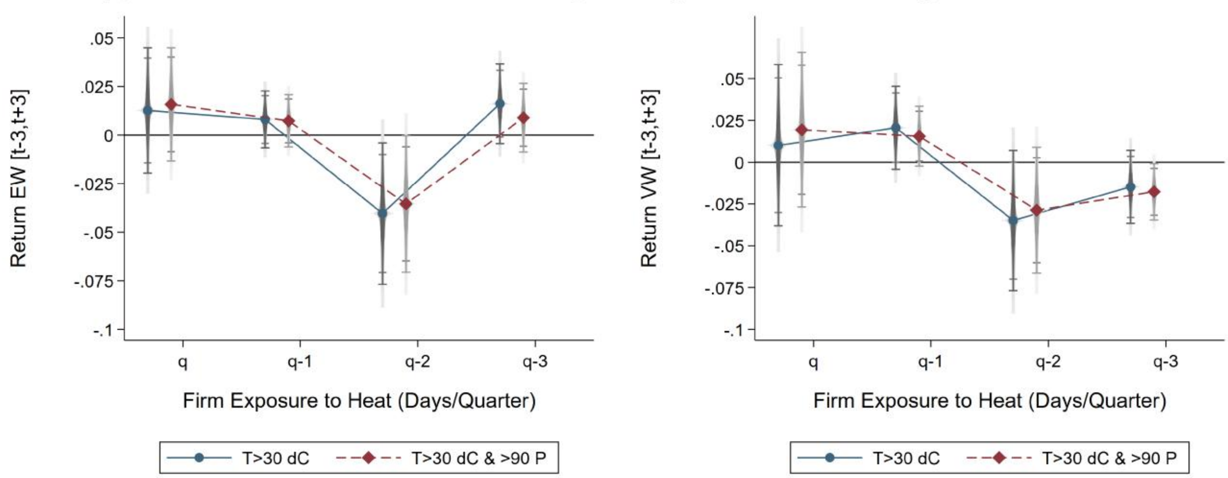
Notes. This figure shows how we match temperatures, firm performance, analyst forecast errors, and announcement returns. In all tests, the measure *Heat Exposure* is the number of days on which temperatures exceed a certain threshold in a given quarterly fiscal period t, labeled *Affected Fiscal Period*. The earnings of the respective fiscal period are announced with a lag so that every *Affected Fiscal Period* is associated with a subsequent *Announcement Date* in the future. The maximum length of these lags differs by jurisdictions; the exact timing of earnings announcements is, hence, firm- and time-specific. To correctly match all components, we calculate earnings surprises and announcement returns for the announcement date and match this information with the heat exposure over the associated preceding fiscal period. The time window available to analysts and investors to adjust their expectations depends on how quickly the effects of heat on firms' financial performance materialize. If there is an instant effect of temperatures in t on firm performance in t, analysts and investors have the opportunity to update forecasts in the time between the end of the fiscal period and the announcement date (*Adjustment Time*(a)). Even in this extreme case, temperatures are realized and publicly available to analysts and investors. If there is a longer lag between temperatures and consequences for firm performance, the window widens, and investors have more time to acquire information on heat. For instance, if temperatures in $t-1$ affect firm performance in t, the adjustment time window grows to *Adjustment Time*(b). If temperatures in $t-2$ affect firm performance in t, the adjustment time window grows to *Adjustment Time*(c).

Figure A.6. (Color online) Heat Exposure and Announcement Returns: Additional Specifications

(a) Effects on Operating Income and Alternative Exchange-Rate Conversion



(b) Effects on Abnormal Returns over Equal Weighted- and Value-Weighted Benchmark



(c) Effects on Abnormal Returns over Market Model Using Equal Weighted- and Value-Weighted Benchmark

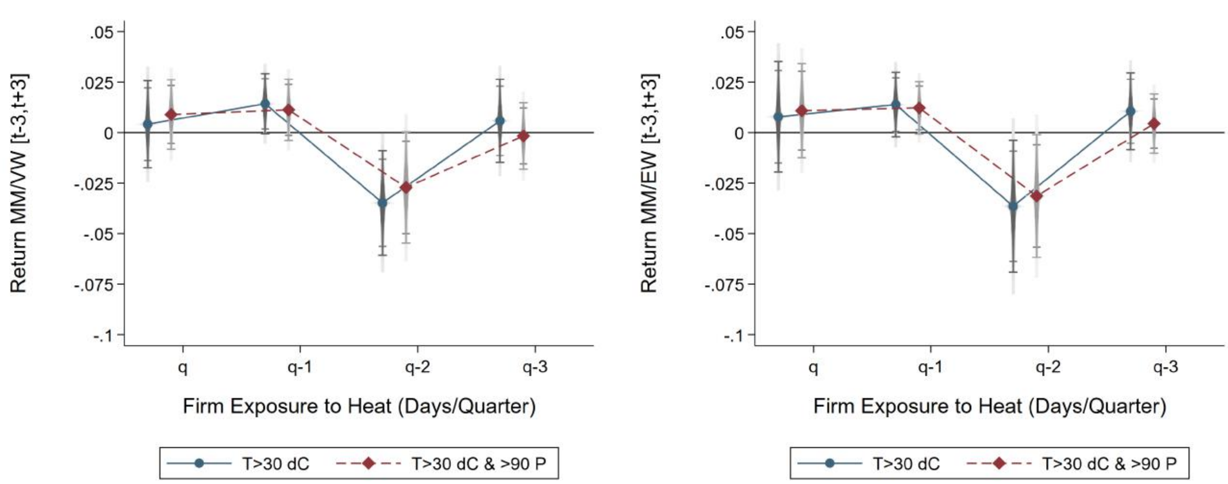
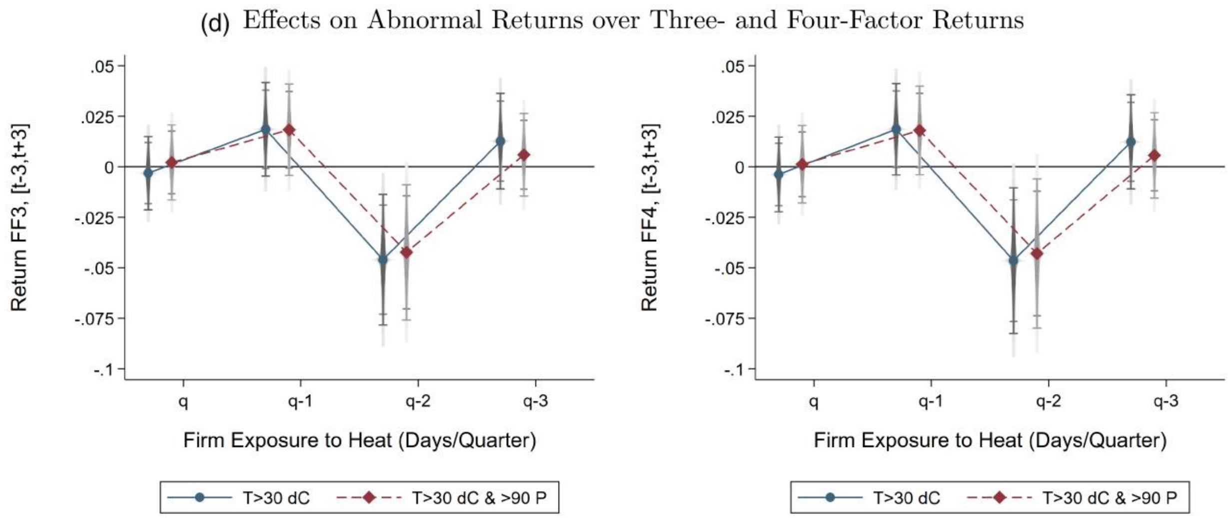


Figure A.6. (Continued) (Color online) Heat Exposure and Announcement Returns: Additional Specifications



Notes. (a) Effects on operating income and alternative exchange-rate conversion. (b) Effects on abnormal returns over equal- and value-weighted benchmark. (c) Effects on abnormal returns over market model using equal- and value-weighted benchmark. (a) Effects on abnormal returns over three- and four-factor returns. This figure reports additional tests related to the effects of heat exposure on announcement returns. In panel (a), the figure shows the effects of heat exposure on operating income over assets for the subsample of firms with information on earnings-announcement returns available (left). Further, panel (a) shows the seven-day return relative to the return on a value-weighted (VW) benchmark but after converting stock prices using the contemporaneous exchange rate. Panel (b) shows the effects of heat on the seven-day announcement return (–3, +3 days) relative to the return on an equal-weighted (EW) and VW benchmark composed of all stocks in the sample. Panel (c) shows seven-day abnormal returns (–3, +3) derived from estimating firms' equity betas in market models (MM, using EW and VW as market portfolio) of their stock returns. Panel (d) shows seven-day announcement returns using three- and four-factor models. Market and factor models of returns estimated are based on a maximum of 365 daily returns, ending 46 days before the announcement date. Stock returns are from Compustat Global Security Daily, converted to U.S. dollars with the exchange rate lagged by one year, and trimmed at the 1st and 99th percentiles. Heat exposure indicated by $T > 30°C$ is measured by the number of days in a financial quarter on which temperatures exceeded 30°C. Heat exposure indicated by $T > 30°C$ and > 90th percentile is the number of days on which temperatures exceeded not only 30°C, but also the 90th percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days. Coefficients pertain to heat exposure in the current quarter and as well as three lagged quarterly heat exposures ($q-1$, $q-2$, $q-3$); all specifications include the indicated fixed effects and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. Two-way standard errors are clustered at the country and year-quarter level. Small bars indicate 90% and 95% confidence intervals.

Table A.1. Robustness Test: Conley HAC Standard Errors

Panel A: Days with temperatures > 30°C				
	Revenues/assets		Operating income/assets	
	(1)	(2)	(3)	(4)
Heat exp. (q)	−0.0005		−0.0004	
	(0.0048)		(0.0010)	
Heat exp. ($q-1$)	−0.0087		−0.0030***	
	(0.0065)		(0.0011)	
Heat exp. ($q-2$)	−0.0031		−0.0008	
	(0.0035)		(0.0011)	
Heat exp. ($q-3$)	0.0025		−0.0004	
	(0.0036)		(0.0008)	
Heat exp. (q) (Conley)		−0.0005		−0.0004
		(0.0044)		(0.0011)
Heat exp. ($q-1$) (Conley)		−0.0087		−0.0030**
		(0.0054)		(0.0013)
Heat exp. ($q-2$) (Conley)		−0.0031		−0.0008
		(0.0043)		(0.0010)
Heat exp. ($q-3$) (Conley)		0.0025		−0.0004
		(0.0045)		(0.0011)

Table A.1. (Continued)

Panel A: Days with temperatures > 30°C				
	Revenues/assets		Operating income/assets	
	(1)	(2)	(3)	(4)
R^2	0.7511	0.0000	0.5780	0.0001
Number of observations	599,347	599,347	599,347	599,347

Panel B: Days with temperatures > 30°C and above 90th percentile				
	Revenues/assets		Operating income/assets	
	(1)	(2)	(3)	(4)
Heat exp. (q)	−0.0031		−0.0013**	
	(0.0035)		(0.0006)	
Heat exp. ($q-1$)	−0.0104		−0.0028***	
	(0.0082)		(0.0011)	
Heat exp. ($q-2$)	−0.0061**		−0.0014	
	(0.0030)		(0.0011)	
Heat exp. ($q-3$)	−0.0022		−0.0004	
	(0.0037)		(0.0007)	
Heat exp. (q) (Conley)		−0.0031		−0.0013
		(0.0037)		(0.0009)
Heat exp. ($q-1$) (Conley)		−0.0104**		−0.0028***
		(0.0046)		(0.0011)
Heat exp. ($q-2$) (Conley)		−0.0062		−0.0014*
		(0.0038)		(0.0009)
Heat exp. ($q-3$) (Conley)		−0.0022		−0.0004
		(0.0041)		(0.0009)
R^2	0.7511	0.0001	0.5781	0.0001
Number of observations	599,347	599,347	599,347	599,347

Notes. This table reports the effects of high temperatures on quarterly revenues as a percentage of assets (Revenues/assets, columns (1) and (2)) and operating income as a percentage of total assets (Op. income/assets, columns (3) and (4)); see specifications (1) and (2) in Section 3. Panel A (B) shows the effects for temperatures exceeding 30°C (Days with temperatures above 30°C and above > 90th percentile of the time- and location-specific distribution of temperatures). All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$). The number of observations refers to firm quarters. For comparison, we report two sets of standard errors below the coefficient estimates. The first is calculated using two-way clusters at the firm and year-quarter levels. The second uses standard errors adjusted for spatial correlation, following the method of Conley (1999).

Significance at the *10%, **5%, and ***1% levels.

Table A.2. Robustness: Heat Exposure and Firm Performance: Fixed Effects

Panel A: Number of days above 30°C								
	Revenues/assets				Op. income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat exp. (q)	−0.0115	−0.0025	0.0018	−0.0004	−0.0059	−0.0016	−0.0021	−0.0005
	(0.0075)	(0.0067)	(0.0069)	(0.0050)	(0.0038)	(0.0013)	(0.0017)	(0.0011)
Heat exp. ($q-1$)	0.0073	−0.0114	−0.0077	−0.0089	−0.0010	−0.0041***	−0.0030**	−0.0030***
	(0.0108)	(0.0086)	(0.0065)	(0.0063)	(0.0021)	(0.0012)	(0.0015)	(0.0011)
Heat exp. ($q-2$)	−0.0159*	−0.0065	−0.0038	−0.0046	−0.0050**	−0.0020	−0.0030	−0.0011
	(0.0086)	(0.0059)	(0.0049)	(0.0032)	(0.0021)	(0.0014)	(0.0021)	(0.0011)
Heat exp. ($q-3$)	0.0034	−0.0000	0.0041	0.0015	0.0026	−0.0015*	−0.0006	−0.0006
	(0.0065)	(0.0038)	(0.0050)	(0.0033)	(0.0026)	(0.0008)	(0.0011)	(0.0008)
Firm fixed effects	Yes	No	No	No	Yes	No	No	No
Firm-qtr fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent-year-qtr fixed effects	No	No	Yes	No	No	No	Yes	No
Cold days controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	No	No	No	Yes	No	No	No	Yes
$\sum$ heat exposure	−0.0167	−0.0205	−0.0057	−0.0123	−0.0093***	−0.0092***	−0.0087**	−0.0051**
Joint p-value	(0.46)	(0.28)	(0.74)	(0.25)	(0.00)	(0.00)	(0.02)	(0.01)

Table A.2. (Continued)

Panel A: Number of days above 30°C								
	Revenues/assets				Op. income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
R^2	0.7171	0.7485	0.7516	0.7512	0.5024	0.5755	0.5798	0.5782
Number of observations	599,347	599,347	599,328	599,347	599,347	599,347	599,328	599,347

Panel B: Number of days above 30°C and the 90th percentile								
	Revenues/assets				Op. income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat exp. (q)	−0.0013	−0.0050	−0.0013	−0.0027	−0.0042	−0.0023**	−0.0026**	−0.0013*
	(0.0087)	(0.0064)	(0.0063)	(0.0039)	(0.0040)	(0.0010)	(0.0013)	(0.0007)
Heat exp. ($q-1$)	0.0128	−0.0127	−0.0096	−0.0102	−0.0035**	−0.0036***	−0.0028**	−0.0028**
	(0.0111)	(0.0094)	(0.0072)	(0.0080)	(0.0017)	(0.0010)	(0.0011)	(0.0011)
Heat exp. ($q-2$)	−0.0229**	−0.0081	−0.0061	−0.0071**	−0.0043***	−0.0023*	−0.0037*	−0.0016
	(0.0091)	(0.0053)	(0.0038)	(0.0033)	(0.0015)	(0.0013)	(0.0019)	(0.0011)
Heat exp. ($q-3$)	−0.0163**	−0.0038	−0.0015	−0.0027	0.0029	−0.0012*	−0.0007	−0.0004
	(0.0064)	(0.0046)	(0.0046)	(0.0038)	(0.0027)	(0.0007)	(0.0009)	(0.0007)
Firm fixed effects	Yes	No	No	No	Yes	No	No	No
Firm-qtr fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent-year-qtr fixed effects	No	No	Yes	No	No	No	Yes	No
Cold days controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	No	No	No	Yes	No	No	No	Yes
$\sum$ heat exposure	−0.0277	−0.0296	−0.0185	−0.0227*	−0.0091***	−0.0095***	−0.0099***	−0.0061***
Joint p-value	(0.23)	(0.14)	(0.28)	(0.09)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.7172	0.7485	0.7516	0.7512	0.5019	0.5756	0.5798	0.5782
Number of observations	599,347	599,347	599,328	599,347	599,347	599,347	599,328	599,347

Notes. This table reports the effects of high temperatures on quarterly revenues as a percentage of assets (Revenues/assets, columns (1)–(4)) and operating income as a percentage of total assets (Op. income/assets, columns (5)–(8)); see specifications (1) and (2) in Section 3. Panel A (B) shows the effects for temperatures exceeding 30°C (Number of days above 30°C and > 90th percentile of the time- and location-specific distribution of temperatures). All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$). Firm–Qtr fixed effects indicates firm–financial quarter fixed effects. Ind–Year fixed effects indicates industry–year fixed effects. Continent–Year–Qtr fixed effects indicates continent–year–quarter fixed effects. Cold days controls indicates controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. In addition, the sum of coefficients on the four quarterly heat exposures (q, $q-3$) are presented along with p values for tests of their joint significance (joint p-value). The number of observations refers to firm quarters. Columns (4) and (8) also include country linear trends. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

Table A.3. Robustness: Heat Exposure and Firm Performance: Financial Crisis

	Rev (t)/assets ($t-1$)			OpI (t)/Assets ($t-1$)		
	Full sample (1)	Excl. 2008–2009 (2)	Excl. 2008–2010 (3)	Full sample (4)	Excl. 2008–2009 (5)	Excl. 2008–2010 (6)
Heat exp. (q)	−0.0004	−0.0016	−0.0023	−0.0005	−0.0011	−0.0018**
	(0.0050)	(0.0054)	(0.0061)	(0.0011)	(0.0010)	(0.0007)
Heat exp. ($q-1$)	−0.0089	−0.0116*	−0.0113	−0.0030***	−0.0040***	−0.0029***
	(0.0063)	(0.0066)	(0.0069)	(0.0011)	(0.0011)	(0.0011)
Heat exp. ($q-2$)	−0.0046	−0.0055	−0.0046	−0.0011	−0.0018*	−0.0032***
	(0.0032)	(0.0037)	(0.0036)	(0.0011)	(0.0010)	(0.0010)
Heat exp. ($q-3$)	0.0015	0.0016	−0.0046	−0.0006	−0.0008	−0.0010
	(0.0033)	(0.0038)	(0.0028)	(0.0008)	(0.0007)	(0.0007)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes
$\sum$ heat exposure	−0.0123	−0.0170	−0.0228	−0.0051**	−0.0077***	−0.0088***
Joint p-value	(0.25)	(0.16)	(0.13)	(0.01)	(0.00)	(0.00)

Table A.3. (Continued)

	Rev (t)/assets $(t-1)$			OpI (t)/Assets $(t-1)$		
	Full sample (1)	Excl. 2008–2009 (2)	Excl. 2008–2010 (3)	Full sample (4)	Excl. 2008–2009 (5)	Excl. 2008–2010 (6)
R^2	0.7512	0.7598	0.7638	0.5782	0.5920	0.5985
Number of observations	599,347	536,361	499,093	599,347	536,361	499,093
Number of firms	17,591	15,909	14,942	17,591	15,909	14,942
Number of countries	93	93	93	93	93	93

Notes. This table reports the effects of high temperatures on quarterly revenues as a percentage of assets (Revenues/assets, results columns (1)–(3)) and operating income as a percentage of total assets (Op. income/assets, columns (4)–(6)) after excluding years of the financial crisis. Columns (1) and (4) refer to full-sample results, columns (2) and (5) report results after dropping years 2008 and 2009, columns (3) and (6) report results after omitting the period 2008–2010. Heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C. All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$); firm–financial quarter fixed effects; industry–year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. In addition, the sum of coefficients on the four quarterly heat exposures (q, $q-3$) are presented along with p values for tests of their joint significance (joint p-value). The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

Figure A.7. (Color online) Robustness: Heat Exposure and Firm Performance: Temperature Data

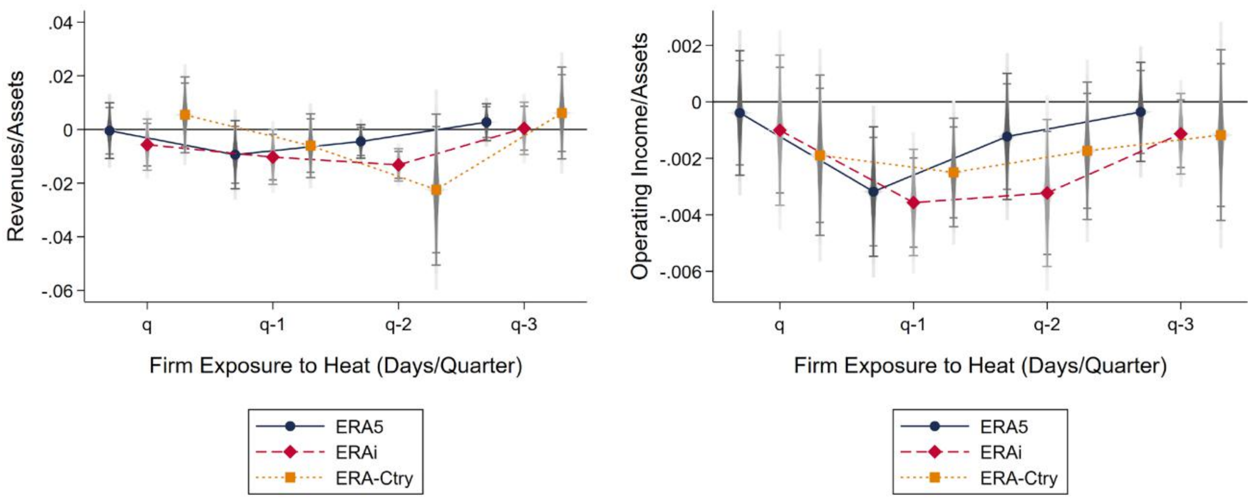


Table A.4. Robustness: Heat Exposure and Firm Performance: Temperature Thresholds

	Revenues/assets							Operating income/assets						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
$\sum$ heat exp. > 25°C	−0.0019 (0.0059)							−0.0011 (0.0011)						
$\sum$ heat exp. > 25°C & > 90thPctl		−0.0051* (0.0028)							−0.0013*** (0.0005)					
$\sum$ heat exp. > 25°C & > 95thPctl			−0.0041 (0.0034)							−0.0016*** (0.0005)				
$\sum$ heat exp. > 30°C				−0.0032 (0.0028)							−0.0013** (0.0005)			
$\sum$ heat exp. > 30°C & > 90thPctl					−0.0059* (0.0034)							−0.0016*** (0.0005)		
$\sum$ heat exp. > 30°C & > 95thPctl						−0.0048 (0.0038)							−0.0019*** (0.0005)	
$\sum$ heat exp. > 35°C							−0.0061 (0.0055)							−0.0006 (0.0008)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.7512	0.7512	0.7512	0.7512	0.7512	0.7512	0.7512	0.5782	0.5782	0.5782	0.5782	0.5782	0.5782	0.5782
Number of observations	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347	599,347
Number of firms	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591	17,591
Number of countries	93	93	93	93	93	93	93	93	93	93	93	93	93	93

Notes. This table reports the effects of high temperatures on quarterly revenues as a percentage of assets (Revenues/assets, columns (1)–(7)) and operating income as a percentage of total assets (Op. income/assets, columns (8)–(14)); see specifications (1) and (2) in Section 3. Columns (1)–(7) ((8)–(14)) present different measures of firm-level heat exposure (the sum of coefficients on the four quarterly heat exposures (q, $q-3$)). Heat exp. > 25°C (Heat exp. > 30°C, Heat exp. > 35°C) indicates the number of days in a financial quarter on which temperatures exceeded 25°C (30°C, 35°C). Heat exp. > 25°C & 90thPctl (Heat exp. > 25°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 25°C and also the 90th (95th) percentile of the location's historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days. Heat exp. > 30°C & 90thPctl (Heat exp. > 30°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 30°C, but also the 90th (95th) percentile of the location's historic distribution of temperatures. All specifications include firm–financial quarter fixed effects; industry–year fixed effects; controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C; and country linear trends. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

Table A.5. Heat Exposure and Firm Heterogeneity

	Revenues/assets							Op. income/assets						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
∑ heat exp. > 30°C	0.0008	−0.0134*	0.0045	−0.0028	−0.0025	−0.0042	−0.0033	0.0004	−0.0018	−0.0012	−0.0012**	−0.0013***	−0.0014**	−0.0013**
	(0.0035)	(0.0074)	(0.0084)	(0.0031)	(0.0029)	(0.0028)	(0.0028)	(0.0008)	(0.0012)	(0.0011)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Labor/total expenses $_{it}$	−0.0026							−0.0001						
	(0.0026)							(0.0002)						
∑ heat exp. > 30°C × Labor/total expenses $_{it}$	−0.0001***							−0.0000***						
	(0.0000)							(0.0000)						
∑ heat exp. > 30°C × Wages/employees		0.0002**							−0.0000					
		(0.0001)							(0.0000)					
∑ heat exp. > 30°C × Pct outdoors			−0.0372							−0.0008				
			(0.0420)							(0.0047)				
∑ heat exp. > 30°C × OSHA definition				−0.0024							−0.0009			
				(0.0074)							(0.0008)			
∑ heat exp. > 30°C × Food					−0.0286							0.0036		
					(0.0337)							(0.0025)		
∑ heat exp. > 30°C × Agriculture					−0.0044							−0.0062***		
					(0.0097)							(0.0024)		
∑ heat exp. > 30°C × Utilities						0.0278							0.0009	
						(0.0182)							(0.0017)	
∑ heat exp. > 30°C × Scandinavia							0.1264							0.0684
							(0.1120)							(0.0550)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Joint p-value				(0.44)		(0.18)	(0.27)				(0.03)		(0.78)	(0.23)
R^2	0.7856	0.8178	0.7647	0.7512	0.7512	0.7512	0.7512	0.6441	0.6744	0.5955	0.5782	0.5782	0.5782	0.5782
Mean dep. variable	24.23	24.23	24.23	24.23	24.23	24.23	24.23	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Number of observations	295,750	161,889	322,619	599,347	599,347	599,347	599,347	295,750	161,889	322,619	599,347	599,347	599,347	599,347
Number of firms	9,167	4,502	9,511	17,591	17,591	17,591	17,591	9,167	4,502	9,511	17,591	17,591	17,591	17,591
Number of countries	90	87	85	93	93	93	93	90	87	85	93	93	93	93

Notes. This table reports the effects of heat exposure on revenues as a percentage of assets and operating income as a percentage of total assets in interaction with, respectively, the share of average labor expenses relative to total expenses, the average wage per employee, the percentage of time spent outdoors by industry, an indicator of heat-sensitive industries derived from the Occupational Safety & Health Administration, a dummy variable indicating firms from agricultural industries, and a dummy variable that identifies utilities. Reported are the sum of coefficients on the four quarterly heat exposures (q, $q-3$), and their interaction effects. Heat exposure is measured by the number of days on which temperatures exceeded 30°C. For indicator variables, the joint significance of the coefficient on heat exposure and the interaction variable are shown below the table (joint p-value). All specifications additionally include firm–financial quarter fixed effects; industry–year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm quarters. Two-way standard errors clustered in parentheses at the country and year-quarter levels.

Significance at the *10%, **5%, and ***1% levels.

Table A.6. Robustness: Heat Exposure and Analyst Forecast Errors

Panel A: Median forecasts

	Revenues/assets				Pretax income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat exp. (q)	0.0019	0.0018	0.0004	0.0004	0.0003	0.0004	−0.0004	−0.0003
	(0.0033)	(0.0033)	(0.0026)	(0.0027)	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Heat exp. ($q-1$)	0.0012	0.0011	0.0003	0.0002	−0.0008	−0.0009	−0.0004	−0.0005
	(0.0015)	(0.0015)	(0.0018)	(0.0019)	(0.0013)	(0.0012)	(0.0012)	(0.0013)
Heat exp. ($q-2$)	−0.0048***	−0.0049***	−0.0042**	−0.0043**	−0.0022**	−0.0023**	−0.0016*	−0.0016*
	(0.0018)	(0.0017)	(0.0018)	(0.0019)	(0.0010)	(0.0010)	(0.0009)	(0.0009)
Heat exp. ($q-3$)	0.0004	0.0005	−0.0010	−0.0010	0.0015	0.0014	0.0017**	0.0017**
	(0.0021)	(0.0021)	(0.0023)	(0.0023)	(0.0012)	(0.0012)	(0.0007)	(0.0008)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	No	Yes	No	Yes	No	Yes	No	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2650	0.2655	0.2650	0.2654	0.2977	0.2981	0.2977	0.2980
Mean dep. variable	−0.15	−0.15	−0.15	−0.15	−0.16	−0.16	−0.16	−0.16
Number of observations	55,920	55,920	55,920	55,920	40,602	40,602	40,602	40,602
Number of firms	1,125	1,125	1,125	1,125	737	737	737	737
Number of countries	64	64	64	64	52	52	52	52

Panel B: Mean forecasts, lagged assets

	Revenues/assets				Pretax income/assets			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Heat exp. (q)	0.0025	0.0025	0.0011	0.0012	−0.0009	−0.0009	−0.0013	−0.0012
	(0.0031)	(0.0030)	(0.0023)	(0.0024)	(0.0009)	(0.0010)	(0.0008)	(0.0009)
Heat exp. ($q-1$)	−0.0013	−0.0013	−0.0010	−0.0009	−0.0002	−0.0003	−0.0002	−0.0002
	(0.0018)	(0.0019)	(0.0024)	(0.0025)	(0.0016)	(0.0015)	(0.0015)	(0.0015)
Heat exp. ($q-2$)	−0.0051**	−0.0054**	−0.0050**	−0.0054**	−0.0018**	−0.0019**	−0.0018	−0.0019*
	(0.0023)	(0.0022)	(0.0024)	(0.0025)	(0.0007)	(0.0008)	(0.0011)	(0.0011)
Heat exp. ($q-3$)	0.0003	0.0003	−0.0013	−0.0013	0.0027*	0.0027*	0.0023***	0.0023***
	(0.0026)	(0.0026)	(0.0020)	(0.0021)	(0.0015)	(0.0015)	(0.0006)	(0.0008)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	No	Yes	No	Yes	No	Yes	No	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.3028	0.3037	0.3028	0.3036	0.3396	0.3400	0.3396	0.3401
Mean dep. variable	−0.13	−0.13	−0.13	−0.13	−0.17	−0.17	−0.17	−0.17
Number of observations	43,901	43,901	43,901	43,901	31,942	31,942	31,942	31,942
Number of firms	843	843	843	843	555	555	555	555
Number of countries	59	59	59	59	52	52	52	52

Notes. This table reports robustness tests for the effects of high temperatures on errors in analyst forecasts of revenues and pretax income; see Equation (3). In columns (1), (3), (5), and (7), heat exposure is the number of days in a financial quarter on which temperatures exceeded 30°C. In columns (2), (4), (6), and (8), heat exposure is the number of days on which temperatures exceeded not only 30°C but also the 90th percentile of the time- and place-specific historic distribution of temperatures. In panel A, the forecast error in columns (1)–(4) ((5)–(8)) is the difference between the actual revenue (pretax income) and the median, instead of mean, forecast revenue (income) from IBES scaled by total assets. Panel B shows the effects for surprises based on mean forecasts, using lagged assets to scale the dependent variable. All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$), firm-financial quarter fixed effects, industry-year fixed effects, and country linear trends. Columns (2), (4), (6), and (8) additionally include controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm-quarters. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Table A.7. Robustness: Analyst Forecast Errors—Financial Crisis

	Quarterly revenues mean surprise/assets			Quarterly pretax income mean surprise/assets		
	Full sample (1)	Excl. 2008–2009 (2)	Excl. 2008–2010 (3)	Full sample (4)	Excl. 2008–2009 (5)	Excl. 2008–2010 (6)
Heat exp. (q)	0.0013	0.0024	0.0035	0.0003	−0.0000	−0.0003
	(0.0032)	(0.0030)	(0.0031)	(0.0012)	(0.0012)	(0.0013)
Heat exp. ($q-1$)	0.0010	0.0012	0.0023	−0.0010	−0.0011	−0.0004
	(0.0016)	(0.0016)	(0.0016)	(0.0011)	(0.0011)	(0.0012)
Heat exp. ($q-2$)	−0.0057***	−0.0054***	−0.0043***	−0.0020**	−0.0021**	−0.0018**
	(0.0017)	(0.0017)	(0.0015)	(0.0009)	(0.0008)	(0.0009)
Heat exp. ($q-3$)	0.0002	−0.0003	−0.0005	0.0016	0.0017	0.0021**
	(0.0022)	(0.0021)	(0.0019)	(0.0011)	(0.0011)	(0.0009)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2619	0.2733	0.2810	0.2962	0.3068	0.3143
Number of observations	58,017	54,168	51,292	42,187	39,581	37,453
Number of firms	1,731	1,509	1,376	1,153	998	912
Number of countries	65	64	64	52	52	51

Notes. This table reports the effects of high temperatures on errors in analyst forecasts of revenues and pretax income after excluding years of the financial crisis. The forecast error in columns (1)–(3) is the difference between the actual revenue and the mean forecast revenue from IBES scaled by total assets. The forecast error in columns (4)–(6) is the difference between actual pretax income and the mean forecast pretax income IBES scaled by lagged assets. Columns (1) and (3) refer to full-sample results, columns (2) and (5) report results after dropping years 2008 and 2009, columns (3) and (6) report results after omitting the period 2008–2010 Heat exposure is the number of days in a financial quarter on which temperatures exceed 30°C (Days > 30°C. p.q). All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$); firm-financial quarter fixed effects; industry-year fixed effects;, country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm-quarters. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Figure A.8. (Color online) Robustness: Analyst Forecast Errors—Temperature Data

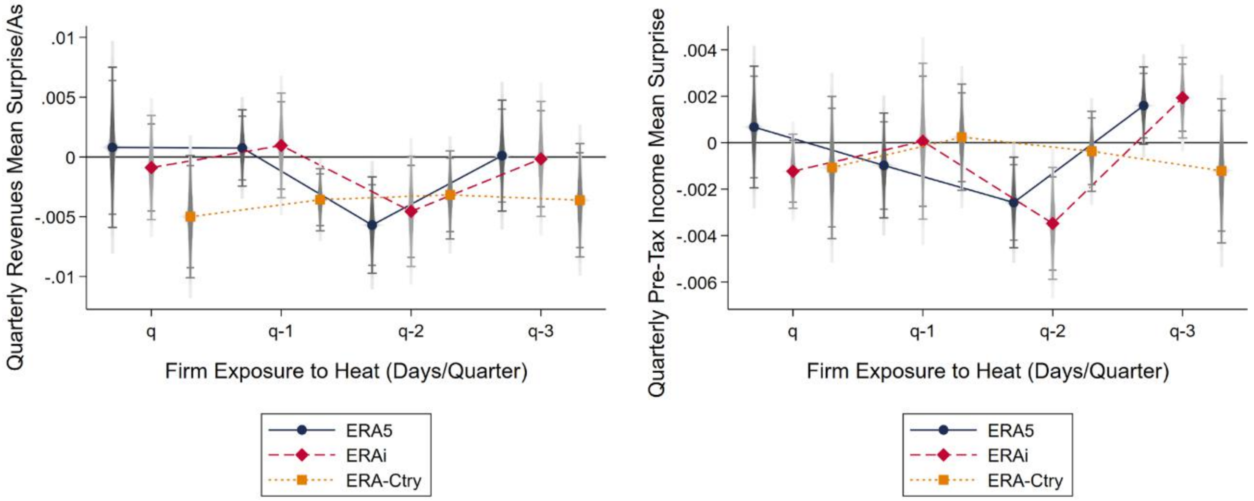


Table A.8. Robustness: Analyst Forecast Errors—Temperature Thresholds

	Quarterly revenues mean surprise/assets							Quarterly pretax income mean surprise/assets						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
∑ heat exp. > 25°C	0.0001 (0.0025)							−0.0008 (0.0007)						
∑ heat exp. > 25°C & > 90thPctl		−0.0032** (0.0013)							−0.0019*** (0.0006)					
∑ heat exp. > 25°C & > 95thPctl			−0.0040*** (0.0012)							−0.0016** (0.0007)				
∑ heat exp. > 30°C				−0.0058*** (0.0016)							−0.0020** (0.0008)			
∑ heat exp. > 30°C & > 90thPctl					−0.0049*** (0.0018)							−0.0018** (0.0008)		
∑ heat exp. > 30°C & > 95thPctl						−0.0056*** (0.0020)							−0.0012 (0.0011)	
∑ heat exp. > 35°C							−0.0136*** (0.0029)							−0.0006 (0.0021)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2617	0.2618	0.2618	0.2618	0.2618	0.2618	0.2620	0.2960	0.2962	0.2961	0.2961	0.2961	0.2960	0.2960
Number of observations	58,017	58,017	58,017	58,017	58,017	58,017	58,017	42,187	42,187	42,187	42,187	42,187	42,187	42,187
Number of firms	1,731	1,731	1,731	1,731	1,731	1,731	1,731	1,153	1,153	1,153	1,153	1,153	1,153	1,153
Number of countries	65	65	65	65	65	65	65	52	52	52	52	52	52	52

Notes. This table reports the effects of high temperatures on errors in analyst forecasts of revenues and pretax income; see Equation (3). The forecast error in columns (1)–(7) is the difference between the actual revenue and the mean forecast revenue from IBES scaled by total assets. The forecast error in columns (8)–(14) is the difference between actual pretax income and the mean forecast pretax income IBES scaled by lagged assets. Across columns (1)–(7) ((8)–(14)), different measures of firm-level heat exposure are presented (the sum of coefficients on the four quarterly heat exposures ($q, q-3$)). Heat exp. > 25°C (Heat exp. > 30°C, Heat exp. > 35°C) indicates the number of days in a financial quarter on which temperatures exceeded 25°C (30°C, 35°C). Heat exp. > 25°C & 90thPctl (Heat exp. > 25°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 25°C but also the 90th (95th) percentile of the historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days. Heat exp. > 30°C & 90thPctl (Heat exp. > 30°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 30°C but also the 90th (95th) percentile of the historic distribution of temperatures. All specifications include firm-financial quarter fixed effects; industry-year fixed effects; controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C; and country linear trends. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Table A.9. Robustness: Earnings Announcement Returns—Financial Crisis

	Return ($t-1, t+1$)			Return ($t-5, t+5$)		
	Full sample (1)	Excl. 2008–2009 (2)	Excl. 2008–2010 (3)	Full sample (4)	Excl. 2008–2009 (5)	Excl. 2008–2010 (6)
Heat exp. (q)	0.0008	−0.0018	−0.0029	−0.0241***	−0.0259**	−0.0120
	(0.0059)	(0.0063)	(0.0056)	(0.0084)	(0.0099)	(0.0073)
Heat exp. ($q-1$)	0.0111	0.0129*	0.0108	0.0045	0.0073	0.0121
	(0.0068)	(0.0068)	(0.0080)	(0.0104)	(0.0116)	(0.0155)
Heat exp. ($q-2$)	−0.0180**	−0.0201***	−0.0181**	−0.0358**	−0.0341**	−0.0201
	(0.0078)	(0.0074)	(0.0079)	(0.0152)	(0.0166)	(0.0175)
Heat exp. ($q-3$)	0.0062	0.0060	0.0097	0.0008	−0.0008	−0.0107
	(0.0067)	(0.0073)	(0.0075)	(0.0157)	(0.0169)	(0.0135)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2367	0.2504	0.2600	0.2524	0.2651	0.2727
Number of observations	40,209	37,544	35,094	40,209	37,544	35,094
Number of firms	3,075	2,657	2,304	3,075	2,657	2,304
Number of countries	64	63	63	64	63	63

Notes. This table reports the effects of high temperatures on quarterly earnings announcement returns, measured over 3 (− 1, + 1) and 11 (− 5, + 5) days surrounding the earnings announcement date. We match firms and temperatures based on headquarter location but require firms to hold at least 10% of their assets in their home country. Heat exposure is measured by the number of days in a financial quarter on which temperatures exceeded 30°C. Columns (1) and (3) refer to full-sample results, columns (2) and (5) report results after dropping years 2008 and 2009, columns (3) and (6) report results after omitting the period 2008–2010. All specifications include heat exposures augmented with three lagged quarterly exposures (q, $q-3$); firm-financial quarter fixed effects; industry-year fixed effects; country linear trends; and controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C. The number of observations refers to firm-quarters. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Figure A.9. (Color online) Robustness: Earnings Announcement Returns—Temperature Data

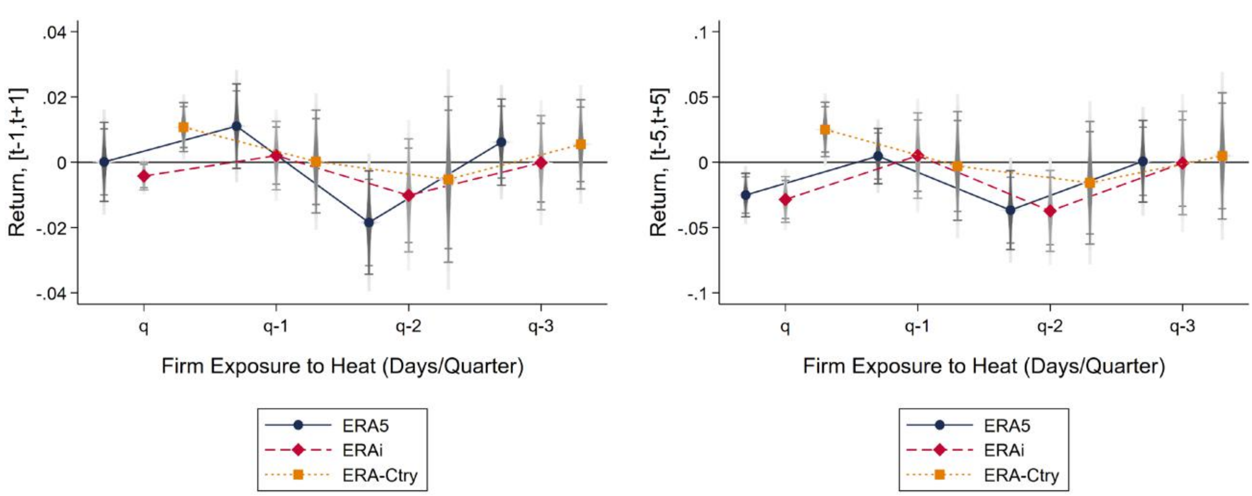


Table A.10. Robustness: Earnings Announcement Returns—Temperature Thresholds

	Return ($t-1$, $t+1$)							Return ($t-5$, $t+5$)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
∑ heat exp. > 25°C	−0.0100							0.0126						
	(0.0071)							(0.0251)						
∑ heat exp. > 25°C & > 90thPctl		−0.0131***							−0.0106					
		(0.0042)							(0.0117)					
∑ heat exp. > 25°C & > 95thPctl			−0.0192***							−0.0086				
			(0.0063)							(0.0159)				
∑ heat exp. > 30°C				−0.0179**							−0.0357**			
				(0.0089)							(0.0153)			
∑ heat exp. > 30°C & > 90thPctl					−0.0169**							−0.0277**		
					(0.0064)							(0.0137)		
∑ heat exp. > 30°C & > 95thPctl						−0.0229**							−0.0265	
						(0.0091)							(0.0164)	
∑ heat exp. > 35° C							−0.0227**							−0.0642***
							(0.0104)							(0.0182)
Firm-qtr fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cold day controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country linear trends	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.2364	0.2366	0.2367	0.2366	0.2366	0.2367	0.2364	0.2518	0.2519	0.2518	0.2522	0.2521	0.2520	0.2521
Number of observations	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209	40,209
Number of firms	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075	3,075
Number of countries	64	64	64	64	64	64	64	64	64	64	64	64	64	64

Notes. This table reports the effects of high temperatures on quarterly earnings announcement returns. The first seven columns pertain to cumulative stock return measured over three days surrounding the earnings announcement date (− 1, + 1), whereas the last seven columns pertain to the cumulative return over 11 days surrounding the announcement date (− 5, + 1). Across columns (1)–(7) ((8)–(14)) different measures of firm-level heat exposure are presented (the sum of coefficients on the four quarterly heat exposures (q, $q-3$)). Heat exp. > 25°C (Heat exp. > 30°C, Heat exp. > 35°C) indicates the number of days in a financial quarter on which temperatures exceeded 25°C (30°C, 35°C). Heat exp. > 25°C & 90thPctl (Heat exp. > 25°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 25°C but also the 90th (95th) percentile of the historic distribution of temperatures that occurred on the same day as well as the five preceding and subsequent days. Heat exp. > 30°C & 90thPctl (Heat exp. > 30°C & 95thPctl) indicates the number of days on which temperatures exceeded not only 30°C but also the 90th (95th) percentile of the historic distribution of temperatures. All specifications include firm–financial quarter fixed effects; industry-year fixed effects; controls for cold days between 0°C and −5°C, −5°C and −10°C, and below −10°C; and for country linear trends. Two-way standard errors are clustered at the country and year-quarter level and reported in parentheses.

Significance at the *10%, **5%, ***1% levels.

Endnotes

[1] The task force aims to help "companies disclose decision-useful information which will enable financial markets to better understand climate-related financial risks and opportunities" and was formed by the Financial Stability Board in 2015 (Bloomberg 2018).

[2] In robustness tests, we estimate the results for alternative thresholds and investigate the functional form of firm-performance responses to temperatures using a bin specification.

[3] Reanalyses combine past climate-related observations with scientific models to generate time series of temperatures, and are commonly used in the geophysical sciences (Copernicus Climate Change Service 2019).

[4] Studies show that electricity prices (water supply) increase (decrease) with heat exposure (Mishra and Singh 2010, Pechan and Eisenack 2014).

[5] The negative relation between heat and output appears to persist not only across, but also within countries with a documented decrease of 1.2% to 1.9% in municipal income per additional degree Celsius (Dell et al. 2009). Countries in tropical and subtropical climates are found to be more severely affected by rising temperatures (Hsiang 2010, Dell et al, 2012). However, Burke et al. (2015) document that the negative effect holds for both developed and developing countries and in and outside the agricultural sector. Moreover, Bansal et al. (2016) find that long-run temperature changes carry a positive equity risk premium.

[6] We calculate the hypothetical, daily figure as the quarterly revenues or operating income divided by 90.

[7] One standard deviation of this within-firm-quarter variation accounts for 5.4 and 6.3 days. To put this short-run variation in context, the mean projected increase in days above 30°C from 2006–2019 to midcentury (calculated based on daily temperature projections for 2040–2059) is 12 days for a scenario assuming some degree of policy intervention (RCP 4.5) and 22 days for a scenario closer to a business-as-usual approach to mitigation (RCP 8.5). The numbers are calculated as the average of all ensembles of the MPI-ESM-LR model of the fifth phase of the Coupled Model Intercomparison Project (CMIP5).

[8] The objective of this study is to understand if investors anticipate the net impact of heat exposure on firm performance. The decomposition of the effect by economic channels is important but is not the focus of this paper.

[9] Furthermore, Fiedler et al. (2021) point out limitations to using current climate models in assessing (future) financial risks.

[10] Whereas reanalysis data on global temperatures may become public with a delay, market participants concerned with the performance of individual firms have timely access to local forecasts, weather, and news reports.

[11] On average, our sample includes 3.6 estimates per revenue and income prediction.

[12] Furthermore, we use measures of heat that can be consolidated with projections for increases of extreme-temperature days of the IPCC and estimate our main tests with controls for cold days to ensure that our results are driven by heat and not other extremes.

[13] Also, considerable literature reports the direct effect of the weather on investors' sentiments and returns (Kamstra et al. 2003, Cao and Wei 2005, Symeonidis et al. 2010).

[14] Specifically, Stroebel and Wurgler (2021) survey finance professionals, academics, and regulators about their views on climate issues, whereas Krueger et al. (2020) survey institutional investors. In Stroebel and Wurgler (2021), most respondents agree that climate risk is insufficiently priced in markets, a view that is especially pronounced among respondents with a professional interest in climate finance. In Krueger et al. (2020), institutional investors state the view that climate risks may not be fully reflected in equity valuations.

[15] More recently, studies propose textual analysis of corporate disclosures to measure firm-level climate-risk exposure. Sautner et al. (2020) extract exposures from earnings conference calls. Their measure of regulatory risk is associated with lower firm value, whereas their measure of physical risk displays a statistically insignificant association. The insignificant response to physical risk could imply that investors undervalue physical climate risks, consistent with our results. On the other hand, the absence of attention for physical risks among analysts directly affects the content of conference calls, and this, in turn, could affect measurements of physical risk based on call transcripts.

[16] "Article 173 of the French Law on Energy Transition and Green Growth passed August 2015 requires major institutional investors and asset management companies to … report on the impacts of both physical risks and transition risks caused by climate change" (Four Twenty Seven 2018a).

[17] "The EU laid out a clear plan to move towards mandatory climate risk disclosure as part of a new set of regulations to finance sustainable growth and support the transition to a low-carbon economy. The European Commission's Action Plan lays out a two year time line for implementation, with a goal to create a taxonomy for climate adaptation finance by the end of 2019" (Four Twenty Seven 2018b).

[18] Applying this threshold leads to an exclusion of 7,638 firms with unknown asset concentration or less than 10% of assets in the country of their headquarters. Later in the paper, we conduct additional tests to better understand our results' sensitivity to different asset-concentration thresholds.

[19] This approach is common in the finance and accounting literature, as accounting-based financial variables often exhibit extreme values (see Chen and Yang 2019 and Hsu et al. 2021 for recent examples). Subsequently, we scale both revenues and operating income by firms' total assets lagged by one year and convert all values from local currencies to U.S. dollars by using Wharton Research Data Services tables on exchange rates.

[20] Compared with the overall U.S. stock market capitalization—the corresponding share of firms on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX)—the firms in our sample are similar in size to a large share of U.S. firms. According to statistics by the U.S. Securities and Exchange Commission (2005), firms with less than 568 million U.S. dollars in assets make up the lower 76% of firms listed on the NYSE and AMEX. In terms of their other financial characteristics, the firms in this sample have a mean operating income before depreciation (revenue) over assets of 2.1% (24.2%) per quarter.

[21] This approach is commonly used to reflect different local conditions when characterizing heat waves (Perkins and Alexander 2013) and for projections of future temperature days in the IPCC reports (Intergovernmental Panel on Climate Change 2013, chapter 11).

[22] To address the potential spatial or temporal dependence of heat exposure, standard errors have to be clustered at the level of treatment. In practice, choosing the right clustering dimensions is challenging as heat can be spatially heterogeneous within large and small countries and as spatial correlations are unlikely to be represented well by administrative boundaries. Additionally, the correlation between grid nodes is contingent on unobserved variables, such as topography. Reflecting these challenges, related papers show a wide range of different approaches to clustering standard errors. In our main specification, we cluster standard errors at the country and year–quarter levels as temperatures are likely to be correlated across firms in the same country and within seasons. However, the country level could be too narrow or broad depending on country size and

climate-zone heterogeneity, and temperatures may be correlated mostly within or also across seasons. Further, we find that the results are robust to adjusting for spatial and serial correlation in errors using the approach of Conley (1999) (Table A.1).

[23] For instance, firm characteristics could be "bad controls" (Angrist and Pischke 2008) if heat exposure affects those variables through financial performance or if the strength of the effect depends on certain firm characteristics.

[24] Naturally, our results are likely to be driven by channels other than employee performance.

[25] To put a one-standard-deviation increase in short-run fluctuations in perspective, we obtain data from the fifth phase of the CMIP5. Based on the average of all ensembles of the MPI-ESM-LR model, the mean projected increase in days above 30°C from 2006 to 2019 to midcentury (calculated based on daily temperature projections from 2040–2059) is seven days for a scenario assuming substantial policy intervention (RCP 2.6) and 22 days for a scenario closer to a business-as-usual approach to mitigation (RCP 8.5).

[26] As we focus on an increase of approximately one week in firms' exposure to heat, this magnitude is naturally much smaller than the performance response to large-scale environmental shocks. For instance, Barrot and Sauvagnat (2016) find that natural disasters (lasting less than 30 days with total estimated damages above $1 billion 2013 constant dollars) decrease sales growth by approximately 30%. Nevertheless, the observed 1.8% decrease in income is relevant given the projection that the number of extreme temperature days might increase substantially. For instance, days above 30°C may increase by four standard deviations on average based on CMIP5 RCP 8.5 projections. Moreover, the dollar value of a 1.8% decrease by itself appears relevant from an operations-management perspective.

[27] In this test, the observed effects may be attenuated as we estimate average effects of heat exposure across four quarters despite the fact that previous tests show that the responses are heterogeneous across these lags.

[28] The coefficients of bins >30°C are marginally significant. Because we estimate the results across a global sample with heterogeneous average temperatures, the limited precision could relate to heterogeneity in what constitutes a high temperature. For instance, temperatures around 25°–30°C may be mild or unusually high in different locations, leading to mixed magnitudes and signs of the estimate across space, which we average by bin. Moreover, the support changes at the top of the temperature distribution. Whereas a few firm–financial quarters are exposed to temperatures above 30°C every day of the quarter, the occurrence of such temperatures is extremely rare in many other areas.

[29] The differences could arise for several reasons: First, we divide annual income and revenues by their firm-specific average instead of scaling the measures by assets as there could be confounding shocks on assets (i.e., through inventories or cash). The longer time horizon makes it difficult to scale the dependent variable in ways that keep the estimates unaffected. Second, requiring the existence of a longer series of observations decreases the size of our sample and potentially also affects the composition. Third, by testing the effects on annual revenues and income, we rely on observations at the end of the financial year. For most firms, the financial year ends in December, which means that the highest temperatures could be recorded with a lag of three instead of two quarters.

[30] In comparing the effects of heat on COGS, SGA, and wages, we find that days of heat affect wages after two quarters, whereas COGS and SGA expenses respond immediately. Unfortunately, our empirical setting does not allow us to causally study how different outcomes interact, and we remain cautious about interpreting the differences between wages, SGA, and COGS as wages are only reported by a subset of firms.

[31] Custodio et al. (2022) focus on distinguishing whether firm-level temperature shocks are demand- or supply-driven and find evidence in support of supply-side shocks based on within variation in shocks to firms with the same corporate customer. Pankratz and Schiller (2021) focus on customer firms' adaptation in response to changes in the frequency of climate-related shocks and also show that transitory shocks in heat exposure lead to increases in the probability of corporate customers ending supply chain relationships. Beyond corporate customers, there is evidence that consumer purchases respond to weather conditions, whereas consumers' adaptation (i.e., switching from outdoor to indoor shopping) appears limited (e.g., Bahng and Kincade 2012, Zwebner et al. 2013, Busse et al. 2015, Roth Tran 2020, Tian et al. 2021).

[32] It is important to note that the cross-sectional setting does not allow a causal interpretation as individual firm characteristics may be correlated with other (un)observed characteristics that attenuate or reinforce the effect. We show the results for various interactions with the count of days on which temperatures exceeded both 30°C and the place- and time-contingent 90th percentile temperature. The results for the interactions with the 30°C threshold are shown in Table A.5.

[33] Labor and total expenses are reported with error. To remove outliers, we trim the ratio of labor over total expenses at the 1st and 99th percentiles. Further, we remove observations if labor expenses exceed total expenses. On average, labor expenses are 35% of total expenses. For summary statistics, see Table 1, panel A.

[34] Consistent with this result, Addoum et al. (2020) find a significant positive effect of cold days on energy companies' sales and no effect of hot days.

[35] Temperatures and economic growth are known to be endogenous (e.g., Dell et al. 2012), and the cross-sectional setting does not allow us to disentangle both effects.

[36] We also interact heat exposure with an indicator for firms located in Scandinavia in Table 5. In line with the evidence that effects are attenuated in wealthier and colder countries, we find economically large positive but insignificant coefficients for the interaction terms. Joint tests of the main effect and the interaction term indicate that heat exposure does not significantly affect revenues and operating income in Scandinavia.

[37] The assumption that the variation is quasi-random is conditional on spatial and temporal fixed effects.

[38] Conceptually, this difference should not be problematic. The main difference between the values lies in the firms' interest expenses, which should be orthogonal to the firms' exposure to high temperatures because this exposure is exogenous and varies from year to year.

[39] This deviation from the estimates for the full sample could be because a larger share of firms in this subsample are located in cold areas and are more profitable. Both revenues and operating income decrease in response to heat although the effect on revenues is less precisely estimated than in the first set of tests. Alternatively, the less-pronounced effects in columns (2) and (6) could be explained by the fact that the number of hot days alone is much lower in the areas of these subsamples, leading to limited variation in hot days under the absolute–relative definition.

[40] This result is robust when we estimate the effects on median instead of mean surprises and when we lag assets by one year before scaling the dependent variable in Table A.6. In the main tests, assets are contemporaneous as the lag substantially reduces the sample size.

[41] We lag exchange rates by one year to ensure that our results are not confounded by potential macrofinancial effects of heat on aggregate

economic output. We also estimate the results without this adjustment and find no effects of this choice on our results (see Figure A.6).

[42] We trim the returns below the 1st and above the 99th percentile. This approach is common in the finance and accounting literature as accounting-based financial variables often exhibit extreme values (see Chen and Yang 2019 and Hsu et al. 2021 for recent examples).

[43] Similar to the analysis in Section 4, firms with available return data are more profitable. The mean operating income over assets is 3.4% (versus the 2.1% mean for the full sample). The mean revenues over assets is 25.9% (versus 24.2%).

[44] For the expected returns, we estimate the market model out of sample based on a maximum of 365 days ending 46 days before the announcement date. We require at least 20 observations per firm and announcement date and drop daily stock rates of return outside of −2 and +4 times the market rate of return following Welch (2019).

[45] For the main specification, we rely on raw returns. In a multicountry setting, the choice of a benchmark can induce bias if individual countries load differently on the benchmark returns, depending on how well the aggregate factor returns represent the conditions in local financial markets. For a firm-level analysis, this heterogeneity could potentially raise questions about whether the results are driven by country exposures. For the market model, we estimate factor loadings out of sample based on a maximum of 365 days ending 46 days before the announcement date. The coefficients for the seven-day window are plotted in panel (c) and are consistent with the main results.

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