Sellin' in the Rain: Weather, Climate, and Retail Sales

- Online Appendix B -

Brigitte Roth Tran

Table B1: Alternative specifications examining cumulative responses of sales to weather over time

Dep var: ln(Net Sales$_{it}$)	(1)	(2)	(3)	(4)	(5)
Positive Weather Shock, $t = 0$	0.069***	0.068***	0.069***	0.068***	0.068***
Positive Weather Shock, $t = 21$	0.060***	0.055**	0.061***	0.081***	0.061***
Negative Weather Shock, $t = 0$	-0.072***	-0.072***	-0.072***	-0.088***	-0.072***
Negative Weather Shock, $t = 21$	-0.088***	-0.086***	-0.088***	-0.097***	-0.087***
Store Time Trends	Yes	No	Yes	Yes	Yes
First or last month control	Yes	Yes	No	Yes	Yes
Date FE	Yes	Yes	Yes	No	Yes
Alternative time FE	No	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	MSA	State
Observations	96,877	96,877	96,672	96,963	94,901
Adjusted R^2	0.913	0.903	0.913	0.894	0.913

Note: This table shows cumulative results from alternative specifications of regressions of net sales at store i on day $t = 0$ on a series of leads and lags of weather shocks as measured by the "weather index." With a mean of 0 and standard deviation of 1, the weather index measures how favorable weather conditions are for sales. A more positive value corresponds to a more positive weather shock. Constructed using the lasso machine learning method with cross-validation in a residuals-on-residuals framework to select among thousands of potential interacted and non-linear weather variables, the index flexibly reflects the contemporaneous weather shock for a specific store on a specific day. The results in this table are for the cumulative responses starting from seven days before the shock up to $t = 0$ and $t = 21$, to examine robustness of the results shown in Figure 4.

Column 1 shows the results from Figure 4 and controls for date, store-month, store-month, and store-day of week fixed effects as well as store-specific trends and indicators for store openings and closings. Column 2 excludes the store-specific linear and quadratic time trends. Column 3 drops sales that occur in the first or last month of a store (its opening or closing.) Column 4 replaces the date fixed effect with fixed effects for year, day-of-the-year, and holiday fixed effects. In column 5, standard errors are clustered by state rather than MSA.

Source: Proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B2: Alternative specifications for analysis on sales shifting between indoor and outdoor store types

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)
Weather index	0.056***	0.056***	0.058***	0.056***
Counterpart weather index	−0.009***	−0.007**	−0.008**	−0.009***
Number of Stores Control	Yes	No	Yes	Yes
Date FE	Yes	Yes	No	Yes
Alternative time FE	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	State
Observations	32,036	32,036	32,036	32,036
Adjusted R^2	0.958	0.957	0.952	0.958

Note: This table shows results from alternative specifications for regressing the log of aggregate net sales at all stores of type j (indoor or outdoor) in MSA m on day t on the "weather index" for that store type as well as the weather index for the counterpart store type. With a mean of 0 and standard deviation of 1, the weather index measures how favorable weather conditions are for sales. A more positive value corresponds to a more positive weather shock. Constructed using the lasso machine learning method with cross-validation in a residuals-on-residuals framework to select among thousands of potential interacted and non-linear weather variables, the index flexibly reflects the contemporaneous weather shock for a specific store on a specific day. For observations of sales at indoor stores, the "counterpart" weather index refers to the weather index for outdoor stores, and vice versa. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather.

Column 1 shows the version presented in Table 1, which controls for date, MSA-weekday, and MSA-month fixed effects, MSA-specific trends and number of stores, with robust standard errors clustered at the MSA and date levels. Column 2 drops a control for how many stores are within the MSA. Column 3 replaces date fixed effects with a set of alternative date controls including the year, day of the year, and a set of holiday indicators. In column 4 standard errors are clustered at the state rather than MSA level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B3: Relationship between indoor and outdoor weather indexes when heat events are defined as occurring when average temperature > 80F

Dep var: Weather index	Indoor Stores		Outdoor Stores	
	(1)	(2)	(3)	(4)
Avg temp > 80F	−0.137		−0.122	
Max temp < 0C	−0.573		−0.959**	
Positive precipitation	0.341***		−0.108	
Positive snowfall	−1.225*		−1.855***	
Positive snow depth	−1.196***		−1.158***	
Counterpart weather index		0.802**		0.374***
Counterpart weather index × Avg Temp > 80F		0.167		0.188*
Counterpart weather index × Max temp < 0C		−0.226		0.488**
Counterpart weather index × Positive precipitation		−0.631***		−0.292***
Counterpart weather index × Positive snowfall		0.431		0.715***
Counterpart weather index × Positive snow depth		0.323*		−0.023
Observations	16,016	16,016	16,016	16,016
Adjusted R^2	0.134	0.369	0.267	0.488

Note: This table shows results from regressing the average MSA m "weather index" for store type j (indoor or outdoor) on a set of indicators for weather events, which in columns (2) and (4) are interacted with the weather index for the counterpart store type. With a mean of 0 and standard deviation of 1, the weather index measures how favorable weather conditions are for sales. A more positive value corresponds to a more positive weather shock. Constructed using the lasso machine learning method with cross-validation in a residuals-on-residuals framework to select among thousands of potential interacted and non-linear weather variables, the index flexibly reflects the contemporaneous weather shock for a specific store on a specific day. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. For observations of sales at indoor stores, the "counterpart" weather index refers to the weather index for outdoor stores, and vice versa. Regressions include only MSAs with indoor and outdoor stores and control for date, MSA-weekday, and MSA-month fixed effects as well as MSA-specific trends and number of stores. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B4: Alternative specifications for analysis on sales shifting between stores and ecommerce

Dep var: ln(Net Sales$_{mt}$)	(1)	(2)	(3)	(4)
Days in Weather Index Range				
(Mean of Indoor and Outdoor Indexes)				
$< 5^{th}$ percentile	−0.009	−0.012	−0.002	−0.009
$5^{th} - 10^{th}$ percentile	−0.001	0.002	−0.001	−0.001
$10^{th} - 20^{th}$ percentile	−0.001	0.008*	0.003	−0.001
$20^{th} - 40^{th}$ percentile	0.003	0.008	0.007	0.003
$60^{th} - 80^{th}$ percentile	0.004	0.004	0.008	0.004
$80^{th} - 90^{th}$ percentile	0.006	0.006	0.014***	0.006
$90^{th} - 95^{th}$ percentile	0.001	0.000	0.004	0.001
$> 95^{th}$ percentile	0.017***	0.020***	0.025***	0.017***
MSA-specific time trends	Yes	No	Yes	Yes
Weekly Fixed Effects	Yes	Yes	No	Yes
Year, holiday, month FE	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	State
Observations	11,116	11,116	11,116	11,116
Adjusted R^2	0.954	0.952	0.947	0.954

Note: This table shows results from alternative specifications for regressing log of sales on the firm's website for week k in MSA m on counts of the number of days in which the "weather index" falls within the noted ranges that week. The figure shows results from three separate regressions where the weather index is averaged over just indoor stores, just outdoor stores, or equally across the two types. With a mean of 0 and standard deviation of 1, the weather index measures how favorable weather conditions are for sales. A more positive value corresponds to a more positive weather shock. Constructed using the lasso machine learning method with cross-validation in a residuals-on-residuals framework to select among thousands of potential interacted and non-linear weather variables, the index flexibly reflects the contemporaneous weather shock for a specific store on a specific day. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. Regressions control for week and MSA-month fixed effects as well as MSA-specific linear and quadratic time trends, with standard errors clustered at the MSA and week levels.
Column 1 shows the same results as those depicted in Figure 3. In column 2, MSA-specific time trends have been excluded. In column 3, the weekly fixed effects have been replaced with holiday and year fixed effects, and in column 4 the standard errors are clustered at the state level rather than the MSA level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Source: Proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B5: Effects of extreme weather events on ecommerce

Dep var: ln(Net Sales)	(1)	(2)	(3)
Extreme heat			
TAVG $\geqslant$ 80F	0.001		
80F $<$ TAVG $\leqslant$ 90F			0.001
TAVG $\geqslant$ 90F		-0.003	-0.003
Extreme Cold			
TMAX $\leqslant$ 0C	-0.030*		
TMAX $\leqslant$ 0C and TAVG $<$ -15F			-0.034*
TAVG $\leqslant$ -15F		-0.017*	-0.015*
Precipitation			
PRCP $\geqslant$ 1 in	-0.003		
1 in $<$ PRCP $\leqslant$ 2 in			-0.002
PRCP $\geqslant$ 2 in		-0.008	-0.007
Snowfall			
SNOW $\geqslant$ 1 in	0.019		
1 in $<$ SNOW $\leqslant$ 6 in			0.027
SNOW $\geqslant$ 6 in		-0.024	0.001
Snow Depth			
SNWD $\geqslant$ 1 in	-0.017**		
1 in $<$ SNWD $\leqslant$ 6 in			-0.011
SNWD $\geqslant$ 6 in		-0.034***	-0.034***
Observations	2,145	2,145	2,145
Adjusted R^2	0.976	0.976	0.976

Note: The table shows results from regressing log of weekly MSA online sales on the count of days for which the local weather falls into each category. The online sales have been aggregated to the weekly level with a week starting on a Tuesday because the recorded date is the date on which an order is filled, which is typically the same or following business day after an order has been placed. The regressions control for week and MSA-month fixed effects as well as MSA-specific linear and quadratic time trends, with standard errors clustered at the MSA and week levels. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B6: Alternative specifications for Adaptation to Means

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Temperature					
Max Temp (F)	0.0150***	0.0140***	0.0140***	0.0142***	0.0150***
Max Temp $\times \mu_{id}^{TMAX}$	−0.0002***	−0.0002***	−0.0002***	−0.0002***	−0.0002***
Precipitation					
Precipitation (in)	−0.0955***	−0.1007***	−0.1000***	−0.1173***	−0.0955***
Precip $\times \mu_{id}^{PRCP}$	0.4892***	0.5248***	0.5172***	0.5902***	0.4892***
Snowfall					
Snowfall (in)	−0.1302***	−0.1280***	−0.1278***	−0.1477***	−0.1302***
Snowfall $\times \mu_{id}^{SNOW}$	0.1084*	0.1036*	0.1033*	0.1433***	0.1084*
Snow Depth					
Snow Depth (in)	−0.0174***	−0.0158***	−0.0156***	−0.0154***	−0.0174***
Snow Depth $\times \mu_{id}^{SNWD}$	0.0037***	0.0031***	0.0031***	0.0017	0.0037***
Store Time Trends	Yes	No	Yes	Yes	Yes
First or last month control	Yes	Yes	No	Yes	Yes
Date FE	Yes	Yes	Yes	No	Yes
Alternative time FE	No	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	MSA	State
Observations	136,935	136,935	136,174	136,937	136,935
Adjusted R^2	0.907	0.897	0.898	0.885	0.907

Note: This table shows results from alternative specifications for regressing log of daily store level sales on weather and interactions between contemporaneous weather observations and their historical normals (μ_{id}^{E}). The historical normals are calculated for each calendar day d using Bartlett kernel weights to smooth over historical observations from 1980-2009. Column 1 shows the Table 3 specification, which controls for date, store-month, and store-day-of-week fixed effects as well as store-specific trends, indicators for store openings and closings, and the uninteracted historical normals. Robust standard errors are clustered by MSA and by date. Column 2 excludes the store-specific linear and quadratic time trends. Column 3 drops sales that occur in the first or last month of a store (its opening or closing.) Column 4 replaces the date fixed effect with fixed effects for year, day-of-the-year, and holiday fixed effects. In column 5, standard errors are clustered by state rather than MSA. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B7: Alternative specifications for Adaptation to Means and Standard Deviations

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Temperature					
Max Temp (F)	0.0069**	0.0048*	0.0048	0.0060*	0.0069**
Max Temp $\times \mu_{id}^{TMAX}$	−0.0002***	−0.0001***	−0.0001***	−0.0002***	−0.0002***
Max Temp $\times \sigma_{id}^{TMAX}$	0.0005***	0.0006***	0.0006***	0.0005***	0.0005***
Precipitation					
Precipitation (in)	−0.1407***	−0.1478***	−0.1461***	−0.1740***	−0.1407***
Precip $\times \mu_{id}^{PRCP}$	−0.1814	−0.1772	−0.1643	−0.2735	−0.1814
Precip $\times \sigma_{id}^{PRCP}$	0.3628***	0.3791***	0.3690***	0.4655***	0.3628***
Snowfall					
Snowfall (in)	−0.1676***	−0.1686***	−0.1696***	−0.1803***	−0.1676***
Snowfall $\times \mu_{id}^{SNOW}$	−0.0867	−0.1077	−0.1164	−0.0310	−0.0867
Snowfall $\times \sigma_{id}^{SNOW}$	0.0976**	0.1058**	0.1093***	0.0866**	0.0976**
Snow Depth					
Snow Depth (in)	−0.0349***	−0.0338***	−0.0334***	−0.0336***	−0.0349***
Snow Depth $\times \mu_{id}^{SNWD}$	−0.0064*	−0.0071**	−0.0070**	−0.0089**	−0.0064*
Snow Depth $\times \sigma_{id}^{SNWD}$	0.0134***	0.0136***	0.0135***	0.0141***	0.0134***
Store Time Trends	Yes	No	Yes	Yes	Yes
First or last month control	Yes	Yes	No	Yes	Yes
Date FE	Yes	Yes	Yes	No	Yes
Alternative time FE	No	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	MSA	State
Observations	136,935	136,935	136,174	136,937	136,935
Adjusted R^2	0.907	0.898	0.898	0.885	0.907

Note: This table shows results from alternative specifications for regressing log of daily store level sales on weather and interactions between contemporaneous weather observations and their historical normals (μ_{id}^{E}) and standard deviations (σ_{id}^{E}). The historical normals and standard deviations are calculated for each calendar day d using Bartlett kernel weights to smooth over historical observations from 1980-2009.

Column 1 shows the Table 3 specification, which controls for date, store-month, and store-day-of-week fixed effects as well as store-specific trends, indicators for store openings and closings, and the uninteracted historical normals. Robust standard errors are clustered by MSA and by date. Column 2 excludes the store-specific linear and quadratic time trends. Column 3 drops sales that occur in the first or last month of a store (its opening or closing.) Column 4 replaces the date fixed effect with fixed effects for year, day-of-the-year, and holiday fixed effects. In column 5, standard errors are clustered by state rather than MSA. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B8: Alternative specifications for adaptation to extremes

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Heat					
Avg Temp $\geqslant$ 80F	-0.0004	0.0089	0.0082	0.0091	-0.0004
Avg Temp $\geqslant$ 80F $\times$ (share $\geqslant$ 80F)	-0.1192*	-0.1636**	-0.1620**	-0.1805**	-0.1192*
Cold					
Max Temp $\leqslant$ 0C	-0.1805***	-0.1717***	-0.1733***	-0.2195***	-0.1805***
Max Temp $\leqslant$ 0C $\times$ (share $\leqslant$ 0C)	0.8945***	0.8334**	0.8513**	1.2031***	0.8945***
Precipitation					
Precip $\geqslant$ 1 in	-0.1531***	-0.1622***	-0.1627***	-0.1795***	-0.1531***
Precip $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)	3.6248***	3.9571***	3.9472***	4.3875***	3.6248**
Snowfall					
Snowfall $\geqslant$ 1 in	-0.4821***	-0.4799***	-0.4804***	-0.5405***	-0.4821***
Snowfall $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)	4.5891***	4.4765***	4.5300***	5.8904***	4.5891***
Snow Depth					
Snow depth $\geqslant$ 1 in	-0.1070***	-0.0916***	-0.0897***	-0.0943***	-0.1070***
Snow depth $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)	0.2637	0.1387	0.1001	0.0280	0.2637
Store Time Trends	Yes	No	Yes	Yes	Yes
First or last month control	Yes	Yes	No	Yes	Yes
Date FE	Yes	Yes	Yes	No	Yes
Alternative time FE	No	No	No	Yes	No
Spatial cluster level	MSA	MSA	MSA	MSA	State
Observations	136,846	136,846	136,085	136,848	136,846
Adjusted R^2	0.906	0.896	0.897	0.884	0.906

This table shows results from alternative specifications for regressing log of daily store level sales on indicators for weather events and interactions between those indicators and measures of the historical frequency of those events. Based on observations from 1980-2009, the share of historical observations on which a weather event occurs remains fixed over time for any given store.

Column 1 shows the Table 4 specification, which controls for date, store-month, and store-day-of-week fixed effects as well as store-specific trends, indicators for store openings and closings, and the uninteracted historical normals and standard deviations. Robust standard errors are clustered by MSA and by date. Column 2 excludes the store-specific linear and quadratic time trends. Column 3 drops sales that occur in the first or last month of a store (its opening or closing.) Column 4 replaces the date fixed effect with fixed effects for year, day-of-the-year, and holiday fixed effects. In column 5, standard errors are clustered by state rather than MSA. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B9: Adaptation to extremes by indoor versus outdoor stores

Dep var: ln(Net Sales)	(1)	(2)	(3)
Outdoor Stores			
Extreme heat			
Avg Temp $\geqslant$ 80F	−0.038**	−0.024	−0.028
Avg Temp $\geqslant$ 80F $\times$ (share $\geqslant$ 80F)		−0.066	
(TAVG $\geqslant$ 80F) $\times$ (top half)			−0.014
Extreme Cold			
Max Temp $\leqslant$ 0C	−0.078**	−0.189***	−0.251**
Max Temp $\leqslant$ 0C $\times$ (share $\leqslant$ 0C)		1.212***	
(TMAX $\leqslant$ 0C) $\times$ (top half)			0.178*
Precipitation			
Precip $\geqslant$ 1 in	−0.080**	−0.261***	−0.146***
Precip $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		5.228***	
(PRCP $\geqslant$ 1 in) $\times$ (top half)			0.090
Snowfall			
Snowfall $\geqslant$ 1 in	−0.365***	−0.454***	−0.500***
Snowfall $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		4.499	
(SNOW $\geqslant$ 1 in) $\times$ (top half)			0.136
Snow Depth			
Snow depth $\geqslant$ 1 in	−0.098***	−0.157**	−0.638***
Snow depth $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		0.758	
(SNWD $\geqslant$ 1 in) $\times$ (top half)			0.542***
Indoor Stores			
Extreme heat			
Avg Temp $\geqslant$ 80F	−0.021	0.021	0.010
Avg Temp $\geqslant$ 80F $\times$ (share $\geqslant$ 80F)		−0.252**	
(TAVG $\geqslant$ 80F) $\times$ (top half)			−0.036
Extreme Cold			
Max Temp $\leqslant$ 0C	−0.045*	−0.052	−0.061
Max Temp $\leqslant$ 0C $\times$ (share $\leqslant$ 0C)		0.122	
(TMAX $\leqslant$ 0C) $\times$ (top half)			0.019
Precipitation			
Precip $\geqslant$ 1 in	0.050*	−0.034	−0.003
Precip $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		2.345	
(PRCP $\geqslant$ 1 in) $\times$ (top half)			0.070*
Snowfall			
Snowfall $\geqslant$ 1 in	−0.202***	−0.388**	−0.127*
Snowfall $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		10.893	
(SNOW $\geqslant$ 1 in) $\times$ (top half)			−0.083
Snow Depth			
Snow depth $\geqslant$ 1 in	−0.043	0.033	−0.412***
Snow depth $\geqslant$ 1 in $\times$ (share $\geqslant$ 1 in)		−1.640	
(SNWD $\geqslant$ 1 in) $\times$ (top half)			0.378***
Observations	59,708	59,708	59,708
Adjusted R^2	0.927	0.927	0.927

Note: This table shows results from regressing log of daily store level sales on indicators for weather events and interactions between those indicators and measures of the historical frequency of those events (column 2) or indicators for whether the historical frequency of those events is above the median historical frequency (column 3). Based on observations from 1980-2009, the share of historical observations on which a weather event occurs remains fixed over time for any given store. All of the weather variables are interacted with an indicator equal to one if the store is outdoor and with an indicator equal to one if the store is indoor, jointly regressing the potentially heterogeneous impacts and indoor and outdoor stores. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. MSAs with only one type of store are excluded. All columns control for date, store-month, and store-day-of-week fixed effects as well as store-specific trends and indicators for store openings and closings. Robust standard errors are clustered by MSA and by date. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B10: Adaptation to severe extremes including only stores that experience those extremes at some point in sample

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)	(6)
Extreme heat						
TAVG ⩾ 80F	−0.020***	0.000	−0.006			
(TAVG ⩾ 80F) × (share ⩾ 80F)		−0.119*				
(TAVG ⩾ 80F) × (top half)			−0.019			
TAVG ⩾ 90F				−0.041***	−0.041**	−0.032
(TAVG ⩾ 90F) × (share ⩾ 90F)					−0.008	
(TAVG ⩾ 90F) × (top half)						−0.010
Extreme Cold						
TMAX ⩽ 0C	−0.085***	−0.176***	−0.406**			
(TMAX ⩽ 0C) × (share ⩽ 0C)		0.867**				
(TMAX ⩽ 0C) × (top half)			0.326*			
TAVG ⩽ 15F				−0.055**	−0.079	0.268***
(TAVG ⩽ 15F) × (share ⩽ 15F)					0.525	
(TAVG ⩽ 15F) × (top half)						−0.302***
Precipitation						
PRCP ⩾ 1 in	−0.038**	−0.149***	−0.060***			
(PRCP ⩾ 1 in) × (share ⩾ 1 in)		3.524***				
(PRCP ⩾ 1 in) × (top half)			0.032			
PRCP ⩾ 2 in				−0.127***	−0.150**	−0.173***
(PRCP ⩾ 2 in) × (share ⩾ 2 in)					3.520	
(PRCP ⩾ 2 in) × (top half)						0.073
Snowfall						
SNOW ⩾ 1 in	−0.348***	−0.482***	−0.373***			
(SNOW ⩾ 1 in) × (share ⩾ 1 in)		4.590***				
(SNOW ⩾ 1 in) × (top half)			0.023			
SNOW ⩾ 6 in				−0.761***	−0.868***	−0.752***
(SNOW ⩾ 6 in) × (share ⩾ 6 in)					47.725	
(SNOW ⩾ 6 in) × (top half)						
Snow Depth						
SNWD ⩾ 1 in	−0.081***	−0.106***	−0.344***			−0.360**
(SNWD ⩾ 1 in) × (share ⩾ 1 in)		0.256				
(SNWD ⩾ 1 in) × (top half)			0.265***			0.262*
SNWD ⩾ 6 in				−0.073**	−0.139***	
(SNWD ⩾ 6 in) × (share ⩾ 6 in)					2.269**	
Observations	132,694	132,694	132,694	70,808	70,808	70,808
Adjusted R^2	0.905	0.905	0.905	0.896	0.896	0.896

Note: This table shows results from regressing log of daily store level sales on indicators for weather events and interactions between those indicators and measures of the historical frequency of those events (columns 2 and 5) or indicators for whether the historical frequency of those events is above the median historical frequency (columns 3 and 6). Based on observations from 1980-2009, the share of historical observations on which a weather event occurs remains fixed over time for any given store. All of the weather variables are interacted with an indicator equal to one if the store is outdoor and with an indicator equal to one if the store is indoor, jointly regressing the potentially heterogeneous impacts and indoor and outdoor stores. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. The samples include only stores that have at least one observation where the average temperature falls above the extreme heat threshold. The "top half" for the extreme heat category has been calculated to reflect the median share of days of extreme heat in this subsample. All columns control for date, store-month, and store-day-of-week fixed effects as well as store-specific trends and indicators for store openings and closings. Robust standard errors are clustered by MSA and by date. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B11: Adaptation to severe extremes with alternative category cutoffs for extreme heat

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Extreme heat					
80F ⩽ TAVG < 90F	−0.020***	−0.000	−0.001	−0.009	−0.009
80F ⩽ TAVG < 90F × (share 80F ⩽ TAVG < 90F)		−0.116*	−0.114*		
80F ⩽ TAVG < 90F × (top half TAVG ⩾ 80F)				−0.015	−0.015
TAVG ⩾ 90F	−0.061***	−0.044	−0.063***	−0.097***	−0.078
TAVG ⩾ 90F × (share 80F ⩽ TAVG < 90F)		−0.107			
(TAVG ⩾ 90F) × (share ⩾ 90F)			−0.128		
TAVG ⩾ 90F × (top half TAVG ⩾ 80F)				0.035	
(TAVG ⩾ 90F) × (top half)					0.015
Extreme Cold					
TMAX ⩽ 0C	−0.087***	−0.181***	−0.181***	−0.409***	−0.409***
(TMAX ⩽ 0C) × (share ⩽ 0C)		0.894***	0.894***		
(TMAX ⩽ 0C) × (top half)				0.328**	0.328**
TAVG ⩽ 15F					
(TAVG ⩽ 15F) × (share ⩽ 15F)					
(TAVG ⩽ 15F) × (top half)					
Precipitation					
PRCP ⩾ 1 in	−0.039**	−0.154***	−0.154***	−0.063***	−0.063***
(PRCP ⩾ 1 in) × (share ⩾ 1 in)		3.646***	3.650***		
(PRCP ⩾ 1 in) × (top half)				0.034	0.034
PRCP ⩾ 2 in					
(PRCP ⩾ 2 in) × (share ⩾ 2 in)					
(PRCP ⩾ 2 in) × (top half)					
Snowfall					
SNOW ⩾ 1 in	−0.350***	−0.482***	−0.482***	−0.379***	−0.379***
(SNOW ⩾ 1 in) × (share ⩾ 1 in)		4.588***	4.588***		
(SNOW ⩾ 1 in) × (top half)				0.029	0.029
SNOW ⩾ 6 in					
(SNOW ⩾ 6 in) × (share ⩾ 6 in)					
(SNOW ⩾ 6 in) × (top half)					
Snow Depth					
SNWD ⩾ 1 in	−0.081***	−0.107***	−0.107***	−0.334***	−0.334***
(SNWD ⩾ 1 in) × (share ⩾ 1 in)		0.264	0.264		
(SNWD ⩾ 1 in) × (top half)				0.256***	0.256***
SNWD ⩾ 6 in					
(SNWD ⩾ 6 in) × (share ⩾ 6 in)					
Observations	136,846	136,846	136,846	136,846	136,846
Adjusted R^2	0.906	0.906	0.906	0.906	0.906

Note: This table shows results from regressing log of daily store level sales on indicators for weather events and interactions between those indicators and measures of the historical frequency of those events (columns 2 and 5) or indicators for whether the historical frequency of those events is above the median historical frequency (columns 3 and 6). Based on observations from 1980-2009, the share of historical observations on which a weather event occurs remains fixed over time for any given store. All of the weather variables are interacted with an indicator equal to one if the store is outdoor and with an indicator equal to one if the store is indoor, jointly regressing the potentially heterogeneous impacts and indoor and outdoor stores. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. All columns control for date, store-month, and store-day-of-week fixed effects as well as store-specific trends and indicators for store openings and closings. Robust standard errors are clustered by MSA and by date. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B12: Adaptation to weather normals: Separate regressions by weather element

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Max Temp (F)	0.0183***				
Max Temp $\times\mu_{id}^{TMAX}$	−0.0003***				
Min Temp (F)		0.0100***			
Min Temp $\times\mu_{id}^{TMIN}$		−0.0002***			
Precipitation (in)			−0.1193***		
Precip $\times\mu_{id}^{PRCP}$			0.6376***		
Snowfall (in)				−0.1526***	
Snowfall $\times\mu_{id}^{SNOW}$				0.1236*	
Snow Depth (in)					−0.0364***
Snow Depth $\times\mu_{id}^{SNWD}$					0.0064***
Observations	137,345	137,340	137,622	137,908	137,883
Adjusted R^2	0.9053	0.9044	0.9042	0.9058	0.9043

Note: This table shows results from regressing log of daily store level sales on weather observations on their own and interacted with their historical normals (μ_{id}^{E}). The historical normals are calculated for each calendar day d using Bartlett kernel weights to smooth over historical observations from 1980-2009. All columns control for date, store-month, and store-day-of-week fixed effects as well as store-specific trends, indicators for store openings and closings, and the uninteracted historical normals. Robust standard errors are clustered by MSA and by date. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Table B13: Adaptation to weather normals and standard deviations: Separate regressions by weather element

Dep var: ln(Net Sales)	(1)	(2)	(3)	(4)	(5)
Max Temp (F)	0.0110***				
Max Temp $\times\mu_{id}^{TMAX}$	−0.0002***				
Max Temp $\times\sigma_{id}^{TMAX}$	0.0005**				
Min Temp (F)		0.0115***			
Min Temp $\times\mu_{id}^{TMIN}$		−0.0002***			
Min Temp $\times\sigma_{id}^{TMIN}$		−0.0001			
Precipitation (in)			−0.1794***		
Precip $\times\mu_{id}^{PRCP}$			−0.2415		
Precip $\times\sigma_{id}^{PRCP}$			0.4810***		
Snowfall (in)				−0.2012***	
Snowfall $\times\mu_{id}^{SNOW}$				−0.1075	
Snowfall $\times\sigma_{id}^{SNOW}$				0.1189***	
Snow Depth (in)					−0.0597***
Snow Depth $\times\mu_{id}^{SNWD}$					−0.0079**
Snow Depth $\times\sigma_{id}^{SNWD}$					0.0187***
Observations	137,345	137,340	137,622	137,908	137,883
Adjusted R^2	0.9053	0.9045	0.9044	0.9059	0.9044

Note: This table shows results from regressing log of daily store level sales on weather observations on their own and interacted with their historical normals (μ_{id}^{E}) and standard deviations (σ_{id}^{E}). The historical normals and standard deviations are calculated for each calendar day d using Bartlett kernel weights to smooth over historical observations from 1980-2009. All columns control for date, store-month, and store-day-of-week fixed effects as well as store-specific trends, indicators for store openings and closings, and the uninteracted historical normals and standard deviations. Robust standard errors are clustered by MSA and by date. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Source: proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)

Figure B1: Map of climate regions

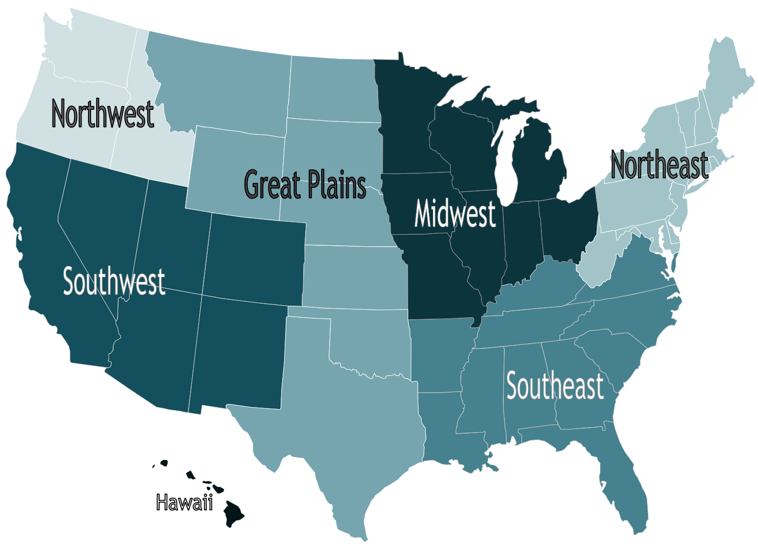
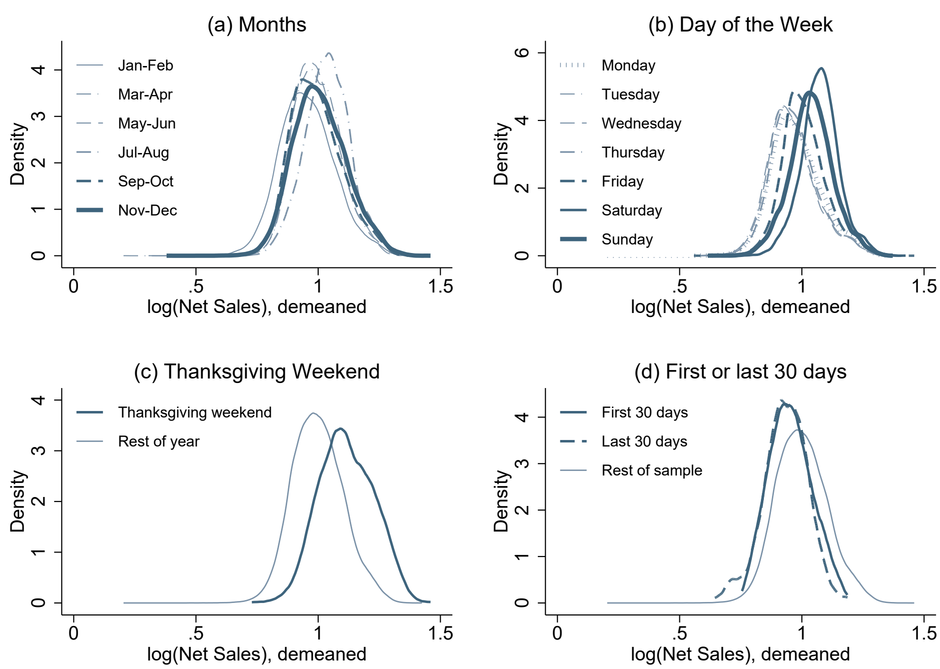
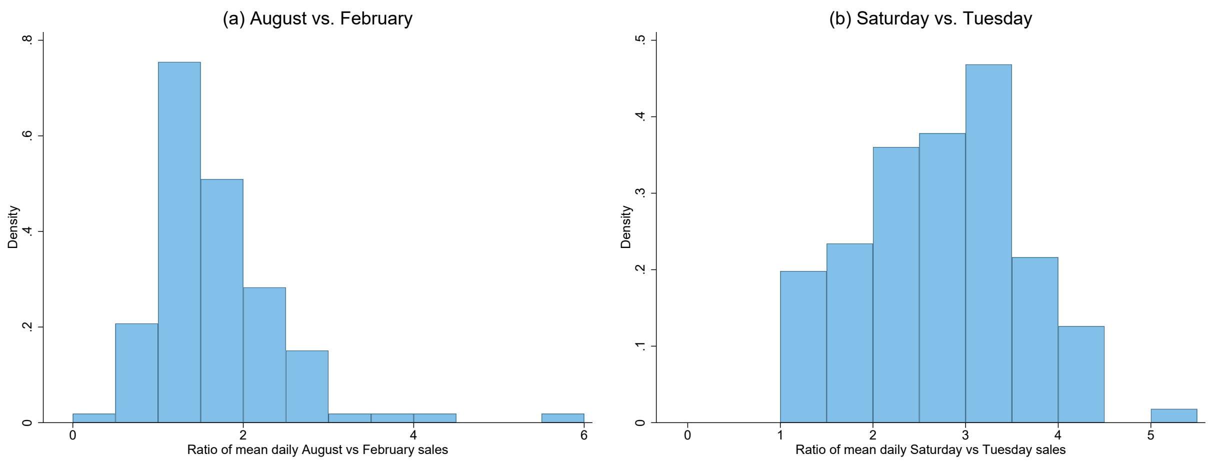


Figure B2: Seasonality of store sales



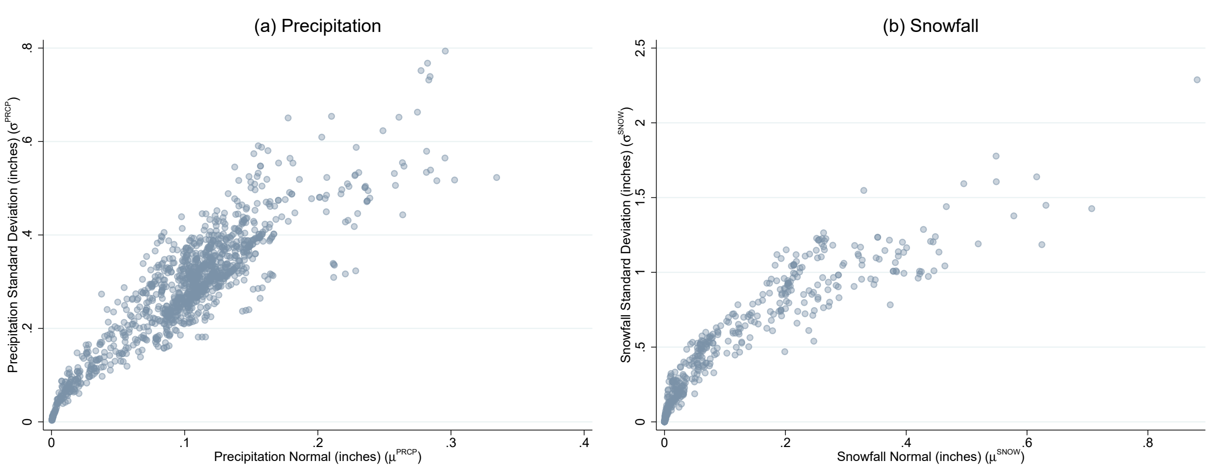
Note: Plots show kernel density distributions of daily store level log(Net Sales) which have been divided by the sample mean of log(Net Sales). Thanksgiving weekend includes sales from Thanksgiving Day (Thursday) through the Sunday immediately thereafter. The first (or last) 30 days apply to stores that enter (or exit) the sample after the start (or before the end.)
Source: Proprietary retail sales data.

Figure B3: Variation in store level seasonality patterns



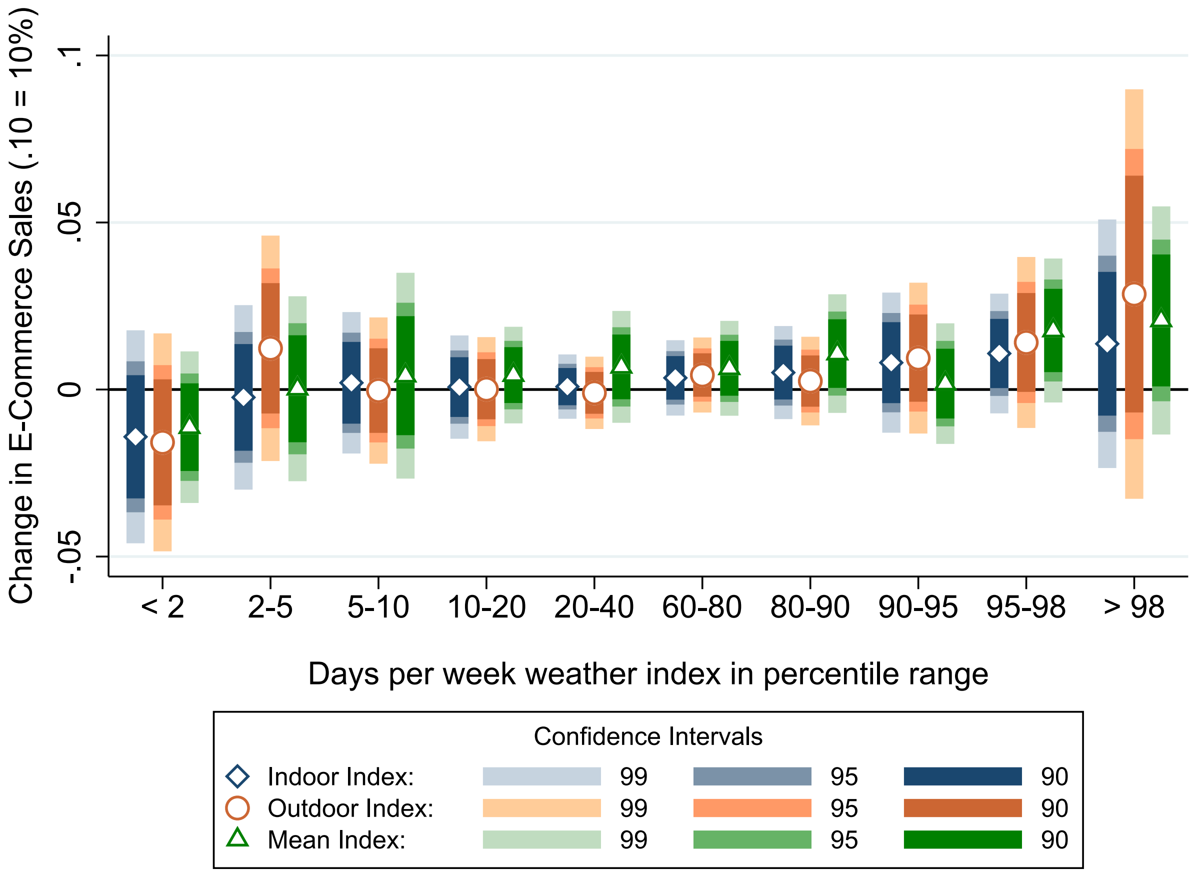
Note: Plots show histograms of ratios of store mean sales in August vs. February in panel (a) and on Saturdays vs. Tuesdays in panel (b).
Source: Proprietary retail sales data.

Figure B4: Historical normals and standard deviations of precipitation and snowfall



Plots show historical normals and standard deviations based on weather observed on the first day of each month from 1980 - 2009. These statistics have been estimated using a Bartlett weighting kernel to smooth over the 14 days before and after a particular day of the year at each station. Station normals and standard deviations are inverse-distance weighted based on store locations. *Source:* NOAA NCDC GHCND weather station observations.

Figure B5: Weather Effects on Online Sales with More Extreme Tail Bins



Note: This figure shows results from regressing sales on the firm's website for week k in MSA m on counts of the number of days in which the "weather index" falls within the noted ranges that week. The figure shows results from three separate regressions where the weather index is averaged over just indoor stores, just outdoor stores, or equally across the two types. With a mean of 0 and standard deviation of 1, the weather index measures how favorable weather conditions are for sales. A more positive value corresponds to a more positive weather shock. Constructed using the lasso machine learning method with cross-validation in a residuals-on-residuals framework to select among thousands of potential interacted and non-linear weather variables, the index flexibly reflects the contemporaneous weather shock for a specific store on a specific day. "Indoor" stores are in shopping centers where patrons can move between stores without being exposed to weather. Regressions control for week and MSA-month fixed effects as well as MSA-specific linear and quadratic time trends, with standard errors clustered at the MSA and week levels.
Source: Proprietary sales data; NOAA, National Centers for Environmental Information (NCEI). *Global Historical Climatology Network Daily.* (Accessed April 22, 2015.)