WEATHER TO SHOP?

A STATISTICAL INVESTIGATION INTO HOW TEMPERATURE AFFECTS UK RETAIL SALES

A joint study by the BRC and Met Office

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EXECUTIVE SUMMARY

It's a truth universally acknowledged that the weather can strongly influence what we buy. According to previous research by the Met Office, nearly half of UK retailers say weather is among the top three external drivers of demand[1] and the idea is pretty intuitive: if it rains, retailers sell more umbrellas, if it's cold more coats are sold and if it's hot shops can find themselves out of stock of paddling pools and barbeque equipment

However, there is surprisingly little research into some aspects of the relationship between weather and sales. That's particularly true when we consider the impact of weather on sales at the whole UK level, rather than just on individual products or specific locations. Despite regular commentary blaming or praising the weather for how retailers are doing, how much the weather affects sales is not well understood.

Through application of machine learning techniques to their combined datasets, the BRC and the Met Office sought to shed some light on this question, focussing on to what extent temperature can predict growth in Non-Food sales. The findings of the study have implications for both retailers and market observers:

- Differences in temperature, are a good predictor of growth in Non-Food sales growth, but only at certain times of the year.

- While some periods, particularly the Christmas season, show little relationship with the weather others are highly sensitive to temperature. During the Summer to Autumn transition, nearly half of the variation in weekly sales growth from year to year over this period can be accounted for by differences in temperature between years. The analysis implies that for each degree warmer the first week of September is relative to the previous year, the rate of growth of Non-Food sales is reduced by 1.1%, equivalent to around £40m of sales.

- When there is a relationship, it doesn't always work in the same direction. At sometimes of year warmer weather can help sales, at other times it can hinder them.

- The study found little evidence that, at an aggregate level, temperature has a permanent impact on sales. If September is warmer and consumers do not buy as many cold weather products, they spend more on these products once cooler weather finally arrives. However, unseasonal weather can strongly affect monthly growth figures and be easily mistaken for changes in underlying consumer confidence. It can also impact profitability, with retailers selling more stock on discount following a period of unexpectedly weak sales.

- The strength and pattern of relationship to the weather differs across categories of Non-Food (See Table 1). It is particularly strong in Clothing, during the transition to Autumn. Temperature differences can explain more than 70% of year to year variations in growth of Men's Clothing in mid-September to early October and can reduce the rate of sales growth by 2.4 percentage points for each degree it is warmer than the previous year, equivalent to £6m a week.

- The bigger the variation in year to year in temperature, the more likely temperature is to be the key driver of sales growth. During the first weeks of the year the analysis showed that the temperature is a poor predictor of sales growth, however if we only look at temperature differences of more than five degrees, then there is strong relationship between sales growth and temperature.

[1] Met Office. "Understanding the role of weather in the supply chain." 2015

Table 1: Summary of periods of peak temperature influences on sales and size of the effect

CATEGORY	PERIODS MOST AFFECTED BY TEMPERATURE DIFFERENCES	EFFECT ON WEEKLY SALES FOR EACH DEGREE IT IS WARMER THAN LAST YEAR (£)
All Non-food	Mid-August to early October	-£41m
Women's Clothing	Mid-August to early October	-£11m
	Late March to mid-June	+ £8m
Men's Clothing	September to early October	-£6m
Women's Footwear	March – May	+£3m
	Mid-August to early October	-£2m
Men's Footwear	September to early October	-£2m
Children's Footwear	March	+£1m
	September to early October	-£1m
Furniture	Mid-June to mid-August	-£5m
House Textiles	Late March to early October	-£2m

WEATHER TO SHOP?

That change in the weather influences the products we buy is well understood by most in the retail industry. A previous study by the Met Office found that nearly half of retailers rank weather among the top three drivers of demand .

Weather variations, and particularly changes in temperature, which we focus on in this study, change consumers' needs; if it's a hot day people wear Summer clothes and spend time outdoors, if it's cold they wear jackets and think about improving the inside of their homes. Weather can also influence shoppers' mood and willingness to pay .

However, aggregating the experience of consumers and individual businesses to determine the impact on the whole industry is not straightforward, because:

a.   The weather is often not consistent across the country. During 2015 and 2016 weekly temperatures in Heathrow (West London) and Glasgow differed by more than 3 degrees on average , and by a maximum of nearly 9 degrees.

b.   The weather can work in different directions on different products, with an ambiguous effect overall on sales. While warmer temperatures may lead people to buy more Summer dresses, retailers will probably sell fewer coats and duvet covers.

c.   The weather can also interact with other factors, such as the timing of public holidays or major national events, to produce a complex range of effects, working in different directions.

Many of the studies to date which have attempted to estimate the aggregate (rather than product level) impact of sales at a national level have focussed on extreme weather events; which, while of interest, do not necessarily tell us much about the role weather plays under "normal" conditions.

By combining weekly sales data from the BRC-KPMG Retail Sales Monitor with data on average temperatures across the UK, the BRC and the Met Office sought to offer unique insight into the relationship between sales growth and the weather.

THE DATA

The sales data used for this analysis are taken from the aggregate weekly BRC-KPMG Retail Sales Monitor. This series takes weekly sales information directly from retailers, and creates a market benchmark across 19 categories, In-Store and Online. The series covers approximately 60% of UK retail sales. For this study data was used from 2008 up to 2018, although the service has been running since 1995. For this study analysis was undertaken on

Women's and Men's Clothing & Footwear, Children's Footwear, Furniture, House Textiles and Non-Food as a whole.

Temperature data is taken from the NCIC (National Climate Information Centre) 5km gridded daily maximum temperature data series. The maximum daily temperature is taken from 5km squares across each one of the 11 different metropolitan areas in the UK and averaged to give a single daily figure for each metropolitan area. Those daily figures are then weighted by population to give a single average maximum temperature for the UK. These daily temperatures were then averaged again to give a weekly temperature figure.

In this report, weeks are referred to by numbers, following the Office for National Statistics system, where the first week of January is week 1 and so on. All weeks start on Sunday and finish on a Saturday, so the precise dates each numbered week covers shifts slightly from year to year.

[2] Met Office. "Understanding the role of weather in the supply chain". 2015.

[3] Parker and Nader. "Homeostasis and consumer behaviour across cultures". Intern. J. of Research in Marketing 17 2000 33–53.
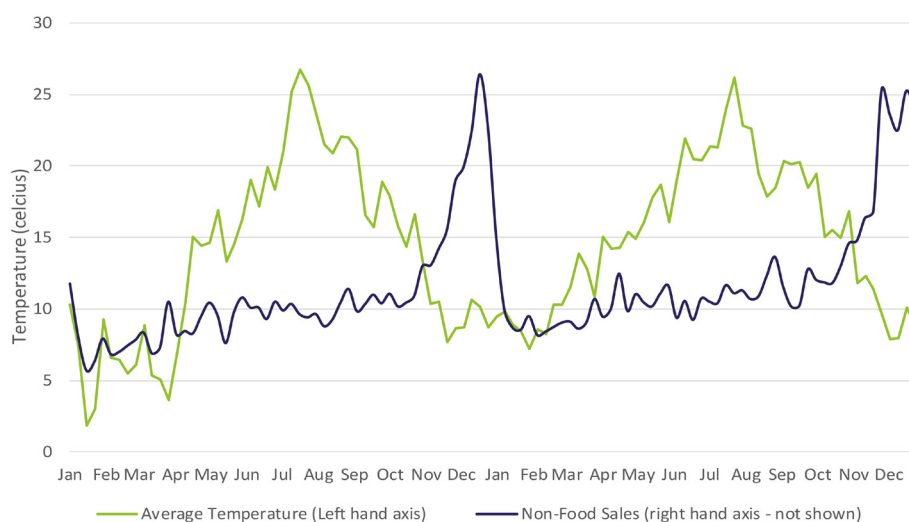
[4] Murray, Muro, Finn, Leszczyc. "The effect of weather on consumer spending". Journal of Retailing and Consumer Services 17 (2010) 512–520.

[5] This is the average of the absolute differences in average weekly temperatures

THE POUNDS VALUE OF SALES AND TEMPERATURE DO NOT MOVE TOGETHER

The yearly profile of UK retail sales (Non-Food) and average temperatures are shown in Figure 1 below. In £ terms they show a very strong, annually repeating pattern. Sales broadly trend upwards over the year, to a crescendo around Christmas. The temperature also follows an annual cycle, peaking in July-August and reaching its lowest point in January-February.

Figure 1: Profile of Average weekly temperatures (Celsius) and Non-Food sales (Indexed) over 2013 & 2014 (Right axis is not shown for reasons of confidentiality)

While shoppers change many of the products they buy as the temperature changes across the year, Figure 1 clearly shows that their total spending doesn't simply rise and fall with the temperature across the year. In fact, when we allow for the fact that there is an annual cycle to both series, any correlation between pounds spent and the temperature that week disappears.

That result doesn't come as a huge surprise, as a large proportion of our total Non-Food spending is not directly linked to the weather. On the one hand there are things we need to buy consistently throughout the year, on the other hand events such as Christmas, drive peaks in spending. Moreover, our spending is constrained by our income. None of these have much directly to do with weather for many of us.

What this means is that the absolute level of temperature is a poor predictor of total sales in any week.

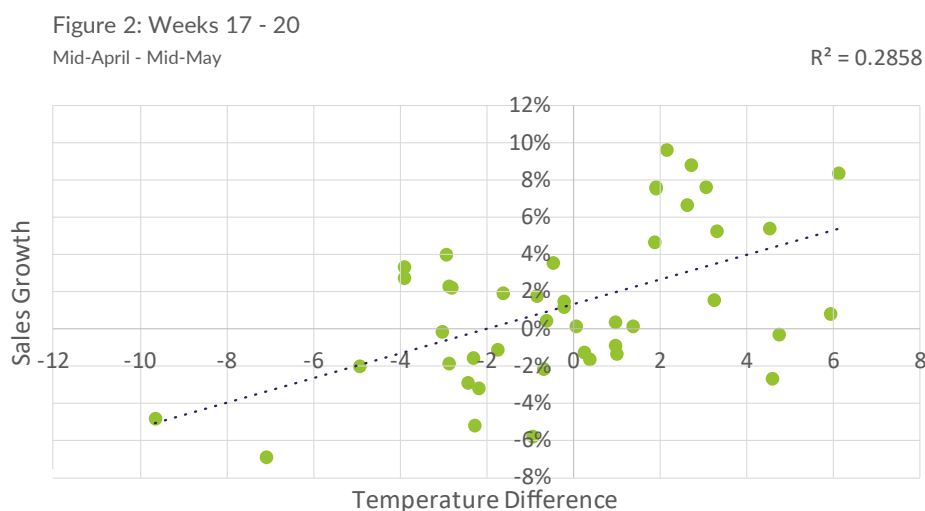## HOWEVER, TEMPERATURE IS A GOOD PREDICTOR OF SALES GROWTH. SOMETIMES.

To analyse the data, we used a series of linear regressions of sales growth against differences in year to year temperature in that week. This is a statistical technique which seeks to fit a line through the data points that minimises the distance of all of the datapoints from the line. In Figures 2 – 7 you can see the resulting "lines of best fit" through the data.

We tried a number of formulations, but the most interesting results emerged from grouping data into four-week periods. This seems to be because temperature changes have different impacts depending on when in the year they happen.

For all Non-Food sales, temperature differences are particularly important in weeks 33-36 (Early August to early September) and weeks 37-40 (Early September through to early October). Weeks 17-20 (mid- April through to mid-May) also show a significant, but slightly weaker, relationship.

The strength of the relationship is measured by the "coefficient of variation" (R^2) values. Roughly speaking, the R^2 tells us how much of the growth (of Non-Food sales) is explained by temperature differences. So, for weeks 33-36, the R^2 is 0.44, which indicates that about 44% of the variation in Non-Food sales growth is explained by the changes in temperature over that period. However, in weeks 45-48 (early November to early December) and in weeks 29-32 (mid-July to mid-August), the R^2 is close to 0, indicating temperature is not a good predictor of sales growth. Other factors, such as shopping for Christmas swamp the impact of temperature at that time.

Figure 2-7 Temperature differences and Non-Food sales growth (year-on-year) for selected weeks

Figure 2: Weeks 17 - 20

Mid-April - Mid-May   R² = 0.2858

Figure 3: Weeks 33 - 36
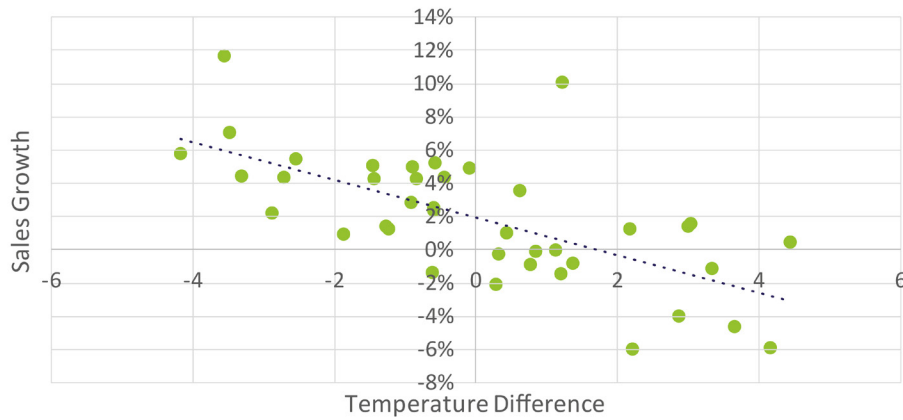
Early August - Early September

R² = 0.4414

Figure 4: Weeks 37 - 40
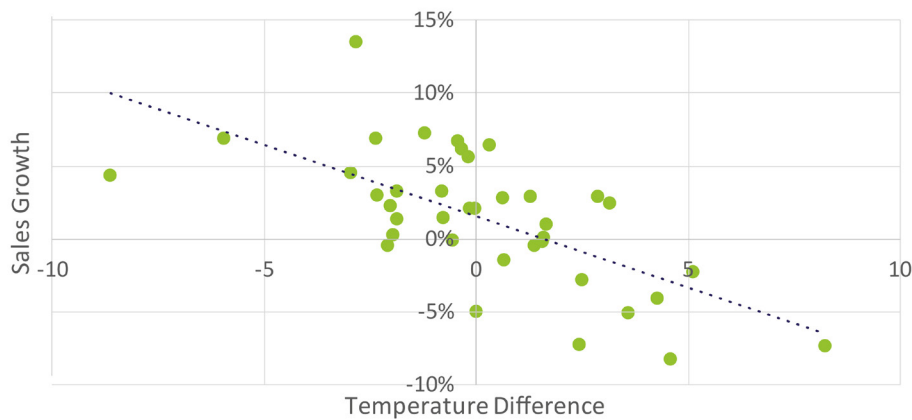
Early September - Early October

R² = 0.427

Figure 5: Weeks 41 - 44

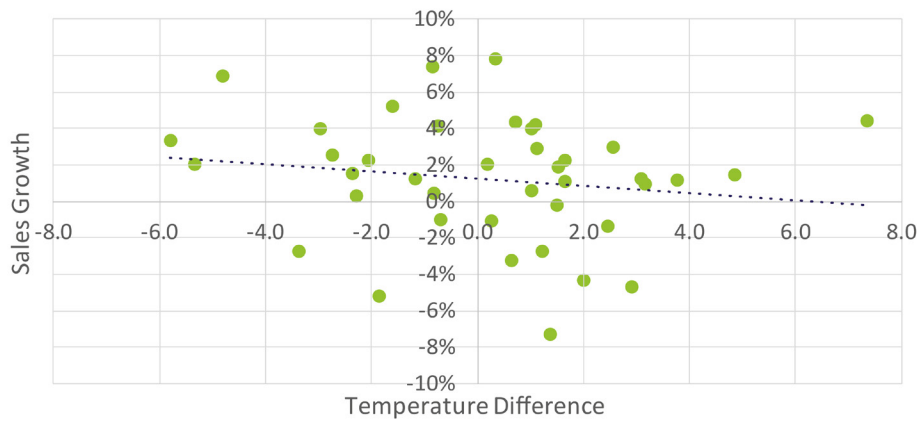Early October - Early November

R² = 0.0254

Figure 6: Weeks 45 - 48
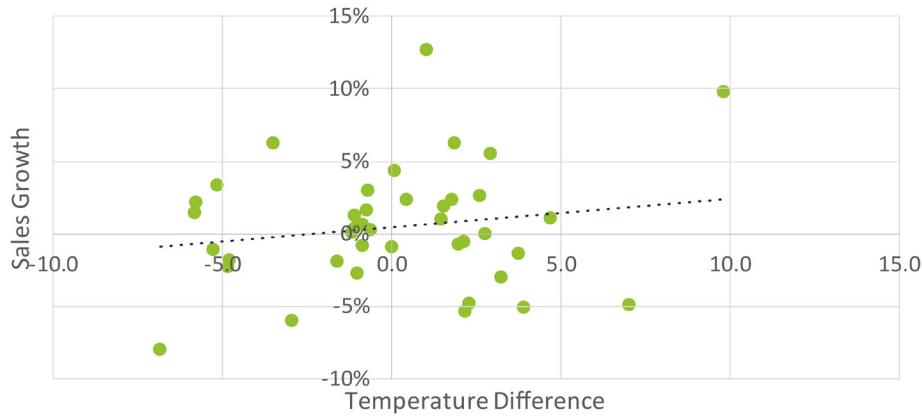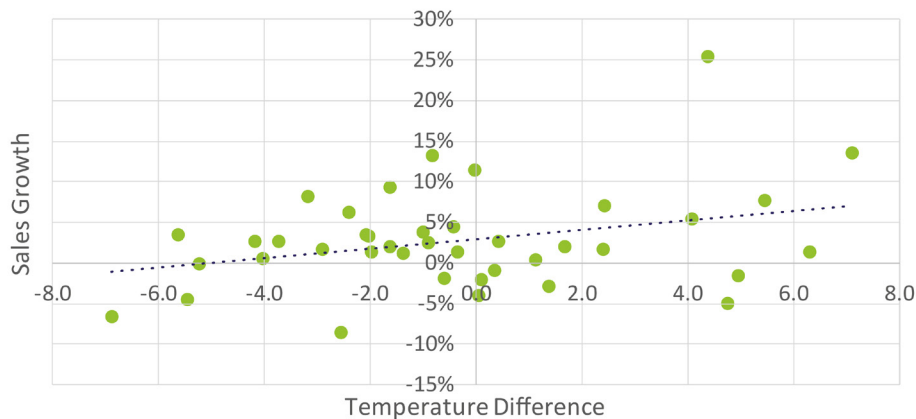
Early November - Early December $R^2 = 0.0302$
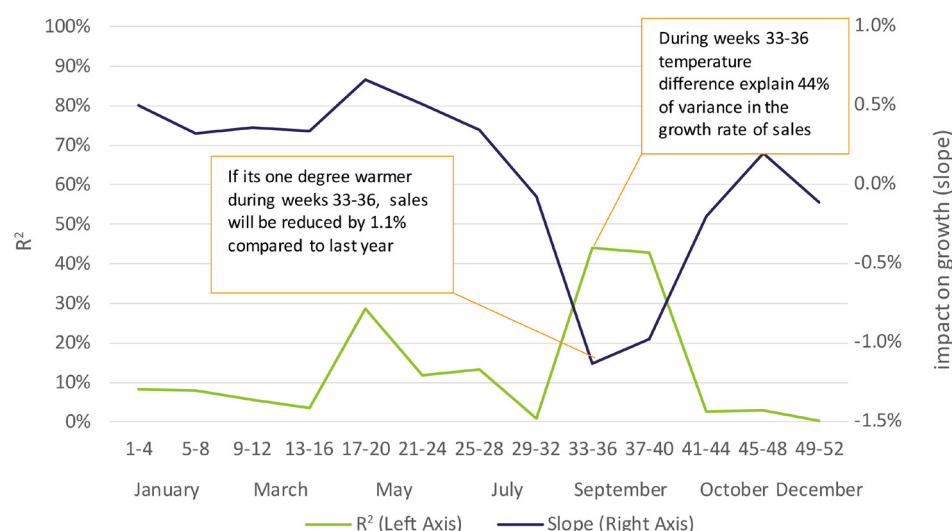

Figure 7: Weeks 1 - 4

End December - January $R^2 = 0.1015$

The steepness of the lines in the charts tells us the impact a change of one degree of temperature has on the growth of sales during that period. During weeks 33-36 (Figure 3), for each degree higher the temperature compared to last year, growth of Non-Sales decreases by 1.1 percentage points. During weeks 17-20 (Figure 2) for each degree higher the temperature is, growth increases by 0.7 percentage points.

 We can plot the key figures (R^2 and line slope values) from these scatter plots to show the strength of the temperature relationship (R^2) and the sensitivity of the temperature relationship (the line slope). Figure 8 shows how temperature differences play a particularly strong role over the Summer to Autumn transition.

Figure 8: Profile of R^2 values and line slope values for regression of temperature differences on Non-Food sales growth

It makes sense that temperature plays a stronger role in the overall picture at certain times of the year. When we're at the threshold of being able to spend time outdoors or, vice versa, when we're starting to wrap up warm tend to be where shoppers focus on seasonal purchases and so changes in the timing of these thresholds have a strong impact on sales. The cycle of the retail year in a number of Non-Food categories has also emphasised this pattern by, at least traditionally, having two major new ranges a year coinciding with the Spring-Summer and Summer-Autumn transitions.

In contrast, Christmas, a significant driver of shopping, happens whatever the weather. That's not to say there's no weather driven purchasing at these times of year, but that other factors tend to play a stronger role, so the impact of temperature is weaker

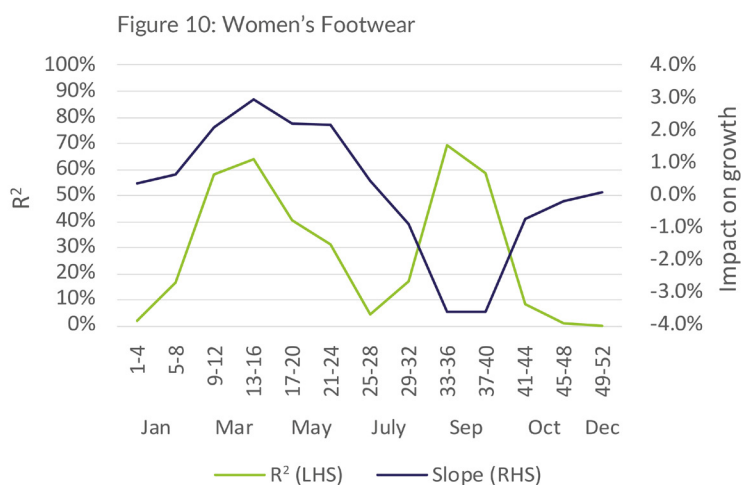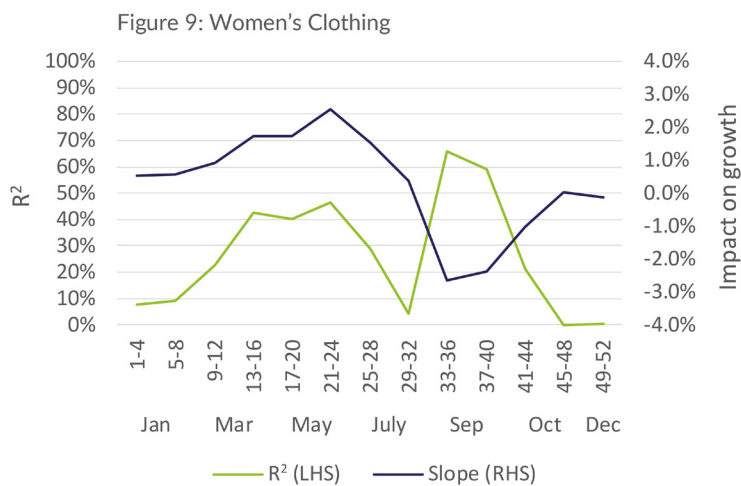## TEMPERATURE DIFFERENCES ALSO HAVE AN IMPACT ON THE GROWTH OF SUB-CATEGORIES OF NON-FOOD

Looking more closely at some of the categories which make up Non-Food sales, revealed different relationships with temperature over the year.

Temperature plays a strong role in growth over both the Spring-Summer and Summer-Autumn transitions for Women's Clothing, with temperature deviations from the previous year explaining around 66% of variation in growth in weeks 33-36 (mid-August to mid-September - See Figure 9) and 40% in weeks 17-20 (mid-April to mid-May). If everything else were equal, we could expect an increase in temperature of one degree compared to the previous year would lift sales of Women's Clothing by 1.7 percentage points during weeks 17-20 and reduce it by 2.7 percentage points in weeks 33-36.

The results for other categories can be seen in the charts below and are summarised in Table 2. Men's Clothing shows a strong relationship with temperature over the transition to Autumn, but not from Spring to Summer. Women's, Men's and Children's Footwear all follow similar patterns to Clothing, with differences in temperature having the biggest impact on sales growth during the transition to Autumn.

Furniture's relationship to temperature is quite different, exhibiting the greatest weather sensitivity during the Summer. In the Summer, cooler weather can drive sales in a period in which consumers are less likely to be indoors and when retailers don't traditionally engage in heavy promotional campaigns. House Textiles also sees the sensitivity to weather peak in mid-Summer for similar reasons, but also experiences a second peak around the Spring to Summer transition (17-20), where an extra week of wintery weather can boost sales.

Figures 9-15: Profile of R^2 values and slope coefficients for regression of temperature differences on Non-Food sales growth sub categories
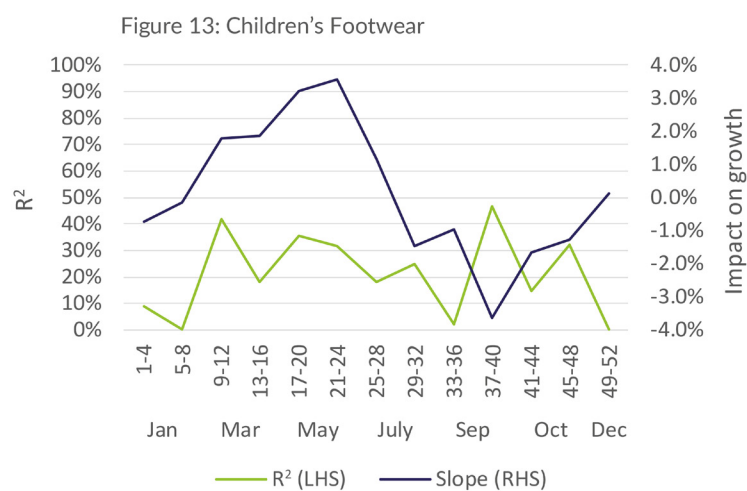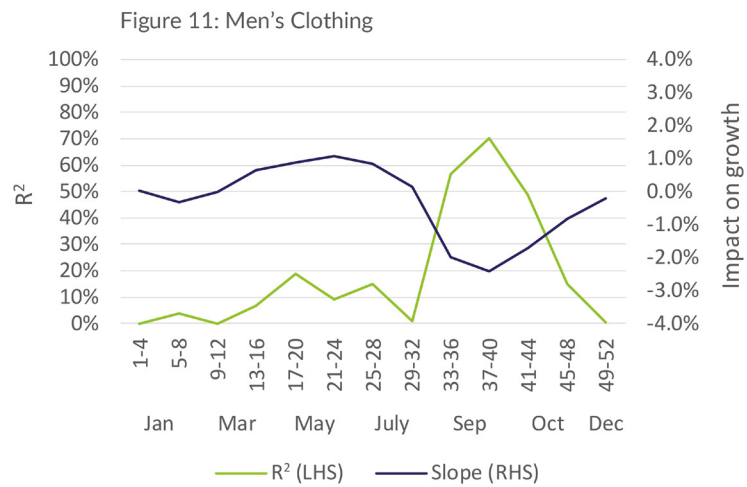
Figure 9: Women's Clothing

Figure 10: Women's Footwear

Figure 11: Men's Clothing

Figure 12: Men's Footwear

Figure 13: Children's Footwear
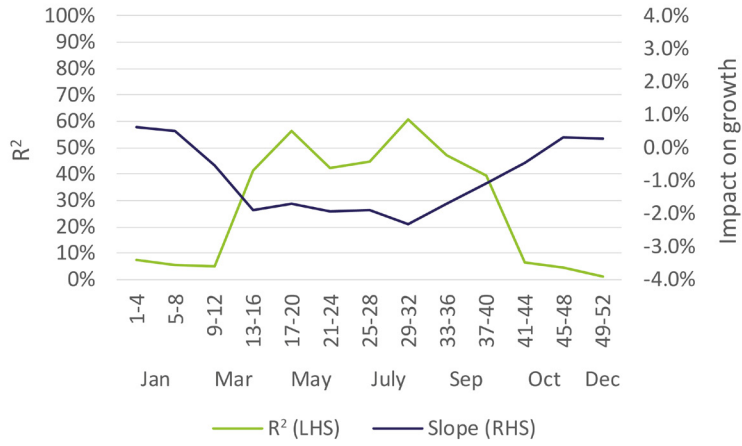
Figure 14: House Textiles
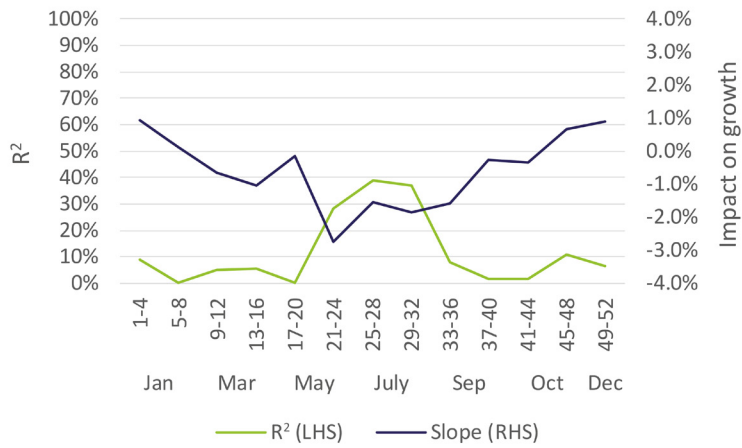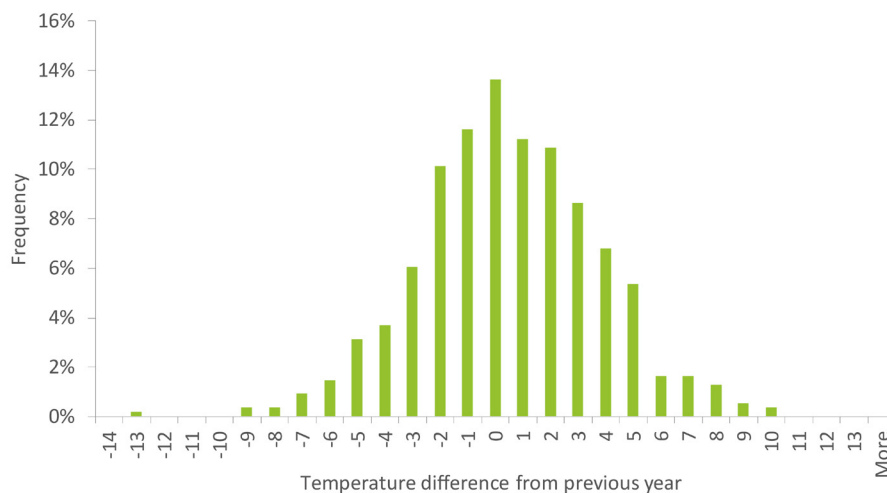

Figure 15: Furniture

Table 2: Summary of periods of peak temperature influences on sales and size of the effect

CATEGORY	PERIOD MOST AFFECTED BY TEMPERATURE DIFFERENCES	EFFECT ON WEEKLY SALES GROWTH FOR EACH DEGREE ITS WARMER THAN LAST YEAR	EFFECT ON WEEKLY SALES GROWTH FOR EACH DEGREE ITS WARMER THAN LAST YEAR (£)
All Non-food	Mid-August to early October	-1.1% (mid-August to mid-September)	-£41m
Women's Clothing	Mid-August to early October	-2.7% (mid-August to mid-September)	-£11m
	Late March to mid-June	+2.5% (mid-May to mid-June)	+ £8m
Men's Clothing	September to early October	-2.4% (September to early October)	-£6m
Women's Footwear	March – May	+2.9% (late March to early April)	+£3m
	Mid-August to early October	-2.5% (mid-August to early October)	-£2m
Men's Footwear	September to early October	-2.4% (September to early October)	-£2m
Children's Footwear	March	+1.8% (March)	+£1m
	September to early October	-3.6% (September to early October)	-£1m
Furniture	Mid-June to mid-August	-1.5% (mid-June to mid-July)	-£5m
Home Textiles	Late March to early October	-2.3% (mid-July to mid- August)	-£2m

WHILE AT SOMETIMES OF YEAR TEMPERATURE DIFFERENCES ARE UNLIKELY TO PLAY A BIG ROLE IN SALES GROWTH, UNUSUALLY LARGE FLUCTUATIONS CAN HAVE A SIGNIFICANT IMPACT.

Estimating linear relationships does not allow for the fact that at extremes the relationship may differ. Figure 16, below shows that in around 90% of cases the temperature fluctuates year to year by no more than plus or minus 5 degrees.

Figures 16: Distribution of year to year average weekly temperature differences

To explore whether large changes in temperature are more likely to make an impact on sales, we re-estimated the relationships between sales and temperature but only using fluctuations of greater than plus or minus five degrees; using eight-week periods rather than four in order to ensure sufficient data points for the analysis. The charts below show that while large year to year temperature differences don't affect how much sales change for each degree of change in temperature (the line slope) that much, they explain a lot more of the variation in sales growth (R^2) in most periods.

With big swings in temperature, the total effect on sales growth is large and so dominates other influences. That means weeks where there are big variations in temperature one can expect weather to be a key driver of sales that week. That applies across the year, except for Easter (falling somewhere in weeks 9 to 16) and the festive season (weeks 41 onwards).

Figures 17&18: Profile of R^2 values and slope coefficients for regression of temperature differences on Non-Food sales, split by temperature differences greater and less than five.
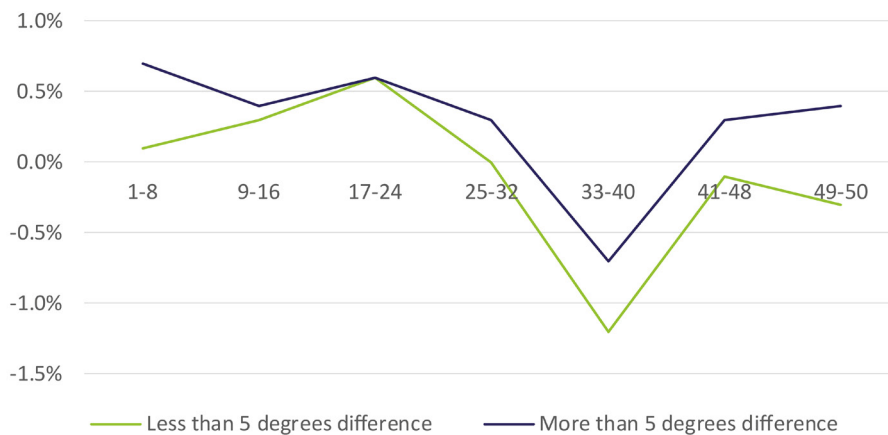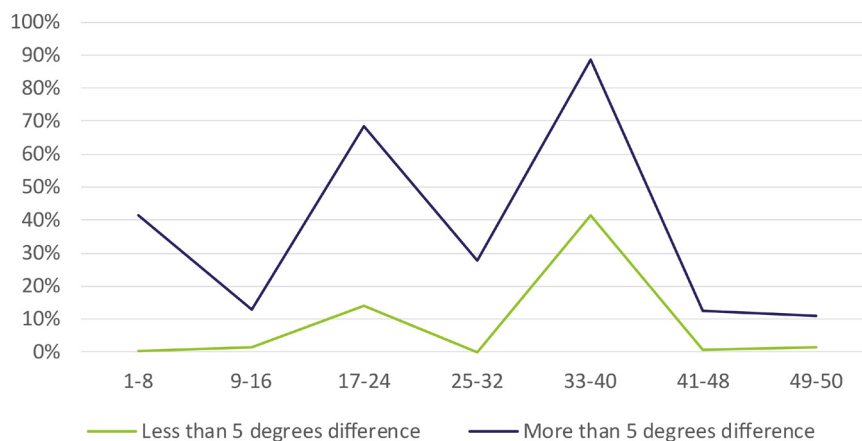
Figure 17: Line Slopes

Figure 18: R^2 Values

Although we haven't fully explored it in our study, heavy precipitation can also physically prevent or dissuade people shopping and so play a decisive role in sales growth. Episodes of heavy snow, such as that in March of this year (2018), are a prime example. With the temperature nearly 8 degrees lower than for the same period of 2017, our analysis (albeit the model for this time of year is very weak) suggests that sales should have fallen by around 2%. In fact, the heavy snow resulted in Non-Food sales dropping around 15% in the first week of March compared to the same week of 2017.

IT'S DIFFICULT TO DETERMINE WHETHER ANY OF THESE IMPACTS ON WEEKLY SALES ARE PERMANENT

The analysis above demonstrates that temperature can be a significant driver of sales growth in any week. However, assessing whether that impact is permanent is somewhat more tricky. On the one hand, we can see that, if there is an up or downswing in the data, driven by temperature or otherwise, often a correction takes place in subsequent weeks or months. However, it is not clear whether the correction is 100 percent. Given that this correction could play out over weeks and months and may be impacted by subsequent weather patterns or other factors, estimating it is complicated and an area for further research. The lack of relationship between average temperature difference over a year and sales growth provides some comfort that permanent impacts are likely to be small, at an aggregate level at least.

THIS STUDY HIGHLIGHTS THE NEED FOR RETAILERS TO CONSIDER THE WEATHER, BOTH IN PLANNING AHEAD AND ASSESSING PAST PERFORMANCE.

With the weather playing such an important role in year on year sales growth, retailers need to be prepared to react. A cooler spell in mid-August is likely to see a rush to buy Winter clothing, and to make the most of it retailers need to have the right stock in the right places. On the other hand, if retailers understand that it's warm weather in September that is slowing sales, rather than weaker underlying demand, then they can avoid the temptation to discount too early, protecting margin. While weather can't be controlled, getting the forecast of and response to the weather right can have huge impact on both revenue and profit.

For commentators and analysts, this study demonstrates that temperature can really matter in the short term for sales growth and should therefore be considered when interpreting monthly market data. However, by the same token care should be exercised not to attribute changes in trend growth to weather effects.

The Met Office can offer tailored weather sensitivity analysis and consultancy to really understand the impact of weather on product lines down to store level.

Their accurate and robust weather and climate data can help prepare and adapt your business, to maximise opportunities.

Visit https://www.metoffice.gov.uk/services/industry/retail for more information or contact them on 0370 900 0100.

If you'd like to find out more about the weekly sales and other data and analysis available to BRC members please get in touch with retailinsight@brc.org.uk