

Weather Sensitivity to Clothing Expenditure in Two Climate Zones in South Korea

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Abstract The fashion industry must adapt to increasingly unpredictable weather events caused by climate change. Accurate demand forecasting is essential for achieving Sustainable Development Goals. This study examines the influence of key weather factors on seasonal clothing expenditures in Seoul and Busan, South Korea utilizing both weather and economic data from 2010 to 2022. Hierarchical regression analysis is used to examine the impact of these weather factors on clothing expenditures for each season. The findings indicate that clothing expenditures vary significantly by season. The clothing sentiment index has a positive impact on expenditures across all seasons. While clothing expenditure in spring and winter shows only minor sensitivity to weather changes, temperature fluctuations in summer and fall have a more significant impact. Consumers in Seoul are sensitive to variations in relative humidity during summer, while those in Busan show no significant relationship between relative humidity and their purchasing behavior. Additionally, clothing expenditure in Seoul is more sensitive to changes in the wet bulb globe temperature compared to those in Busan. This study carries important practical implications, offering the potential for more accurate demand forecasting and improved business decision-making within the fashion industry.

Keywords Clothing expenditure, Clothing price index, Clothing sentiment index, Weather sensitivity

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Introduction

Of the many possible factors, climate change is frequently cited for impacting operations and profits, affecting supply and demand (Pankratz & Christoph, 2022; Parker, 2018). The fashion industry's "new season, new styles, buy more, buy cheap, move on, throw away" approach has been identified as a significant harmful factor in climate change (United Nations Environment Programme, 2022). Vice versa, climate change-induced weather events have been identified as significantly impacting the fashion industry (Changnon, 1999; Judd et al., 2023; Oh & Jo, 2011). For example, in the United Kingdom, women's clothing sales have decreased by 11 million pounds when the temperature in early fall (mid-August to mid-September) is 1°C higher than the

previous year (Danila et al., 2018). Warm temperatures also significantly impacted winter clothing sales in the USA (Changnon, 1999; Oh & Jo, 2011). Like other northern hemisphere countries, temperatures in the winter of 2015/2016 in South Korea (hereafter Korea) were 2°C higher than climate normal, causing winter clothing sales to decrease by a maximum -13.92% and a minimum -2.56% compared to previous years, winter clothing overstock increase compare to previous years with maximum 17% and minimum 3.85% (Oh, 2023a).

The clothing supply chain is a global and multi-layered interweaving system, so long lead times make it challenging to adapt to unexpected weather changes within a season.

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Climate change-induced weather events can disrupt production and distribution, leading to supply chain delays and increased costs (Bauer et al., 2023). Due to climate change-induced weather events, fashion industry seasons do not coincide with meteorological seasons, and this misalignment leads to errors in demand forecasts. Demand forecast errors in the fashion industry can lead to overstocking and markdowns, resulting in lower returns and enormous losses for enterprises (Fisher & Raman, 1996). Efficient and precise demand forecasts are crucial for optimizing stock levels, which benefits the enterprise financially and helps reduce overproduction. Already, problems of overproduction in the fashion industry are worsening environmental issues such as resource depletion, wastewater, and landfills.

Therefore, the fashion industry can respond to climate change-induced weather events, which are becoming more volatile, allowing accurate demand forecasting to contribute to Sustainable Development Goals (SDG) 12: Responsible consumption and production. The industry can make a tangible difference by identifying the relationship between weather factors and clothing sales and implementing a demand forecasting model that applies sensitivity analysis according to weather factors. While previous studies (Agnew & Palutikof, 1999; Arunraj & Ahrens, 2016; Bahng & Kincade, 2012; Bertrand & Pamaudeau, 2019; Jang & Lim, 2003; Martinez-de-Albeniz & Belkaid, 2021; Oh, 2024; Oh et al., 2017; Steinker et al., 2017; Tran, 2023) have advanced understanding of how weather affects the fashion industry, the direct influence of weather sensitivity on clothing expenditure remains underexplored. This study investigates the key weather factors affecting seasonal clothing expenditure in Korea. It evaluates weather sensitivity with economic indicators, the consumer price index (CPI) and the consumer sentiment index (CSI). The conclusions of this study provide management implications, including improved demand forecasting, business decision-making in the fashion industry, and strategic insights to achieve sustainable production goals.

Background

Climate and Climate Change in Korea

Korea is located in temperate zones with four distinct seasons. Geographically, it is located in the northern hemisphere's mid-latitude, on the Eurasian continent's east coast, and adjacent to the Western Pacific. Hence, it shows complex climatic characteristics that reveal continental and marine thermodynamic characteristics. The temperature difference between summer and winter is significant, with more precipitation than on the continent (Korea Meteorological Administration, n.d.). According to Köppen climate classification for climate normal 1981-2020, Korea is divided into Dwa (cold, dry winter and hot summer), Cwa (dry winter and humid subtropical summers), and Dfa (cold, no dry season, and hot summer) (Yun et al., 2020).

As climate change-induced weather events become more severe and frequent in the 2000s, Korea has been experiencing extreme temperatures, such as cold spells and heat waves (Korea Meteorological Administration, 2020; Lee, 2017; Min et al., 2015). In particular, extreme precipitation has heavily influenced the increase in summer precipitation, exceeding average precipitation, and the extreme precipitation index has become even higher in urban areas (Kim et al., 2023). According to the short-term climate outlook for 2022-2050 on temperature, precipitation, and anomalies, the mean temperature is expected to rise from 1.33°C to 1.93°C, and the season onset date or length is also expected to be changed (Korea Meteorological Administration, 2020). These temperature or season changes, in turn, significantly alter consumer preferences (Fildes et al., 2022), impacting fashion industry inventory management. Specifically, clothing retailers in Korea have been concerned about the season's changing onset date and length, which was despondently discussed in the media from 2000 to 2020 (Oh, 2023b).

Effect of Weather Factors on Clothing Demand and Sales

Weather is one of the most immediate and influential environmental factors on consumer behavior, especially clothing consumption. Clothing serves both aesthetic and

functional purposes, and the functional purpose is directly affected by external climate conditions such as temperature, precipitation, humidity, and wind. Therefore, short-term weather variability and long-term climate patterns play a significant role in what consumers buy and the timing and frequency of their clothing purchases.

Previous studies found that weather factors like temperature, (relative) humidity, wind, and precipitation are associated with clothing demand and sales. Temperature is the most widely studied factor in clothing studies because one primary origin of clothing is protection from harsh environments. Temperature changes affect consumers' motivation to select clothing (Kwon, 1987), ultimately triggering consumer demand. However, the effect of temperature changes on clothing demand is insignificant within a specific period of a season (Arunraj & Ahrens, 2016; Bahng & Kincade, 2012; Oh, 2024; Oh et al., 2017) and by types of clothing (Oh et al., 2021). The end of a season is the beginning of a new season; thus, consumers want to or plan to purchase new season clothes at the end of a season. When summer becomes hotter than usual, clothing sales decrease and anomalously high temperatures have a more negative impact (Agnew & Palutikof, 1999). This trend can also be seen in summer dressing practices. Temperatures rise no matter how high, and people dress light only to the socially acceptable limit. Therefore, temperature changes are essential for predicting clothing demand, but they are less effective at certain times or temperatures.

The effect of humidity on the human body varies from season to season. However, in Korea, where humidity is high in summer, it is necessary to consider thermo-physiological comfort in the skin-clothing microclimate. High humidity negatively affects clothing sales in the summer (Arunraj & Ahrens, 2016; Badorf & Hoberg, 2020; Bertrand & Parnaudeau, 2019; Martinez-de-Albeniz & Belkaid, 2021). Increasing humidity makes it difficult for water to evaporate regardless of temperature, leading to increased heat stress. In addition, relative humidity factors are more important than temperature in determining heat waves in summer (Ha et al., 2022). Therefore, humidity plays an important role in summer heat stress and temperature. Whether direct or indirect, heat stress significantly impacts human health and

life (Ebi et al., 2021; Park et al., 2015). The heat stress index, which is wet bulb globe temperature (WBGT), measures apparent temperature by considering weather, temperature, humidity, wind speed, sun, and clouds (National Weather Service, n.d.a). It is an indicator of public health and safety in managing the effects of summer humidity and temperature.

Of the weather factors, the oldest studied about sales or demand is precipitation (Bulletin American Meteorological Society, 1931; Douglas, 1919; Linden, 1959; Petty, 1963; Steele, 1951). Before online shopping, visiting offline stores on snowy and rainy days was not preferred, negatively affecting store traffic and decreasing sales. On a rainy day, 7.4% of store traffic was decreased (Martinez-de-Albeniz & Belkaid, 2021), and 1-inch snowfall reduced sales by 17% for regions where snowfall is historically uncommon (Tran, 2023). There are contradictory results between online shopping and weather factors. Steinker et al. (2017) found a positive relationship between online clothing sales and rain, while Tran (2023) showed no evidence of an effect of unfavorable weather on online clothing sales.

Wind affects apparent temperature and contributes negatively or positively to thermo-physiological comfort levels, leading to varying consequences for the demand or sale of clothing (Jang & Lim, 2003; Badorf & Hoberg, 2020; Martinez de-Albeniz & Belkaid, 2021). The impact of wind on temperature varies depending on the speed and direction of the wind. In general, wind aids in the evaporation of sweat, making the apparent temperature colder. In winter, wind significantly influences the apparent temperature, known as windchill. Windchill, a key factor in predicting the demand for winter clothing, uses air temperature without wind speed to gauge the heat loss of bare skin due to a combination of actual dry-bulb temperature and wind (National Weather Service, n.d.b). Therefore, the media and public health services utilize windchill to provide a more accurate representation of how cold it feels. A study by Oh et al. (2022) found that windchill is a significant factor in predicting the demand for winter clothing, and consumers searched for information about winter clothing the day after a drop in windchill.

Clothing expenditure has long been recognized as a predictable consumption pattern based on seasonal trends and

local climate. However, recent climate change-induced weather changes are gradually weakening the predictability of this traditional consumption structure. Previous studies have mainly focused on explaining consumer behavior based on consistent seasonality within the same region. However, today's consumers are more sensitive to perceived temperatures and rapidly changing weather, leading to nonlinear and immediate consumption behavior (Bertrand et al., 2015; Oh et al., 2021; Oh et al., 2022; Oh, 2024). In addition, discrepancies between forecasted and actual weather lead to significant changes in consumers' purchasing channel choices and overall shopping patterns (Gallino et al., 2019).

In this context, unpredictable weather can reduce the accuracy of sales forecasts in the fashion industry, increase the difficulty of managing inventory overstock or shortages, and lead to serious financial risks (Bertrand et al., 2015). This implies that clothing expenditure no longer depends on cyclical, seasonal patterns. Therefore, it should be understood as a holistic approach. Local climate and consumers' subjective emotional and perceptual responses to seasonal changes and various economic, psychological, sociocultural, and climatic factors influencing clothing consumption decisions should be investigated.

Statement of Objectives

Sensitivity analysis, a scientific method to explore causal relationships and the effects of various processes, parameters, and their combinations and interactions on outcomes, holds the potential to identify the most critical exposure or risk factors and develop priorities for risk mitigation (Frey & Patil, 2002). Thus, it is decision support to quantify the sensitivity of expected outcomes to various decision options, constraints, assumptions, or uncertainties (Saltelli, 2002). In this study, weather sensitivity refers to how weather factors influence clothing expenditure. The fashion industry, often challenged by unexpected weather changes within a season, can benefit from efficient and accurate demand forecasting, which causes lower returns and environmental problems due to overstocking. Accurate forecasting leads to financial benefits for enterprises and plays a crucial role in achieving SDG 12 by reducing overproduction. Therefore, this study

aims to seasonally explore important weather factors affecting clothing expenditure and measure the weather sensitivity of clothing expenditure.

People living in different environments have shown that weather-related psychological assessments of apparent temperature differ despite similar climate conditions (Kenz & Throsson, 2006; Sung & Kim, 2001). In addition to the influence of weather parameters, thermal comfort is also related to psychological and cultural cognition (Elnabawi & Jamie, 2024; Ju et al., 2023). Hence, this study selected Seoul and Busan, two metropolitan cities in Korea with a homogeneous social and cultural foundation but different climate zones, to assess the identifiable impact of weather on the fashion industry by measuring the weather sensitivity of seasonal clothing expenditure in Korea. Although previous studies have made strides in understanding the effects of weather on the fashion industry, the practical implications of weather sensitivity on clothing expenditure remain to be determined. Consumer expenditure is influenced by income and price (Jones & Hayes, 2002; Kim, 2008; Norum, 1990).

As noted in the background, the specific effect of weather sensitivity on consumer clothing expenditure remains insufficiently explored. This study addresses that gap by comprehensively identifying the factors influencing consumer expenditure. In particular, it measures the weather sensitivity of clothing expenditure by accounting for key economic indicators such as inflation and consumer financial confidence. The analysis compares two cities using weather factors, CPI, and CSI to assess their combined impact on clothing expenditure. The study has four specific objectives:

1. Analyze seasonal differences in clothing expenditure between the two cities.
2. Identify major influencing factors among seasonal weather factors in the two cities.
3. Evaluate the sensitivity of clothing expenditure to weather factors after considering the CPI and CSI in the two cities.
4. Evaluate the impact of apparent temperature on clothing expenditure in the two cities.

Methodology

This study selected two metropolitan cities, Seoul and Busan, in Korea. Seoul is located in the northwestern region, in the Dwa climate zone, and has a continental climate. Busan is located in the southeastern region of the Cwa climate zone and has a marine climate. Long-term analyses of climate variability and changes in weather factors have revealed distinct differences in weather characteristics between the two cities (Jeon et al., 2023). Two data sets from 2010 to 2022 were employed. The first data set is weather data from the Korea Meteorological Administration (KMA). The second data set is economic data from the Bank of Korea's economic statistics system. As a weather factor, this study employed daily mean temperature (TEMP), precipitation (PREC), relative humidity (RH), and wind speed (WIND). In addition, the apparent temperature, including WBGT and Windchill, was employed because it is a composite measure that considers various weather factors and provides a comprehensive understanding of feels like temperature, which impacts consumer lifestyle. Based on previous studies (Jones & Hayes, 2002; Kim, 2008; Norum, 1990), income and price were used as economic factors. CPI measures the change in consumer clothing prices, and CSI measures consumer sentiment on consumer confidence in clothing spending. CPI, CSI, and monthly and daily credit card clothing spending were used.

Korea has four distinctive seasons. Seasons are divided into natural seasons, such as Spring (March ~ May), Summer (June ~ August), Fall (September ~ November), and Winter (December ~ January). Objective 1 was to examine seasonal differences in clothing expenditure; therefore, descriptive analysis with a box-plot diagram, t-test, one-way variance test with post hoc test, and correlation analysis were conducted. Correlation analysis was performed between weather factors and clothing expenditure to identify key impact factors among weather factors for each season (Objective 2). Finally, this study performed hierarchical regression analysis to build a model that explains all significant factors of clothing expenditure (Objectives 3 and 4). The first model (Model 1) includes economic factors CPI and CSI. The next step (Model 2) includes the identified

weather factors for the model, ensuring a thorough understanding of the factors influencing clothing expenditure.

$$\text{Model 1: Clothing Expenditure} = \text{intercept} + \text{CPI} + \text{CSI}$$

$$\text{Model 2: Clothing Expenditure} = \text{intercept} + \text{CPI} + \text{CSI} + \text{Weather factor(s)}$$

Results

Seasonal Differences in Clothing Expenditure

This study examined seasonal differences in clothing expenditure and used descriptive analysis, including a box plot diagram, t-test, one-way ANOVA with post-test, and correlation analysis. Figure 1 presents seasonal clothing expenditure using a box plot diagram. The diagram illustrates that clothing expenditure in Seoul is more than in Busan (spring $t=30.769$, $p=0.000$; summer $t=33.552$, $p=0.000$; fall $t=27.305$, $p=0.000$; winter $t=22.967$, $p=0.000$). Notably, the median values of all seasons, except spring, were marginally lower than the center of the box, indicating the presence of some high expenditure values that elevate the mean. Monthly fluctuations in consumer spending on clothing significantly influence this variation (Agnew & Palutikof, 1999; Arunraj & Arhens, 2016; Oh, 2024; Oh et al., 2022). In particular, the standard deviation for winter was 1338.771 in Seoul and 359.747 in Busan, which reveals substantial month-to-month and year-to-year variability in clothing expenditure.

These figures highlight marked seasonal and annual fluctuations. One compelling reason for this fluctuation is the noticeable reduction in clothing expenditure during the COVID-19 pandemic from 2019 to 2020, a period marked by stringent social distancing measures (Son & Yoon, 2023).

In Seoul, the one-way variance test revealed a significant difference in expenditure by season ($F=9.389$, $p=0.000$), indicating a substantial variation in clothing expenditure across seasons. Fall ($M=7396.87$, $SD=1271.200$) emerged as the highest spending season, followed by spring ($M=7030.90$, $SD=1106.909$), followed by winter ($M=6510.59$, $SD=1338.771$). Summer ($M=6094.10$, $SD=905.449$) was the lowest spending season. The pattern was consistent in Busan. The one-way

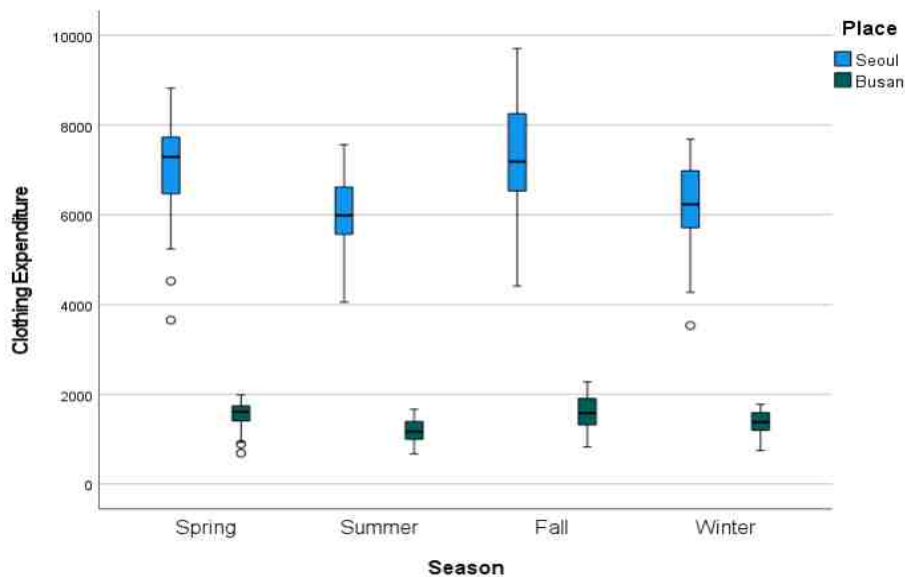


Figure 1. Box plot diagram for clothing expenditure

variance test revealed a significant difference in expenditure by seasons ($F=11.543$, $p=0.000$), with fall ($M=1603.46$, $SD=359.717$) emerging as the highest spending season and followed by Spring ($M=1503.07$, $SD=328.083$), followed by Winter ($M=1394.95$, $SD=359.747$). Summer ($M=1190.79$, $SD=262.249$) was the lowest spending season. Clothing expenditures were higher in spring and fall when there were more outdoor activities than in summer and winter when the weather was too hot or cold to be suitable for outdoor activities (Kim, 2016).

The associations among CPI, CSI, and clothing expenditure were found. In the case of Seoul, CPI and clothing expenditure had a negative association ($r=-0.482$, $p=0.001$), and CSI and clothing expenditure had a positive relationship ($r=0.682$, $p=0.000$). Also, the associations among CPI, CSI, and clothing expenditure were found in Busan. CPI and clothing expenditure had a negative association ($r=-0.510$, $p=0.001$), and CSI and clothing expenditure had a positive relationship ($r=0.610$, $p=0.000$). The results of both cities showed that CPI and clothing expenditure had a negative association, while CSI and clothing expenditure had a positive relationship. Compared to the association between clothing expenditure in Seoul and Busan, Seoul has a

relatively stronger association with CSI than Busan, and Busan has a relatively stronger association with CPI than Seoul. The study's results provided that a higher CPI and lower CSI led to decreased clothing expenditure, confirming that they aligned with previous studies (Jones & Hayes, 2002; Kim, 2008; Norum, 1990), thereby validating this study.

Association Between Weather Factors and Clothing Expenditure

Correlation analysis was conducted to identify the key weather factors shown in Table 1. In Seoul, clothing expenditure showed a positive association with WIND ($r=0.333$, $p=0.05$) in spring and a negative association with TEMP ($r=-0.590$, $p=0.001$) and RH ($r=-0.548$, $p=0.001$) in summer. In the fall, clothing expenditure was negatively associated with RH ($r=-0.575$, $p=0.001$), TEMP ($r=-0.550$, $p=0.001$), and PREC ($r=-0.362$, $p=0.001$), and positively associated with WIND ($r=0.327$, $p=0.001$). WIND ($r=0.327$, $p=0.05$) positively associated with clothing expenditure in winter. In Busan, clothing expenditure showed no association with weather factors in spring and winter, a negative association with TEMP ($r=-0.610$, $p=0.01$) in summer, and negative associations with RH ($r=-0.568$, $p=0.01$) and TEMP

Table 1. Correlation analysis between weather factors and clothing expenditure (N=39)

			TEMP	PREC	RH	WIND
Spring	Seoul	Expenditure	0.276	-0.048	-0.022	0.333*
	Busan	Expenditure	0.254	0.173	0.042	-0.044
Summer	Seoul	Expenditure	-0.611**	-0.069	-0.553**	0.199
	Busan	Expenditure	-0.610**	-0.233	-0.130	-0.211
Fall	Seoul	Expenditure	-0.550**	-0.362*	-0.575**	0.327*
	Busan	Expenditure	-0.547**	-0.188	-0.568**	-0.082
Winter	Seoul	Expenditure	-0.184	0.114	-0.074	-0.327*
	Busan	Expenditure	-0.109	0.088	-0.013	0.170

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

($r=-0.547, p=0.01$) in fall.

The climate characteristics of Seoul and Busan are closely tied to the seasonal variations in clothing expenditures. Seoul's association with weather factors is evident in all four seasons, while Busan's is limited to summer and fall. Seoul has hot and humid summers and cold winters. It was found that clothing expenditure in Seoul increases when the summer is relatively cool and less humid and when the fall is cold, less humid, and windy. On the other hand, Busan has a hot and humid summer and mild winter. When the temperature drops in the summer, clothing expenditure in Busan increases, and if the temperature drops and becomes less humid in the fall, clothing expenditure in Busan also increases.

Weather Sensitivity on Clothing Expenditure

To build a model of weather sensitivity after accounting for all significant factors on consumers' expenditure for clothing, the first model (Model 1) includes economic factors CPI and CSI. The next step (Model 2) includes the identified weather factors for the model. In spring, there is no association factor between clothing expenditures and weather factors in Busan (refer to Table 1); thus, sensitivity analysis was not performed. In Seoul, WIND was the factor associated with spring. In Seoul, wind was the factor associated with spring. Model 1 for Seoul explained 57.2% of the variance in clothing expenditure ($F=26.411, p=0.000$). CSI ($\beta=0.639, t=4.761, p=0.000$) positively impacted on clothing expenditures.

After an associated factor, WIND, included in model 2, the F change was insignificant (F change =0.490, $p=0.488$). Hence, it concluded that the clothing expenditure model in Seoul, which includes WIND, has no significant impact on expenditure.

Table 2 presents the results of the models for summer. Model 1 explained 34.9% of the variance in expenditure ($F=10.433, p=0.000$). CSI ($\beta=0.582, t=3.738, p=0.001$) positively influenced clothing expenditure in Seoul. After the associated weather factors, TEMP and RH in model 2 explained 60.0% of the variance in clothing expenditure ($F=17.835, p=0.000$). Notably, TEMP ($\beta=0.419, t=4.073, p=0.000$) and RH ($\beta=-0.297, t=-2.840, p=0.007$) were found to affect clothing expenditure in Seoul negatively. In Busan, model 1 explained 33.3% of the variance in expenditure ($F=11.234, p=0.000$), with CSI ($\beta=0.439, t=3.155, p=0.003$) positively influencing expenditure. Including TEMP in model 2 led to an explanation of 64.4% of the variance in expenditure ($F=25.726, p=0.000$), with TEMP ($\beta=-0.556, t=-5.923, p=0.000$) negatively affecting expenditure.

Comparing the results of the two cities, the change in Seoul consumers' clothing expenditure in summer was 41.9% due to temperature changes and 29.7% due to relative humidity change, and the change in Busan consumers' clothing expenditure was 55.6% due to temperature changes. Seoul consumers' summer clothing expenditure is more sensitive to relative humidity than Busan's. Due to the marine climate, Busan is more humid than Seoul; thus, Busan

Table 2. Hierarchical regression analysis of the summer clothing expenditure predictors

Predictors	Seoul				Predictors	Busan			
	Model 1		Model 2			Model 1		Model 2	
	B	β	B	β		B	β	B	β
(Constant)	-3736.883		758.618		(Constant)	-350.799		1600.976	
CPI	-1.783	-0.016	-1.072	0.078	CPI	-9.534	-0.275	-9.963	-0.288**
CSI	102.158	0.582**	69.960	0.405**	CSI	26.117	0.439**	21.729	0.365**
TEMP			-214.884	-0.419***	TEMP			-60.853	-0.556***
RH			-38.811	-0.297**					
F-value	10.433***		17.835***		F-value	11.234***		25.726***	
R ²	0.349		0.600		R ²	0.333		0.644	
R ² change			0.310***		R ² change			0.305***	

*p<0.05; **p<0.01; ***p<0.001.

Table 3. Hierarchical regression analysis of the fall clothing expenditure predictors

Predictors	Seoul				Predictors	Busan			
	Model 1		Model 2			Model 1		Model 2	
	B	β	B	β		B	β	B	β
(Constant)	-3855.073		5026.950		(Constant)	-244.833		1783.244	
CPI	-29.915	-0.159	-43.547	-0.232	CPI	-13.856	-0.242	-20.366**	7.286**
CSI	141.739	0.605**	96.101	0.410**	CSI	33.722	0.462**	26.828**	8.780**
TEMP			-79.444	-0.376***	TEMP			-49.971**	-0.591**
PREC			-41.164	-0.173	RH			1.987	0.050
RH			-3.436	-0.120					
WIND			381.503	0.092					
F-value	19.903***		22.392***		F-value	12.211***		19.875***	
R ²	0.525		0.808		R ²	0.404		0.700	
R ² change			0.283***		R ² change			0.296***	

*p<0.05; **p<0.01; ***p<0.001.

consumers are less sensitive to relative humidity than in Seoul. However, relative humidity and temperature both play a vital role in the apparent temperature of summer, and this result needs to be investigated further.

Table 3 shows the models for fall. Model 1 for Seoul explained 52.5% of the variance in clothing expenditure (F=19.903, p=0.000). CSI ($\beta=0.605$, t=3.778, p=0.001)

positively effect on clothing expenditure. After the associated weather factors, TEMP, RH, PREC, and Wind, were included in Model 2, the model explained 80.8% of the variance in clothing expenditure (F=22.392, p=0.000). TEMP ($\beta=-0.376$, t=-4.025, p=0.000) negatively affected clothing expenditure. Model 1 in Busan explained 40.4% of the variance in clothing expenditure (F=12.211, p=0.000). CSI ($\beta=0.462$,

$t=2.903$, $p=0.006$) positively affected on expenditure. Weather factors, which are TEMP and RH, are included in model 2, and the variance explained is 70.0% ($F=19.875$, $p=0.000$). TEMP ($\beta=-591$, $t=-3.517$, $p=0.001$) negatively affects expenditure.

Comparing the results of the two cities, the change in Busan consumers' clothing expenditure was 59.1% due to temperature changes, and the change in Seoul consumers' clothing expenditure was 37.6% due to temperature changes. Busan consumers spend more sensitively than Seoul consumers due to temperature changes. This result can be attributed to the marine climate of Busan, which has a winter with relatively mild climatological temperatures, making consumers living in Busan more sensitive to temperature drops in the fall than Seoul consumers.

In winter, there is no association between expenditure and weather factors in Busan (refer to Table 1), and thus, sensitive analysis related to weather factors was not performed. In Seoul, wind was the factor that influenced winter expenditure. Model 1 for Seoul explained 52.5% of the variance in clothing expenditure ($F=19.903$, $p=0.000$). CSI ($\beta=0.691$, $t=4.037$, $p=0.000$) positively affected on expenditure. After an associated weather factor, wind, included in model 2, the F change was insignificant (F change =0.811, $p=0.74$). It can be concluded that the model, which includes wind, does not affect expenditure. Winter is the seasonally lowest temperature, a period of increased irregular expenditures due to the heating costs and cultural events such as Christmas and Lunar New Year (Korea Economic Daily, 2023). This insight into the role of financial confidence in winter expenditure enlightens us about the complex factors influencing consumer spending behavior.

Effect of Apparent Temperature Index on Clothing Expenditure

The above results indicate that weather factors significantly impact clothing expenditure in both cities, particularly during the summer and fall seasons. In both cities, consumer spending tends to decrease as temperatures rise in the summer and increase as temperatures drop in the fall. However, weather factors do not significantly affect clothing expenditure during the spring and winter in both cities.

Consequently, this study does not examine the impact of windchill on winter clothing expenditure, which represents an apparent temperature in winter. Additionally, the study further explores how WGBT, which indicates the apparent temperature in the summer, influences clothing expenditures during the summer.

Consumers in both cities reduced their spending when temperatures rose in summer. In particular, changes in relative humidity in summer affect consumer spending in Seoul, with spending decreasing as relative humidity increases. A t-test comparing relative humidity in Busan and Seoul showed a significant difference in relative humidity between the two cities ($t=-5.577$, $p=0.000$). Busan ($M=78.14$, $SD=5.116$) had higher relative humidity than Seoul ($M=70.74$, $SD=6.918$). The analysis above found that although relative humidity is higher in Busan than in Seoul, it does not affect summer clothing expenditure in Busan (see Table 2). Therefore, this study analyzes summer clothing expenditure in Seoul and Busan using WGBT, representing summer heat stress. This heat stress index provides a comprehensive understanding of apparent temperature by measuring relative humidity and temperature.

Table 4 shows the result of the model for summer model 1 for Seoul, explaining 34.9% of the variance in clothing expenditure ($F=10.433$, $p=0.000$), CSI ($\beta=0.582$, $t=3.739$, $p=0.001$) effect on expenditure positively. After WGBT was included in model 2, the explained variance was 58.8% ($F=18.048$, $p=0.000$), and WGBT ($\beta=-0.501$, $t=-3.455$, $p=0.001$) negatively affected CE. In Busan, model 1 explained that 36.6% of the variance in clothing expenditure ($F=11.234$, $p=0.000$) and CSI ($\beta=0.439$, $t=3.155$, $p=0.003$) positively affected expenditure. After WGBT was included in model 2, the explained variance was 53.8% ($F=16.945$, $p=0.000$), and WGBT ($\beta=-0.463$, $t=-4.285$, $p=0.001$) negatively affected expenditure.

Comparing the results of the two cities, the change in clothing expenditure in Seoul was 51.0% due to the change in WGBT, and the change in clothing expenditure in Busan due to the change in WGBT was 46.3%. Heat stress is a significant factor influencing clothing expenditure. Seoul consumers are more sensitive to heat stress in summer clothing expenditure than Busan consumers. This result can

Table 4. Hierarchical regression analysis of the summer clothing expenditure predictors

Predictors	Seoul				Predictors	Busan			
	Model 1		Model2			Model 1		Model 2	
	B	β	B	β		B	β	B	β
(Constant)	-3736.883		7343.343		(Constant)	-350.799		1185.684	
CPI	-1.783	-0.016	-0.291	-0.003	CPI	-9.534	-0.275	-9.624	-0.279*
CSI	102.158	0.582**	78.131	0.445**	CSI	26.117	0.439**	20.816	0.350**
WBGT			-297.007	-0.510***	WBGT			-35.188	-0.463***
F-value	10.433***		18.048***		F-value	11.234***		16.945***	
R ²	0.349		0.588		R ²	0.366		0.572	
R ² change			0.239***		R ² change			0.207***	

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

be explained by the fact that humans more exposed to a specific temperature environment are less sensitive to a specific temperature environment than those less exposed to that environment (Leppäluoto et al., 2001). In addition, the study results show that Busan residents feel less heat stress at the same temperature as Seoul residents (Ju et al., 2022).

Conclusions

Given the fashion industry's global and multi-layered nature, adapting to unexpected weather changes within a season is a significant challenge. Efficient and rapid demand forecasting is crucial for reducing overproduction, optimizing inventory levels, and contributing to SDG12 while benefiting enterprises financially. In a departure from previous research, this study employed hierarchical regression analysis to investigate the impact of weather factors on clothing expenditures by season. Unlike previous studies, this study measured the seasonal weather sensitivity in two metropolitan cities with significantly different climate zones. The results of the study are summarized as follows.

First, in both cities, there is a significant difference in expenditures by season, with fall being the highest spending season, followed by spring and winter. Summer was the lowest spending season. Clothing expenditures were higher

in spring and fall, when there were more outdoor activities, than in summer and winter when the weather was too extreme for outdoor activities. These findings highlight the importance of aligning strategies with seasonal consumer spending behavior changes and provide implementing insights that can empower industry professionals to make better decisions.

Second, clothing expenditure in Seoul was unaffected by CPI, regardless of the season. However, CSI did influence clothing expenditure across all seasons. In contrast, CPI affected clothing expenditure in spring, summer, and fall in Busan, while CSI influenced clothing expenditure in all seasons. These results suggest that consumers in Seoul are less sensitive to clothing price inflation, with their financial confidence in clothing expenditures responding accordingly. On the other hand, consumers in Busan are more affected by clothing price inflation, except in winter, and their financial confidence influences clothing expenditures across all seasons.

Third, in both Seoul and Busan, clothing expenditure in spring and winter was not sensitive to weather, while temperature changes in summer and fall were sensitive to clothing expenditure. Previous studies (Arunraj & Ahrens, 2016; Bahng & Kincade, 2012; Oh et al., 2017; Oh et al., 2022; Oh, 2024) on temperature and clothing sales/demand partially support the findings of this study. An interesting finding is that clothing expenditure decreases as temperatures

increase in summer. This is consistent with the findings of a study (Agnew & Palutikof, 1999), which found that clothing sales declined towards the end of the extremely hot summer. In particular, it has been reported that energy consumption increases due to heat waves (Kim et al., 2022) and that many vulnerable groups in Korea feel that insulation performance is low or that they feel the burden of air conditioning costs due to heat waves in Seoul in summer (Seoul Metropolitan Government, 2023). Therefore, it can be inferred that more money is spent on air conditioning than clothing, a non-essential part of income, discretionary income in hot summer.

Fourth, regarding relative humidity, Busan has higher relative humidity variability than Seoul. However, Seoul consumers were sensitive to relative humidity variability in clothing expenditure in summer, and Busan consumers were unrelated to relative humidity and clothing expenditure in summer. Also, regarding the WBGT, Seoul consumers' clothing expenditure was more sensitive than Busan consumers' clothing expenditure. Active thermoregulation behaviors, which include changes in body posture, indoor temperature control, and wearing or removing clothes, are influenced by weather conditions. Although there is a time gap, the motivation for purchasing clothing according to weather or season is related to these behaviors. Human adaptation to climate directly affects thermoregulatory behavior, which can be observed through physiological and subjective indicators such as apparent temperature. This may be because Busan consumers, characterized by a maritime climate, are less sensitive to humidity and heat stress than Seoul consumers, who have a continental climate.

Clothing expenditure varies depending on economic factors and weather. In particular, weather factors that affect clothing expenditure differ depending on the climate zone. According to the Representative Concentration Pathway 8.5 scenario, which represents a future where greenhouse gases will be emitted at the current trend, the Korean climate will be predicted to belong to the subtropical climate zone in the second half of the 21st century. However, climate and weather variability, economic instability, and changing consumer behavior are risks, but they are opportunities for the industry. Applying the results of this study is intended to enhance demand forecasting, which is a roadmap for

adapting fashion business models to new climate-responsive and data-driven consumption needs that can contribute to SDG 12. Four directions are recommended:

1. From season-based to climate-responsive production: Develop dynamic production schedules informed by weather forecasts and regional climate variability, using short-run or on-demand manufacturing where feasible. To mitigate risk, integrate risk management into the supply chain planning and develop early warning systems for strategic changes.
2. Integrated data-driven forecasting as a competitive advantage: Invest in AI-powered forecasting platforms that combine CPI, CSI, weather anomalies, and real-time consumer signals. Also, build partnerships for open data exchange and collaborative forecasting innovation and participate in multi-stakeholder platforms.
3. Reframing clothing as climate-adaptive technology: Expand R&D in smart textiles, develop performance lines for extreme conditions (UV-resistant, moisture-wicking, windproof), and segment indoor/outdoor lines based on functionality.
4. Sustainability alignment demand-responsive decision: Adopt lean production, seasonal collections, and recyclable materials within a flexible production model, which will not only improve profitability but also achieve sustainability goals through reduced resource use and waste.

Limitations and Recommendations for Future Studies

This study analyzed monthly data from 2010 to 2022. In particular, from 2019 to 2020, Korea actively implemented social distancing measures due to the COVID-19 pandemic, so the impact of the pandemic affected clothing expenditure. This unprecedented event imprinted on consumer behavior and affected consumption patterns. However, this study did not analyze this period separately. After the amount of data is sufficient to analyze, this period may be a meaningful time to study and prepare for future events. In addition, there are limitations in research as demographic factors such as

population, gender, household type, age, income, and occupation of the two major cities are not used in the analysis. Climate plays a decisive role in what to buy, and weather is a decisive factor in what to wear. Including climate and weather data in research is beneficial and necessary to understand and respond to weather changes caused by climate change across supply chains. For sustainable production in the fashion industry, it is essential to identify and predict important factors, such as weather, of business performance.

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