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POTENTIAL IMPACT OF CLIMATE CHANGE ON FOOD CONSUMPTION THROUGH PRICE CHANNEL: CASE FOR TURKEY[1]

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Abstract

Like many MENA countries, the factors leading to climate change in Turkey have drastically escalated in the last two decades. This paper mainly focuses on the issue of ensuring food security. We aim to examine the significance of climate shocks in Turkey's food prices. The unique structures of this paper are threefold: First, we define climate shocks as persistent deviations from the long-term mean in a region regarding temperature and precipitation due to climate change; second, controlling for possible shocks, we examine the role of climate change in food price processes; and third, we examine the causal effect of food price on per capita food expenditure based on the demand equation. We find the most prominent climate change effect on prices of bread and cereals, and other food products. The estimates of the second phase of the analysis suggest that both price and the wealth effects on food consumption increase more in regions where climate change exists than in regions with no significant change in climate figures. However, we do not observe significant differences in the wealth effect on non-food consumption among the regions.

Keywords: Climate change, Household consumption, Mitigation, Precipitation, Temperature.
JEL Classifications: C23, D11, O52, Q11, Q54, R11.

ملخص

كما حدث في العديد من دول الشرق الأوسط وشمال إفريقيا، تصاعدت العوامل المؤدية إلى تغير المناخ في تركيا بشكل كبير في العقدين الماضيين. وتركز هذه الدراسة بشكل أساسي على قضية ضمان الأمن الغذائي. والهدف هو دراسة تأثير الصدمات المناخية على أسعار الغذاء في تركيا. وتتكون البنية الفريدة لهذه الدراسة من ثلاثة جوانب: أولاً تحديد الصدمات المناخية على أنها انحرافات مستمرة عن المتوسط طويل الأجل في منطقة ما فيما يتعلق بدرجة الحرارة ومعدل هطول الأمطار بسبب تغير المناخ. ثانيًا بافتراض ثبات الصدمات المحتملة، ندرس دور تغير المناخ في عمليات تسعير الغذاء. ثالثًا فحص الأثر السببي لأسعار الغذاء على نصيب الفرد من الإنفاق على الغذاء بناءً على معادلة الطلب. وقد وجدت الدراسة أن أبرز تأثير لتغير المناخ على الأسعار يقع على أسعار الخبز والحبوب وغيرها من المنتجات الغذائية. وتشير تقديرات المرحلة الثانية من التحليل إلى أن تأثيرات الأسعار والثروة على استهلاك الغذاء تزداد في المناطق التي يوجد بها تغير مناخي كبير أكثر من المناطق التي لا يوجد بها تغير مناخي كبير. ومع ذلك لم نلاحظ فروقًا ذات دلالة إحصائية في تأثير الثروة على الاستهلاك غير الغذائي بين المناطق المختلفة.

1. Introduction

Climate change is one of the significant challenges in the 21st century. Like many MENA countries, the factors leading to climate change in Turkey have drastically escalated in the last two decades. Turkey has faced various circumstances stemming from climate change, such as rising temperatures, drought, unseasonable rains, and the increasing prevalence of extreme weather events. The first factors are the increasing population and ongoing rapid industrialization of an emerging country, aggressive export-oriented policies, unconscious agricultural implementation, lack of inspection, and insufficient past policies.

Severe risks in Turkey's river basins may occur due to possible new climate conditions in the future. One of these issues is the declining tendency in rainfall throughout Turkey, particularly in the southern and inner parts of Anatolia and especially in Tigris–Euphrates Basin. An increase in temperatures is another issue, especially in the winter season, which may cause the precipitation type to alter, from snow to rain, during the winter. Rising temperatures may also trigger the prevalence of extreme weather events like tornados, hail, and storms (Demircan et al., 2017). Additionally, the increased precipitation in the summer season in the west and north coastal parts of Anatolia may cause increasing numbers of flood disasters in these regions.

We observe the impact of climate change in various fields. There is a growing literature analyzing the consequences of climate change in the economy as a whole (Gbetibouo & Hassan, 2005; Tol, 2010; Hsiang, 2017), particularly in the tourism sector (Scott et al., 2019; Pang et al., 2013; Steiger et al., 2019; Aygün & Baycan, 2020), agricultural sector (Adams, 1989; Walthall et al., 2013; Pathak et al., 2018), and construction sector (White et al., 2010; Dino & Akgül, 2019).

This paper mainly focuses on the issue of ensuring food security that has three pillars in related literature: affordability, availability, and accessibility (Aborisade & Bach, 2014; Masipa, 2017). In Turkey, availability and accessibility are not considered as significant concerns for economic agents. TURKSTAT figures indicate that the sum of the agricultural sector and food industry are net exporters in Turkey. Besides, the retail sector has experienced substantial growth in the last ten years in Turkey. These figures point out that availability and accessibility are not concerning issues from a broad point of view. However, high food inflation has been hitting consumers recently and has become a prior policy-making area. Thus, affordability is inevitably determined as the focus of this study.

The effect of climate change on food consumption is the most minor studied area within the food security concept (Zewdie, 2014). Therefore, investigating this relationship for Turkey in our paper assumes a significant role in guiding and designing policies for climate change and the agricultural sector.[1]

[1] The extreme temperatures and asymmetrical distribution of rainfall affect especially agricultural food production. Accordingly, climate change results in inevitable stress on food security, primarily through food prices. This impact is relatively perceived more in developing and emerging countries (Erokhin, 2017).

We aim to examine the significance of climate shocks in Turkey's food prices. The unique structures of this paper are threefold: First, we define climate shocks as persistent deviations from the long-term mean in a region regarding temperature and precipitation due to climate change; second, controlling for possible shocks, we examine the role of climate change in food price processes; and third, we examine the causal effect of food price on per capita food expenditure based on the demand equation. The results imply a five percent increase in the region's food prices where climate change exists according to our specification compared to other regions. The results also emphasize that the sole effects of both precipitation and temperature remain limited, but the combined effect grove apace. In our second stage, the estimates suggest that both price and the wealth effects on food consumption increase more in regions where climate change exists than in the regions where there is no significant change in regions climate figures. However, we do not observe significant differences in the wealth effect on non-food consumption among the regions.

The research outline is as follows: We begin by describing the leading climate figures of Turkey in Section 2. In Section 3, we present Turkey's efforts on mitigation and adaptation to climate change. In Section 4, we provide a comprehensive literature review related to our research. Section 5 describes the datasets. We present our main findings in Section, and then we conclude.

2. Conceptual Framework

Turkey is a crossroads between Western Europe, the Middle East, and Asia. Having a profound land area with diversified geographical formations and 7,200 kilometers of coastline brings many climatic types to Turkey. We can group under four major headings:

a) Continental Climate (Inland)
b) Mediterranean Climate (Southern and Western Region)
c) Black Sea Climate (Northern Region)
d) Transition Climate (Marmara Region)

Like many MENA countries, Turkey has faced a series of circumstances stemming from climate change, such as rising temperatures, drought, unseasonable rains, and the increasing prevalence of extreme weather events (Bayram & Öztürk, 2014; GDMS, 2020).

In the 2011-2019 period, there were many remarkable deviations from long-term averages observed in Turkey for annual average temperatures and precipitation. Turkey's annual average temperature was recorded as 14.4°C for the 2011-2019 period, while it was 13.5°C for the 1981-2010 period, 0.9 points lower. Similar anomalies occurred in precipitation figures. The annual mean areal precipitation in 1981-2010 was only 574 mm, which has risen by 8.1% and reached 620.7 mm within the 2011-2019 period. Another significant issue is the irregularity of precipitation across the years (GDMS, 2020).

Table 1. Average Temperature and Precipitation in Turkey and Deviations from the Long Run Average

	Temperature (°C)	Precipitation (mm)	*Deviation from 1981-2010 average* Temperature (points)	Precipitation (%)
2011	13.2	654.7	-0.3	14.1
2012	14.2	745.0	0.7	29.8
2013	14.1	564.0	0.6	-1.7
2014	14.9	697.3	1.4	21.5
2015	14.3	577.0	0.8	0.5
2016	14.5	598.0	1.0	4.2
2017	14.2	506.6	0.7	-11.7
2018	15.4	658.7	1.9	14.8
2019	14.7	585.1	1.2	1.9
2011-2019 Average	14.4	620.7	0.9	8.1
1981-2010 Average	13.5	574.0		

Source: GDMS, 2020

In latest two decades, the factors leading to climate change in Turkey have drastically escalated. Turkey was doing better than the global average in CO2 emission per capita; however, it exceeded the global average in the last three years.[2] On the other hand, between 1999 and 2019, forest land per capita shrank 16.5%. The first factors are the increasing population and ongoing rapid industrialization of an emerging country, aggressive export-oriented policies, unconscious agricultural implementation, lack of inspection, and insufficient past policies.

Due to such deterioration in climate change indicators in Turkey, the outlook in precipitation regime and annual average temperatures exhibited a worse course in the last decade. Precipitation has deviated from the 1981-2010 period's average remarkably upwards each year, causing excessive precipitation (and untimely in many cases).[3] Similarly, the upward deviation of annual temperature from the long-term average has an increasing tendency over the years. Accordingly, the rate of deviation in Turkey exceeded that of the global average in latest two years.

The current hazardous outlook of climate change in Turkey brings questions for the future. The predictive modeling studies shed light on the possible outcomes of climate change over decades. For the 2015-2100 period, the recent study by the GDMS expects the average annual temperature to rise 1-2°C in 2016-2040, 1.5-4°C in 2041-2070, and 1.5-5 ° C in 2071-2099. In this projection, the annual temperature rise will be 3°C in winters and 6°C in summers (Demircan et al., 2017).

[2] In 2019 CO_2 emission per capita lowered and was close to the global average. This decrease was a result of the decline in economic activities that started in the second half of 2018, due to sharp depreciation in Turkish Lira.
[3] Only two years were exceptional throughout the decade.

2.1. Data

2.1.1. Data about Climate Change Indicators

Investigating the climate change process and constructing climate change indicators for regions in Turkey are the starting points of our study. The climate change process may co-occur for all regions, or remarkable variations among regions and months could arise. We may use these variations to obtain causal inferences about the effect of climate change on our variables of interest. Therefore, we first investigate whether climate change differs within regions and months of the year in Turkey.

Climate change generally is defined as a persistent deviation in a climate-related indicator from its long-term averages. Note that there may be some short-term deviations, which cannot be defined as climate change, which could temporarily affect food prices. In order to eliminate these short-term effects, we will employ region and time-fixed effects as control variables in our estimation strategy.

Table 2. Structural Break Analysis for Temperature

Region	1999-2019	2000-2019	2001-2019	2002-2019	2003-2019	Decision
TR10	Apr 2012***	Apr 2012***	Apr 2012**	Apr 2012***	Aug 2006***	April 2012
TR21	Apr 2012***	Apr 2012***	Apr 2012***	Jan 2007***	Jan 2007***	April 2012
TR22	Aug 2015***	Aug 2015***	Aug 2015***	Aug 2015***	Aug 2015***	August 2015
TR31						No Structural Break
TR32						No Structural Break
TR33						No Structural Break
TR41						No Structural Break
TR42	Aug 2006**	Aug 2006**	Aug 2006*	Aug 2006**	Aug 2006***	August 2006
TR51	Aug 2006**	Aug 2006**	Aug 2006*	Aug 2006***	Aug 2006**	August 2006
TR52						No Structural Break
TR61						No Structural Break
TR62	Aug 2015***	Aug 2015***	Aug 2015***	Aug 2015***	Aug 2015***	August 2015
TR63						No Structural Break
TR71						No Structural Break
TR72						No Structural Break
TR81	Aug 2006	Aug 2006	Aug 2006	Aug 2006**	Aug 2005***	August 2006
TR82						No Structural Break
TR83	Aug 2006**	Aug 2006**	Jan 2014	Aug 2006**	Aug 2005***	August 2006
TR90	Apr 2012***	Apr 2012***	Apr 2012***	Apr 2012***	Aug 2006***	April 2012
TRA1						No Structural Break
TRA2						No Structural Break
TRB1	Nov 2013***	Nov 2013***	Nov 2013***	Nov 2013***	Nov 2013***	November 2013
TRB2						No Structural Break
TRC1	Sep 2015**	Sep 2015**	Sep 2015**	Sep 2015**	Sep 2015**	September 2015
TRC2	Sep 2015*	Sep 2015*	Sep 2015*	Dec 2005	Sep 2015	September 2015
TRC3						No Structural Break

*** p<0.01, ** p<0.05, * p<0.1.

We choose temperature and precipitation as climate indicators, and we use GDMS's monthly average temperature and precipitation data for each region of Turkey between the years 1969 and 2019. To analyze whether temperature and precipitation levels differ from their long-term averages as statistically significant, we firstly use simple regression analysis:

$$CCI_{my} = \beta_0 + \beta_1((\sum_{i=-30}^{-1} CCI_{my_i})/30) + \varepsilon_{my} \quad (1)$$

where CCI_{my} is one of the climate change indicators in month m and year y, the independent variable is the 30 years moving averages for temperature or precipitation. After we repeat Equation (1) for every region of Turkey, we investigate whether there is a structural break in those relations. For that, we perform a test of whether the coefficients β_1 in regressions vary over the periods defined by an unknown break date.

Table 3. Structural Break Analysis for Precipitation

Region	1999-2019	2000-2019	2001-2019	2002-2019	2003-2019	Decision
TR10						No Structural Break
TR21						No Structural Break
TR22						No Structural Break
TR31						No Structural Break
TR32						No Structural Break
TR33						No Structural Break
TR41						No Structural Break
TR42						No Structural Break
TR51	Jan 2009*	Jan 2009*		Jan 2009**	Jan 2009**	January 2009
TR52	Dec 2008**			Dec 2008*	Dec 2008**	December 2008
TR61		Mar 2010*	Mar 2010*	Mar 2010*		March 2010
TR62				Jan 2009*		No Structural Break
TR63						No Structural Break
TR71	Sep 2008*	Sep 2008*	Sep 2008**	Sep 2008**	Sep 2008***	September 2008
TR72						No Structural Break
TR81						No Structural Break
TR82						No Structural Break
TR83						No Structural Break
TR90		Feb 2017*	Feb 2017**	Feb 2017*	Feb 2017*	February 2017
TRA1						No Structural Break
TRA2		Jul 2011*	Jul 2011**	Jul 2011**	Jul 2011*	July 2011
TRB1						No Structural Break
TRB2						No Structural Break
TRC1						No Structural Break
TRC2						No Structural Break
TRC3						No Structural Break

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

After all these steps, we construct three climate change indicators such as $T_{temp_{mry}}$, $T_{prec_{mry}}$ and $T_{both_{mry}}$. $T_{temp_{mry}}$ is a binary variable that takes one after month m and year y if there is a structural break between temperature and its long-term average in region r and, otherwise, is zero. $T_{prec_{mry}}$ is also a binary variable which is one after month m and year y if there is a structural break between precipitation and its long-term average in region r and, otherwise, is zero. Finally, $T_{both_{mry}}$ is the interaction of the other two climate change indicators. We present the decisions of the structural breaks for both precipitation and temperature in Tables 2-3.

2.1.2. Data about Food Price

Our food price variable is FP_{irmy}, which indicates the average price of item i, in region r, in month m and year y. We construct our food price variable using data from Turkstat's Central Dissemination System for consumer price. We first get COICOP (Classification of Individual

Consumption According to Purpose) 7 digit level indices of food products from the TURKSTAT database for each region. However, since there are some problems in 7 digit-level indices such as empty cells, we aggregate indices from 7 digit-level to 5 digit-level using CPI weights. Moreover, we construct categorical variables for a three-digit level to control group-specific trends.

2.1.3. Data about Household Consumptıon

Our primary data source will be the Household Budget Survey (HBS) micro datasets between 2003 and 2019. This survey reveals consumption patterns and income levels of individuals and households by socio-economical groups and regions. Using this information, we can produce consumption expenditures, consumption habits, and variety of spending for goods and services on socio-economic features of households, the total income of households, employment status of household members, and source of income.

We use HBS data and regional CPI to construct our food and non-food consumption variable for 2005 prices. Moreover, we construct household controls such as income groups of households, household size, household mortgage payments, food or lunch aid of households; and household head controls such as gender, age, education, insurance, and labor market condition. We also construct variables to control the effect of different consumption expenditures on our variable of interest, such as tobacco and alcohol, rent, and durable goods.

3. Turkey's efforts on mitigation and adaptation to climate change

The policies aiming to mitigate greenhouse gases (GHG) have usually been ignored in Turkey because they account for only 1% of global CO_2 emissions. Therefore, the substantial efforts of Turkey on mitigation and adaptation to climate change can be considered a relatively new field for policy-making.

Turkey has participated in many international conferences and collaborations that target defining and creating awareness against climate change. The first considerable step of Turkey, as an OECD member, was the accession to United Nations Framework Convention on Climate Change (UNFCCC). Nevertheless, UNFCCC has not obliged countries to take concrete measures against climate change; instead, UNFCCC highlights countries' main principles and historical responsibilities.

As an extension of UNFCCC and a necessity of setting concrete targets for reducing greenhouse gas emissions, Kyoto Protocol was signed by 191 countries, including Turkey as an OECD member, in 1997. According to the criteria set, Turkey did not assume any emission reduction liability, but Kyoto Protocol paved the way for Turkey's climate change studies and policy-making efforts. The National Strategy against Climate Change and the National Action Plan against Climate Change mainly focus on reducing greenhouse gas emissions by increasing efficiency and mitigating energy needs in leading industries, increasing the share of renewable energy sources, enhancing financial supports and governmental incentives. In recent years, the government has prepared some regional action plans, as well.

The latest and most significant step for Turkey is the Paris Agreement, which was accepted in 2015 and signed in 2016 by Turkey and became effective as of 2020. Assessing country-based concrete commitments in GHG reduction makes Paris Agreement a milestone in the challenge with climate change. Within this context, in the "intended nationally determined contributions (INDC)" document, Turkey declared an up to 21% reduction in GHG emissions by 2030. This effort is expected to prevent 1.920 million tons of GHG emissions in 2012-2030 (246 million tons only in 2030) in Turkey (UNFFC, 2015; Tuğaç, 2020).

Unfortunately, the Paris Agreement has not officially been ratified and legislated by the Turkish Grand National Assembly (TGNA). Therefore, Turkey is one of the six countries that still have not ratified the Paris Agreement. However, TGNA formed the commission investigating climate change in February 2021. We expect that Paris Agreement will be ratified very soon in 2021 by TGNA, thanks to the decisive and quick initiative of the parliamentary commission of investigation and the Ministry of Environment and Urbanization.

On the policy implementation side, Turkey has a clear target to align with the European Union (EU) Acquis for entitling full membership in the EU. Therefore, the European Commission monitors Turkey's commitments in 33 chapters and publishes annual progress reports. According to the latest report in 2020, Turkey has some pros and cons in the "environment and climate change" chapter.

The main criticism is that Turkey did not formulate a national strategy consistent with the EU 2030 climate and energy framework. Mainstreaming climate action into other sector policies was still limited. In contrast, the existing national strategy and action plan partially addressed climate change mitigation and short-term perspectives. On the other hand, some improvements aim to protect the environment, for example, local clean air action plans. A ban on the free distribution of lightweight plastic bags for waste management came into force in January 2019. Turkey also plans to announce a deposit fee for plastic bottles by 2021. In the area of water quality, the legislative alignment is advanced according to EU Commission's remark. (European Commission, 2020).

The macro results of policy implementation highlight a disparity between resources and uses. The most prominent advantage for Turkey is being one of the countries having higher environmental tax revenue to GDP ratio among all OECD countries in the last decade, which consists of energy, transportation, resource, and pollution taxes. The environmental tax revenue to GDP ratio was 3.2% for Turkey, while it remained 2.6% for the OECD average in 2017. (It fell to 2.4% and 2.2% respectively in 2018 and 2019 for Turkey, but OECD data has not been announced for 2018 and 2019 yet). However, the environmental protection expenditures of Turkey fall behind the OECD average. In 2017, Turkey's environmental expenditures to GDP ratio was 1.1%, while OECD countries spent 1.9% on average. This figure points out that Turkey invests less for "green," although having much more tax resources comparing many OECD countries. However, on the other hand, this difference may be attributed to some obligations within Kyoto Protocol and Paris Agreement aiming specifically at developed OECD countries to mitigate carbon emissions.

4. Related Literature

The global food price crises in 2006-2008 and 2010-2012 have stimulated the interest of researchers regarding the relationship between food prices and food consumption in the latest decade. There is plenty of studies unveiling the effects of the changes of food prices on the food consumption patterns within many different aspects, such as considering changes in food consumption of different income groups, substitution effects between food consumption and non-food consumption, wealth effects, price elasticities of demand for various food categories and effects on poverty. Some of these studies focus on an individual country, while others find a global result by combining different individual studies.

The following studies deserve to be mentioned as they quantify the changes in behavioral patterns of households against price shocks. Avalos (2016) investigates the effects of food price shocks within the 2006-2008 and 2010-2012 periods on poor Mexican households' food and non-food consumption. He finds that poor households in rural and urban areas, who are net food buyers and spend 30% of their budgets on food, are the most vulnerable segments of the society to food price shocks. Therefore, they make adjustments to their budgets to mitigate food price hikes by cutting down non-food consumption. They are also using social network strategies (bartering, sharing) to preserve their food consumption level.

Similar to our first stage analysis, the following papers also examine the effects of climate change on food prices. Bandara (2014) mainly focuses on five large South Asia countries to evaluate the impact of climate change on food production, security, and prices through the global dynamic computable general equilibrium model. The study finds that climate change-caused productivity losses may lead to a food shortage by 2030, a concerning prediction since the agricultural sector accounts for a large portion of GDP in these countries. Therefore, one can expect food prices to rise sharply for almost all crop types. Hertel (2010) considers three scenarios for agricultural productivity for 15 developing countries. In a low productivity scenario, major staples' prices will rise 10-60% by 2030 while causing poverty rates to rise for non-agricultural households.

Climate change affects food consumption through different channels. It deteriorates food production, and then it affects the nutritional requirements (Zewdie, 2014). In this sense, the study of Tai (2014) quantifies the individual and combined effects of temperature and ozone pollution on the production of selected crops and undernourishment rates in developing countries for the 2000-2050 period by conducting simulations with the Community Earth System Model. In this study, it is estimated that combined effects are devastating on both food production and nutrition. Food production is estimated to decline 15%, while the undernourishment rate rises 9% within 50 years in developing countries under the combined effects scenario.

A similar mechanism is depicted in Phalkey et al. (2015). In their paper, climate change affects food consumption by declining the availability of crops and the production of small-scale farmers. As a result, significant links were found between the variations in weather and child stunting at households.

Another study, Hasegawa et al. (2014), which employs a global computable general equilibrium model, found that the adaptation measures significantly effectively reduce the risk of hunger due to climate change, while population and economic development had a significant impact than climate change on the risk of hunger. According to the results of this study, if Turkey can not achieve adaptation to climate change, per-capita calorie intake may diminish by more than 5%.

5. Research Methodology

5.1. Empirical Strategy

This research will examine the relationship between household consumption expenditure and extreme weather conditions For this aim, we will implement a difference-in-differences estimation strategy to obtain the causal effect of climate change on household consumption.

First, we reveal the effect of climate change on food price by exploiting geographical and temporal variation in extreme weather conditions as a source of reasonably exogenous variation in food price. This identification strategy is very similar to Balkan & Tumen (2016), in which they investigate the causal relationship between price and forced immigration. In the first stage of the estimation, we will estimate a two-way fixed effects model of the following form using regional food price indexes:

$$FP_{irm} = \beta_0+\beta_1 CC_{rm} + \theta_i + \omega_r + \tau_m + \alpha_1(T_m * R_r) + \alpha_2(T_m * I_i)+\alpha_3(M_m * I_i) + \alpha_4(Y_m * I_i * R_r) + \varepsilon_{irm}, \quad (2)$$

where FP_{irm} is the natural logarithm of the food price index of item I, in region r, in time m. Our primary independent variable of interest, CC_{rm}, is one of the indicators of climate change. The variables θ_i, ω_r, τ_m represent the item, region, and month fixed effects that capture permanent differences that are likely time-invariant. We use region (broader definition i.e. nuts1) and item (broader definition i.e. COICOP 3 digit level) specific linear time trends ($T_m * R_r$ and $T_m * I_i$) to any unmeasured region and item-related trends. We also use item-specific month fixed effect to control seasonality ($M_m * I_i$) and use region-item specific year fixed to control agriculture year effect. Finally, ε_{irm} is the idiosyncratic error term.

In the second stage of the estimation, using micro-data drawn from the 2005-2019 Household Budget Surveys and a weighted difference-in-differences (DD) approach, we will examine the impact of climate change on household consumption through the price and budget channel. We estimate the demand equation as:

$$CE_{irm} = \beta_0 + \beta_1 P_{rm} + \beta_2 P_{rm} * CC_{rm} + \beta_3 RB_{irm} + D'_{irm}\theta + E'_{irm}\varphi + Z'_{irm}\varphi + \omega_r + \delta_m + \varepsilon_i \quad (3)$$

where CE_{irm} is the natural logarithm of consumption expenditure in terms of 2005 price of households i, in region r and in time m. P_{rm} is the natural logarithm of the food price index in region r and in time m. RB_{irm} is the real purchasing power of household i, in region r and time m, which means how much a household can consume from goods and services of CPI basket. The vector D_{irm}, E_{irm}, and Z_{irm} represent time-varying household, household heads' and consumption controls. The variables ω_r, δ_m represent region and month fixed effects that capture permanent differences that are likely time-invariant. Our primary independent variable of interest, $P_{rm} \times CC_{rm}$, is the interaction of the food price index and one of the indicators of climate change. Therefore, β_2 is the causal effect of climate change on per capita food expenditure through a price channel. Finally, ε_{irm} is the idiosyncratic error term.

We will also implement Equation (3) to non-food household expenditure to analyze climate change's substitution and income effect on household expenditure. Moreover, we conduct Equation (3), in which the primary independent variable of interest is $RB_{irm} \times CC_{rm}$ to investigate the effect of climate change on household consumption via a budget channel.

Finally, we conduct a triple difference in difference estimate strategy in Equations (2)-(3) by adding interactions of all climate change indicators with price and budget variables. Therefore, we could test our results' stability and consistency via using different strategies.

6. Results

In the first phase of the analysis, we build a model to investigate the effect of climate change on food prices. In line with this aim, we define climate change with different specifications and estimate the following models in Table 4. Each row in this table presents a different model, and the values in the parenthesis are the standard errors. We also have various standard errors based on different clustering levels.

In the first model, we use only temperature values while analyzing the expected effect of climate change on food prices. While the second model uses only precipitation figures, the third one exploits only the interaction values, and the last model incorporates all variables.

Table 4. DD Estimate of Relationship between Climate Change and Food Price

N=135,720	Clustering Level					
Variables	Region	Item	Month	Item-Region	Region-Month	Item-Month
DD TE_{temp}	-0.0021	-0.0021	-0.0021	-0.0021	-0.0021	-0.0021
	(0.0077)	(0.0074)	(0.0029)	(0.0111)	(0.0021)	(0.0025)
DD TE_{prec}	0.0142	0.0142	0.0142***	0.0142	0.0142***	0.0142***
	(0.0113)	(0.0120)	(0.0024)	(0.0152)	(0.0020)	(0.0023)
DD TE_{both}	0.0499***	0.0499**	0.0499***	0.0499**	0.0499***	0.0499***
	(0.0149)	(0.0238)	(0.0055)	(0.0252)	(0.0047)	(0.0051)
DDD TE_{both}	0.0509***	0.0509*	0.0509***	0.0509*	0.0509***	0.0509***
	(0.0164)	(0.0252)	(0.0053)	(0.0286)	(0.0049)	(0.0056)

*** p<0.01, ** p<0.05, * p<0.1.

The estimations in Table 4 indicate that climate change does not cause a variation in food price if we consider only temperature levels. Although the amount of precipitation designates a statistically significant difference in food prices compared to the regions with no significant structural breaks in the precipitation levels, the effect remains limited by around 1.4 percent.

The last two models show that the interaction term implies a five percent increase in the region's food prices where climate change exists according to our specification compared to other regions. The results emphasize that the sole effects of both precipitation and temperature remain limited, but the combined effect grove apace.

Table 5. DD Estimates of Relationship between Climate Change and Sub-Group Food Price

		Clustering Level					
Group	Variables	Region	Item	Month	Item-Region	Region-Month	Item-Month
Bread& Cereals	DD TE_{both}	0.0633***	0.0633	0.0633***	0.0633	0.0633***	0.0633***
		(0.0123)	(0.0335)	(0.0068)	(0.0581)	(0.0066)	(0.0091)
	DDD TE_{both}	0.0626***	0.0626	0.0626***	0.0626	0.0626***	0.0626***
		(0.0151)	(0.0460)	(0.0083)	(0.0659)	(0.0075)	(0.0109)
Animal Products	DD TE_{both}	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
		(0.0066)	(0.0062)	(0.0017)	(0.0279)	(0.0018)	(0.0034)
	DDD TE_{both}	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
		(0.0082)	(0.0075)	(0.0027)	(0.0392)	(0.0024)	(0.0035)
Fruit& Vegetables	DD TE_{both}	-0.0064	-0.0064	-0.0064	-0.0064	-0.0064	-0.0064
		(0.0080)	(0.0043)	(0.0045)	(0.0137)	(0.0040)	(0.0053)
	DDD TE_{both}	-0.0194	-0.0194**	-0.0194***	-0.0194	-0.0194***	-0.0194***
		(0.0167)	(0.0060)	(0.0057)	(0.0223)	(0.0050)	(0.0073)
Other Food Products	DD TE_{both}	0.0204**	0.0204	0.0204***	0.0204	0.0204***	0.0204***
		(0.0086)	(0.0319)	(0.0025)	(0.0288)	(0.0025)	(0.0066)
	DDD TE_{both}	0.0120	0.0120	0.0120***	0.0120	0.0120***	0.0120*
		(0.0142)	(0.0329)	(0.0026)	(0.0371)	(0.0033)	(0.0063)

*** p<0.01, ** p<0.05, * p<0.1.

It is essential to decompose the climate effect on food prices among different food groups. We run the leading models for each food group in which interaction terms represent the climate change effect on food price. Note that the deviations from the long-run average of temperature and precipitation levels are essential in our specifications. For this reason, unseasonal rains or temperature levels may also result in a decrease in food production—the decrease in production results in an essential effect on food prices. We find the most prominent climate change effect on bread and cereals and other food products. In addition, there is no substantial effect of the structural breaks in climate figures on the prices of animal products, fruits, and vegetables.

Table 6. DD estimates of the relationship between climate change and household consumption via budget channel

	Food		Non-Food	
	DDD	DD	DDD	DD
Treatment Effect	0.0106***	0.0058**	-0.0021	-0.0024
	(0.0031)	(0.0028)	(0.0017)	(0.0015)
Budget	0.7414***	0.7403***	1.0809***	1.0810***
	(0.0073)	(0.0073)	(0.0040)	(0.0040)
Constant	6.2537***	6.3036***	3.7073***	3.7323***
	(0.2218)	(0.2185)	(0.1081)	(0.1072)
R^2	0.5459	0.5459	0.9449	0.9449
Outcome Mean	9.7451	9.7451	10.9251	10.9251
	(0.6652)	(0.6652)	(0.8688)	(0.8688)

*** p<0.01, ** p<0.05, * p<0.1.

We present our DD estimates of the effect of climate change on household consumption behavior through both price and budget channels in Tables 6-7.

Table 6 gives the estimates of the relation between climate change and household consumption behavior through budget channels. These estimates suggest that the wealth effect on food consumption increases more in the regions where climate change exists (i.e., there exists a structural break in the combination of precipitation and temperature data.) than in the region where there is no significant change in climate figures. However, we do not observe significant differences in the wealth effect on non-food consumption among the regions.

Note that the results confirm the expected signs and magnitude for the wealth effect on food consumption that is positive and lower than one and on non-food consumption that is positive and more than one. These propose that, on average, while food consumption is a necessity good, non-food consumption is a luxury good in Turkey.

Table 7 gives the estimates of the relation between climate change and household consumption behavior through price channels. These estimates suggest that the price effect on food consumption increases more in the regions where climate change exists than in regions with no significant change in climate figures. However, we do not observe any differences in the price effect on non-food consumption among the regions when analyzing the DD estimates. The DDD estimates show that the price effect on non-food consumption decreases more in regions where climate change exists than regions with no significant change in climate figures. This finding implies a loss in real wealth and a possible no change in food consumption causes a decrease in non-food consumption in the regions where we observe a significant structural break in climate figures, i.e., climate change exists.

Table 7. DD estimates of the relationship between climate change and household consumption via price channel

	Food		Non-Food	
	DDD	DD	DDD	DD
Treatment Effect	0.0111***	0.0055*	-0.0042**	-0.0013
	(0.0035)	(0.0030)	(0.0019)	(0.0017)
Price	-0.2398**	-0.3214***	-1.0063***	-1.0061***
	(0.1061)	(0.1008)	(0.0047)	(0.0047)
Constant	6.4520***	6.8306***	7.0120***	6.7923***
	(0.4929)	(0.4678)	(0.2634)	(0.2511)
R^2	0.5454	0.5454	0.9450	0.9450
Outcome Mean	9.7451	9.7451	10.9251	10.9251
	(0.6652)	(0.6652)	(0.8688)	(0.8688)

*** p<0.01, ** p<0.05, * p<0.1.

Note that the results also confirm the expected signs and magnitude for the price effect on both food consumption and non-food consumption that are negative. As expected, the results also suggest that non-food consumption is more price-sensitive compared to food consumption.

To observe the effect of climate change on household food and non-food consumption behavior, we control for demographics of households and consumption controls in various models. We tabulate the DDD estimates of these models in the Appendix. After controlling the consumption controls, the results reveal the expected sign and magnitudes for the wealth and price effects on food and non-food consumption. We assume that the monthly consumption data results consist of the households' consumption decisions in the observed month. Additionally, the models provide a consistent treatment effect of climate change that is not dependent on the control chosen for the models.

7. Discussion

In this paper, we have investigated the effect of climate shocks on Turkey's food prices. Controlling for possible shocks, we have examined the role of climate change in food price processes. We have observed the causal effect of food price on per capita food expenditure based on the demand equation.

The first stage of the analysis showed about a five percent increase in the food prices in the region where climate change exists according to our specification compared to other regions. The results also emphasized that the sole effects of both precipitation and temperature remain limited, but the combined effect grove apace. In the second stage of the analysis, the DD estimates show a significant climate change impact on household food consumption behavior through price and budget channels. We have shown that the price effect on non-food consumption decreases more in regions where climate change exists than regions with no significant change in climate figures.

Although we aim to reveal the effect of climate change on food prices, there are other factors other than climate change, such as lack of agricultural policies, insufficient irrigation, converting agricultural areas to industrial or residential areas, which apparently can cause production losses and price hikes. Unfortunately, there are few data sets regarding these types of fields. Moreover, production and consumption data cannot be matched due to a lack of detail on the production side. Hence, this prevents us from studying the effects of climate change on production, productivity, irrigation and drives our study to concentrate on the consumption side, which provides richer data sets.

8. Policy Implications

There are still many targets for Turkey to be achieved in adopting and mitigating climate change. Turkey has the advantage of being an emerging country that exhales less carbon emission than advanced countries and has an excellent opportunity to make "green investments" in economic development. Given the low-mid level of per capita income in recent years and secular structural fragilities in the economy, the unique possible drawback against achieving these targets may be financing issues. Therefore, rationalizing environmental tax and expenditure policy, even implementing a rule-based and transparent carbon tax, could help Turkey improve despite economic difficulties. This type of improvement can be gradually carried out in a few years by having the power of social and political consensus over the Paris Agreement.

The remarkable ongoing slowdown in economic activities since 2018, which has stemmed from the sharp depreciation in national currency and the Covid-19 pandemic, has contributed to the GHG mitigation process. However, GHG emission is likely to hike again in a couple of years due to the expected economic recovery relying on the unprecedentedly fast development of vaccines against Covid-19 and the accelerating pace of vaccination in Turkey. Hence, besides the GHG mitigation policies already being implemented, which are beneficial for the entire society, not only for the food market, it is inevitable to design policies aiming at food security and inherently, to restrain the rise in food prices, as an integral part of adaptation to climate change.

Investments in the agricultural sector may preserve agricultural production from the detrimental effects of climate change and mitigate the price pressures. In this sense, extending and improving greenhouse cultivating, which accounts only for 0.2% of total agricultural areas as of 2020 (Turkstat, 2021), maybe one of the main targets. In Turkey, there are some sincere but weak efforts to promote greenhouse cultivating. Although the Turkish government has been providing incentives for greenhouse investments through subsidizing loan interest rates and tax exemptions (Official Gazette, 2019), growing economic difficulties have been forcing agricultural households to shift towards non-agricultural activities in urban areas and causing a drop in the agricultural sector's share in GDP and agricultural lands to shrink. Hence, even as conventional agricultural practices have faced difficulties, financial incentives for greenhouse cultivating have not attracted much attention. Therefore, founding new state-owned enterprises (SOE) in eligible areas may be a much more concrete initiative than subsidizing farmers severally for greenhouse cultivating, and high-end investments of these SOEs for greenhouse cultivating can reduce the dependency of agricultural output on weather conditions and assume a significant role on adopting climate change and awakening public awareness against it.

Alternatively, cultivating new crops resistant to high temperature, drought, and needless inputs and increasing efficiency in water use and fertilizer may improve food security and mitigate the pressure on food prices while providing higher profits to farmers. In particular, unconscious and excessive groundwater use in agricultural areas like Konya province is quite problematic. As of early 2021, there have been more than 600 sinkholes in Konya, which threatens agricultural activities due to groundwater use for irrigation (NTV, 2021). Therefore, investments for surface-water-based irrigation systems and legislation limiting groundwater use seem indispensable for preserving groundwater and agricultural areas.

Last but not least, public service ads may assume an essential role in enhancing public awareness and sensitivity to combating climate change. According to the world values survey, the share of persons in Turkey affiliated with an environmental organization was 1.3% in 2007. This ratio increased to 5.1% in 2018 that points out the increasing public awareness for environmental issues. Although the awareness has been rising, there is still a large room to capture. People may become more sensitive to this issue by public service ads explicitly focusing on the devastating effects of climate change on agricultural activities, food availability, and the sincere efforts of non-profit environmental organizations. Moreover, this may increase the donations for environmental NGOs, which will be an additional financial resource for "green investments."

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Appendix

Table A1. DDD estimates of the relationship between climate change and household food consumption via budget channel

N=152,020	(1)	(2)	(3)	(4)	(5)
Treatment Effect		0.0135***	0.0128***	0.0116***	0.0106***
		(0.0034)	(0.0032)	(0.0032)	(0.0031)
Budget	0.5822***	0.6308***	0.5767***	0.7435***	0.7414***
	(0.0039)	(0.0071)	(0.0076)	(0.0073)	(0.0073)
Constant	7.3372***	6.7254***	5.9027***	5.7828***	6.2537***
	(0.0517)	(0.2445)	(0.2318)	(0.2225)	(0.2218)
R-squared	0.3706	0.4161	0.4674	0.5296	0.5459
Household Controls	N	N	Y	Y	Y
Consumption Controls	N	N	N	Y	Y
Household Head Controls	N	N	N	N	Y

*** p<0.01, ** p<0.05, * p<0.1.

Table A2. DDD estimates of the relationship between climate change and household non-food consumption via budget channel

N=152,020	(1)	(2)	(3)	(4)	(5)
Treatment Effect		-0.0029	-0.0027	-0.0026	-0.0021
		(0.0019)	(0.0019)	(0.0018)	(0.0017)
Budget	1.1790***	1.1520***	1.1532***	1.0813***	1.0809***
	(0.0016)	(0.0038)	(0.0041)	(0.0041)	(0.0040)
Constant	3.6448***	3.6348***	3.7454***	3.8568***	3.7073***
	(0.0250)	(0.1125)	(0.1124)	(0.1088)	(0.1081)
R-squared	0.9258	0.9342	0.9360	0.9434	0.9449
Household Controls	N	N	Y	Y	Y
Consumption Controls	N	N	N	Y	Y
Household Head Controls	N	N	N	N	Y

*** p<0.01, ** p<0.05, * p<0.1.

Table A3. DDD estimates of the relationship between climate change and household food consumption via price channel

N=152,020	(1)	(2)	(3)	(4)	(5)
Treatment Effect		0.0119***	0.0117***	0.0119***	0.0111***
		(0.0038)	(0.0037)	(0.0036)	(0.0035)
Price	-0.1005***	-0.0868	-0.0975	-0.2296**	-0.2398**
	(0.0123)	(0.1207)	(0.1164)	(0.1077)	(0.1061)
Constant	7.3372***	7.4678***	7.4838***	6.2569***	6.4520***
	(0.0517)	(0.5564)	(0.5383)	(0.5003)	(0.4929)
R-squared	0.3706	0.4148	0.4664	0.5291	0.5454
Household Controls	N	N	Y	Y	Y
Consumption Controls	N	N	N	Y	Y
Household Head Controls	N	N	N	N	Y

*** p<0.01, ** p<0.05, * p<0.1.

Table A4. DDD estimates of the relationship between climate change and household non-food consumption via price channel

N=152,020	(1)	(2)	(3)	(4)	(5)
Treatment Effect		-0.0042**	-0.0041**	-0.0048**	-0.0042**
		(0.0021)	(0.0021)	(0.0020)	(0.0019)
Price	-0.8535***	-0.9164***	-0.9149***	-1.0140***	-1.0063***
	(0.0060)	(0.0050)	(0.0048)	(0.0047)	(0.0047)
Constant	3.6448***	6.5834***	6.5884***	7.0976***	7.0120***
	(0.0250)	(0.2822)	(0.2778)	(0.2648)	(0.2634)
R-squared	0.9258	0.9343	0.9361	0.9435	0.9450
Household Controls	N	N	Y	Y	Y
Consumption Controls	N	N	N	Y	Y
Household Head Controls	N	N	N	N	Y

*** p<0.01, ** p<0.05, * p<0.1.