2024

BSP DISCUSSION PAPER

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Jean Christine A. Armas
Ranelle Jasmin L. Asi
Dyan Rose L. Mandap
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Series No. 02

BANGKO SENTRAL NG PILIPINAS

Macroeconomic effects of temperature shocks in the Philippines: Evidence from impulse responses by local projections

Jean Christine A. Armas, Ranelle Jasmin L. Asi, Dyan Rose L. Mandap, and Gabrielle Roanne L. Moral[1]

This version: December 2023

ABSTRACT

This study is the first in the country to quantify the contemporaneous and long-term effects of temperature shocks on output growth and other channels of economic activity as well as on inflation, which are the primary considerations of the Bangko Sentral ng Pilipinas in its assessment of the appropriate monetary policy stance.

We find that, on the average, the short-run marginal impact of a 1-degree Celsius increase in the country's annual mean temperature reduces aggregate output growth by 0.37 percentage point (ppt). This result is robust and consistent even after introducing other model specifications. The decline in output growth is larger at 0.47 ppt when we control for episodes of El Niño Southern Oscillation (ENSO) events vis-à-vis the 0.30 ppt drop in output growth after controlling for the occurrence of floods and storms. On crop production, we find that temperature shocks have negative effect on palay and corn but positive impact on mango production. On sectoral output, the manufacturing and services sectors are negatively affected by an increase in mean temperature, with the magnitude of drop more evident in the manufacturing sector at 1.8 ppt vis-à-vis the 0.7 ppt decrease in the services sector. However, we find that temperature shocks do not significantly affect labor productivity in heat-exposed industries such as construction, transportation, and manufacturing.

Meanwhile, we find that temperature shocks generate inflationary pressures and remain persistent up to 4 years, with a cumulative increase of 0.77 ppt in headline inflation. On a disaggregated level, the inflationary impact of temperature shocks on food prices is deeper in magnitude and long-lasting in period at 0.79 ppt vis-à-vis the effect on non-food prices, which is rather small at 0.31 ppt and transitory up to 2 years only.

JEL classification	:	O13, O44, Q54, Q58
Key words	:	climate change, temperature shocks, economic growth, inflation, climate policy
Corresponding authors	:	Ranelle Jasmin L. Asi (asirl@bsp.gov.ph) Dyan Rose L. Mandap (mandapdl@bsp.gov.ph) Gabrielle Roanne L. Moral (glavina@bsp.gov.ph)

Disclaimer: The views expressed in this discussion paper are those of the authors and do not represent the official positions of the Bangko Sentral ng Pilipinas or the BSP Research Academy.

[1] The authors are economists at the Monetary Policy Research Group (MPRG) of the Department of Economic Research (DER). The authors are grateful to Director Lara Romina E. Ganapin (MPRG) for her helpful comments and suggestions to improve the draft.

I. Introduction

Climate change is undoubtedly one of the pressing and multi-dimensional challenges confronting each country on every continent, with the average global temperature projected to increase by 2.6℃ to 4℃ by the end of this century without urgent actions to curb carbon emissions (IPCC, 2013). Over the last three decades, changes in climate[2] have significantly reduced global agricultural production in the range of 1 to 5 percent per decade (Porter et al., 2014).

While national governments are the primary agent in responding to the call of mitigating climate change, central banks also play an equally important role especially when it comes to managing the impact of climate change on the central banks' ability to deliver on their price and financial stability mandates. Central banks are currently putting forward plans and initiatives to incorporate climate change in their mandates or policy frameworks. For instance, the Bank of England (BOE) incorporated in its mandates climate change-related matters (Faccia et al., 2021) while the European Central Bank (ECB) crafted a detailed action plan to include climate change considerations in its monetary policy framework (ECB, 2021). Likewise, the Network for Greening the Financial System (NGFS)[3] has grown to 121 members[4] since its inception in December 2017 – a testament of central banks' increasing recognition of the important implications of climate change on the delivery of their mandates.

In the Philippines, climate change is estimated to cost the economy approximately P26 billion per year by 2050 based on the study conducted by Dikitanan et al. (2017). Despite the increasing attention and the growing literature on the economic effects of climate change, there is not much empirical evidence on this in the Philippine setting. To the best of the authors' knowledge, this study is the first to quantify the contemporaneous and long-term effects of temperature shocks on output growth and other channels of economic activity as well as on inflation, which are the primary considerations of the Bangko Sentral ng Pilipinas (BSP) in its assessment of the appropriate monetary policy stance. We define temperature shocks in this paper as an increase in the annual mean temperature by 1 degree Celsius.

The specific channels that we investigated through which economic growth is potentially affected by temperature shocks include crop production, livestock, fishing, manufacturing, services, real investment, and labor productivity in heat-exposed industries such as agriculture, fishery, and forestry (AFF), construction (CON), transportation (TRA), manufacturing (MFG), mining (MIN), and utility (UTI)

[2] As defined in Acevedo et al., (2020), climate refers to a distribution of weather outcomes for a given location while weather refers to a realization from that distribution. Climate change typically implies that the whole distribution of weather outcomes changes, with a possible increase in the likelihood of extreme outcomes. While there is no exact timeline on when climate change actually happens, most scientists and researchers argue that extreme weather outcomes are recorded since the pre-industrial periods (1850s-1900s). So, for instance, a 1℃ increase in temperature could be viewed as a realization from the existing possible distribution of weather outcomes. But, with climate change, these high levels of temperature might become the norm and thus, in essence, there is just a slight nuance in the use of weather and climate change terminologies. The weather and climate change terminologies, in this paper, are interchangeably used.

[3] The NGFS is a global association of central banks and supervisory authorities advocating for a more sustainable financial system.

[4] The number of members to Network for Greening the Financial System (NGFS) as of 3 October 2022.

Classification: GENERAL

sectors.[5] To the extent that high levels of temperature affect agricultural production via the supply-side channel, these would also influence the level and volatility of inflation. Hence, we also examined the effect of temperature shocks on headline or Consumer Price Index (CPI), food, and non-food prices.

Using the Local Projections method proposed by Jórda (2005) to trace the impulse responses of output growth and inflation on temperature shocks, we find that on the average, the short-run marginal impact of a 1° Celsius increase in the country's annual mean temperature reduces aggregate output growth by 0.37 ppt. This result is robust and consistent even after introducing other model specifications. The decline in output growth is larger at 0.47 ppt when we control for episodes of El Niño Southern Oscillation (ENSO) events vis-à-vis the 0.30 ppt drop in output growth after controlling for the occurrence of floods and storms.

On crop production, we find that temperature shocks have negative effect on palay and corn but a positive impact on mango production. On sectoral output, the manufacturing and services sectors are negatively affected by an increase in mean temperature, with the magnitude of drop more evident in the manufacturing sector at 1.8 ppt vis-à-vis the 0.7 ppt decrease in the services sector. Meanwhile, we find long-term marginal effect of temperature shocks on output growth when we control for the occurrence of floods/storms, with output growth declining by a cumulative of 1.12 ppt eight (8) years after the shock. This result presents important implications on the significance of government policies pertaining to climate change adaptation (CCA) and disaster risk management (DRM) programs. Likewise, the findings highlight the importance of increased spending and investment on agricultural research and development to reinforce the resiliency and adaptation of agriculture sector to climate change.

In addition, we find that temperature shocks generate inflationary pressures and remain persistent up to four (4) years, with a cumulative increase of 0.77 ppt in headline inflation. On a disaggregated level, the inflationary impact of temperature shocks on food prices is deeper in magnitude and long-lasting in period at 0.79 ppt vis-à-vis the effect on non-food prices, which is rather small at 0.31 ppt and transitory up to two (2) years only. These results underscore the significance of coordinated policy responses from the monetary and fiscal authorities. On the one hand, the inflationary effects of temperature shocks in the short-run are best addressed by the timely implementation of non-monetary policy interventions since monetary policy adjustment typically works with a lag. On the other hand, if inflation remains persistent and evidence of second-round effects materialized, the central bank will respond and adjust its policy interest rates accordingly.

The remainder of the paper is outlined as follows. The historical trends and developments on temperature in the Philippines are presented in Section 2. The empirical literature on the macroeconomic effects of climate change is reviewed in Section 3. The variables and the econometric strategy used in the study are discussed in Section 4. The estimation results for the macroeconomic effects of temperature shocks on output growth and other channels of economic activity, and

[5] Classification of heat-exposed industries based on definitions from National Institute for Occupational Safety and Health (Graff Zivin and Neidell, 2014).

price inflation are analyzed in Section 5. Finally, key takeaways and policy implications are summarized in Section 6.

Historical Trends and Developments on Temperature in the Philippines

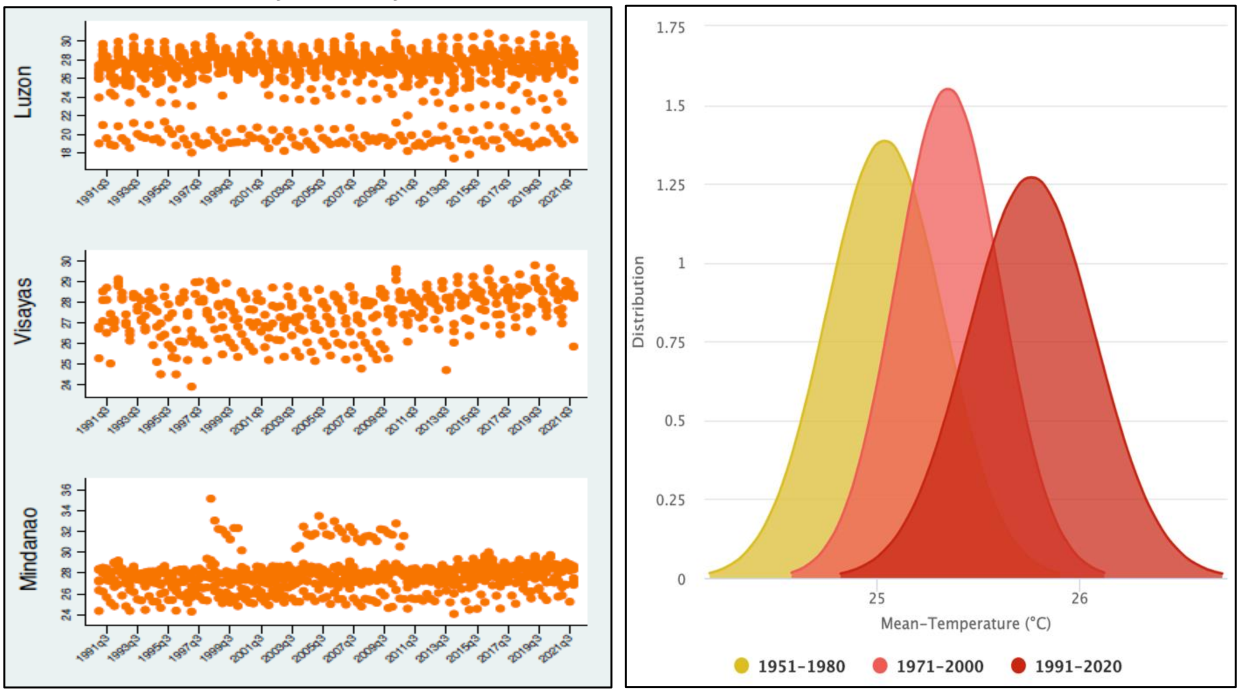
The Philippines is highly vulnerable to natural hazards being archipelagic and having one of the world's longest coastlines with commonly occurring climate-related and natural disaster risks such as floods, droughts, typhoons, landslides, earthquakes, and volcanic eruptions. The country is also characterized by high levels of temperature and heavy rainfall for inherently having a humid equatorial climate. On average, there are twenty (20) tropical cyclones that enter the Philippine Area of Responsibility every year. In 2019, INFORM global risk index ranks the Philippines as the most susceptible country to climate change and natural hazards. Likewise, the 2019 Global Climate Risk Index ranks the country as the fifth most vulnerable to climate change-induced natural calamities. Meanwhile, the 2016 UN Natural Disaster Risk index ranks the Philippines as the third most vulnerable in terms of the country's exposure, vulnerability, susceptibility, as well as lack of coping and adaptive capacities.

The available information on the historical trends of climate conditions such as changes in mean temperature, albeit might be lacking, is important in underpinning our analysis of the rapidly changing climate. Historical observations on the variability of mean temperature across different time horizons serve as one of the policymakers' analytical tools in assessing climate conditions as well as in devising climate change-resilient policy responses.

Figure 1: Historical Trends in the Mean Temperature of the Philippines

Panel A: by Major Island, in degree Celsius (1991Q1 - 2021Q4)

Panel B: Change in Distribution of Mean Temp Over a 30-year Interval Period



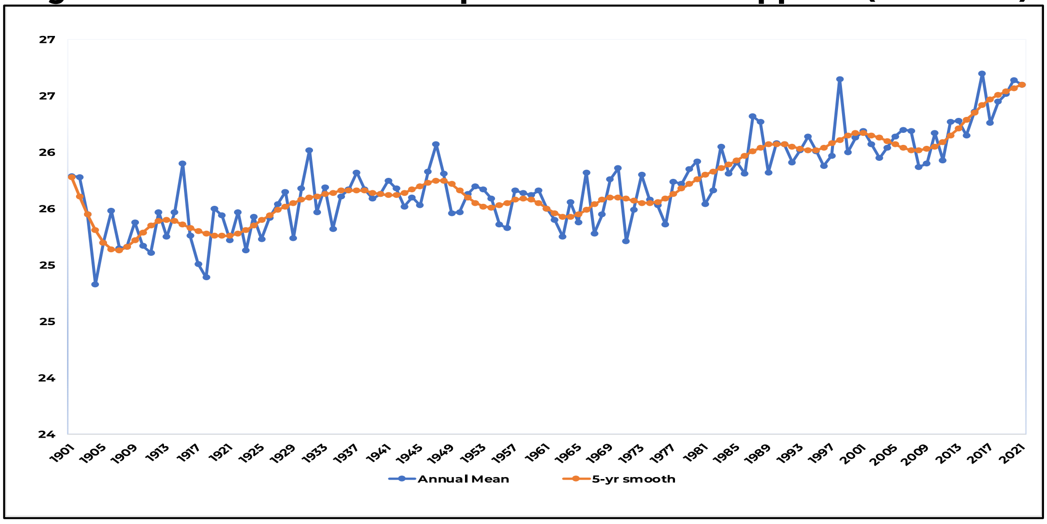
Source: Authors' representation; PAGASA

Source: Climate Knowledge Portal World Bank

The average temperature in the Philippines by major island group – Luzon, Visayas, and Mindanao – is illustrated in Figure 1-Panel A. The mean temperature levels are generally high in the valleys and plains particularly in Luzon and Visayas. According to Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)[6], the hottest months are April and May with an average temperature recorded at 28.3℃ while the coolest months are experienced in December, January, and February. By region, the observed highest and lowest temperature levels are felt in the Bicol Region (Region 5) and Cordillera Administrative Region (CAR), respectively.

Meanwhile, the possible changes or shifts in the distribution of mean temperature in the Philippines to assess whether temperature levels are becoming hotter as the years pass by are presented in Figure 1-Panel B using a 30-year climatology interval period. The mean temperature in the country increased by 0.31℃ from 1951-1980 to 1971-2000 and by 0.41℃ from 1971-2000 to 1991-2020. At the same time, using a longer data series spanning over the last century and two (2) decades, we note that the observed annual mean temperature in the Philippines has risen by 1℃ from 26℃ in 1901 to 27℃ in 2021, indicating a generally warming trend throughout these periods (Figure 2).

Figure 2: Historical Mean Temperature in the Philippines (1901-2021)



Source: Authors' representation; raw data from World Bank Climate Change Knowledge Portal

II. Review of Related Literature

Macroeconomic Effects of Climate Change

In the recent years, there has been an increasing body of empirical literature in estimating the macroeconomic effects of climate change-related risks ranging from weather shocks such as temperature and rainfall to natural disasters such as floods, storms, hurricanes, and droughts. The results of these empirical studies

[6] PAGASA is the government's weather bureau.

generally point to downside risks on economic activity and upward pressures on prices or inflation (Faccia et al., 2021).

On the effect of temperature increases on economic output, the seminal studies of Dell et al. (2012) and Burke et al. (2015) provided evidence on the uneven effects of temperature shocks using a sample of 166 countries, with the brunt of the negative impact borne by low-income economies which are also geographically located in tropical climate regions. The existing literature on climate economics has been centered on quantifying the effect of temperature shocks on aggregate output but, less is known about the channels through which economic growth is affected. The recent study of Acevedo et al. (2020) provided new evidence on the effects of weather shocks on different channels of economic activity. They find that the negative effect of temperature on output in countries with hot climates operates through weaker investment, reduced labor productivity, poorer human health conditions, and lower agricultural and industrial output.

On a micro-level, there are also studies that documented the negative impact of high temperature levels on labor supply and productivity using surveys or experiments as applied in the context of individual countries. Based on an experimental study of night-time ventilative cooling in office buildings,[7] Seppänen et al. (2003) found that productivity or work performance of employees is estimated to decline by an average of 2 percent for every 1℃ increase in temperature above 25℃. On a country-specific basis, there is evidence of reduced workers' productivity and increased absenteeism on hot days in India using a sample of Indian manufacturing firms, resulting to an estimated average decline of 2 percent per degree Celsius (Somanathan et al., 2017). Similar findings were observed in the context of advanced country like the United States where states with relatively warmer climates generate lower output per capita (Deryugina and Hsiang, 2014).[8]

Meanwhile, the effects of temperature on mortality and health outcomes were also studied. For example, Acevedo et al. (2020) showed that a 1℃ increase in temperature raises infant mortality by 0.12 percentage point following the shock, which in turn, reduces future supply of labor. They also noted that this negative effect of temperature shock on infant mortality is magnified by potential food insecurity and weather-related lower income. In Japan, Piver et al. (1999) found that daily maximum temperature and nitrogen dioxide emissions in Tokyo, Japan are linked with increased hospital emergency transport for heat stroke. For a more comprehensive review of the empirical literature on the effect of extreme weather and climate events on human health and mortality in many countries, see Deschênes (2012).

While the existing evidence on the economic effects of climate-related variables on prices or inflation has been less investigated, the following studies provide reference for more future research initiatives on this topic of interest. In a sample of 15 Carribean countries, Heinen et al. (2019) claimed that natural disasters such as floods and hurricane shocks lead to inflationary pressures. Meanwhile, Parker (2018) argued that the impact of natural disasters on inflation is dependent on the type of natural disaster and measure of inflation under studied. Regarding

[7] The night-time ventilative cooling is an energy-efficient method of controlling daytime temperatures.

[8] For instance, the authors find that Northern Minnesota with relatively cooler climate generates an estimated $2,000 more yearly than Southern Texas.

the impact of temperature on inflation, Mukherjee and Ouattara (2020) showed that temperature shocks lead to persistent inflationary pressures based on a sample of developed and developing economies.

In the Philippines, the empirical studies on the impact of climate change on macroeconomic outcomes are still at the early stages. Among these studies include that of Rosegrant et al. (2015), claiming that the effects of climate change are capable of disrupting crop productivity and can stimulate changes in international and local commodity prices that can lead to negative results on the country's agricultural sector output and economy, in general. Findings from the 2020 research implemented by the Frontiers in Marine Science showed that the impact of climate change in Philippine marine capture fisheries is projected to cause a decline in the fisheries GDP. This impact can result to an income reduction for urban and rural households in the Philippines (Suh and Pomeroy, 2020).

Our study aims to contribute to the scant literature on the macroeconomic effects of temperature shocks in the Philippine setting. To the best of our knowledge, we are the first in the Philippines to investigate both the contemporaneous and long-term effects of temperature shocks on the following macroeconomic variables: (a) output growth; (b) other channels of economic activity such as crop production, livestock, fishing, manufacturing, services, real investment, and labor productivity in heat exposed industries; and (c) inflation.

III. Data and Empirical Strategy[9]

In estimating the macroeconomic effects of temperature shocks, we used two (2) sets of data for a panel of 17 regions in the Philippines: (1) annual data over a 21-year period from 2000 to 2021 for the variables on output and other channels of economic activity;[10] and (2) quarterly data from 1994:Q1 to 2021:Q4 for the variables on price indices or inflation.

The time series data on temperature and ENSO events such as El Niño and La Niña are obtained from the PAGASA while information on the occurrence of storms and floods in the country is culled from the Emergency Events International Disaster Database (EM-DAT). Meanwhile, the macroeconomic variables covered in this research are real GDP, sectoral output for manufacturing and services, crop production, livestock, fishing, real investment, labor productivity in heat-exposed industries, headline, food, and non-food inflation.[11] These data are sourced from the Philippine Statistics Authority (PSA). The description of these variables and the summary statistics for the underlying data are presented in Appendices 1 and 2, respectively.

Empirical Strategy

In investigating both the contemporaneous and long-term effects of a 1℃ increase in the annual mean temperature on output growth and other channels of

[9] This section provides details on the variables used, data sources, and the estimation methodologies employed in the study.
[10] The earliest available annual data on regional output and other channels of economic activity is year 2000.
[11] Real GDP per capita and inflation data are based on 2018 prices.

economic activity as well as on different measures of inflation, we adopted the same methodology employed by the IMF (Acevedo et al., 2020) and the ECB (Faccia et al., 2021). We will also use the Local Projections method proposed by Jórda (2005) to trace the impulse response function of the macroeconomic variables under study to temperature shocks.

The Local Projections method is a recent alternative econometric approach to estimating impulse responses since this method is robust to non-linearities in dynamic response and can be estimated by simple regression techniques. The estimation of impulse response functions using local projections has also been widely used as an appealing alternative to the Vector Autoregression (VAR) models since the former does not impose dynamic restrictions that are often associated with the latter. Thus, this approach is more robust when a linear VAR is mis-specified. We then obtain the dynamic impulse responses of our outcomes of interest to a 1℃ increase in the annual mean temperature by estimating the baseline panel regression below:

$$\Delta Y_{i,t+h} = \beta_1^h T_{i,t} + \beta_2^h T_{i,t}^2 + \delta_1^h \rho_1 T_{i,t-1} + \delta_2^h \rho_2 T_{i,t-1}^2 + \gamma_1^h \Delta Y_{i,t-1} + \mu_i^h + \theta_t^h + \varepsilon_{i,t}^h \qquad eq.(1)$$

where $\Delta Y_{i,t+h} = ln\ (Y_{i,t+h}) - ln\ (Y_{i,t-1})$ is the log difference (or approximately, the year-on-year growth rate of our macroeconomic outcomes of interest between horizons $t-1$ and $t+h$. The subscript i pertains to the region while t is the index for time period with annual frequency. The superscript h denotes time horizon (from horizon 1 up to horizon 8, which captures the contemporaneous impact and the effect 8 years after the shock). The region fixed-effects, μ_i^h, control for the time-invariant, region-specific differences such as average growth rates and geographical attributes. Meanwhile, the time or year fixed effects that account for the common effect of annual shocks across the regions are denoted by θ_t^h. The total error term in equation (1) is written as $\varepsilon_{i,t}^h$.

The baseline model specified in equation (1) is purposely parsimonious[12] just like the approach adopted by Acevedo et al., (2020), Kalkuhl and Wenz (2020), and Dell et al. (2012). Thus, to avoid running into the issue of "overcontrol" or "bad controls" bias, the usual variables found in the standard growth regression models are not included in our model specification. However, to the extent that these determinants of growth are region-specific and time-invariant such as institutional quality, educational attainment, among others, these are already incorporated in the fixed effects (μ_i^h and θ_t^h).

The quadratic function in our baseline parametric regression model in equation (1) captures the non-linear relationship between annual mean temperature and real output growth (Burke et al., 2015). Significant estimated coefficients for β_1 and β_2, which should have alternate signs, suggest the existence of transitory or long-run growth impact of temperature shocks (Kalkuhl and Wenz, 2020).

[12] The parsimony principle in statistical models uses few parameters in explaining the predicted impact of selected variables on the outcome of interest.

Using the estimation framework specified in equation (1), the marginal effects of an increase in temperature on the macroeconomic variables under study are analytically given by the equation below:

$$\frac{d[ln\,(Y_{i,t+h}) - ln\,(Y_{i,t-1})]}{d(T_{i,t})} = \beta_1^h + 2\beta_2^h T_{i,t} \qquad eq.(2)$$

Robustness Checks

To ensure the robustness of the model and validate that the empirical results are not conditional on the authors' data and variable selection, we also estimate the impact of temperature shocks on our outcomes of interest using other alternative model specifications.

First, we estimate equation (1) by excluding the lag of GDP growth as explanatory variable to evaluate the consistency of the results. Second, we also control for the occurrence of floods and storms since changes in temperature can influence economic activity through its effects on the incidence of floods and storms. This alternative specification is important considering that the Philippines is an archipelagic country prone to natural disasters such as storms and typhoons. Third, we also control for ENSO episodes as these events tend to change the global atmospheric circulation, which in turn, influences temperature and precipitation.[13]

IV. Analysis of Empirical Results

The first part of this section examines the impact of temperature shocks on output and other channels of economic activity such as the temperature effects on crop production, livestock, fishing, manufacturing, services, real investment, and labor productivity in heat exposed industries. Meanwhile, the second part of this section evaluates whether temperature shocks lead to inflationary pressures.

Impact of Temperature Shocks on Output and Channels of Economic Activity

While there is broad consensus on the negative effects of high temperature levels on economic growth of developing and/or tropical countries, less is known about the specific channels through which economic output growth is affected. In this study, we investigated the broader effects of temperature shocks on economic activity – extending our analysis beyond its impact on aggregate output – to quantify the magnitude of the impact of temperature shocks on cultivation of crops, livestock production and fishing, especially for tropical countries like the Philippines where agriculture sector contributes approximately 12 percent of the country's domestic output from 2000-2021. At the same time, we examined whether temperature shocks affect other channels of economic activity such as manufacturing, services, real investment, and labor productivity in heat-exposed industries.

[13] ENSO events particularly El Niño refers to the warming of oceanic temperatures and thus, contribute to the increase in temperature.

a. Aggregate Output

The results from estimating our baseline model, equation (1), as well as the alternative model specifications mentioned in Section 4.3, are presented in Table 1. It reports the estimated coefficients on the contemporaneous impact of temperature on aggregate output (horizon, h=1).

Table 1: Contemporaneous Impact of Temperature Shocks on Output

	(1) baseline model	(2) exclude lag of GDP	(3) control for floods/storms	(4) control for ENSO events (El Niño/La Niña)
$Temperature$	-7.18** (2.49)	-5.79** (2.01)	-4.82* (2.33)	-5.15** (2.43)
$Temperature^2$	0.13** (0.04)	0.10** (0.04)	0.08* (0.04)	0.09* (0.04)
$Floods/Storms$			-4.59*** (0.40)	
$ENSO\ events$				-1.99*** (0.48)
$No. of\ regions$	17	17	17	17
$No. of\ obs.$	340	357	340	340
R^2	0.01	0.01	0.71	0.02

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level for all model specifications.*

Overall, our results are consistent with the findings of Burke et al. (2015) where the relationship of economic growth and temperature is non-linear for all countries. The findings of our study support the widely-held view on the negative effect of temperature on output in countries with hot weather. Likewise, the significant coefficients for $temperature\ (\beta_1)$ and $temperature^2\ (\beta_2)$ confirm the existence of transitory growth effects of temperature as specified in the climate-growth conceptual framework of Kalkuhl and Wenz (2020).

In the Philippine setting, the quadratic functional form of our baseline model takes a "U-shape" curve instead of the usual parabolic curve – that is, $temperature\ (\beta_1)$ is negative and $temperature^2\ (\beta_2)$ is positive. The results satisfy the condition of estimating a quadratic form where coefficients on the level and squared terms should have opposite signs to prevent generating explosive path estimates.

We attribute the "U-shape" curve effect to our sample observations where about 86 percent of the sample observations covered in the study has annual average temperature levels of 26℃, with the highest mean temperature recorded at 32℃ for the past 22 years. Considering that climate in the Philippines is generally characterized by high temperature and humidity, the resulting "U-shape" curve in our study is justified. At the same time, since majority of the sample in the study has relatively high mean temperature levels, the impact on output growth beyond the estimated break-even point of 29℃ does not significantly matter and is no longer economically meaningful.

Thus, when using quadratic functions in applied economic research, it is more useful in analysis to interpret the estimated coefficients of the partial or marginal effect of temperature shocks using equation (2). Table 2 presents the estimated coefficients on the short-term (h=1) marginal effect on output of a 1℃ increase in temperature estimated at the average temperature of each island group and region. The table below also shows the results for estimating the baseline model and alternative model specifications.

Table 2: Short-term Marginal Effect of Temperature Shocks on Output, by Major Island Group and Region

	(1) baseline model	(2) exclude lag of GDP	(3) control for floods/storms	(4) control for ENSO events (El Niño/ La Niña)
Philippines	-0.37**	-0.16	-0.30*	-0.47**
	(0.13)	(0.14)	(0.17)	(0.18)
Panel A: By Major Island Group (at h = 1)				
Luzon	-0.47***	-0.25	-0.37*	-0.54**
	(0.15)	(0.16)	(0.19)	(0.21)
Visayas	-0.21*	-0.03*	-0.18	-0.36**
	(0.12)	(0.13)	(0.13)	(0.14)
Mindanao	-0.16	0.01	-0.16	-0.32**
	(0.12)	(0.12)	(0.12)	(0.13)
Panel B: By Region (at h = 1)				
Ilocos	-0.19	-0.02	-0.18	-0.35**
	(0.12)	(0.13)	(0.13)	(0.14)
Cagayan Valley	-0.56***	-0.34*	-0.43*	0.60**
	(0.17)	(0.18)	(0.22)	(0.23)
Central Luzon	-0.24*	-0.06	-0.21	-0.38**
	(0.12)	(0.12)	(0.14)	0.14
CALABARZON	-0.14	0.01	-0.15	-0.31**
	(0.12)	(0.12)	(0.12)	(0.13)
MIMAROPA	-0.21*	-0.03	-0.19	-0.36**
	(0.12)	(0.13)	(0.13)	(0.14)
Bicol	-0.20	-0.02	-0.18	-0.35**
	(0.12)	(0.13)	(0.13)	(0.14)
CAR	-2.26***	-1.73**	-1.55*	-1.77**
	(0.75)	(0.62)	(0.74)	(0.78)
NCR	0.02	0.16	-0.04	-0.20*
	(0.14)	(0.13)	(0.11)	(0.11)
West Visayas	-0.30**	-0.10	-0.25	-0.42**
	(0.12)	(0.13)	(0.15)	(0.16)
Central Visayas	-0.12	0.04	-0.13	-0.30**
	(0.12)	(0.12)	(0.12)	(0.12)
East Visayas	0.21*	-0.03	-0.19	-0.36**
	(0.12)	(0.13)	(0.13)	(0.14)
Zamboanga	-0.06	0.09	-0.09	-0.26**
	(0.13)	(0.13)	(0.11)	(0.12)
Northern Mindanao	-0.66***	-0.41*	-0.13	-0.67**
	(0.20)	(0.20)	(0.12)	(0.26)
Davao	-0.03	0.12	-0.07	-0.23*
	(0.13)	(0.13)	(0.11)	(0.11)

	(1) baseline model	(2) exclude lag of GDP	(3) control for floods/storms	(4) control for ENSO events (El Niño/ La Niña)
SOCCSKSARGEN	-0.15 (0.12)	0.02 (0.12)	-0.15 (0.12)	-0.32** (0.13)
CARAGA	-0.13 (0.12)	0.03 (0.12)	-0.14 (0.12)	-0.30** (0.13)
BARMM	-0.13 (0.12)	0.03 (0.12)	-0.14 (0.12)	-0.31** (0.13)
No. of obs.	340	357	340	340
R^2	0.01	0.01	0.71	0.02

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level for all model specifications.*

From Table 2, we see that on an aggregate level, a temperature increase lowers output growth by 0.37 ppt using the baseline model (1). The magnitude of the negative impact of temperature increase on aggregate output growth is larger when we control for ENSO events at 0.47 ppt as compared when we control for the occurrence of floods/storms at 0.30 ppt.

By major island group, the magnitude of the effect of a 1℃ increase in the mean temperature varies from a range of -0.16 ppt to -0.47 ppt (Table 2). However, the negative effect of temperature shocks on output growth of Mindanao is statistically insignificant. But, if we control for ENSO events, the negative effect is highly significant across major island groups.

By region, we observe similar results in the baseline model as well as in the specifications controlling for storms/floods and ENSO events. We observe the adverse impact of temperature shocks to regions in Luzon particularly those that are major producers of agricultural commodities such as Cagayan Valley, Central Luzon, MIMAROPA, and Cordillera regions. Meanwhile, comparable results were derived in the Visayas and Mindanao regions and we find that temperature increase lowers output growth particularly in the Western and Eastern parts of Visayas and Northern Mindanao. We also note that with temperature levels exacerbated by ENSO events, the decline in output is observed across all provinces in Visayas and Mindanao.

Table 3: Long-term (Cumulative) Marginal Effect of Temperature Shocks on Output, by Major Island Group and Region

	(1) baseline model	(2) exclude lag of GDP	(3) control for floods/storms	(4) control for ENSO events (El Niño/ La Niña)
Philippines	-1.07 (0.66)	-0.21 (0.44)	-1.12** (0.44)	-0.58 (0.55)
Panel A: By Major Island Group (at h = 8)				
Luzon	-1.23 (0.74)	-0.25 (0.49)	-1.40** (0.51)	-0.73 (0.64)

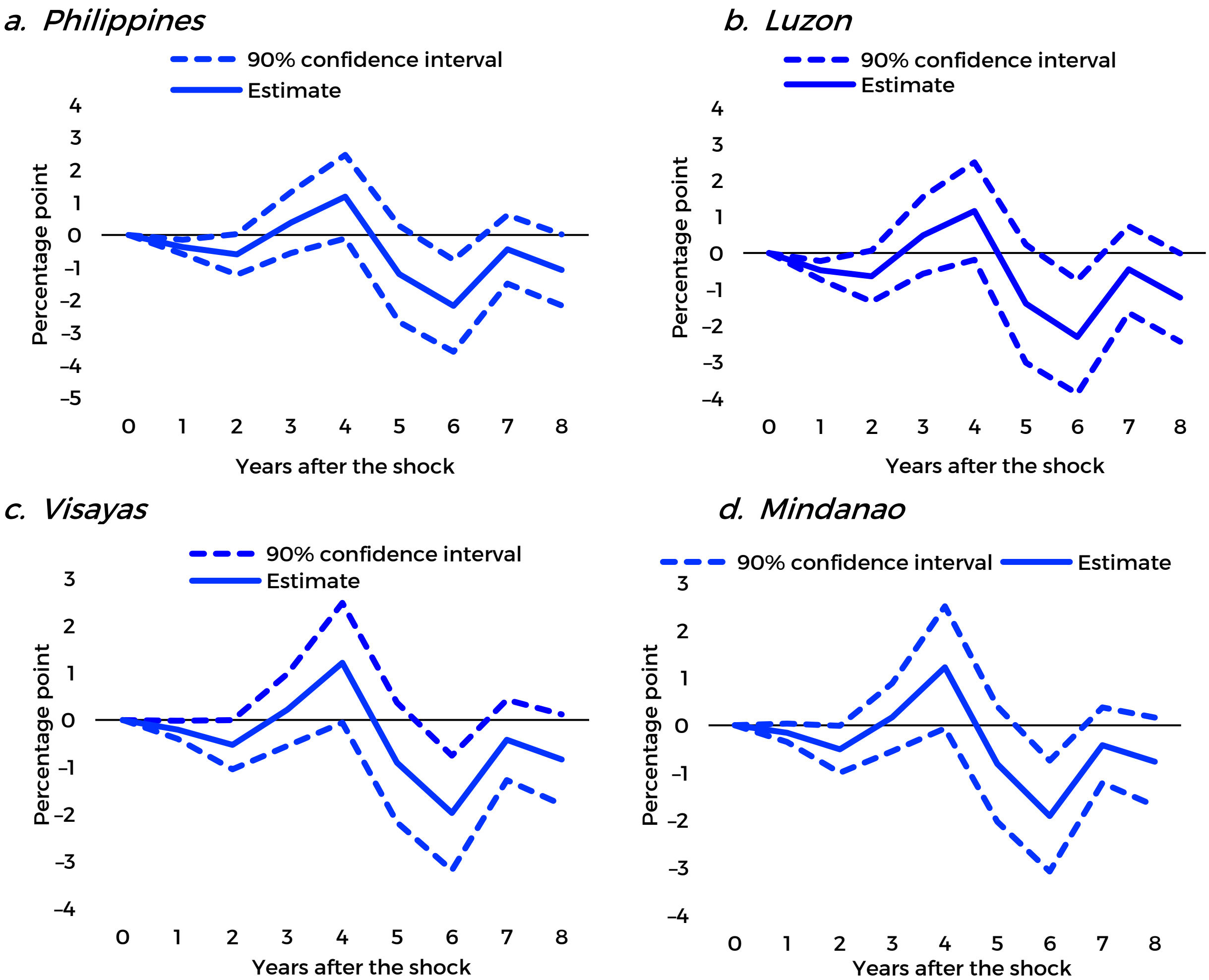
	(1) baseline model	(2) exclude lag of GDP	(3) control for floods/storms	(4) control for ENSO events (El Niño/ La Niña)
Visayas	-0.84 (0.58)	-0.14 (0.41)	-0.71* (0.34)	-0.36 (0.42)
Mindanao	-0.77 (0.56)	-0.12 (0.41)	-0.58* (0.31)	-0.30 (0.38)
Panel B: By Region (at h = 8)				
Ilocos	-0.82 (0.58)	-0.13 (0.41)	-0.67* (0.33)	-0.34 (0.41)
Cagayan Valley	-1.36 (0.81)	-0.28 (0.55)	-1.63** (0.56)	-0.85 (0.71)
Central Luzon	-0.89 (0.60)	-0.15 (0.41)	-0.80** (0.36)	-0.41 (0.45)
CALABARZON	-0.75 (0.56)	-0.11 (0.42)	-0.55* (0.31)	-0.28 (0.37)
MIMAROPA	-0.84 (0.58)	-0.14 (0.41)	-0.71* (0.34)	-0.37 (0.42)
Bicol	-0.83 (0.58)	-0.14 (0.41)	-0.69* (0.34)	-0.35 (0.41)
CAR	-3.84 (2.58)	-0.98 (2.17)	-6.03*** (1.66)	-3.18 (2.16)
NCR	-0.51 (0.55)	-0.04 (0.48)	-0.12 (0.22)	-0.05 (0.25)
West Visayas	-0.97 (0.62)	-0.17 (0.42)	-0.93** (0.39)	-0.48 (0.49)
Central Visayas	-0.71 (0.56)	-0.10 (0.42)	-0.48 (0.29)	-0.24 (0.35)
East Visayas	-0.84 (0.58)	-0.14 (0.41)	-0.72* (0.34)	-0.37 (0.42)
Zamboanga	-0.63 (0.55)	-0.08 (0.44)	-0.33 (0.26)	-0.16 (0.31)
Northern Mindanao	-1.50 (0.90)	-0.33 (0.62)	-1.89*** (0.62)	-0.99 (0.80)
Davao	-0.57 (0.55)	-0.06 (0.45)	-0.24 (0.24)	-0.11 (0.28)
SOCCSKSARGEN	-0.75 (0.56)	-0.11 (0.42)	-0.55* (0.31)	-0.28 (0.37)
CARAGA	-0.72 (0.56)	-0.11 (0.42)	-0.50 (0.30)	-0.25 (0.36)
BARMM	-0.73 (0.56)	-0.11 (0.42)	-0.51 (0.30)	-0.26 (0.36)
No. of obs.	340	357	340	340
R^2	0.09	0.01	0.10	0.15

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level for all model specifications.*

Using the baseline model, we do not observe a long-term significant effect of temperature shocks on output growth. However, if we control for the occurrence of floods/storms, domestic output growth declines by a cumulative 1.12 ppt eight (8) years after the shock (Table 3). The results present important implications on the significance of government policies pertaining to climate change adaptation (CCA) and disaster risk management (DRM) alongside the long-term agricultural productivity-enhancing programs. Likewise, the findings highlight the importance of increased spending and investment on agricultural research and development to reinforce the resiliency and adaptation of agriculture sector to climate change.

The Philippines has already established institutional structures and policy frameworks for DRM and CCA with initiatives to develop data and information, and available financial instruments that aim to strengthen its resilience to climate-related disasters. However, despite the high-level conceptual convergence on CCA and DRM policies and institutional arrangements, the progress of implementation has been slow in many areas due to parallel strategies, action plans, tools, and reporting mechanisms, compounded by capacity gaps at the local government level (OECD, 2020). Thus, it is crucial to strengthen the institutional, technical, and financial capacity of concerned groups to develop CCA and DRM plans for its effective implementation given the potential impact of climate-related risks to output growth.

Figure 3: Impulse Response of Output to Temperature Shocks Over Time By Major Island Group



Source: Authors' estimates

Figure 3 presents the impulse response of output to temperature shocks over time. We find that across major island group, the contemporaneous effect of temperature shocks on output is negative using our baseline model. We note that starting year 2, the impulse response function is no longer statistically significant, which implies that the impact of temperature shocks on output is only transitory (i.e., significant at year 1). Our findings support the study conducted by the Asian Development Bank (ADB), which notes that there are several coping measures that the government can do to address the impact of rising temperature on output such as food importation, provision of emergency funds to farmers, among others. Thus, we expect the transitory effect of temperature shocks on output.

The results are also true for the 17 regions[14] of the Philippines, confirming the existence of transitory growth effects of temperature as specified in the climate-growth conceptual framework of Kalkuhl and Wenz (2020).

b. Crop Production, Livestock, and Fishing

Crop production is one of the most important channels through which temperature impacts overall economic growth. In the Philippines, the contribution of agriculture sector to total economic output is significant at about 12 percent from 2000-2021. At the same time, the latest results from the November 2022 Labor Force Survey (LFS) show that about 23 percent of the economically active population is employed in the agriculture sector. The combination of these structural characteristics of agriculture sector, alongside its vulnerability to climate-induced catastrophes, makes building a climate-resilient agriculture in the country extra challenging.

Thus, we looked at the marginal effects of temperature shocks on the country's top five (5) agricultural crops: palay, corn, coconut including copra, banana, and mango. We also examined the effect of a 1℃ increase in annual mean temperatures of the major island groups and regions on livestock and poultry as well as on fishing industry (Table 4).

Table 4: Short-term Marginal Effect of Temperature Shocks on Crop Production, Livestock and Poultry, and Fishing, by Major Island Group and Region

	(1) Palay	(2) Corn	(3) Coconut	(4) Banana	(5) Mango	(6) Livestock	(7) Fishing
Philippines	-1.83*	-3.51**	-0.26	-1.65	3.70***	0.85	0.61
	(0.92)	(1.24)	(0.81)	(1.08)	(0.83)	(0.89)	(1.07)
Panel A: By Major Island Group							
Luzon	-2.05**	-4.02***	-0.46	-2.04	3.92***	0.73	0.46
	(0.95)	(1.23)	(0.92)	(1.22)	(0.87)	(1.02)	(1.19)
Visayas	-1.50	-2.72*	0.05	-1.05	3.37***	1.04	0.84
	(0.98)	(1.35)	(0.71)	(0.96)	(0.76)	(0.71)	(0.93)
Mindanao	-1.40	-2.50*	0.14	-0.88	3.27***	1.10	0.91
	(1.02)	(1.40)	(0.70)	(0.95)	(0.74)	(0.65)	(0.91)

[14] The impulse response of output on temperature shocks over time, by region is available upon request from the authors.

	(1) Palay	(2) Corn	(3) Coconut	(4) Banana	(5) Mango	(6) Livestock	(7) Fishing
Panel B: By Region							
Ilocos	-1.47 (0.99)	-2.65* (1.36)	0.08 (0.70)	-0.99 (0.95)	3.34*** (0.75)	1.06 (0.69)	0.86 (0.92)
Cagayan Valley	-2.24** (1.02)	-4.47*** (1.27)	-0.64 (1.03)	-2.38* (1.35)	4.10*** (0.91)	0.63 (1.13)	0.33 (1.31)
Central Luzon	-1.58 (0.96)	-2.91** (1.31)	-0.02 (0.73)	-1.19 (0.98)	3.44*** (0.77)	1.00 (0.75)	0.88 (0.96)
CALABARZON	-1.37 (1.03)	-2.43 (1.41)	0.17 (0.70)	-0.83 (0.94)	3.25*** (0.74)	1.11 (0.64)	0.93 (0.90)
MIMAROPA	-1.50 (0.98)	-2.74* (1.34)	0.05 (0.71)	-1.06 (0.96)	3.37*** (0.76)	1.04 (0.71)	0.84 (0.93)
Bicol	-1.48 (0.99)	-2.69* (1.35)	0.07 (0.71)	-1.03 (0.96)	3.35*** (0.76)	1.05 (0.70)	0.85 (0.93)
CAR	-5.74 (4.12)	-12.71** (4.52)	-3.92 (3.72)	-8.64* (4.86)	7.57*** (1.81)	-1.35 (3.34)	-2.07 (4.22)
NCR	-1.03 (1.23)	-1.62 (1.64)	0.49 (0.73)	-0.22 (1.00)	2.91*** (0.68)	1.31** (0.49)	1.16 (0.89)
West Visayas	-1.68* (0.93)	-3.15** (1.28)	-0.12 (0.76)	-1.38 (1.01)	3.55*** (0.80)	0.94 (0.81)	0.72 (1.00)
Central Visayas	-1.32 (1.06)	-2.30 (1.44)	0.22 (0.69)	-0.73 (0.94)	3.19*** (0.73)	1.14* (0.61)	0.97 (0.89)
East Visayas	-1.51 (0.98)	-2.75* (1.34)	0.04 (0.71)	-1.07 (0.96)	3.38*** (0.76)	1.04 (0.71)	0.84 (0.94)
Zamboanga	-1.20 (1.12)	-2.03 (1.52)	0.33 (0.70)	-0.52 (0.96)	3.08*** (0.71)	1.21** (0.56)	1.05 (0.88)
Northern Mindanao	-2.44** (1.12)	-4.94*** (1.34)	-0.83 (1.16)	-2.74* (1.52)	4.30*** (0.96)	0.51 (1.26)	0.19 (1.46)
Davao	-1.12 (1.16)	-1.84 (1.57)	0.40 (0.71)	-0.38 (0.97)	3.00*** (0.69)	1.25** (0.52)	1.10 (0.88)
SOCCSKSARGEN	-1.37 (1.03)	-2.43 (1.41)	0.17 (0.70)	-0.83 (0.94)	3.25*** (0.74)	1.11 (0.64)	0.93 (0.90)
CARAGA	-1.34 (1.05)	-2.35 (1.43)	0.20 (0.70)	-0.77 (0.94)	3.21*** (0.73)	1.13* (0.62)	0.95 (0.90)
BARMM	-1.34 (1.04)	-2.36 (1.43)	0.20 (0.69)	-0.78 (0.94)	3.21*** (0.73)	1.13* (0.62)	0.95 (0.90)
No. of obs.	340	340	340	340	340	340	340
R^2	0.03	0.06	0.01	0.08	0.03	0.02	0.08

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

For palay and corn, the impact of 1℃ increase in annual mean temperature is negative at -1.83 ppt and -3.51 ppt, respectively. However, for mango production, results showed positive effect as mangoes prefer climate conditions with warm temperatures and light amount of rainfall especially during fruit development stage.

The results indicated that the impact of temperature shocks on output of the fisheries sector is insignificant in the aggregate level, as well as per island group and by region. This may be partly attributed to adaptation strategies developed by the

Bureau of Fisheries and Aquatic Resources (BFAR). These adaptation programs and the National Action Plan of BFAR in response to the effects of changing environment include: i) vulnerability assessment and establishment of rapid alert systems; ii) diversification of livelihoods - mariculture parks (fish cages for livelihood), expansion of aquaculture production areas targeting abandoned or unproductive fish farms, iii) formulation and implementation of High Value Fish Species Development Plan; and iv) conduct of more research and development (Santos, et. al. 2011).

Meanwhile, we find that the temperature shock has no long-term significant effect on crop production, livestock, and fisheries sectors. While statistical inference is invalid, we may possibly infer that the insignificant results on long-term effects of temperature shocks on crop production, livestock, and fisheries sectors lend credence to the relative effectiveness of the National Government's timely non-monetary policy measures to respond to temperature shocks-induced supply-side constraints. Based on the study conducted by the Asian Development Bank (ADB), there are several coping measures that the government can do to address the impact of rising temperature on output, hence, we expect the transitory effect of temperature shocks on output. In essence, the impact of climate change (e.g., temperature increase, higher precipitation, sea level rise, and natural disasters) that lead to ecological consequences on factors of production and output can be addressed by several coping measures. Such measures include the government's ability to raise emergency funds, agricultural insurance, and governance readiness including implementation of relevant policies and programs (Lee et al., 2016).

c. Manufacturing and Services

Estimating our baseline model in equation (1) but with the real value added in manufacturing and services sectors as the outcome variables, we find that both sectors are negatively and contemporaneously affected by a 1°C increase in annual mean temperature. We also show that the magnitude of drop is more evident in the real value added of manufacturing sector at 1.8 ppt vis-à-vis the 0.7 ppt decrease in the services sector output (Table 5).

Our results on the manufacturing sector are consistent with the 2020 IMF study where manufacturing output falls as temperature rises in countries with hot climates such as the Philippines. One possible, non-mutually exclusive justification for this finding could be due to labor productivity losses especially in heat-exposed manufacturing industries or factories with no air conditioning units (Dell et al., 2012).

Table 5: Marginal Effect of Temperature Shocks on Sectoral Output, by Island and Region

	Short-term		***Long-term***	
	Manufacturing	Services	Manufacturing	Services
Philippines	-1.76** (0.80)	-0.67** (0.30)	-6.70*** (1.55)	-1.03 (0.88)
Panel A: By Major Island Group				
Luzon	-1.97** (0.88)	-0.76** (0.35)	-7.83*** (1.77)	-1.10 (0.99)
Visayas	-1.44* (0.69)	-0.54** (0.24)	-4.97*** (1.22)	-0.92 (0.75)

	Short-term		Long-term	
	Manufacturing	Services	Manufacturing	Services
Mindanao	-1.35* (0.67)	-0.50** (0.22)	-4.46*** (1.12)	-0.88 (0.71)
Panel B: By Region				
Ilocos	-1.41* (0.68)	-0.53** (0.23)	-4.81*** (1.18)	-0.91 (0.73)
Cagayan Valley	-2.15** (0.96)	-0.82** (0.39)	-8.81*** (1.96)	-1.16 (1.08)
Central Luzon	-1.52** (0.72)	-0.57** (0.25)	-5.38*** (1.29)	-0.94 (0.77)
CALABARZON	-1.32* (0.66)	-0.49** (0.22)	-4.33*** (1.09)	-0.88 (0.70)
MIMAROPA	-1.45* (0.69)	-0.54** (0.24)	-5.00*** (1.22)	-0.92 (0.75)
Bicol	-1.43* (0.69)	-0.53** (0.24)	-4.89*** (1.20)	-0.91 (0.74)
CAR	-5.50* (2.73)	-2.20* (1.22)	-26.97*** (5.56)	-2.32 (3.15)
NCR	-1.00 (0.60)	-0.36* (0.18)	-2.54*** (0.77)	-0.76 (0.62)
West Visayas	-1.62** (0.75)	-0.61** (0.27)	-5.92*** (1.40)	-0.98 (0.82)
Central Visayas	-1.27* (0.64)	-0.47** (0.21)	-4.03*** (1.04)	-0.86 (0.68)
East Visayas	-1.45* (0.70)	-0.54** (0.24)	-5.03*** (1.23)	-0.92 (0.75)
Zamboanga	-1.16* (0.63)	-0.42** (0.19)	-3.43*** (0.93)	-0.82 (0.65)
Northern Mindanao	-2.35** (1.05)	-0.91* (0.44)	-9.86*** (2.16)	-1.23 (1.19)
Davao	-1.09* (0.61)	-0.39** (0.18)	-3.03*** (0.85)	-0.79 (0.64)
SOCCSKSARGEN	-1.32* (0.66)	-0.49** (0.22)	-4.33*** (1.09)	-0.88 (0.70)
CARAGA	-1.29* (0.65)	-0.48** (0.21)	-4.13*** (1.06)	-0.86 (0.69)
BARMM	-1.30* (0.65)	-0.48** (0.21)	-4.16*** (1.06)	-0.87 (0.69)
No. of obs.	340	221	340	221
R^2	0.05	0.11	0.01	0.05

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

d. Real Investment

One of the channels of economic activity through which the impact of temperature shocks is least investigated is the real or fixed investment. Fankhauser and Tol (2005) noted that lower output due to weather shocks, which translates to fewer resources to be used for investment, could lead to reduced investment and eventually lower production in the future via the capital accumulation effect. Real investment responds negatively to temperature increases because households tend to sell their productive or real assets to smoothen their consumption as a response mechanism to weather shocks.

While our empirical results broadly support the direction of the impact of temperature shock on real investment, we find no statistical significance on an aggregate level and across major island groups as well as regions (Table 6). Though inference is invalid since it is statistically insignificant, the results could possibly imply that the most vulnerable sectors to weather shocks are poor or low-income households who, in the first place, do not possess or own real assets or investments that can either be sold or used as a collateral to obtain money for the purpose of smoothing their consumption.

Table 6: Marginal Effect of Temperature Shocks on Real Investment, by Island and Region

	Short-term	***Long-term***
Philippines	-1.47 (2.56)	0.33 (2.90)
Panel A: By Major Island Group		
Luzon	-1.86 (2.83)	0.04 (3.14)
Visayas	-0.87 (2.22)	0.76 (2.54)
Mindanao	-0.70 (2.15)	0.89 (2.44)
Panel B: By Region		
Ilocos	-0.82 (2.20)	0.81 (2.50)
Cagayan Valley	-2.20 (3.09)	-0.20 (3.36)
Central Luzon	-1.02 (2.29)	0.66 (2.62)
CALABARZON	-0.66 (2.13)	0.93 (2.41)
MIMAROPA	-0.89 (2.23)	0.76 (2.54)
Bicol	-0.85 (2.21)	0.79 (2.52)
CAR	-8.44 (9.03)	-4.79 (7.75)
NCR	-0.04 (1.98)	1.38 (2.08)
West Visayas	-1.20 (2.39)	0.53 (2.73)
Central Visayas	-0.55 (2.09)	1.00 (2.35)
East Visayas	-0.90 (2.23)	0.75 (2.55)
Zamboanga	-0.35 (2.03)	1.15 (2.24)
Northern Mindanao	-2.56 (3.39)	-0.47 (3.60)

	Short-term	***Long-term***
Davao	-0.21 (2.00)	1.26 (2.17)
SOCCSKSARGEN	-0.66 (2.13)	0.93 (2.41)
CARAGA	-0.59 (2.10)	0.98 (2.37)
BARMM	-0.60 (2.11)	0.97 (2.38)
No. of obs.	340	221
R^2	0.04	0.06

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

e. Labor Productivity

If labor productivity is one of the channels through which an increase in temperature levels affect aggregate output growth, the impact is expected to be considerably large for workers employed in heat-exposed sectors or in industries with poor air conditioning environment. In this case, we test the potential impact of temperature shocks on productivity of laborers by regressing labor productivity in heat-exposed industries on a 1℃ increase in annual mean temperature.

The results for the short-term marginal effect of temperature shocks on labor productivity in heat-exposed industries under study are presented in Table 7 below. Although the estimated coefficients show insignificant results, the direction of the sign is generally as expected especially on labor productivity in heat-exposed industries such as construction, transportation, and manufacturing. The results possibly imply that workers in the construction and transportation sectors are already used to the weather conditions in the country. Likewise, in the transportation sector, jeepney and taxi drivers operate on a quota- and boundary-based system such that regardless of the weather conditions, they still need to work to either meet their daily quota or earn back their "boundary fees". Meanwhile, poor condition of equipment and tools, lack of adequate supervision or management, health and safety issues generally contribute to low labor productivity in the Philippines (Quezon & Ibanez, 2021). Similar results were also obtained for the long-term marginal impact of temperature shocks on labor productivity in heat-exposed industries, by major island groups and by regions.

Table 7: Short-term Marginal Effect of Temperature Shocks on Labor Productivity in Heat-Exposed Industries, by Major Island Group and Region

	(1) AFF	(2) CON	(3) TRA	(4) MFG	(5) MIN	(6) UTI
Philippines	0.15 (0.80)	-0.72 (1.11)	-1.45 (1.17)	-0.64 (0.50)	4.36 (2.70)	0.46 (1.73)
Panel A: By Major Island Group						
Luzon	0.08 (0.91)	-0.61 (1.28)	-1.60 (1.35)	-0.69 (0.57)	4.86 (3.09)	0.73 (1.97)
Visayas	0.24 (0.64)	-0.90 (0.93)	-1.23 (0.92)	-0.56 (0.41)	3.59 (2.13)	0.06 (1.38)
Mindanao	0.27 (0.59)	-0.95 (0.90)	-1.16 (0.85)	-0.53 (0.38)	3.36 (1.97)	-0.06 (1.29)

	(1) AFF	(2) CON	(3) TRA	(4) MFG	(5) MIN	(6) UTI
Panel B: By Region						
Ilocos	0.25 (0.62)	-0.91 (0.92)	-1.21 (0.90)	-0.55 (0.40)	3.52 (2.08)	0.02 (1.35)
Cagayan Valley	0.03 (1.00)	-0.51 (1.45)	-1.73 (1.49)	-0.74 (0.64)	5.29 (3.43)	0.95 (2.18)
Central Luzon	0.22 (0.67)	-0.86 (0.96)	-1.28 (0.98)	-0.58 (0.43)	3.77 (2.26)	0.16 (1.46)
CALABARZON	0.28 (0.58)	-0.96 (0.90)	-1.14 (0.83)	-0.53 (0.38)	3.30 (1.93)	-0.09 (1.26)
MIMAROPA	0.24 (0.64)	-0.90 (0.93)	-1.23 (0.93)	-0.56 (0.41)	3.60 (2.14)	0.07 (1.39)
Bicol	0.25 (0.63)	-0.91 (0.92)	-1.22 (0.91)	-0.55 (0.40)	3.56 (2.11)	0.04 (1.37)
CAR	-0.96 (2.82)	1.34 (5.37)	-4.10 (4.36)	-1.58 (2.04)	13.38 (10.13)	5.17 (6.23)
NCR	0.37 (0.43)	-1.14 (0.93)	-0.91 (0.60)	-0.44 (0.33)	2.51 (1.45)	-0.50 (0.96)
West Visayas	0.19 (0.72)	-0.80 (1.01)	-1.35 (1.06)	-0.60 (0.46)	4.01 (2.08)	0.28 (1.57)
Central Visayas	0.29 (0.55)	-0.99 (0.89)	-1.10 (0.79)	-0.51 (0.37)	3.17 (1.84)	-0.16 (1.21)
East Visayas	0.24 (0.64)	-0.89 (0.93)	-1.23 (0.93)	-0.56 (0.41)	3.62 (2.15)	0.07 (1.39)
Zamboanga	0.32 (0.50)	-1.05 (0.89)	-1.03 (0.71)	-0.49 (0.35)	2.91 (1.68)	-0.30 (1.10)
Northern Mindana	-0.03 (1.10)	-0.40 (1.65)	-1.86 (1.66)	-0.78 (0.71)	5.77 (3.81)	1.20 (2.40)
Davao	0.35 (0.46)	-1.10 (0.90)	-0.97 (0.66)	-0.47 (0.34)	2.72 (1.57)	-0.39 (1.03)
SOCCSKSARGEN	0.28 (0.58)	-0.96 (0.90)	-1.14 (0.83)	-0.53 (0.38)	3.30 (1.93)	-0.09 (1.26)
CARAGA	0.29 (0.56)	-0.98 (0.89)	-1.12 (0.81)	-0.52 (0.37)	3.22 (1.88)	-0.13 (1.23)
BARMM	0.28 (0.56)	-0.98 (0.89)	-1.21 (0.81)	-0.52 (0.37)	3.23 (1.88)	-0.13 (1.23)
No. of obs.	340	340	340	340	340	340
R^2	0.14	0.08	0.04	0.15	0.01	0.11

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

Impact of Temperature Shocks on Consumer Prices

For a geographically diverse country like the Philippines, analyzing the implications of temperature shocks on inflation on a regional level is essential from a monetary policy standpoint. For one, the geographical characteristics of these regions such as topography, natural endowments, meteorological diversity, among other things might influence the differences and dynamics in regional inflation. Mapa et al. (2008) noted that food prices are affected by geography wherein regions closer to sources of food benefit from relatively cheaper prices. Likewise, regions that are hit harder by extreme weather events experience volatile prices more than other regions amid frequent supply disruptions.

In this paper, we estimated the same model specifications specified in equation (1), except that the outcome of interest is the headline inflation or CPI. We also tested the robustness of our results by using other consumer price indicators such as food and non-food. Overall, we find a statistically significant and an economically intuitive impact of higher temperatures on headline, food, and non-food inflation. The details on the magnitude of the inflationary effect of temperature shocks on the three measures of consumer prices are discussed in the following sub-sections.

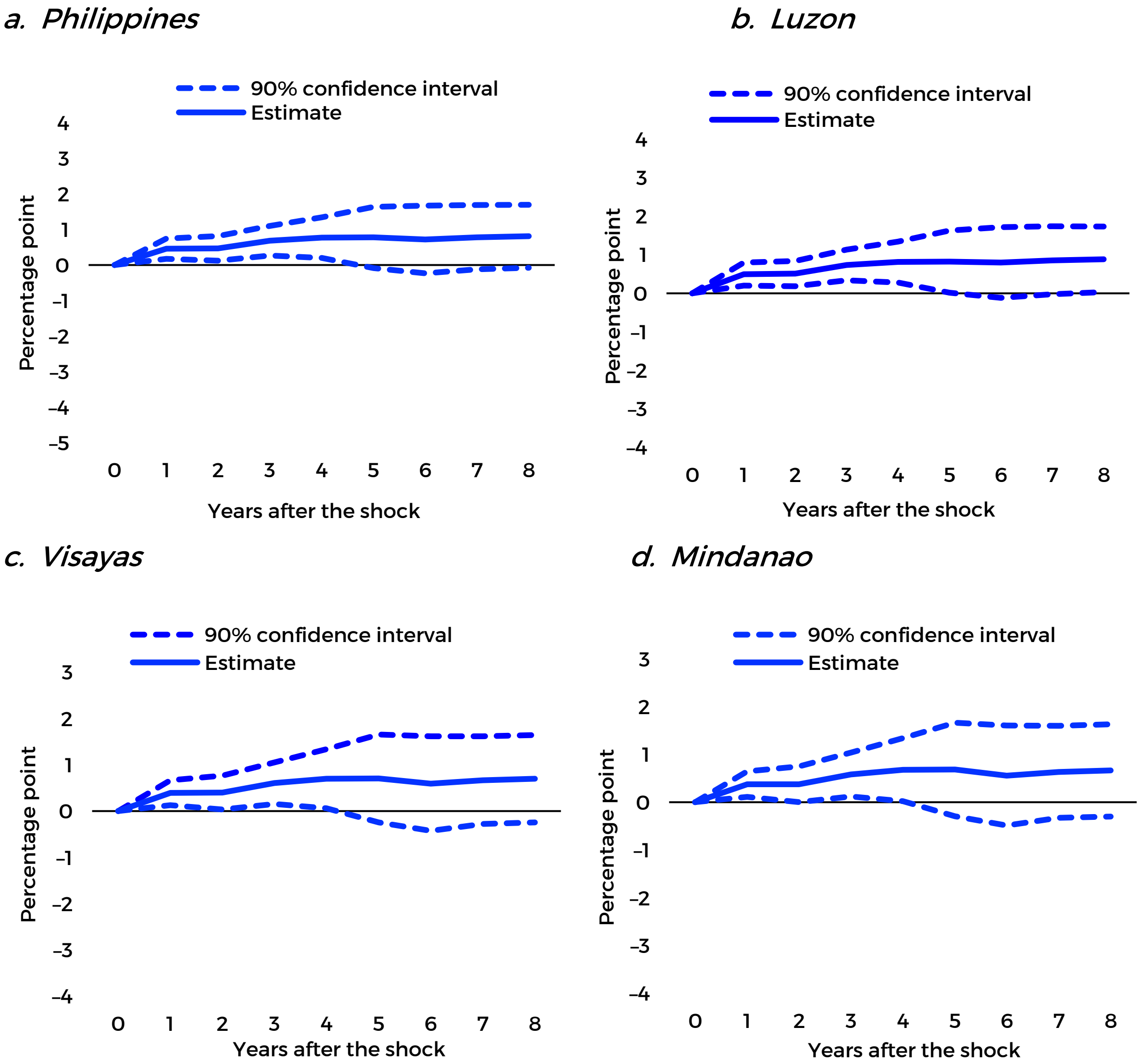
a. Headline CPI

The response of headline inflation to a 1°C increase in annual mean temperature eight (8) years after the shock is presented in Figure 4. The results show that the inflationary effect of temperature shocks is significantly persistent up to year 4, with a cumulative increase of 0.77 ppt. We also observe similar impulse responses across all 17 regions in the country.

Prices of commodities and services may vary across different regions in the country due to factors such as level of output, population, consumer purchasing power, transportation cost, weather conditions, and infrastructure constraints (Paica and Hinlo, 2019). Consumer expenditure by region on food and services also directly affects prices as a high percentage of food expenditure in a particular region encourages sellers/traders to transport products into that region and sell for more profit. Equally important, output level particularly in agriculture tends to determine prices for key food items and any output decline due to supply disruptions such as adverse weather, will likely push prices upward.

The contemporaneous impact on headline inflation of a shock in mean temperature is estimated at 0.46 ppt (Table 8). By major island group, the magnitude of the inflationary effect of temperature shocks in the short- and medium- term is observed to be largest in Luzon at 0.59 ppt and 0.81 ppt, respectively (Table 8). In the case of Luzon, where most of the regions are predominantly agricultural and have various industries including food processing and machinery production, temperature shocks affect the level of output in key production sectors, resulting in deeper magnitude of the inflationary effect.

Figure 4: Impulse Response of Headline Inflation to Temperature Shock Over Time, By Major Island Group



Source: Authors' estimates

Table 8: Marginal Effect of Temperature Shocks on Headline CPI Across Different Horizons, by Major Island and Region

	Short-term (h=1)	***Medium-term (h=4)***	***Long-term (h=8)***
Philippines	0.46** (0.18)	0.77** (0.35)	0.81 (0.54)
Panel A: By Major Island Group			
Luzon	0.59** (0.18)	0.81** (0.32)	0.88 (0.52)
Visayas	0.40** (0.16)	0.70* (0.39)	0.70 (0.57)
Mindanao	0.38** (0.16)	0.68 (0.40)	0.66 (0.59)

	Short-term (h=1)	Medium-term (h=4)	Long-term (h=8)
Panel B: By Region			
Ilocos	0.39** (0.16)	0.69* (0.39)	0.69 (0.58)
Cagayan Valley	0.53** (0.19)	0.85** (0.31)	0.94* (0.50)
Central Luzon	0.41** (0.17)	0.72* (0.38)	0.72 (0.56)
CALABARZON	0.37** (0.16)	0.68 (0.41)	0.65 (0.59)
MIMAROPA	0.39** (0.16)	0.70* (0.39)	0.70 (0.57)
Bicol	0.39** (0.16)	0.70* (0.39)	0.69 (0.58)
CAR	1.18*** (0.40)	1.55** (0.59)	2.13 (0.77)
NCR	0.31* (0.15)	0.61 (0.45)	0.54 (0.64)
West Visayas	0.43** (0.17)	0.74* (0.37)	0.76 (0.55)
Central Visayas	0.36** (0.16)	0.66 (0.41)	0.64* (0.50)
East Visayas	0.39** (0.16)	0.70* (0.39)	0.70 (0.57)
Zamboanga	0.34** (0.16)	0.64 (0.43)	0.60 (0.61)
Northern Mindanao	0.57** (0.20)	0.89*** (0.29)	1.02* (0.49)
Davao	0.33* (0.15)	0.63 (0.44)	0.57 (0.62)
SOCCSKSARGEN	0.37** (0.16)	0.68 (0.41)	0.66 (0.59)
CARAGA	0.37** (0.16)	0.67 (0.41)	0.64 (0.59)
BARMM	0.37** (0.16)	0.67 (0.41)	0.64 (0.59)
No. of obs.	1966	1762	1473
R^2	0.56	0.43	0.23

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **, * denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

b. Food Prices

The food consumer price indicator is an important variable to look at when understanding the impact of temperature shocks on inflation dynamics in the country since food-related items account for 35 percent of the Filipino consumer's basket. Keeping prices stable, particularly for key food items, will help ensure strong and sustainable economic growth and better living standards. However, with inflation being driven by supply-side shocks over the past years, the increasing food inflation also highlights the Philippines' vulnerability to supply constraints. Production disruptions and supply chain issues impact the availability and costs of food domestically, especially with more than a quarter of the local food supply sourced from foreign markets. At the same time, the persistently high food inflation as seen in the previous years were exacerbated by adverse effects of extreme weather conditions and natural calamities.

The results show that the inflationary effect of temperature is deeper in magnitude and persistent on food prices (Table 9) vis-à-vis the impact on non-food prices, which is rather small in size and transitory in period (Table 10). In the short-run, an increase in mean temperature leads to 0.56 ppt increase in food prices as compared with the 0.32 ppt increase in non-food prices (Tables 9 and 10). Likewise, we find that the inflationary effect of an increase in mean temperature by 1℃ is persistent even eight (8) years after the initial shock, with food prices rising by a cumulative 0.79 ppt on an aggregate level (Table 9). The same trends were observed if we analyzed the inflationary effect of temperature shocks on an island group and regional level.

Table 9: Marginal Effect of Temperature Shocks on Food Prices Across Different Horizons, by Major Island and Region

	Short-term (h=1)	***Medium-term (h=4)***	***Long-term (h=8)***
Philippines	0.56*** (0.12)	0.66** (0.27)	0.79** (0.29)
Panel A: By Major Island Group			
Luzon	0.59*** (0.12)	0.68** (0.25)	0.84** (0.31)
Visayas	0.52*** (0.12)	0.63* (0.32)	0.71** (0.29)
Mindanao	0.50*** (0.12)	0.62* (0.34)	0.69 (0.30)
Panel B: By Region			
Ilocos	0.51*** (0.12)	0.63* (0.33)	0.71** (0.29)
Cagayan Valley	0.62*** (0.13)	0.70** (0.26)	0.88** (0.34)
Central Luzon	0.53*** (0.12)	0.64* (0.31)	0.73** (0.29)
CALABARZON	0.50*** (0.13)	0..62* (0.35)	0.68** (0.30)
MIMAROPA	0.52*** (0.12)	0.63* (0.32)	0.71** (0.29)
Bicol	0.51*** (0.12)	0.63* (0.33)	0.71** (0.29)
CAR	1.11*** (0.35)	1.01 (1.26)	1.66 (1.26)
NCR	0.45*** (0.14)	0.59 (0.44)	0.61* (0.34)
West Visayas	0.54*** (0.12)	0.65** (0.29)	0.75** (0.29)
Central Visayas	0.49*** (0.13)	0.62 (0.36)	0.67** (0.30)

	Short-term (h=1)	***Medium-term (h=4)***	***Long-term (h=8)***
East Visayas	0.52*** (0.12)	0.63* (0.32)	0.71** (0.29)
Zamboanga	0.48*** (0.13)	0.60 0.39	0.65* (0.32)
Northern Mindanao	0.65*** (0.13)	0.72** (0.28)	0.92** (0.37)
Davao	0.46*** (0.13)	0.60 (0.41)	0.63* (0.33)
SOCCSKSARGEN	0.50*** (0.13)	0.62* (0.35)	0.68** (0.30)
CARAGA	0.49*** (0.13)	0.62 (0.36)	0.68** (0.30)
BARMM	0.49*** (0.13)	0.62 (0.36)	0.68** (0.30)
No. of obs.	1765	1561	1289
R^2	0.37	0.20	0.01

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

c. Non-food Prices

To the extent that temperature shocks affect food prices, these would also influence non-food inflation through the restaurants and food accommodation services component, which contribute for about 9.6 percent of the Filipinos' total non-food basket.

The results on the marginal effect of an increase in temperature on non-food inflation across different time periods are reported in Table 10. While temperature shocks affect food prices more persistently, the impact on non-food inflation is rather transitory (i.e., lasting for up to 2 years only following the initial shock). At the same time, the magnitude of the contemporaneous impact of temperature shocks on non-food inflation is smaller at 0.32 ppt vis-à-vis the increase in food prices at 0.56 ppt in the short-term (Table 9).

Table 10: Marginal Effect of Temperature Shocks on Non-food Prices Across Different Horizons, by Major Island and Region

	Short-term (h=1)	***Medium-term (h=4)***	***Long-term (h=8)***
Philippines	0.32*** (0.08)	0.13 (0.32)	0.19 (0.49)
Panel A: By Major Island Group			
Luzon	0.34*** (0.08)	0.12 (0.35)	0.19 (0.54)
Visayas	0.30*** (0.07)	0.15 (0.28)	0.19 (0.43)
Mindanao	0.30*** (0.07)	0.16 (0.27)	0.20 (0.41)

	Short-term (h=1)	Medium-term (h=4)	Long-term (h=8)
Panel B: By Region			
Ilocos	0.30*** (0.07)	0.15 (0.28)	0.20 (0.42)
Cagayan Valley	0.36*** (0.08)	0.11 (0.37)	0.19 (0.58)
Central Luzon	0.31*** 0.07	0.15 (0.29)	0.19 (0.44)
CALABARZON	0.29*** (0.07)	0.16 (0.27)	0.20 (0.40)
MIMAROPA	0.30*** (0.07)	0.15 (0.29)	0.19 (0.43)
Bicol	0.30*** (0.07)	0.15 (0.28)	0.20 (0.42)
CAR	0.63*** (0.19)	-0.08 (0.87)	0.15 (1.37)
NCR	0.26*** (0.07)	0.18 (0.24)	0.20 (0.34)
West Visayas	0.31*** (0.07)	0.14 (0.30)	0.19 (0.46)
Central Visayas	0.28*** (0.07)	0.16 (0.27)	0.20 (0.39)
East Visayas	0.30*** (0.07)	0.15 (0.29)	0.19 (0.43)
Zamboanga	0.28*** (0.07)	0.17 (0.26)	0.20 (0.37)
Northern Mindanao	0.37*** (0.09)	0.10 (0.40)	0.19 (0.62)
Davao	0.27*** (0.07)	0.17 (0.25)	0.20 (0.36)
SOCCSKSARGEN	0.29*** (0.07)	0.16 (0.27)	0.20 (0.40)
CARAGA	0.28*** (0.07)	0.16 (0.27)	0.20 (0.40)
BARMM	0.29*** (0.07)	0.16 (0.27)	0.20 (0.40)
No. of obs.	1966	1762	1473
R^2	0.61	0.35	0.26

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **, * denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

We also tested for the robustness of the estimates for headline, food, and non-food inflation by controlling for the occurrence of floods and storms, as well as episodes of ENSO events (Table 11, A and B). Overall, the tests are consistent with the results from the baseline model in terms of the direction of the impact of temperature shocks. The robustness tests show that the inflationary impact of temperature shocks on headline, food, and non-food prices is highly significant and is greater in magnitude vis-à-vis the estimated coefficients generated by our baseline model (see Tables 8, 9, and 10).

Table 11: Alternative Models for the Short-term Marginal Effect of Temperature Shocks on Measures of Consumer Prices, by Major Island and Region

A. Control for the occurrence of floods and storms

	Headline CPI	*Food*	*Nonfood*
Philippines	0.56*** (0.10)	0.57*** (0.12)	0.38*** (0.07)
Panel A: By Major Island Group			
Luzon	0.61*** (0.10)	0.60*** (0.12)	0.38*** (0.07)
Visayas	0.47*** (0.09)	0.54*** (0.12)	0.38*** (0.08)
Mindanao	0.45*** (0.09)	0.52*** (0.12)	0.38*** (0.09)
Panel B: By Region			
Ilocos	0.47*** (0.09)	0.53*** (0.12)	0.38*** (0.08)
Cagayan Valley	0.66*** (0.11)	0.62*** (0.13)	0.38*** (0.06)
Central Luzon	0.49*** (0.09)	0.54*** (0.12)	0.38*** (0.08)
CALABARZON	0.44*** (0.09)	0.52*** (0.12)	0.38*** (0.09)
MIMAROPA	0.48*** (0.09)	0.54*** (0.12)	0.38*** (0.08)
Bicol	0.47*** (0.09)	0.53*** (0.12)	0.38*** (0.08)
CAR	1.56*** (0.23)	1.04** (0.37)	0.41** (0.18)
NCR	0.35*** (0.09)	0.48*** (0.13)	0.37*** (0.10)
West Visayas	0.52*** (0.10)	0.56*** (0.12)	0.38*** (0.08)
Central Visayas	0.43*** (0.09)	0.51*** (0.12)	0.37*** (0.09)
East Visayas	0.48*** (0.09)	0.54*** (0.12)	0.38*** (0.08)
Zamboanga	0.40*** (0.09)	0.50*** (0.12)	0.37*** (0.09)
Northern Mindanao	0.71*** (0.11)	0.65*** (0.14)	0.38*** (0.06)
Davao	0.38*** (0.09)	0.49*** (0.13)	0.37*** (0.10)
SOCCSKSARGEN	0.44*** (0.09)	0.52*** (0.12)	0.38*** (0.09)
CARAGA	0.43*** (0.09)	0.52*** (0.12)	0.38*** (0.09)
BARMM	0.43*** (0.09)	0.52*** (0.12)	0.38*** (0.09)
No. of obs.	1969	1765	1775
R^2	0.54	0.40	0.63

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

Incorporating the dummy variable on the occurrence of floods and storms in the alternative model specification indicate that temperature shocks lead to higher CPI inflation in the near-term at 0.56 ppt (Table 11-A) vis-à-vis the 0.46 ppt estimated coefficient for the same price indicator from our baseline model (Table 8). The same findings can be generalized when we disaggregated consumer prices into its components, with the increase in mean temperature resulting to higher food and non-food inflation at 0.57 ppt and 0.38 ppt, respectively, in the short-term. The inflationary effects are persistent on food prices but only transitory on non-food prices, which are consistent with our results under the baseline model (Tables 9 and 10).

B. Control for episodes of ENSO Events

	Headline CPI	***Food***	***Nonfood***
Philippines	0.49** (0.18)	0.69*** (0.11)	0.49*** (0.07)
Panel A: By Major Island Group			
Luzon	0.53** (0.19)	0.69*** (0.12)	0.48*** (0.07)
Visayas	0.43** (0.17)	0.70*** (0.12)	0.50*** (0.09)
Mindanao	0.41** (0.16)	0.70*** (0.12)	0.50*** (0.07)
Panel B: By Region			
Ilocos	0.42** (0.16)	0.70*** (0.12)	0.50*** (0.09)
Cagayan Valley	0.56** (0.19)	0.69*** (0.12)	0.48*** (0.07)
Central Luzon	0.44** (0.17)	0.70*** (0.12)	0.49*** (0.08)
CALABARZON	0.44** (0.16)	0.70*** (0.13)	0.50*** (0.09)
MIMAROPA	0.43** (0.17)	0.70*** (0.12)	0.50*** (0.09)
Bicol	0.42** (0.17)	0.70*** (0.12)	0.50*** (0.09)
CAR	1.19** (0.42)	0.65 (0.45)	0.39** (0.17)
NCR	0.34** (0.16)	0.70*** (0.15)	0.51*** (0.10)
West Visayas	0.46** (0.17)	0.70*** (0.12)	0.49*** (0.08)
Central Visayas	0.39** (0.17)	0.70*** (0.13)	0.50*** (0.09)
East Visayas	0.43** (0.17)	0.70*** (0.12)	0.50*** (0.09)
Zamboanga	0.37** (0.16)	0.70*** (0.13)	0.50*** (0.10)
Northern Mindanao	0.60** (0.20)	0.69*** (0.13)	0.47*** (0.06)
Davao	0.36** (0.16)	0.70*** (0.14)	0.50*** (0.10)
SOCCSKSARGEN	0.40** (0.16)	0.70*** (0.13)	0.50*** (0.09)

	Headline CPI	***Food***	***Nonfood***
$CARAGA$	0.40** (0.16)	0.70*** (0.13)	0.50*** (0.09)
$BARMM$	0.40** (0.16	0.70*** (0.13)	0.50*** (0.09)
$No. of\ obs.$	1966	1763	1775
R^2	0.56	0.39	0.63

Source: Authors' estimates
*Note: Robust standard errors are in parentheses; ***, **,* denotes p-value less than the 1%, 5% and 10% levels of significance, respectively. Standard errors are clustered at the regional level.*

Compared to the estimated coefficients using the baseline model in Tables 8, 9, and 10, the short-term inflationary effects of temperature shocks on headline, food, and non-food are deeper in magnitude at 0.49 ppt, 0.69 ppt, and 0.49 ppt, respectively, when we incorporated dummy variables for episodes of ENSO events (Table 11-B). Consistent with the results in our baseline model, inflationary pressures following a positive shock in mean temperature are more persistent on food vis-à-vis non-food prices.

V. Conclusions and Policy Implications

Conclusions

Using the recent econometric approach in estimating dynamic impulse response functions, Local Projections method, our paper is the first in the country to quantify the contemporaneous and long-term effects of temperature shocks on output growth and other channels of economic activity as well as on inflation, which are the primary considerations of the Bangko Sentral ng Pilipinas in its assessment of the appropriate monetary policy stance.

Overall, the results of our study are broadly in line with the findings in literature that economic growth and rise in temperature are non-linear and adversely related especially in countries with hot weather. We find that, on the average, the short-run marginal impact of a 1-degree Celsius increase in the country's annual mean temperature reduces aggregate output growth by 0.37 ppt. This finding is robust and consistent across all model specifications. Moreover, the magnitude of the negative impact of an increase in temperature on aggregate output growth is larger when we control for ENSO events at 0.47 ppt. compared to when we control for the occurrence of floods and storms at 0.30 ppt. in the short term. Meanwhile, in the long-run, output growth declined by a cumulative 1.12 ppt. eight (8) years after the shock when controlling for the occurrence of floods and storms while controlling for ENSO periods did not yield a significant result although the sign remained negative.

The study further delved deeper into the channels of economic activity through which temperature shocks affect overall economic growth. On crop production, the study found that a rise in temperature, in the short run, negatively impacts palay production by 1.83 ppt. and corn production by 3.51 ppt., but positively affects mango production by 3.10 ppt. These results show that higher temperatures have varied results on food production which, in turn, could have implications in the formulation of the government's support programs as well as in setting up crop-targeted insurance schemes.

On sectoral output, the results show that both the manufacturing and services sectors are negatively affected by an increase in mean temperature, with the magnitude of drop more evident in the manufacturing sector at 1.8 ppt. vis-à-vis the 0.7 ppt. decrease in the services sector. Meanwhile, we find that temperature shocks do not significantly affect labor productivity in heat-exposed industries such as construction, transportation, and manufacturing. Although the estimated coefficients show insignificant results, the direction of the sign is generally as expected especially on labor productivity in heat-exposed industries such as construction, transportation, and manufacturing. The results possibly imply that workers in the construction and transportation sectors are already used to the weather conditions in the country.

The study also looked at the dynamics between rising temperature and inflation and found that a 1°C-increase in annual mean temperature leads to persistent inflationary pressures up to four (4) years, with a cumulative increase of 0.77 ppt. in headline inflation after the initial shock. Disaggregating the components of consumer prices, the results show that the inflationary impact of temperature shocks on food prices is deeper in magnitude and long-lasting in period at 0.79 ppt. vis-à-vis the effect on non-food prices, which is rather small at 0.31 ppt. and transitory up to 2 years only.

Policy Implications

The results of our study put forward several points that may be of particular interest to the National Government and the BSP as an inflation-targeting central bank and supervisor of the Philippine financial system.

Given the significant contribution of agriculture sector to total economic output of the country and our findings that temperature shocks negatively affect growth, it is crucial for the country to go through a paradigm shift -- from being commodity-driven to taking a holistic agricultural system approach through a rigorous implementation of policies and programs to promote climate-resilient agriculture technology and practices to ensure food security amid rapidly changing climate. Likewise, increased spending and investment on agricultural research and development (R&D) is essential in reinforcing the adaptation and resilience of the agriculture sector. Although agricultural R&D investment is increasing over time, public spending in agricultural R&D is lower in developing countries. In the Philippines and Bangladesh, for instance, only 0.4 percent of their value added in agricultural sector was invested in agricultural research in 2017 and 2016, respectively (Stads et al., 2019, 2020).

The results of this paper also emphasize the equally important role of central banks when it comes to managing the impact of climate change on the central banks' ability to deliver on their price and financial stability mandates. Our findings can provide input to the assumptions incorporated in inflation forecasting and scenario-building exercises, particularly when modeling inflation persistence attributed to changes in temperature. Moreover, the results suggest differentiating between the food and non-food components of inflation as they contribute quite differently in terms of magnitude and persistence to headline inflation.

The study's findings of the persistence of temperature shocks on inflation likewise provide greater support to the BSP's call for the timely implementation of non-monetary measures in the face of supply-side constraints, particularly for food items. Supply-side shocks such as lower-than-expected crop harvests brought on, for instance, by drought can be best addressed by fiscal authorities temporarily through import substitution and, more importantly, sustainably by providing irrigation. The timely implementation of these measures should prevent inflation from becoming more entrenched and permanent.

The findings on the varying impact of rising temperature on different crops can also inform the work of financial regulators, including the BSP, as they strive to create a conducive environment with due regard to having appropriate incentive structures that would encourage financial institutions to offer crop-targeted loan packages and insurance coverage. For instance, the assessment of risk weights for banks and insurers can be aligned and further refined to take into consideration the type of crop being cultivated that is under the loan account or insurance coverage. Adopting a more nuanced view in quantifying the impact of climate change on certain economic activities could help financial institutions develop more suitable financial products that could contribute towards risk adaptation.

Considering that our study is the first empirical attempt to quantify the macroeconomic effects of temperature shocks in the Philippine setting, our findings may serve as starting point of reference for future research initiatives that may include expanding the proxy measures for climate change and the coverage of the study to include other countries in the region. At the same time, the model could be extended to incorporate policy responses from the fiscal and monetary authorities and assess the extent of policy effectiveness in mitigating the impact of temperature shock-induced supply constraints.

References

Acevedo, S., M. Mrkaic, N. Novta, E. Pugacheva, and P. Topalova (2020), "The effects of weather shocks on economic activity: what are the channels of impact?", *Journal of Macroeconomics* Vol. 65. https://doi.org/10.1016/j.jmacro.2020.103207

Burke, M., Hsiang, S. & Miguel, E (2015). Global non-linear effect of temperature on economic production. Nature 527, 235–239. https://doi.org/10.1038/nature15725.

Dell, M., B. Jones, and B. Olken (2012). "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics*, 4 (3): 66-95.

Deryugina, T. and S. Hsiang 2(014). "Does the Environment Still Matter? Daily Temperature and Income in the United States." NBER Working Paper 20750, National Bureau of Economic Research, Cambridge, MA.

Deschênes, O. (2012). "Temperature, Human Health and Adaptation: A Review of the Empirical Literature." NBER Working Paper 18345, National Bureau of Economic Research, Cambridge, MA.

Dikitanan, R. G. Grosjean, A. Nowak, and J. Leyte (2017). Climate-Resilient Agriculture in Philippines. Department of Agriculture - Adaptation and Mitigation Initiative in Agriculture.

European Central Bank (ECB). (2021, July 9). *ECB presents action plan to include climate change considerations in its monetary policy strategy* [Press Release]. https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html

Faccia, D, M. Parker, and L. Stracca (2021), "Feeling the heat: extreme temperatures and price stability", ECB Working Paper Series No. 2626. December 2021.

Fankhauser, S. and R. Tol (2005). On climate change and economic growth, *Resource and Energy Economics*, 27, issue 1, p. 1-17.

Graff Zivin, J. and M. Neidell, 2014. "Temperature and the Allocation of Time: Implications for Climate Change," *Journal of Labor Economics*, University of Chicago Press, vol. 32(1), pages 1-26.

Heinen, A., J. Khadan, and E. Strobl (2019). The Price Impact of Extreme Weather in Developing Countries, *The Economic Journal*, Volume 129, Issue 619, April 2019, Pages 1327–1342, https://doi.org/10.1111/ecoj.12581

Intergovernmental Panel on Climate Change (IPCC), 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jordà, O. (2005). "Estimation and Inference of Impulse Responses by Local Projections," American Economic Review, American Economic Association, vol. 95(1), pages 161-182.

Kalkuhl, M. and L. Wenz (2020). The impact of climate conditions on economic production. Evidence from a global panel of regions, *Journal of Environmental Economics and Management*, 103, issue C, number S0095069620300838.

Lee, M., Villaruel, M., & Gaspar, R. (2016, December). Effects of Temperature Shocks on Economic Growth and Welfare in Asia. *ADB Economics Working Paper Series*, 14 - 17.

Mapa, D., M. Sandoval, and E. Yap II (2008). Investigating the Presence of Regional Economic Growth Convergence in the Philippines Using Kalman Filter. *University of the Philippines School of Statistics Working Paper.*

Mukherjee, K. and B. Ouattara (2021). "Climate and monetary policy: do temperature shocks lead to inflationary pressures?," *Climatic Change*, Springer, vol. 167(3), pages 1-21.

Organisation for Economic Cooperation and Development (2020). Chapter 6. Approaches in the Philippines to increased coherence in climate change adaptation and disaster risk reduction. *Common Ground Between the Paris Agreement and the Sendai Framework: Climate Change Adaptation and Disaster Risk Reduction*, OECD Publishing, Paris, https://doi.org/10.1787/3edc8d09-en.

Paica, C. and J. Hinlo (2019). Regional Food Price Differential in the Philippines. Retrieved from: https://psa.gov.ph/sites/default/files/3.2.2%20Regional%20Food%20Price%20 Differentials %20in%20the%20Philippines.pdf

Parker, M (2018). "**The Impact of Disasters on Inflation**," *Economics of Disasters and Climate Change,* Springer, vol. 2(1), pages 21-48, April.

Piver, W., M. Ando, F. Ye, and C. Portier (1999). "Temperature and Air Pollution as Risk Factors for Heat Stroke in Tokyo, July and August 1980-1995." *Environmental Health Perspectives* 107 (11) (November 1): 911–916.

Porter J.R., L. Xie, A. Challinor, K. Cochrane, M. Howden, M. Iqbal, D. Lobell, and M. Travasso (2014). Chapter 7. Food Security and Food Production Systems. Climate Change 2014: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment Report. Geneva, Switzerland.

Quezon, E. and A. Ibanez (2021). Analysis of influential factors affecting workers' productivity on highway construction projects during COVID-10 pandemic in

Cagayan Valley Region, Philippines. *Global Journal of Engineering and Technology Advances*, 87.

Rosegrant, M. W., Perez, N., & Thomas, T. S. (2015, September). The Impacts of Climate Change on Philippine Agriculture. Retrieved from https://www.ctc-n.org/files/129755.pdf

Santos, M., J. Dickson, and P. Velasco. (2011). Mitigating the impacts of climate change: Philippine fisheries in focus. Southeast Asian Fisheries Development Center, Fish People. Volume 9. Retrieved from https://www.researchgate.net

Seppänen, O., W. Fisk, and D. Faulkner (2003). "Cost Benefit Analysis of the Night-Time Ventilative Cooling in Office Building." Lawrence Berkeley National Laboratory.

Stads, G. J., Rahman, M. M., Nin-Pratt, A., & Gao, L. (2019). Agricultural Science and Technology Indicators (ASTI) Country Brief: Bangladesh.

Stads, G.J., Nin-Pratt, A., Omot, N., & Pham, N. (2020). Agricultural Research in South Asia: A Cross-Countr Analysis of Resource Allocation, Performance, and Impact on Productivity.

Suh, D., Pomeroy(2020 Projected Economic Impact of Climate Change on Marine Capture Fisheries in the Philippines. Retrieved from https://are.uconn.edu/wp-content/uploads/sites/2327/2020/04/fishCCimpactsphilippines.pdf.

Somanathan, E., Somanathan, Sudarshan, Tewari(2021 The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing. *Journal of Political Economy, 129*.

World Bank Climate Change Knowledge Portal (2021). *Current Climate -Trends and Significant Change against Natural Variability (Country: Philippines).* https://climateknowledgeportal.worldbank.org/country/philippines/trends-variability-historical