ECONOMIC NEWSLETTER
No. 23-05 | June 2023

Macroeconomic Effects of Temperature Shocks in the Philippines:
Evidence from Impulse Responses by Local Projections

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Introduction

While national governments are the primary agent in a country's response toward climate change mitigation, central banks play an equally important role especially in managing the impact of climate change on the their ability to deliver price and financial stability mandates. Central banks are currently putting forward plans and initiatives that incorporate climate change in their mandates or policy frameworks.

In the Philippines, climate change is estimated to cost the economy approximately ₱26 billion per year by 2050, according to a 2017 study by Dikitanan et al. Despite 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, their study was 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.

The specific channels the authors 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, construction, transportation, manufacturing, mining, and utility sectors.[1] To the extent that high temperatures affect agricultural production via the supply-side channel, these would also influence the level and volatility of inflation. Hence, the authors also examined the effect of temperature shocks on headline, food, and non-food inflation.

Using the Local Projections (LP) method (Jórda, 2005), the authors find that, on the average, temperature shocks generally lead to a downside risk on economic activity and upward pressure on prices, or inflation.

Climate-Related and Macroeconomic Data

In estimating the macroeconomic effects of temperature shocks, the authors used two types of data: climate-related and macroeconomic, for a panel of 17 regions in the Philippines. The authors used annual data from 2000 to 2021 for the variables on output and other channels of economic activity[2] and quarterly data from 1994:Q1 to 2021:Q4 for the variables on headline, food, and non-food inflation.

The time series data on mean temperature and El Niño-Southern Oscillation (ENSO) events were obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA).[3] Information on the occurrence of storms and

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

[2] The earliest available annual data on regional output and other channels of economic activity is from the year 2000.

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

floods in the country came from the Emergency Events Database (EM-DAT), the international disaster database.

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; as well as headline, food, and non-food inflation.[4] These data are sourced from the Philippine Statistics Authority.

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 economic activity as well as on different measures of inflation, the authors adopted the same methodology employed by Acevedo et al. (2020) and Faccia et al. (2021). Consistent with majority of the literature, a temperature shock is defined, in this paper, as a 1-degree increase in the annual mean temperature of the country, island group, or region.

The LP method is a recent alternative econometric approach to estimating impulse responses as this method is suited to estimating non-linearities and cumulative impulse responses. At the same time, linear projections are easier to estimate since they rely solely on simple regressions such that, instead of extrapolating the parameters from increasingly distant horizons, linear projections estimate the parameters sequentially at each point of interest. Using this approach, the authors estimate the impulse responses of the macroeconomic outcomes of interest to temperature shocks over up to an 8-year period by estimating the baseline panel regression below:

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

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 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, which captures the contemporaneous impact (h=1) and the effect eight years (h=8) 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. 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,[5] 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

[4] Real GDP per capita and inflation data are based on 2018 prices.

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

regression models are not included in the model specification. However, to the extent that these determinants of growth are region-specific and time-invariant such as institutional quality and educational attainment, these are already incorporated in the fixed effects (μ_i^h and θ_t^h).

Using the estimation framework specified in **Equation 1**, the marginal effects of an increase in temperature at time, t, on the macroeconomic variables under study are derived by differentiating **Equation 1** with respect to temperature, based on **Equation 2** below:

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

Robustness Tests

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

First, the authors estimated **Equation 1** by excluding the lag of GDP growth as an explanatory variable to evaluate the consistency of the results. Second, control for the occurrence of floods and storms is introduced in the model, 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 archipelago prone to natural disasters such as typhoons. Third, control for ENSO episodes is incorporated into the alternative model specification, as these events tend to change global atmospheric circulation which, in turn, influences temperature and precipitation.[6]

[6] ENSO events, particularly the El Niño, refers to the warming of oceanic temperatures, contributing to the increase in atmospheric temperatures.

Analysis of the Results

The first part of this section presents the results on the impact of temperature shocks on output and other channels of economic activity such as crop production, livestock, fishing, sectoral output on manufacturing and services, real investment, as well as labor productivity in heat-exposed industries. The second part shows the effect of temperature shocks on headline, food, and non-food inflation.

Output

Overall, an increase in temperature lowers output growth by an estimated 0.37 percentage point (ppt) in the short run. The expected negative impact of high temperatures is robust and consistent across all model specifications. The magnitude of the negative impact of temperature increase on aggregate output growth is larger when ENSO events were introduced in the model at 0.47 ppt, compared to when the occurrence of floods and storms was included in the model at 0.30 ppt. By major island group, the magnitude of the effect of a 1°Celcius increase in mean temperature varies from a range of -0.16 ppt to -0.47 ppt. By region, the adverse impact of temperature shocks was seen in Luzon—particularly among major producers of agricultural commodities such as Cagayan Valley, Central Luzon, MIMAROPA, and the Cordillera region. Comparable results were also observed in the Visayas and Mindanao regions where temperature increase lowers output growth, particularly in the Western and Eastern Visayas, as well as in Northern Mindanao. Likewise, with temperature levels exacerbated by ENSO events, a decline in output is observed across all provinces in Visayas and Mindanao.

Crop production, livestock, and fishing

The authors find that temperature shocks have negative effect on production of palay at 1.83 ppts and corn at 3.51 ppts, but positive impact on mango production as mangoes prefer climate conditions with warm temperatures especially during the fruit development stage.

The study provides evidence that a temperature shock has no long-term significant effect on the crop production, livestock, and fisheries sectors. While statistical inference is invalid, it may possibly imply 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 timely non-monetary interventions of the National Government (NG), such as structural measures to address agricultural production, which 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). Based on a study conducted by the Asian Development Bank (ADB), there are several coping measures that the government can do to address the impact of rising temperatures on output, hence, the transitory effect of temperature shocks on output is supported (Lee et al., 2016).

Sectoral output

On sectoral output, the manufacturing and services sectors are negatively affected by a 1℃-increase in mean temperature. The magnitude of drop is more evident in the manufacturing sector at 1.8 ppts vis-à-vis the 0.7 ppt decrease in services sector.

The results on the manufacturing sector are consistent with the study of Acevedo et al. (2020) where they find that 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 or poor air conditioning units (Dell et al., 2012).

Labor productivity

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."

Headline inflation

The contemporaneous impact of a shock in mean temperature on headline inflation is estimated at 0.46 ppt. 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. 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.

Food inflation

The food consumer price index 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.

The results show that the inflationary effect of a temperature shock is deeper in magnitude and persistent on food prices. In the short run, an increase in mean temperature by 1℃ leads to 0.56 ppt increase in food prices. Likewise, the inflationary effect of a 1℃-increase in mean temperature is persistent even eight years after the initial shock, with food prices rising by a cumulative 0.79 ppt. The same trends were observed if the inflationary effect of temperature shocks is analyzed at the island group or regional level.

Non-food inflation

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

While temperature shocks affect food prices more persistently, the impact on non-food inflation is transitory (i.e., lasting for up to two 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.

The robustness of the estimates for headline, food, and non-food inflation was also tested by controlling for the occurrence of floods and storms, as well as for episodes of ENSO events. Overall, the tests are consistent with the results from the baseline model in terms of the direction of the impact of temperature shocks. Robustness tests show that the inflationary impact of temperature shocks on headline, food, and non-food is highly significant and is greater in magnitude vis-à-vis the estimated coefficients generated by the baseline model.

Policy Implications

The results of this study put forward several points that may be of particular interest to the NG and to the BSP as an inflation-targeting central bank and financial system regulator.

Given the significant contribution of the agriculture sector to the total economic output of the country and the authors' 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 systems approach through a rigorous implementation of policies and programs that aims to promote climate-resilient agriculture technologies and practices to ensure food security amid rapidly changing climate conditions. 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 the agriculture sector was invested in agricultural research in 2017 and 2016, respectively (Stads et al., 2019, 2020).

The findings on the inflationary impact of temperature shocks 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, as monetary policy adjustment typically works with a lag. On the other hand, if inflation pressures remain persistent and evidence of second-round effects materialize, the central bank will respond and adjust its policy interest rates accordingly.

Findings on the varying impacts of rising temperatures 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.

Directions for Further Related Studies

This study is the first empirical attempt to quantify the macroeconomic effects of temperature shocks in the Philippine setting. The authors' findings may serve as a starting point in improving the existing frameworks and developing climate models to help in further understanding the wider consequences and transmission channels of climate change. Future research initiatives 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 and assess the extent of policy effectiveness in mitigating the impact of temperature shock-induced supply constraints. Likewise, since this empirical exercise tested only for the impulse responses of inflation to temperature shocks, a potential extension of this research is to expand the model by explicitly identifying the channels through which temperature shocks impact inflation. Alternatively, including interaction variables that capture the direct link between inflation and temperature shocks can be introduced into the model.

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