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Drought shocks and the Paraguayan macroeconomy: A Bayesian SVAR Analysis[1,2]

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Droughts pose a major threat for most countries around the globe due to spillover effects on the economy. A Bayesian structural vector autoregressive model estimates the impact of drought shocks on the real business cycle of the Paraguayan economy. A one standard deviation increase in the drought index (0.76%) leads to significant peak declines in output (-0.8%) and investment (-2.5%) two quarters later. Consumption exhibits a contemporaneous decline (-0.6%), while the trade balance remains unresponsive. These findings offer insights for policymakers seeking to understand and mitigate the economic consequences of droughts in Paraguay.

[1] Errors and omissions are the sole responsibility of the authors, so the opinions expressed do not necessarily reflect the position of the Central Bank of Paraguay nor can they compromise its institutional interests.

[2] The authors thank Sebastian Diz for his valuable comments and suggestions.

Introduction

Droughts are climate shocks that can have a significant impact on macroeconomic variables such as output, consumption, investment and the trade balance. The transmission of their effects is complex and dependent on various factors, including severity, duration, economic structure, and government response.

One of the most direct ways that droughts can affect macroeconomic variables is through its impact on agricultural production. Droughts can cause crop failure and livestock deaths, which can reduce agricultural sector production and reduce the income of farmers and ranchers. This can have a ripple effect on the rest of the economy, as reduced agricultural production can lead to higher food prices and lower demand for other goods and services.

Droughts can also affect macroeconomic variables through their impact on water resources. Water is essential for many economic activities, including manufacturing, mining and energy production. Droughts can cause water shortages, which can disrupt these activities and reduce economic production.

Furthermore, droughts can have a negative impact on consumer and investor confidence. When people are worried about the future availability of water and food, they are less likely to spend money or invest in new businesses. This can lead to a decline in consumption and investment, which can further slow economic growth.

Finally, they can also affect macroeconomic variables through their impact on trade. If a country relies heavily on agricultural exports, droughts can lead to a decline in export earnings and a deterioration in the trade balance.

Understanding the relationship between drought shocks and real economic cycles is essential to develop policies that mitigate the economic impacts of adverse climate events..

Methodology

The structural vector autoregressive (SVAR) model approach is implemented here to evaluate the quantitative impact of drought shocks on the real business cycle. The model specification is given by:

$$y_t' A = \sum_{t=1}^{p} y_{t-l}' A_l + \epsilon_t' \qquad \forall t = 1, \dots, T, \tag{1}$$

where, y_t is an $n \times 1$ column vector of exogenous and endogenous variables in period t, l is the lag length and T is the sample size. A and A_l are $n \times n$ parameter matrices corresponding to exogenous and endogenous variables, and ϵ_t is an $n \times 1$ column vector of structural disturbances in period t. The disturbances have a Gaussian distribution with $E(\epsilon_t|y_1, \dots, y_{t-1}) = 0_{n\times 1}$ and $E(\epsilon_t\epsilon_t'|y_1, \dots, y_{t-1}) = I_{n\times n}$.

The structural perturbations are normalized so that the covariance matrix is an identity matrix. Post-multiplying equation (1) by A^{-1}, the expression yields the usual representation of the vector autoregressive (VAR) model in its reduced form:

$$y_t' = \sum_{t=1}^{p} y_{t-l}' B_l + u_t' \qquad \forall t = 1, \dots, T. \tag{2}$$

Equation (2) implies a relationship between the covariance matrix of the reduced form residuals and the matrix A, given by: $\sum = (AA')^{-1}$.

The vector of observed variables at time t, denoted by y_t', is partitioned into two subvectors, as $y_t' = [\, y_{1t}' \quad y_{2t}']$, where y_{1t}' is a $1 \times n_1$ vector of exogenous variables (the drought index) and y_{2t}' is a $1 \times n_2$ vector of endogenous domestic variables (where $n_1 + n_2 = n$). The set of variables considered in the model is defined as:

$$y_1' = [di]$$

$$y_2' = [gdp \quad con \quad inv \quad tby]$$

where vector y_1 contains the aggregate drought index of Paraguay (di), while vector y_2 groups the gross domestic product (gdp), consumption (con), investment (inv) and the trade balance relative to the domestic product (tby).

All variables incorporated in the SVAR are in quarterly frequency (seasonally adjusted, except for di), and in (annually differentiated) logarithmic terms (except for tby which is only annually differenced). Except for the drought index, the rest of the variables come from the Central Bank of Paraguay and correspond to the period 2001Q1-2020Q2.

The drought index for the agricultural sector is built from daily data that reflects the percentage of useful water in the soil intended for the technical production of crops such as soybeans, corn, long-cycle wheat and zafriña corn in the departments of Alto Paraná, Caaguazú, Canindeyú, Itapuá and San Pedro. The data comes from estimates provided by the Agricultural Water Balance model (BHAg, from its Spanish acronym), generated by the National Directorate of Meteorology and Hydrology (Dirección Nacional de Meteorología e Hidrología).[3] The drought index is calculated for each crop using monthly averages of useful water by department. These averages are then summed, using time-variable weights

[3] *When estimating the amount of useful water for each crop, the BHAg not only considers water inputs, such as precipitation, but also outputs, such as evaporation, transpiration, runoff, among other factors. In addition, the model takes into account the atmospheric conditions that influence water consumption and the specific water requirements of each crop at different stages of its development, as well as the type of soil in each geographical area.*

based on historical production data by department.[4] Finally, the aggregate index is obtained by adding the individual indexes of each crop in a weighted manner (Figure A.I. in the Appendix shows the interannual quarterly variation rate of the drought index and its normalized series over the period of analysis).

Regarding the identification restriction imposed to the SVAR system, it is assumed that the climate condition variable –the drought index– is totally exogenous, which implies contemporary exogeneity and in all its lags.[5]

The chosen method to estimate the SVAR system is the algorithm proposed by Wagoner and Zha (2003), who formulate a Bayesian structural vector autoregressive model with a two-step Gibbs sampling estimator. For its estimation, two lags have been specified for the Bayesian SVAR and Minnesota priors have been used, generating a total of 10,000 Monte Carlo samples for the model parameters (of which the first 50% generated samples were discarded).

Economic impact of droughts from a Bayesian SVAR approach

The estimated responses of the main macroeconomic variables of the domestic economic cycle to a drought shock are presented in Figure I. As can be seen, an increase in the drought index causes significant decreases in output, consumption, and investment for two quarters subsequent to the onset of the drought. However, the effect on the trade balance is found to be statistically insignificant over the entire response period.

The drought index impulse path, which represents an increase in rainfall scarcity in areas important for agricultural crop production, shows an average and significant duration of one quarter.

In quantitative terms, an increase in the drought index by one standard deviation (0.76%) causes significant peak declines in output and investment two quarters after the shock occurred. The declines reach -0.8% for output and -2.5% for investment. Notably, consumption falls a maximum of -0.6%, but in a contemporaneous manner with the shock, while responses on the trade balance to GDP are nil.

The variance decomposition, as shown in Figure II, reveals the relative importance of drought shocks driving the fluctuations of each endogenous variable within the Bayesian SVAR system. Variance decomposition measures are based on mean estimates using 90% of the credible set at each horizon.

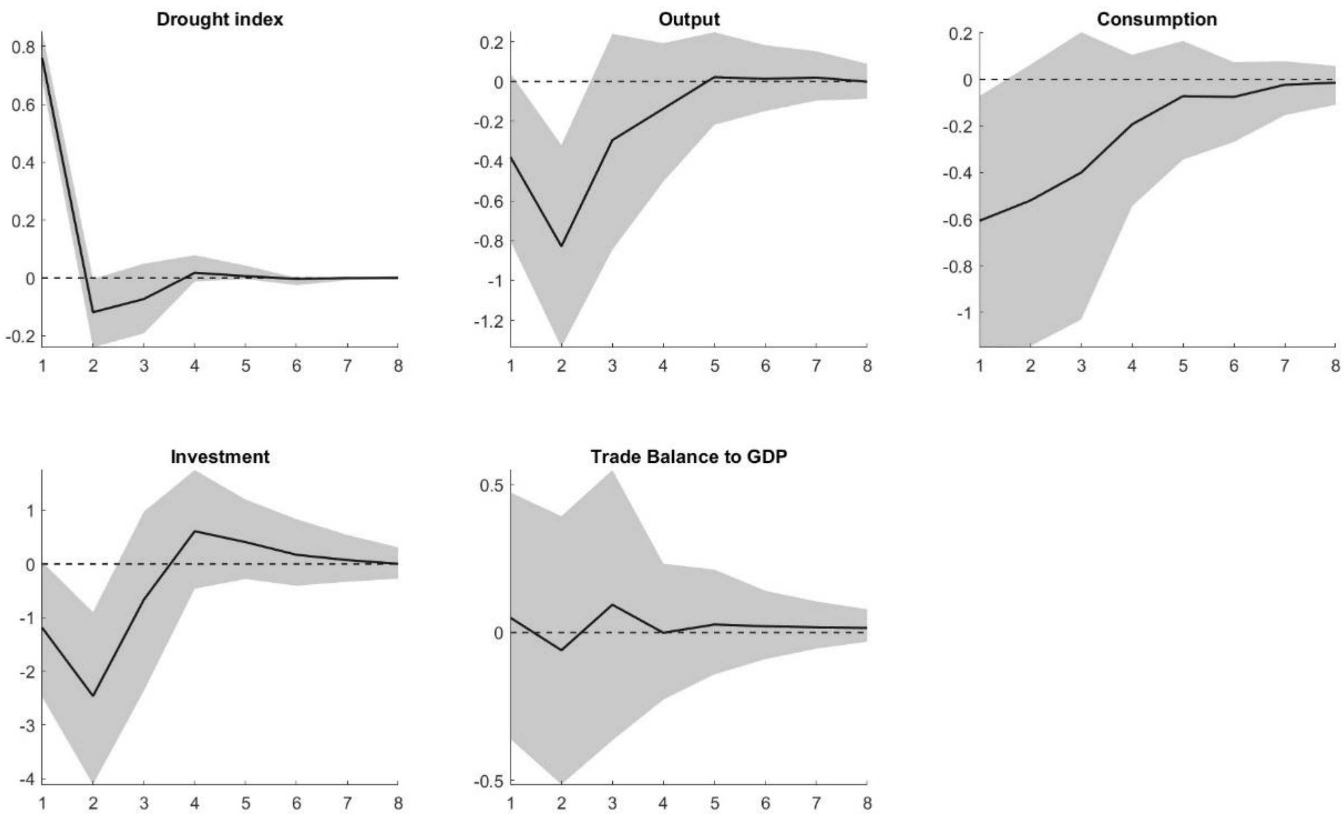
Short-term fluctuations, associated with two quarters forecast error horizon, indicate that drought shocks account for a notable portion of the variation in key macroeconomic variables. Specifically, droughts explain 9.5% of fluctuations in output (GDP), 8.7% in investment, 6.9% in consumption and

[4] *The authors thank Zulma Barrail for sharing data on the drought index.*

[5] *The identification strategy is implemented by performing a Cholesky decomposition where the drought index is ordered first. As a robustness check alternative orderings of the endogenous variables where tried.*

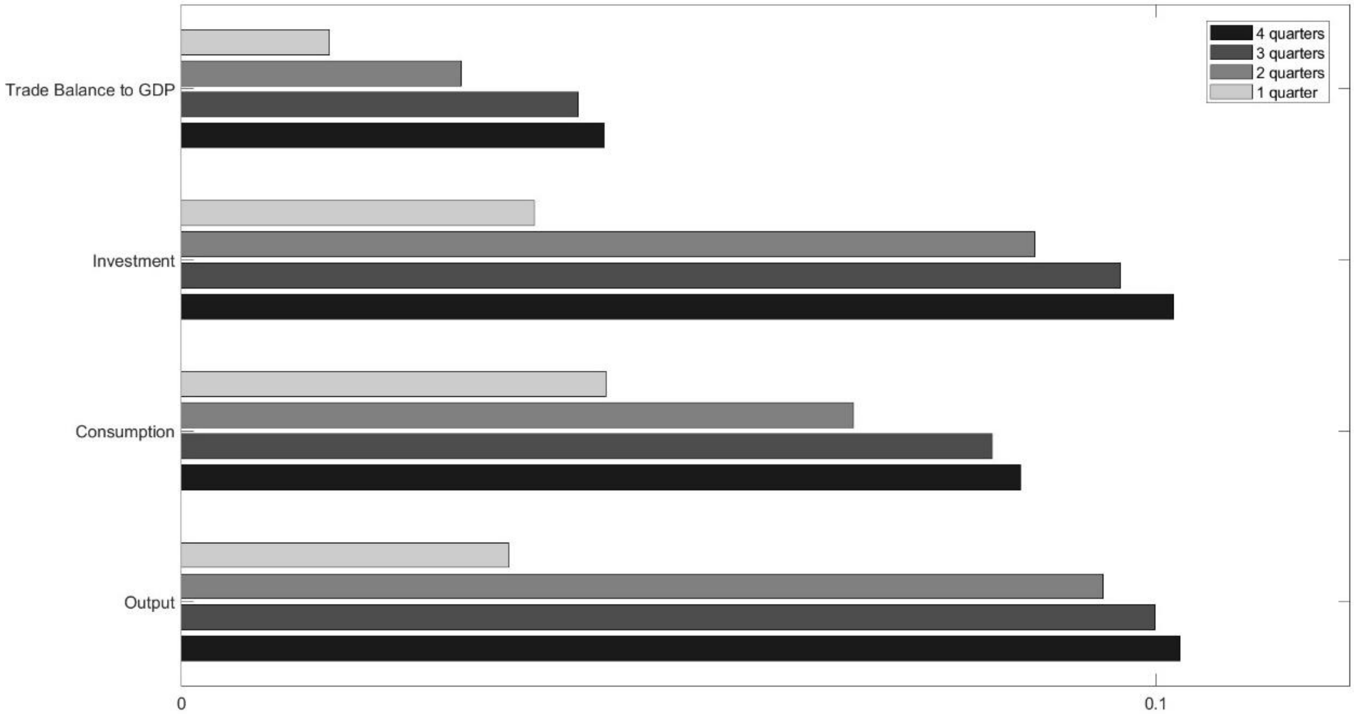
2.9% in the trade balance relative to GDP. The influence of drought shocks on these variables progressively increases up to the four quarters horizon, with output and investment exhibiting the greatest sensitivity at this timeframe. These findings highlight a relevant impact of drought events on economic activity.

Figure I. Responses to a drought shock. (In percentage)



Source: Own calculations.
Note: The solid line corresponds to the median of the shock responses of a standard deviation of the drought index of 0.76%. The shaded area illustrates a 90% confidence interval of the total responses to the same shock. The vertical axes indicate percentage values of each variable and the horizontal axes represent quarters.

Figure II. Drought shocks' contribution to macroeconomic variable fluctuations at selected quarters horizon. (In units)



Source: Own calculations.
Note: The plot shows how much drought shocks explain each one of the macroeconomic variable fluctuations. Corresponding contributions are based on mean estimates for the 90% of the credible set at each horizon.

Final remarks

Drought is a type of climate shock that can have a significant impact on macroeconomic variables. In particular, as documented here, output, consumption, and investment decrease significantly for two quarters after a drought hits the Paraguayan economy.

The transmission mechanism of a climate shock to macroeconomic variables is complex and depends on various factors. However, the design of appropriate policies can contribute to mitigating its negative impacts.

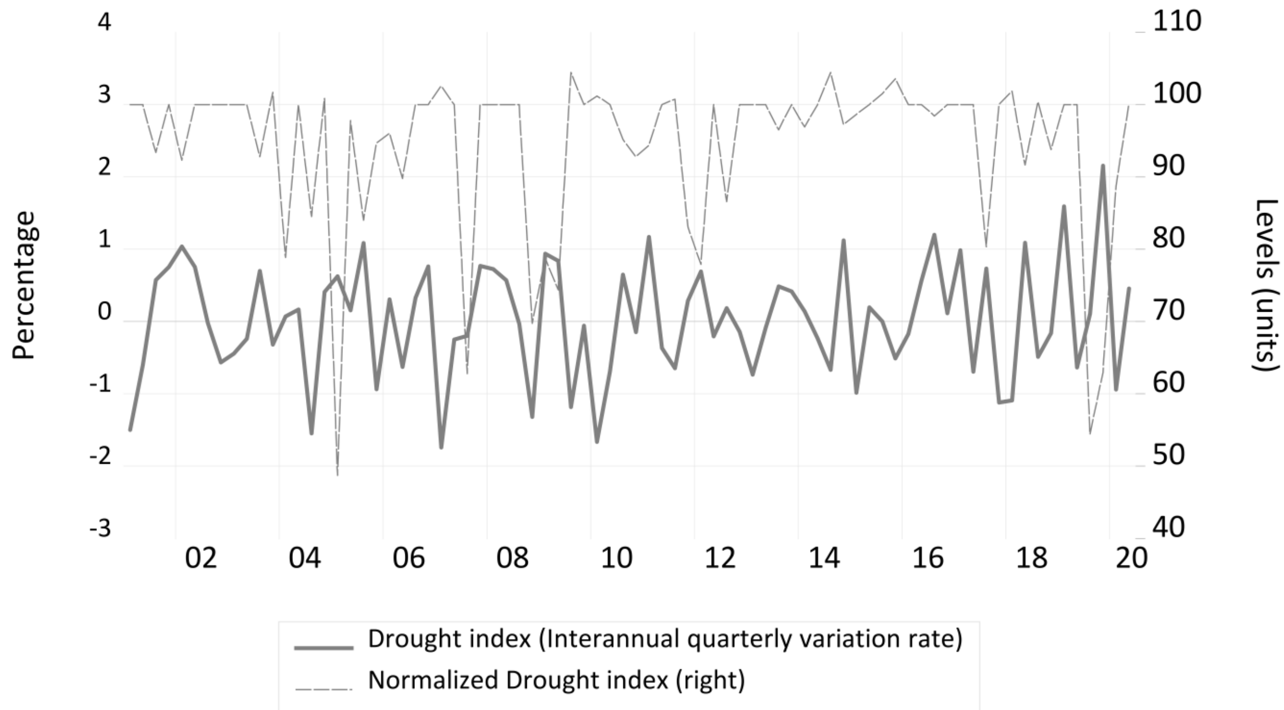
References

Buckle, R. A., Kim, K., Kirkham, H., McLellan, N., & Sharma, J. (2002). A structural VAR model of the New Zealand business cycle (No. 02/26). New Zealand Treasury Working Paper.

Waggoner, D. F., & Zha, T. (2003). A Gibbs sampler for structural vector autoregressions. Journal of Economic Dynamics and Control, 28(2), 349-366.

Appendix

Figure A.I. Drought index (quarterly frequency)



Source: Calculations based on data from the Ministry of Agriculture and Livestock, the National Directorate of Meteorology and Hydrology and the Central Bank of Paraguay.
Note: Normalized drought index = the mean of the drought index is rescaled to 100, while values exceeding one standard deviation of their own series are counted and rescaled as percentage deviations from the normalized mean. Normalized drought index values below 100 indicate low water utility use (water shortages, droughts) in percentage. The quarterly values of the drought index are obtained as a simple average of the monthly values.

Table A.I. Identification restrictions matrix

	di	gdp	con	inv	tby
di	free	free	free	free	free
gdp	0	free	free	free	free
con	0	0	free	free	free
inv	0	0	0	free	free
tby	0	0	0	0	free

Source: Identification strategy.