Response of Inflation to the Climate Stress: Evidence from Azerbaijan

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Research Article

Keywords: inflation, climate, fossil fuel, green energy, BVAR, forecasting

Posted Date: May 19th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1513451/v1

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February 21, 2022

The views expressed in this working paper are those of the author and do not necessarily represent the official views of the Central Bank of the Republic of Azerbaijan.

Abstract

This research analyzes the climate change-related factors' impact on inflation in Azerbaijan between 2005-2020 and forecasts for the 2021-2030 period. For this purpose, the chain impact of temperature on agricultural producer prices is analyzed by the BVAR model. In the second dimension, the transition requirements to green energy's effects on inflation are examined through the exchange rate. According to the model results, climate changes' contribution to inflation is expected to be 1.3 percentage points (pp) in the long run with the normal scenario. On the other hand, climate contribution to inflation is estimated to be 2.2 pp (surpasses half of the inflation target) in the worst scenario of climate change. In the light of these results, the paper highlights the importance of a well-developed climate action plan set by the government and the Central Bank of the Republic of Azerbaijan.

Keywords: inflation, climate, fossil fuel, green energy, BVAR, forecasting

JEL Codes: E31, Q54, E37, E58, C32

1. Background

The Central Banks (CB) are the major organizations to maintain price and financial stability. For this purpose, they have the authority to use several monetary tools to interfere. However, set policies' impacts on the economy are not immediately be seen (Friedman, 1972). Thus, CBs should foresee the economy for appropriate and on-time policies. On this path, they need to know the possibility of risks that threaten the macroeconomic variables they are responsible for.

The CBs risk analyses are primarily based on well-known macroeconomic risk factors such as asset balloons, soaring debts, supply chain, global demand, etc. However, nowadays, the so-called climate change is also partially getting inserted into the major risk factors. But does the climate have enough direct effects on the economy to be accounted as a risk factor?

Since temperature is the major impact variable of climate change, it distracts the precipitation balance, resulting in drought or extreme rainfall; moreover, less productive environment for agricultural foods and more physical damage such as heatwaves, wildfires, floods, etc. Thus, it carries the possibility to be a risk factor. On the other hand, the Paris agreement to prevent climate-related disasters also threatens the fossil fuel sector that holds up several economies like Azerbaijan. Overall, climate change and its related transition to a green environment can risk countries, especially fossil fuel exporters.

To answer the structural question above as “it has” or “it has not” rather than “may” or “can,” this research deeply analyses the structural relations between climate-related factors and inflation in Azerbaijan between the 2005-2020 period in Section 2. As a result, consistent with the previous literature, it concludes that climate had a significant impact on inflation that has been left unnoticed up to now.

In light of shreds of evidence, to estimate the potential impact of climate change on inflation in the future, this paper analyses the exact impact of two climate scenarios between 2021 and 2030 in Section 3. The first scenario is called normal, which is a continuation of historical occasions. The second one is the worst scenario, which encounters i) 1.2 °C higher temperature than the normal scenario in 2030, consistent with World Bank’s (2014) Climate Change projections for Azerbaijan; ii) 4.8 percent less precipitation consistent with Asian Development Bank’s conclusions on droughts (2021); iii) 15 percent higher per capita expenditures on environmental protection; iv) zero fallow land, and v) 26 percent less cereal productivity consistent with the

historical minimum level. These scenarios were implemented into the Bayesian Vector Autoregression (BVAR) model built to estimate inflation in Azerbaijan through an agricultural producer price index between 2021 and 2030. As a result, in 2030, with the worst scenario, water prices became 2.2 times, and inflation became 2.5 times higher than the normal scenario.

In addition, decreasing oil production to meet the Paris agreement's main scope on global temperature is also creating a threat to the exchange rate, which is the main inflation reducer of the economy. According to United Nations-based research (UN) (2020), fossil fuel producer countries must cut 6 percent of fuel production to meet global temperature limiting goals. In the light of this condition and the World Bank's (2021) projections on oil prices, a new worst scenario was generated and implemented into the BVAR model to forecast inflation through Real Effective Exchange Rate (REER) between 2021-2030. According to the worst scenario encountered 21 percent less fossil fuel revenue from export, inflation became two times higher than the normal scenario. In the final step, a combination of the impact of climate change and the transition to a low-carbon economy by reducing fossil fuel production caused approximately 1.8 percent additional inflation each year between 2021 and 2030.

According to the model results, climate change became the proven risk for inflation that was never accounted for before in Azerbaijan. Moreover, similar results could also be obtained for the rest of the world while considering that history and future scenario paths are identical. At this point, this papers' BVAR modeling approach to forecasting the climate changes' impact on inflation (one of the first in the literature under our knowledge) could stimulate future inflation models that account for climate variables as a determinant factor.

After the proof that climate is the risk factor, the main hard task is finding intervention tools against climate-related inflation. Since the existing monetary tools have no direct impact on the reduction of temperature or increment in precipitation, the toolbox of central banks could be widened consistently with their law-determined mandates. "Green quantitative easing" on green energy producer companies could be one of them. Moreover, CBs may use credit channels in a different way to encourage creditor institutions to fund green companies. Although neither will reverse the climate change path, these tools could prevent economies from following the worst scenarios.

2. Climate risks on inflation

From the beginning of the 1990s, Central Banks (CB) have been adopting inflation targeting (IT) regimes (Adam S. Posen, 1999), which led monetary authorities to use interest rate tools as a response to inflation and Gross Domestic Products (GDP) gap (Taylor, 1993). Moreover, the IT regime has become the primary mandate of Central Banks by official law. Alternatively, the countries that have not adopted the IT regime are also setting the CB's mandate to maintain price stability, as in the case of the Republic of Azerbaijan. Thus, "*the main goal of the Central Bank is to maintain price stability within its authorities set by the Law*" (Central Bank of the Republic of Azerbaijan).

Therefore, considering Friedman's (1972) conclusion on a year lag of monetary policies' impact on overall prices, CBs should consider the possible scenarios of future inflation. In this framework, derivers of inflation such as global commodity prices, local factors that affect productivity, trade, demand, expectations, etc., attract immediate attention. Besides that, exchange rate targeting countries have a prior concern about the value of local currencies, which significantly impacts inflation through import prices. Henceforth, all possible risks that could affect future inflation through derivers should be considered while making today's policy decisions. Then the revealed question is, what are the major risks and with which transmission mechanism they will affect the inflation?

The unexpectedly high inflation of the post-pandemic period hustled us to worry about the other risks that we left unnoticed, such as climate change. Is it just a lead trending topic only related to "an environmental change," or is it a real economic threat. If so, what is the impact mechanism of climate on macroeconomic variables? More importantly, will climate significantly affect the overall prices that CBs should maintain their stability?

The basic answer to the last question is "yes." Climate, which uses average temperature as a "gun," could be a serious determinant of inflation. When the temperature increases, the optimal environment for agricultural products changes, which alters the prices. Temperature also increases the risk of decreasing precipitation except for storm-affected areas, affecting the water demand and supply equilibrium. However, globally increased temperature is not an assumption. It increased by 1 °C in 2020 compared to 1951-1980 average temperatures (NASA Global Climate change, 2020).

Moreover, these two conditions are expected to worsen, which will decrease the productivity of land and the quality of agricultural products (Asian Development Bank, 2021) and increase pressure on prices. Besides, climate-related natural disasters such as heatwaves, wildfires, and floods could threaten the insurance system. This risk will also be reflected in the overall prices through insurance prices.

The complex answer is also "yes." Transitioning to a low-carbon economy is a cost factor. It increases the carbon taxes and forces companies to use more expensive green energy. As a result, part of "traditional" energy sources becomes unburnable. For instance, "*a third of oil reserves, half of the gas reserves, and over 80 percent of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2 °C*" (McGlade & Ekins, 2015, p. 187). Thus, fossil fuel producer companies, their stockholders, and the natural source having countries will face negative results during the transition period. Moreover, the countries such as Azerbaijan that strictly depend on fossil fuel revenues from export will be in the major affected group from the transition period.

However, one should note that the direct impact of climate change is and will be greater than the transition costs. For instance, the Bank of England (2021) estimates that transition could lower average annual output growth to 1.4 percent between 6-10 years of transition and increase afterward. On the contrary, no-action to transition could gradually and continuously lower output growth to 1.2 percent in the following 26-30 years. Additionally, no action to transition brings significant physical risks such as natural disasters discussed above. One step further, extremely high temperatures and drought could worsen the economic situation of poorer communities whose income strictly depends on water infrastructure (Asian Development Bank, 2021).[1] Thus, following these significant economic structural impacts, the arguments related to ending the transition cost to reach today's best wealth level are not the subject of this paper.

The previous literature findings also indicate the importance of climate on inflation. Although the global literature is partially developed about the transmission mechanism of climate impacts, it has a significant gap in implementing climate factors into inflation forecasting. Under the transmission mechanism scope, several researchers found a significant effect of climate-related disasters on inflation. For instance, according to Lesk, Rowhani, and Ramankutty (2016), droughts and heatwaves decrease the global cereal productivity by 9-10 percent between 1964 and 2007. A

[1] Explained in detail in Section 2.2.

step further, 1 °C increased temperature over a yearly average of 15 °C or above decreases the general productivity by 1.7 percent (Deryugina & Hsiang, 2014). Parker (2018) found that inflation immediately increases 1.3 percentage points (pp) in response to drought by analyzing the relation between the frequency of disasters and inflation. The latest published research on climate and food inflation was made by Islam et al. (2022), proving that climate negatively affects food security, which is significantly related to inflation.

On the other hand, fossil fuel profusion and transition to green energy are risking fossil fuel producer economies (Bradshaw, Graaf, & Connolly, 2019) through global oil demand (Graaf & Verbruggen, 2015). For instance, the research for Latin America and the Caribbean proves that the oil revenues will decrease by approximately 50 percent due to global oil demand by 2035 (Solano-Rodríguez, et al., 2021).

In general, the climate is proven to have an impact on inflation through agricultural productivity. Moreover, transitioning to a low-carbon environment is risking fuel exporter countries and their currencies. Henceforth, the findings assure that the future of climate change carries a serious risk to inflation and the overall economy that should be estimated.

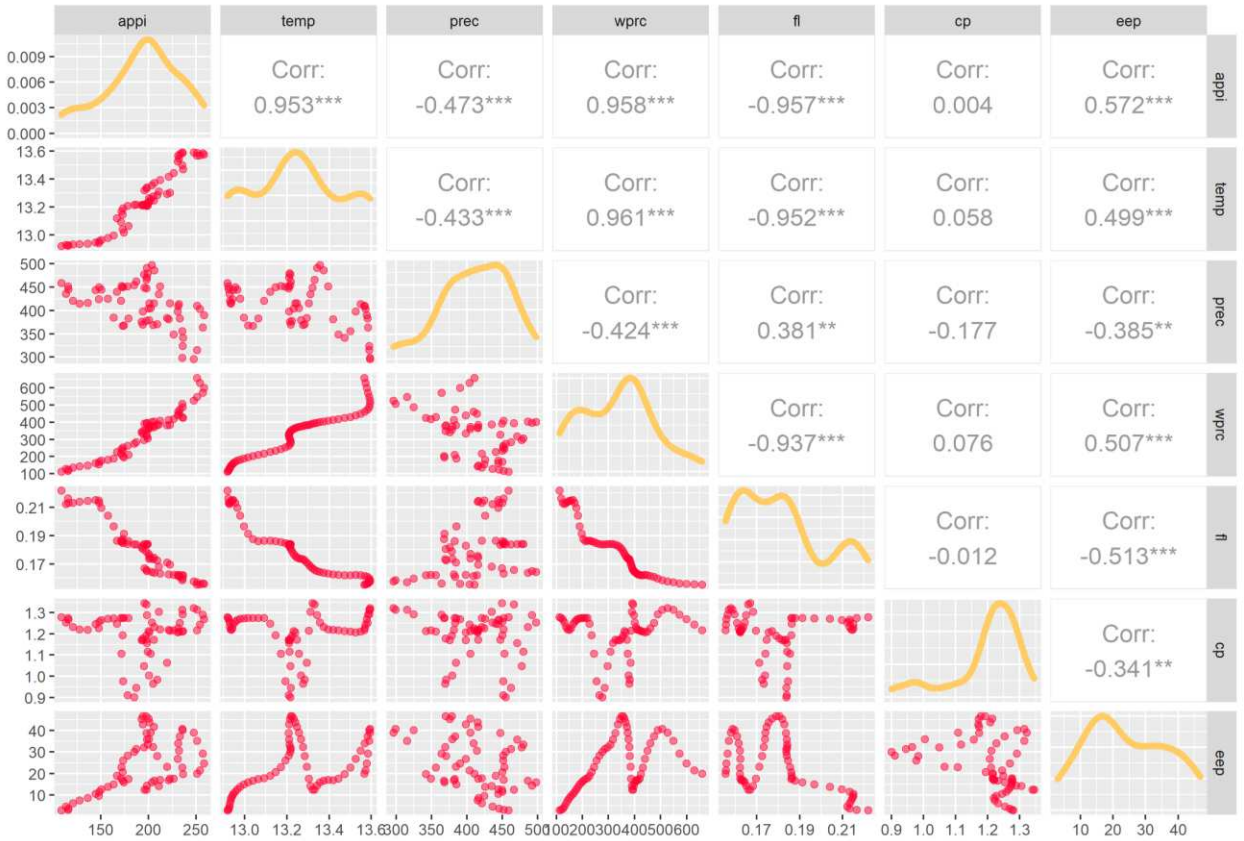
2.1. Data and descriptive statistics

The research is primarily based on exogenous temperature (temp) as a "gun" of climate change and precipitation (prec). Both data cover the 1901-2020 period and are obtained from World Bank Climate Change Knowledge Portal as average annual observations. In relation to change in these variables, for the 2000-2020 period, the following scenario variables are per capita m^2 fallow land (fl), cereal productivity (cp) relative to population, and per capita expenditures on environmental protection (eep) that obtained annually from State Statistics Committee of the Republic of Azerbaijan (AzStat). The first set of focused endogenous variables are water price inflation (wprc) and agricultural producer price inflation (appi); both contain monthly observations between 2005 and 2021 and are obtained from AzStat. The third primary endogenous variable is the Real Effective Exchange Rate (REER) between 2000 and 2021, obtained as monthly observations from the CB of Azerbaijan Republic (CBAR). The scenario variable related to the REER model is fossil fuel revenues from export (oilr) received as yearly observations from AzStat between 2000 and 2021. The final exogenous variable is global oil price projections obtained as yearly observations

from World Bank's Commodity Markets Outlook. The annual data sets were transformed into quarterly ones by Chow-Lin's (1971) methodology. The monthly data sets are converted to the quarterly base by summing or taking an average of three months regarding the data structure.

Since the literature proved the significant relation between agricultural prices and climate-related drought, this research analyzes more detailed impact transmission mechanisms. In the beginning, the descriptive statistics are used to ensure the relationship between inflation and climate variables and are displayed in Table 1.

Table 1. Correlogram



Source: AzStat, World Bank

*** - if the p-value is < 0.001; ** - if the p-value is < 0.01; * - if the p-value is < 0.05

In Table 1, the variable abbreviations are as follows: appi - agricultural producer prices, temp – temperature, prec - precipitation, wprc - water prices, fl - per capita fallow land (m^2), cp- cereal productivity relative to population, eep - per capita expenditures on environmental protection. The lower triangular panel displays the correlation paths, and the upper panel shows the exact correlation values with their statistical significance. The diagonal is the density distribution of observations.

As seen in Table 1, the temperature negatively correlates with precipitation and fallow land; moreover, it has a positive and high correlation with agricultural product prices and water prices. It also has a positive correlation with per capita expenditures on environmental protection. Thus,

we address temperature as the "gun" of climate change. In the inflation dimension, temperature, water prices, and per capita expenditures on environmental protection observations provide a positive correlation; however, precipitation and per capita fallow land (m2) negatively correlate with agricultural product inflation; henceforth with overall price stability. Unlike other scenario variables, cereal productivity does not provide a significant relationship with any other. However, a step ahead, impulse response reveals its negative relation with inflation, discussed in detail in Section 2.4 and displayed in the Appendix.

The evidence from Azerbaijan displays that temperature as a gun of climate change directly and negatively affects the fallow land. Besides, the precipitation is falling,[2] which causes higher water supply prices and higher agricultural product prices. These pieces of evidence are the non-complex part of reality. The complex part is the Paris agreement, which was signed on December 12, 2015. While considering the continuously increasing expenditures on environmental protection as a function of payments for releasing pollutants into the natural environment, the agreement criterion becomes an additional cost factor. In addition, decreasing oil production to meet the Paris agreement's main scope on global temperature is also creating a threat to the exchange rate, which is the main inflation reducer of the economy.

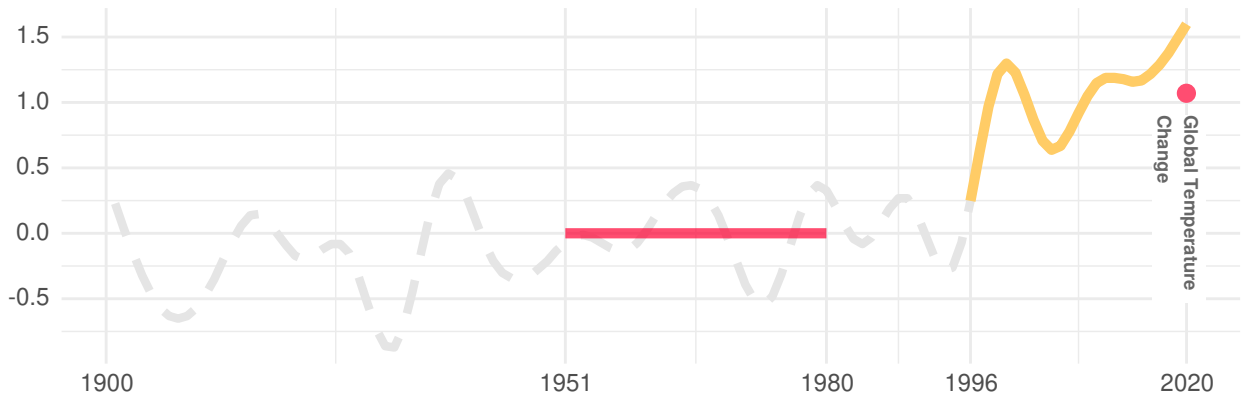
2.2. Changing climate conditions

The global temperature anomaly is 0.85 °C recently (Jan-2021) according to NASA (2021), which is the relative temperature of the current year versus the average temperature of the 1951-1980 pre-industrial period. The anomaly reached its highest level (1.02 °C) in 2020 and decreased in 2021. As displayed in Figure 1, the mean annual temperature in Azerbaijan also follows a similar increased path but is above the world average. Moreover, at the end of 2020, the mean annual temperature increased 0.57 °C higher than the global average, ensuring that climate change has a more negative effect on Azerbaijan than on the world.

[2] It should be noted that increased temperature is expected to increase the extreme rainfall in Azerbaijan. However, extreme rainfall is not the source of agriculture required or a drinkable water supplier rainfall (Lawrence, 2018). Moreover, high temperature causes water evaporation and heavy rains, which reduce the "*water access for humans and ecosystems*" (Society, 2019).

Figure 1. Smoothed Mean Annual Temperature Change in Azerbaijan

relative to 1951-1980 average temperatures



Source: World Bank, NASA

High temperature causes high precipitation volatility and drought (Dore, 2005); moreover, less productive agricultural products (Lesk, Rowhani and Ramankutty 2016; Deryugina and Hsiang 2014). As a result, decreased productivity is directly reflected in food inflation (Parker, 2018; Islam, et al., 2022). In addition, as a result of high temperature, arable lands shrink, and thus, fallow land decreases. Consistent with high volatile precipitation (extreme rainfall), drinkable water supplies fall (Lawrence, 2018), and water prices increase.

On the other hand, the water issue is also threatening the welfare structure of the country. According to ADB (2021), drought carries the possibility to worsen income inequality by reducing the revenues from "rain-fed" agricultural products. Since poor communities and farmers can not reach the local water supply, the rising temperature would have the most significant negative impact on them rather than on the rest of the population (Asian Development Bank, 2021).

Henceforth, understanding the potential climate risk to the economy is essential and requires an analysis of temperature's future path. In this scope, this paper develops two scenarios. The first one is a normal scenario, where the history of variables determines the future. The second is the worst scenario, where variables' future is consistently determined by global projections. It should be highlighted that the normal scenario is not the best scenario that assumes no further change in the climate.

2.3. Normal scenario ARIMA model

The normal scenario variables' forecasts are built on Autoregressive Integrated Moving Average (ARIMA (p, q)) as below:

$$\boldsymbol{y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_p y_{t-p} + u_t + \theta_1 u_{t-1} + \theta_2 u_{t-2} + \cdots + \theta_p u_{t-q}} \quad \textbf{(1)}$$

where y_t is scenario variable (*temp; prec; fl; cp; eep; oilr*) and u_t is the error term.

Each variables' stationarity is checked by the Augmented Dickey-Fuller test, and random walk variables are transformed to stationary. Moreover, the Autocorrelation Function (ACF) denotes the MA (q), and the Partial Autocorrelation Function (PACF) determines the AR (p) lag orders. The model results are displayed in the following section.

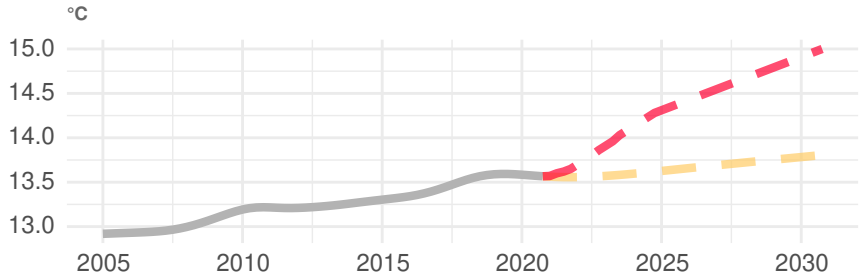
One thing should be noted that, in this research, the ARIMA models are not the main long-run forecast driver models. They used to obtain the trend of variables and provide continuation of them for the 2021-2030 period.

2.4. Climate stress scenarios

In the normal scenario based on history, scenario variable forecasts are determined by the ARIMA model provided above. On the other hand, the worst scenario considers global forecasts and integrates them into local variables. As shown in Figure 2, the mean temperature is expected to grow on two quite different paths. The red forecasts that ended up at 15 °C indicate the worst scenario, based on the 50th percentile of the World Bank's SSP5-8.5 projections (2014). On the other hand, the yellow path indicates the normal scenario, where the temperature increases to 13.8 °C. Following the temperature rise, precipitation decreases to 395.6 mm (Figure 3) at the end of 2030, regarding the worst scenario. The normal scenario's precipitation forecast is 415.6 mm of rainfall for 2030.

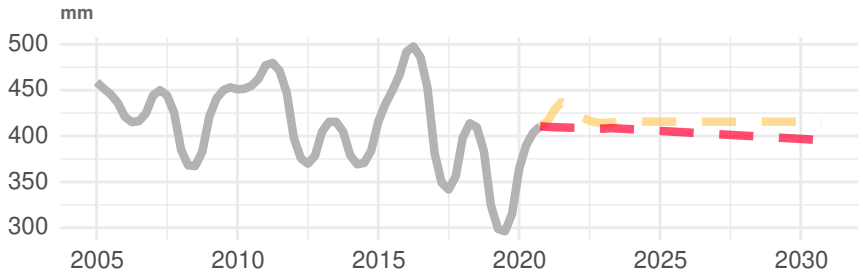
Associated with these changes, fallow lands will decrease in both scenarios (Figure 4). Moreover, in the worst scenario, we assume zero fallow lands, which is the extreme case. Since fallow land is the recovery of arable lands, it is significantly related to productivity. However, productivity also depends on other factors, such as technology and the quality of seeds. Thus, the history of productivity does not provide significant relation with previous variables. Notwithstanding the descriptive statistics, assuming zero technological change in productivity or seed quality, the worst scenario supposes that productivity will decrease to its historical minimum (Figure 5.).

Figure 2. Mean Temperature (temp)



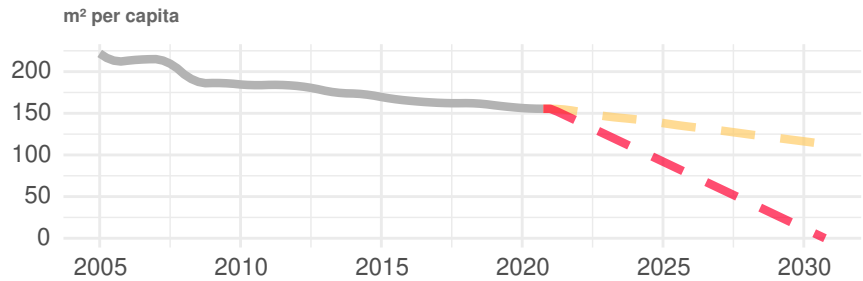
Source: World Bank

Figure 3. Precipitation (prec)



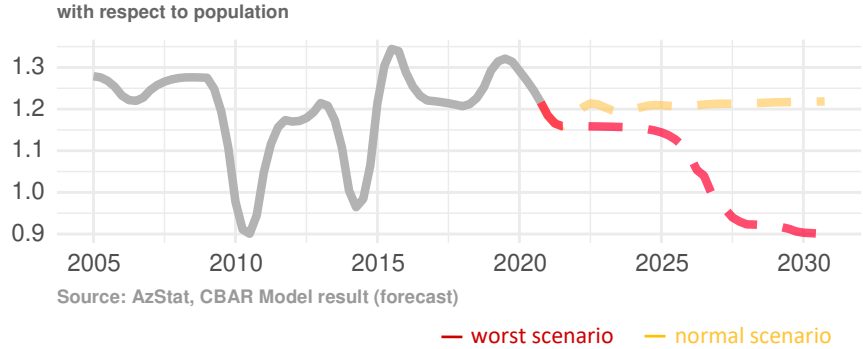
Source: World Bank

Figure 4. Fallow Land (fl)



Source: AzStat, CBAR Model result (forecast)

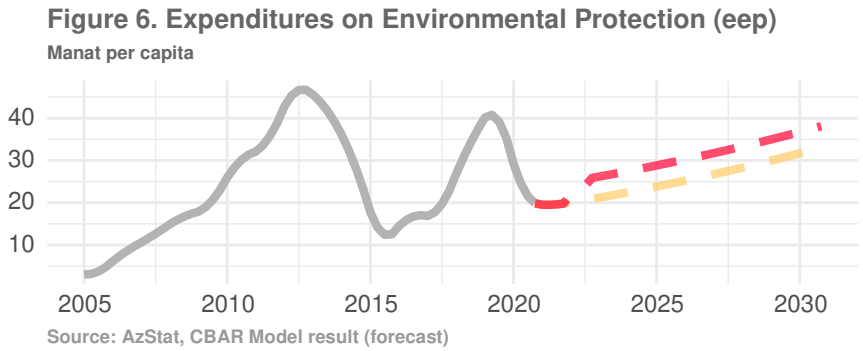
Figure 5. Cereal Productivity (cp)

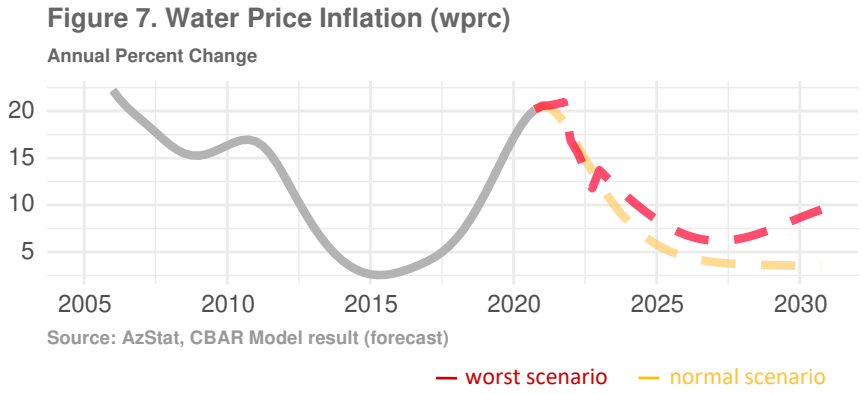


Source: AzStat, CBAR Model result (forecast)

Another critical variable is per capita expenditures on environmental protection, which carries the impact of the Paris agreement. In the worst scenario displayed in Figure 6, *eep* is assumed to be 5 manats (constantly)

higher starting from 2022 in accordance with being a more climate-friendly country. It should be noted that this assumption is entirely dependent on the researcher's initiative.





As the result of climate change, Figure 7 displays the first important result of the BVAR model discussed in the following section. The figure shows that water price inflation is expected to rise sharply after 2027 and reach 9.51 pp at the end of 2030, whereas 3.5 pp is in the normal scenario. Henceforth, regardless of the scenario types, it clearly shows that water prices will create pressure on overall costs.

In the second dimension, the transition to a low-carbon economy with the Paris agreement, fossil fuel producer countries must decrease their production by 6 percent (UN, 2020). Considering Azerbaijan exports' fossil fuel dependency is extremely high (87 percent), reduced production will cause decrement in the export revenues at constant prices. Additionally, according to World Banks' commodity market projections (Commodity Markets Outlook, 2021), oil prices will gradually decrease from 74 USD in 2022 to 67.9 USD in 2030. That fact will be the second shock to the export revenues of Azerbaijan and the rest of other oil-exporting countries. Overall, these shocks are considered the worst scenario, as displayed in Figure 8, for a new model. According to the worst scenario, the fossil fuel revenues will be 21 percent lower than the normal scenario.

In Azerbaijan, fossil fuel revenues from export have a 73 percent correlation (when the 2008 crisis shock is smoothed) with REER, and REER's contribution coefficient to inflation is high

(-0.30).[3] Thus, this research analyzes fuel revenues' relation with REER through the second BVAR model. Without going further into details about the model in this section, Figure 9 displays the forecast for REER as a dependent variable for Fossil Fuel Revenue. According to the figure, the feeder environment started in 2018 for Azerbaijani manat's value will disappear after 2024. Moreover, the environment will continuously have the opposite effect in the worst scenario.

Figure 8. Export Revenue of Fossil Fuel

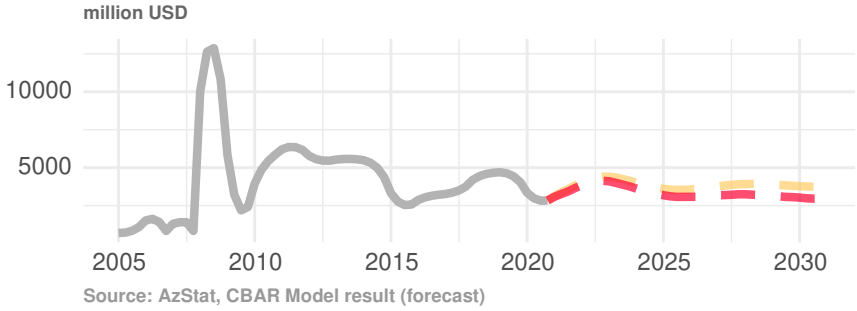
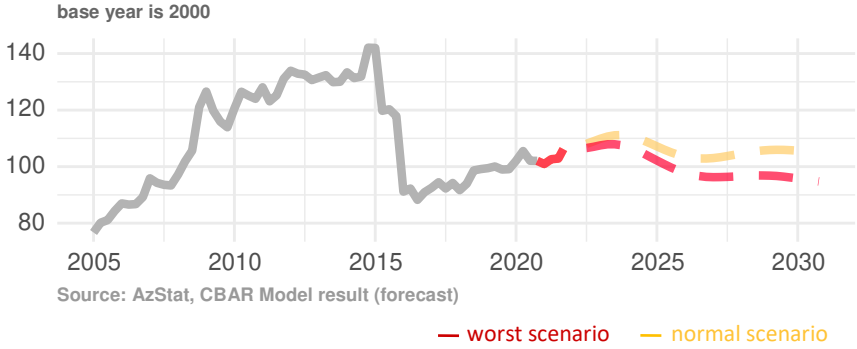


Figure 9. Real Effective Exchange Rate (REER)



It should be noted that one can assume the worst scenario variables' future quite differently. Regardless of the values, the purpose here is to prove that the change in the climate scenario variables significantly alters the headline inflation in the end.

By combining temperature, precipitation, fallow land, cereal productivity, expenditures on environmental protection, and water price inflation variables regarding scenarios, this research firstly obtains a forecast of agricultural product price inflation (*appi*) by the BVAR model (BVAR1). Afterward, it converts *appi* to headline inflation by contribution coefficient (0.27). Besides considering the fossil fuel revenue scenarios, the paper forecasts REER by another BVAR model (BVAR2) and finds its' contribution to inflation. Finally, the contribution from climate change and transition to the low-carbon environment with the Paris agreement are aggregated to obtain climate-related changes' total impact on inflation.

[3] The coefficient was obtained from non-published CBAR research written by R. Rahmanov and T. Yusifzada. It is achieved by a long-run coefficient of the ECM model for inflation decomposition.

3. BVAR model

The BVAR model proposed by Litterman (1980) uses the Bayesian method described to estimate the VAR models. Unlike VAR models that treat parameters as fixed values, BVAR considers them as random variables with prior probabilities. By integrating the Bayes rule, it solves the dimensionality problem of VAR that resulted from the largeness of parameter numbers than the available number of observations (Öğünç, et al., 2013). Moreover, it increases in-sample fitting and out-of-sample forecasting performance (Dua & Ray, 1995), where observations are limited.

However, the main challenge in BVAR models is the selection of true priors (Öğünç, et al., 2013), where different priors result in different estimates (Blake & Mumtaz, 2007). Henceforth, in this paper, the selection of priors is based on the maximization of marginal likelihood proposed by Chib (1995).

Suppose $Y_t = (Y_{1,t}\ Y_{2,t} \dots\ Y_{n,t})'$ is the random variable vector. Therefore, A VAR(p) model is specified as:

$$\boldsymbol{Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + \varepsilon_t} \quad \textbf{(2)}$$

where c is a vector of constants, $\phi_1, \phi_2, \dots, \phi_p$ are lag matrices and ε_t is the white noise terms $\varepsilon_t \sim i.i.d.\ N(0, \Sigma_t)$.

The VAR (p) could be written in another format as:

$$\boldsymbol{Y_t = X_t \Phi + \varepsilon_t} \quad \textbf{(3)}$$

where Y_t is $t \times n$ matrix of model variables, $X_t = \{c, Y_{it-1}, Y_{it-2}, \dots, Y_{it-p}\}$. Moreover, VAR equations have identical regressors that can be shown as:

$$\boldsymbol{y = (I_n \otimes X)\alpha + \varepsilon} \quad \textbf{(4)}$$

where $\varepsilon \sim (0, \Sigma_\varepsilon \otimes I_T)$, α is the vector of ϕ, and I_n is the identity matrix. The likelihood derived from equation 4 is:

$$\boldsymbol{L(\alpha, \Sigma_\varepsilon) \propto |\Sigma_\varepsilon \otimes I_T|^{-\frac{1}{2}} exp\{-\frac{1}{2}(y - (I_n \otimes X)\alpha)'(\Sigma_\varepsilon^{-1} \otimes I_T)(y - (I_n \otimes X)\alpha)\}} \quad \textbf{(5)}$$

Since the maximum likelihood provides unbiased estimates for α ($\alpha_{\text{MLE}} = \alpha_{\text{OLS}}$) and biased estimates for Σ_ε ($\Sigma_{\varepsilon\ \text{MLE}} \neq \Sigma_{\varepsilon\ \text{OLS}}$), we use Bayesian law in the lead of Blake and Mumtaz (2007), which gives an opportunity to introduce prior beliefs about the values of α and Σ_ε. These beliefs are integrated to the model by probability distributions such as:

$$\boldsymbol{p(\alpha|\Sigma_\varepsilon) \sim N(\hat{\alpha}_0, \Sigma_\varepsilon \otimes \mathrm{H})}$$

is the normal probability distribution of prior for α, where $\hat{\alpha}_0$ is prior mean and diagonal elements of $\Sigma_\varepsilon \otimes$ H is the variance of the coefficient prior (high $\Sigma_\varepsilon \otimes$ H indicates high uncertainty about prior). The diagonal elements for the coefficients on lags defined as $(\frac{\lambda_0\lambda_1}{l^{\lambda_3}\sigma_i})^2$ and for the constants defined as $(\lambda_0\lambda_4)^2$ (Sims & Zha, 1998).

$$\boldsymbol{p(\Sigma_\varepsilon) \sim IW\ (\overline{S}, \delta)}$$

is the inverse Wishart distribution of prior for the covariance matrix of VAR, where δ is the prior degrees of freedom and $\overline{S}$ is a prior scale matrix (Blake & Mumtaz, 2007). The matrix for VAR(2) model that used in this research is defined as:

$$\overline{S} = \begin{pmatrix} (\frac{\sigma_1}{\lambda_0})^2 & 0 \\ 0 & (\frac{\sigma_2}{\lambda_0})^2 \end{pmatrix}$$

The hyper-parameters used in this research are $\lambda_0 = 1$ (overall tightness of covariance matrix prior), $\lambda_1 = 0.2$ (overall tightness of coefficient priors on the first lag), $\lambda_3 = 1$ (lag decay) and $\lambda_4 = 100$ (control variable on constant) to maximize the marginal likelihood (Chib, 1995). Moreover, the Gibbs sampling algorithm is used to find marginal posterior distributions by setting the prior with initial observations and the sum of coefficient dummies. However, as suggested by Blake and Mumtaz (2007), initial prior values have limited impact with larger Gibbs iteration. Gibbs sampling run for 100000 draws with 0.1 percent burn-in. Since the data is non-stationary $I(1)$, we set the prior's AR coefficient to 1.

In this research, BVAR1 random variables are:

$$y_t = [appi_t\ \ temp_t\ \ prec_t\ \ fl_t\ \ cp_t\ \ eep_t\ \ wprc_t]'$$

BVAR2 random variables are:

$$y_t = [reer_t\ \ oilr_t]'$$

The variables used in the model were transformed into quarterly observations by Chow-Lin (1971) and manually averaging or summing operations. Afterward, observations are seasonally adjusted by TRAMO-SEATS. Variable shocks are identified with Cholesky decomposition. Both models estimate quarterly variables from 2005 to 2020 and forecast endogenous variables (*wprc; appi; reer*) for the 2021-2030 period. Exogenously given variables are the scenario variables discussed in Section 2.4.

To check the robustness of the model, the BVAR model is compared with Vector Error Correction Model (VECM) via Root Mean Squared Error (RMSE). Since the VECM's RMSE is 1.14 relative to BVAR (Table 2) for agricultural producer price inflation (*appi*), BVAR's *appi* forecasts outperform in our research rather than VECM across forecasting horizons.

Table 2. Averaged 1 to 12 quarters ahead RMSE for BVAR and VECM

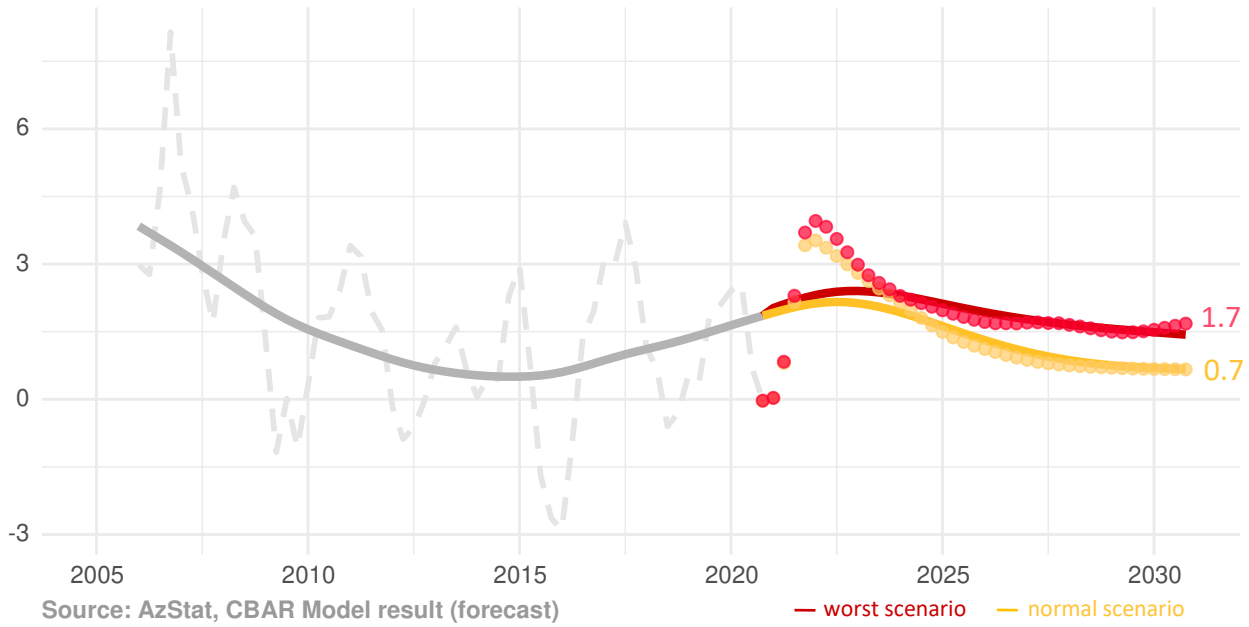
BVAR		VECM		
Variable	RMSE	Variable	RMSE	RMSE Relative to BVAR
APPI	5.795	APPI	6.630	1.144
CP	0.063	CP	0.040	0.634
EEP	7.881	EEP	10.275	1.304
FL	0.008	FL	0.001	0.572
PREC	42.393	PREC	35.850	0.846
WPRC	24.389	WPRC	15.466	0.634

Although in the long run, BVAR generally provides less forecast accuracy in the empirical literature works firstly proved by LeSage (1990), several ones prove BVAR's better or same performance compared with VECM (Kato, 2021); (Giannone, Lenza, & Primiceri, 2018); (Félix & Nunes, 2003). Moreover, considering the relative RMSE of models displayed in Table 2 differs across variables, this research's main purpose is to forecast *appi* "given" other variables. Henceforth, the BVAR is taken as the main model, and impulse responses are displayed in the Appendix. Additionally, BVAR and VECM model output comparison for contribution to inflation is also displayed in the Appendix. It should be noted that ECM and BVAR provide near-identical estimations for REER and fossil fuel revenues model.

4. Result and Discussion

According to the BVAR1 model and scenarios discussed in Section 2, the agricultural producer price inflation forecast for the 2020-2030 period is generated.[4] Moreover, multiplying by the decomposition coefficient, the headline inflation is forecasted as in Figure 10.

Figure 10. Climate Change's Contribution to Inflation
Through Agricultural Producer Price Index



Source: AzStat, CBAR Model result (forecast)

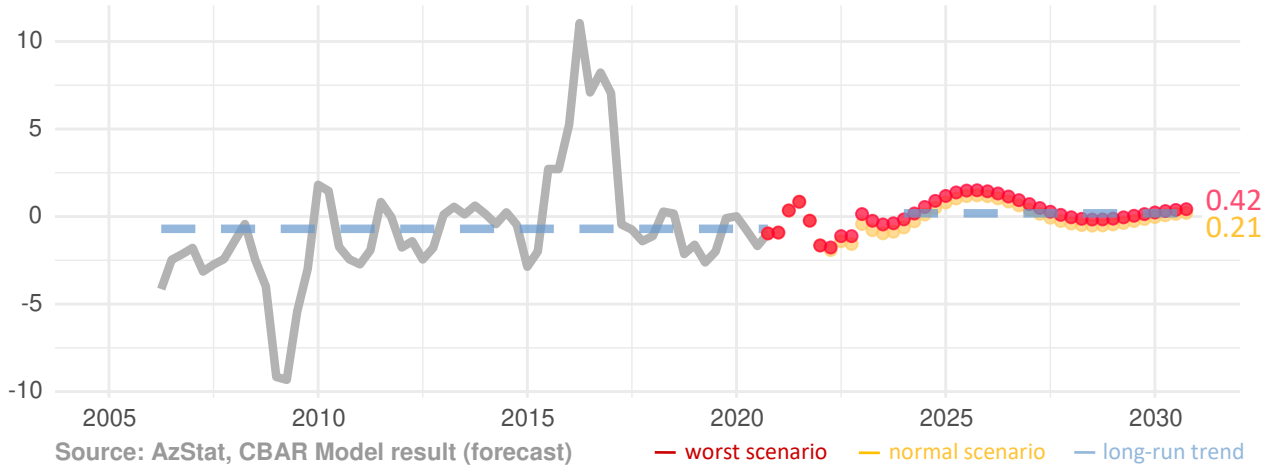
Regarding the figure, climate change-related factors' contribution to inflation is additive for both historical and projections periods. The finding indicates that climate change was always a driver for headline inflation, which should not be ignored. Moreover, the worst scenario indicates 1.7 pp additional inflation in 2030, assuming the rest of the inflation determinants will remain constant. Furthermore, the worst scenario is 1 pp higher than the history-based normal scenario, proving the impact of climate scenario variables.

On the other hand, the transition to the low-carbon environment with the Paris agreement harms REER, considering the BVAR2 model. This impact was firstly shown in the sharp oil price decline

[4] Since its' share in the inflation is constant, the *appi* follows the identical path as the inflation contribution in Figure 10. Thus, its' direct forecast graph is not displayed in the paper.

in 2015,[5] where manat devaluation happened twice, and the cost of 1 USD rose to 1.7 manats from 0.78. As displayed in Figure 11, REER's contribution to inflation reached its historical maximum (11 pp) in the second quarter of 2016 (Q2) due to the impact lag.

Figure 11. REER's Contribution to Inflation



Overall, REER's long-run contribution to inflation was negative between 2005 and 2020, which gives it a bumper[6] function against inflation pass-through from trading partners. However, the transition to low-carbon seems to change this structure. Starting from 2024, REER would not be able to be the bumper; moreover, it would give an additive contribution to inflation between 2024 Q3 – 2027 Q2. Furthermore, the contribution of REER to inflation will be two times higher than the normal scenario in 2030. Considering the magnitude of impact, it may seem unimportant; however, losing of being the bumper function would have a more indirect effect on inflation that will be analyzed in further research.

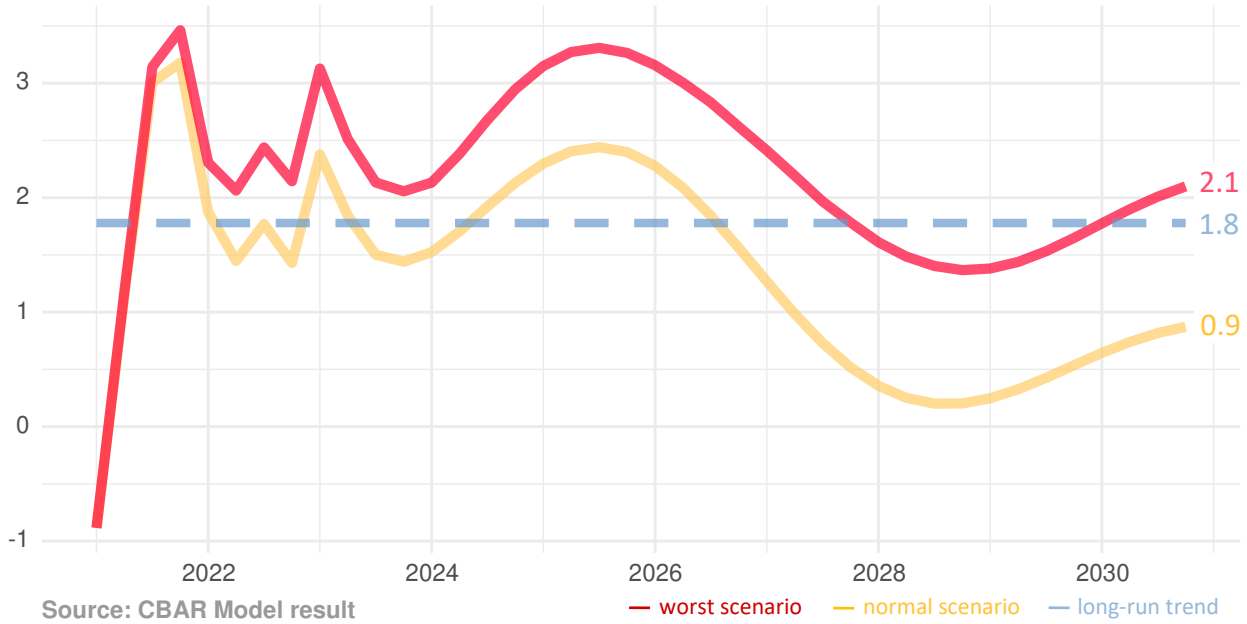
Finally, combining both aspects of the paper, climate-related changes' total impact on inflation is aggregated in Figure 12.

[5] See Figure 8 and 9 simultaneously.

[6] When inflation is high in trading partners, a relatively strong exchange rate of manat help to reduce imported product prices in manat terms. This mechanism prevents inflation pass-though from imported goods; hence it is called the bumper.

Figure 12. Response of Inflation to the Climate Stress

Aggregate contribution of climate change and the fossil fuel revenues to the inflation



Source: CBAR Model result

According to the figure, at the end of 2030, the worst scenario will create 2.1 pp inflation, 1.2 pp higher than the normal scenario, proving the response of inflation to climate factors. In general, regardless of the scenario types, climate changes' impact on inflation is expected to be 1.8, as the long-run trend displays. Considering that the inflation target is 4 ± 2 pp in Azerbaijan (Central Bank of the Republic of Azerbaijan, 2021), only climate-related inflation contributions encounter near half of the target, according to the model results.

Overall, literature findings and our findings display climate change's importance as another significant determinant of inflation. At this point, it is suggested that CBs who have the mandate to maintain price stability or have IT regimes start to give attention to climate change and transition to a low-carbon economy. Henceforth, preserving price stability will require action against inflation; therefore, climate change. But how Central Bank can involve in its actions as an independent monetary organization?

European CB's President Christine Lagarde said that "g*overnments, not central banks, who are primarily responsible for facilitating an orderly transition, and who control the main required tools"* in July 2021 (France 24, 2021). Not primarily but secondarily, CBs could support governments' green and sustainable economic development plans by preserving their structural independence and law-determined mandates. For instance, "green quantitative easing" of CBs:

purchasing of non-polluting sectors firms' bonds (Ferrari & Landi, 2020). Although Ferrari and Landi proved that green quantitative easing is ineffective in reducing pollution, it could permanently solve to reduce the balance sheet risks resulting from sectors with no bright future with the Paris agreement. As it is known that green energy will replace traditional ones sooner or later, fossil fuel companies' shares in balance sheets will lose their values, threatening financial stability (Campiglio, et al., 2018). Moreover, credit agencies that fund fossil fuel companies will also carry the risk of future shrinkage.

In the Azerbaijan dimension, the financial market is not fully developed to reflect transitions' costs on balance sheets. However, the threat is more significant than in other countries because of the fact that fossil fuel exportation undertakes approximately 87 percent of Azerbaijan's total export volume. Moreover, this export is significantly linked to the value of the local currency. Henceforth, hedging against fossil fuel shrinking due to the transition period requires economic diversification based on a competitive economy (Soummane, Ghersi, & Lecocq, 2022). Furthermore, green replacement of traditional fuel could be considered from a new perspective in export-based governmental strategies. Under this condition, CBAR's possible support of green energy exporter organizations by green quantitative easing may benefit the economy. Not just for reducing pollution but also to reduce the negative impact of shrinkage risk on the fossil fuel market and reduce the risk possibility on the value of the local currency.

Conclusion

This research analyzed the climate risks that were previously "not considered valuable enough to be considered." By using historical relations, the paper provided the importance of climate as a derivative of inflation. In more detail, climate risk is considered under two aspects. At first, temperature performs as the main factor called a "gun" and affects inflation through chain impact on precipitation, fallow land, cereal productivity, expenditures on environmental protection, and water prices.

In relation to the first aspect, the historical trend is considered as the base for the 2021-2030 forecast horizon to obtain a normal scenario, and the World Banks' temperature change projection for Azerbaijan is taken into account as the driver of the worst scenario. Since the temperature is

assumed to be 1.2 °C higher in the worst scenario than the normal scenario, precipitation, fallow land, and cereal productivity are supposed to be lower, and water prices have projected higher than the normal scenario. Moreover, the Paris agreement causes additional costs on expenditures on environmental protection. As a result of the climate changes, the contribution to inflation is expected to be 1.7 pp in the worst and 0.7 pp in the normal scenario in 2030. The difference between scenarios ensures that climate factors determine inflation in Azerbaijan, which this study aimed to prove.

The second aspect is the Paris agreement's impact on fossil fuel production and the transition to a low-carbon environment's effects on oil prices. In this aspect, the worst scenario is built on continuously decreased 6 percent fossil fuel production and reduced oil prices from 74 USD in 2022 to 67.9 USD in 2030. By considering the high sensitivity of Azerbaijani manat on fossil fuel revenues, two shocks will significantly affect the economy after 2024, according to the model. Afterward, REER will no longer be able to neutralize high global product prices. Moreover, the model shows that after 2024 feeder environment for the value of Azerbaijani manat will disappear.

Overall, inflation's response to climate stress is alerting, according to 1.8 pp additional contribution of climate to inflation as the long-run trend while considering the inflation target. Moreover, REER's response to oil revenues also forewarns the currency value risks in 2024. With these two aspects in mind, adding a climate action plan to its agenda could increase CBAR's future policy effectiveness until it has the mandate to maintain price stability and the value of the local currency.

One thing is clear CBs themselves have no power over temperature decrement. Under the knowledge of limited ability to have an impact on climate, the government of Azerbaijan and CBAR may be in search of alternative policies to prevent the economy from the damage risks. In this scope, the government might change the direction of energy exports from fossil fuel to green energy. Moreover, by green quantitative easing, CBAR's possible investments in green energy exporter companies worldwide may prevent its reserves against exchange rate shocks. Furthermore, CBAR may encourage local creditor organizations to change the direction of credits to green companies. By this policy, CBAR could avoid the risk of economic shrinking and prevents a more polluted environment that results in the worst scenario. However, the climate action plan and related cost-benefit analyzes should be well-developed and consistent with the rest of the world, which are left for future research.

List of abbreviations

ACF	Auto-correlation function
ADB	Asian Development Bank
APPI	Agricultural producer price inflation
AR	Auto-regressive
ARIMA	Autoregressive integrated moving average
AzStat	State Statistics Committee of the Republic of Azerbaijan
BVAR	Bayesian Vector Autoregression
CB	Central Bank
CBAR	Central Bank of the Republic of Azerbaijan
CP	Cereal productivity
ECM	Error Correction Model
EEP	Expenditures on environmental protection
FL	Fallow land
GDP	Gross Domestic Product
IT	Infltaion Targeting
MA	Moving Average
OILR	Fossil fuel revenues from export
PACF	Partial auto-correlation function
pp	Percentage points
PREC	Precipitation
Q	Quarter
REER	Real Effective Exchange Rate
RMSE	Root Mean Square Error
TEMP	Temperature
USD	United States Dollar
VAR	Vector Autoregression
VECM	Vector Error Correction Model
WPRC	Water price inflation

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The data that used in this study can be obtained from the author upon request.

Competing interests

The author reported no potential competing interests.

Funding

The author declares that the research received no specific funding.

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Authors' contributions

Not applicable.

Acknowledgements

The researcher is grateful to Ramiz Rahmanov for his fruitful comments and suggestions.

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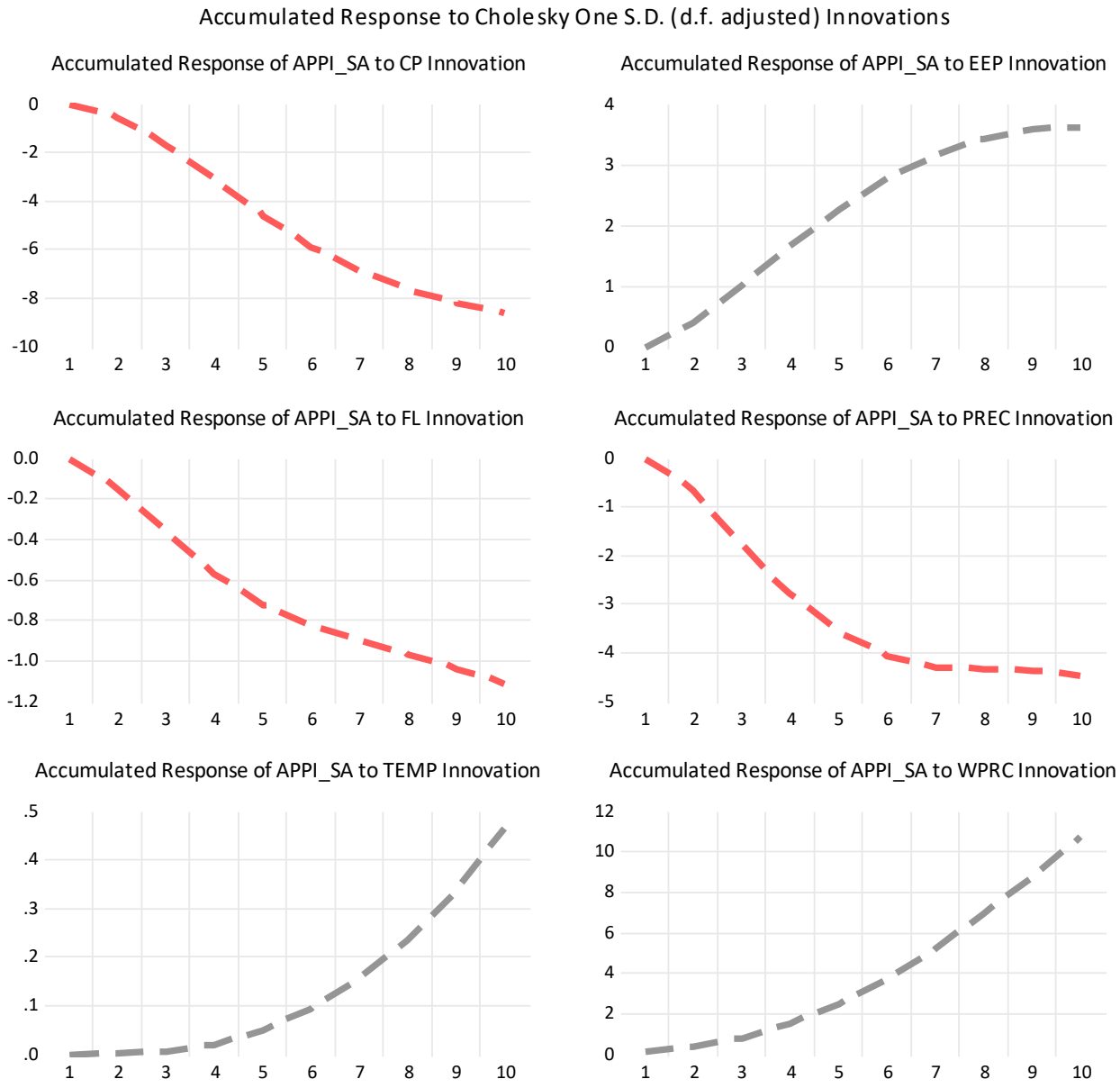
Figure Legends

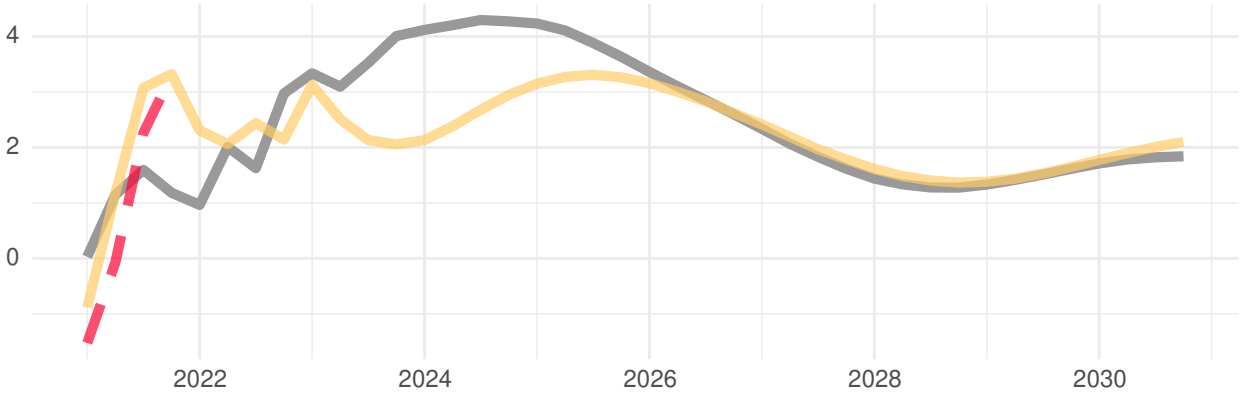
Appendix

1. Impulse Responses:



2. BVAR-VECM Forecast Comparison

Aggregate contribution of climate change and the oil revenues to the inflation in the worst scenario conditional on water prices in 2021



Source: CBAR Models' results — realized contribution in 2021 — BVAR Forecast — VECM Forecast

The long run contribution trend for worst scenario is 2.2 for BVAR and 2.4 for VECM.