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Climate Change and Business Cycle
Case of Tunisia

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Abstract

This paper studies the effects of climate change on Business Cycle through the agricultural sector in a small open economy: Tunisia. Climate change is assimilated to weather shocks that are measured by land productivity index in cereal sector.

We use, in a first step, an SVAR Model for analyzing the transmission mechanism of weather shocks to the economy. The impulse response functions calculated provide a benchmark for developing a structural model. In a second step, we exploit the Dynamic Stochastic General Equilibrium (DSGE) Model of Gallic and Vermandel (2020) with a weather dependent agricultural sector to extract the Busines Cycle implications of weather shocks.

The research conclude that weather shock has an important impact on the Tunisian Economy. A significant spillover mechanism from agricultural sector to the rest of the economy allows the weather to propagate and generate large fluctuations in business cycle.

Keywords: Weather shocks, Agricultural Output, SVAR Model, Dynamic Stochastic General Equilibrium (DSGE).

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1. Introduction

Climate change represents one of the most serious challenge facing humankinds in the twenty first century. The International Consensus of Scientific opinion led by the intergovernmental panel of the climate change (IPCC, 2013) shown that global temperatures is increasing, and the cause is accumulation of Carbon Dioxide and other greenhouse gases in the atmosphere because of human activities.

The scientific opinion is also agreed that the threat posed will become more severe over coming decades, IPCC (2013) also reported that agricultural production in many countries is projected to be severely compromised by climate variability and change.

Effects of climate change in economic literature has developed in two separate ways: short and long run effects are analyzed through empirical analysis and theoretical models investigate only the long-term effects. The lack of an economic framework that cover the short-term dimension of the weather is a major issue in a climate change as policymakers are expected to more frequently cope with short-term adverse weather events with important implications (food insecurity, recessions, currency depreciation).

Empirical studies developed in this context, suggests that rising temperatures and rainfall have highly uneven macroeconomic effects, which the adverse consequences borne disproportionately by countries with hot climates, such as most low-income countries. Dell & al. (2012) show that high temperature has a significant effect on economic growth, but only in poor countries. In contrast, Acevedo & al. (2017) and Mejia (2018) conducted on larger samples, show that relationship between high temperatures and productivity is non-linear, for both poor and rich countries. In addition, Fomby & al, (2013) show that droughts have negative effects on growth, for the agricultural sector in developed countries. Also, Donadelli & al, (2017) developed a Real Business Cycle model, where they introduce temperature levels as explanatory factor of productivity for the US economy. Their results show that a one standard deviation temperature shock causes a 1.4 percentage point decrease in productivity growth and Gallic & Velmander (2020) show the significant impact of the weather with dependent agricultural on economic activity.

Based on climate projections and given inherent uncertainties, the most significant impact of climate change in North Africa (Morocco, Tunisia, Algeria, Libya), will likely include the special water resources stress and agriculture.

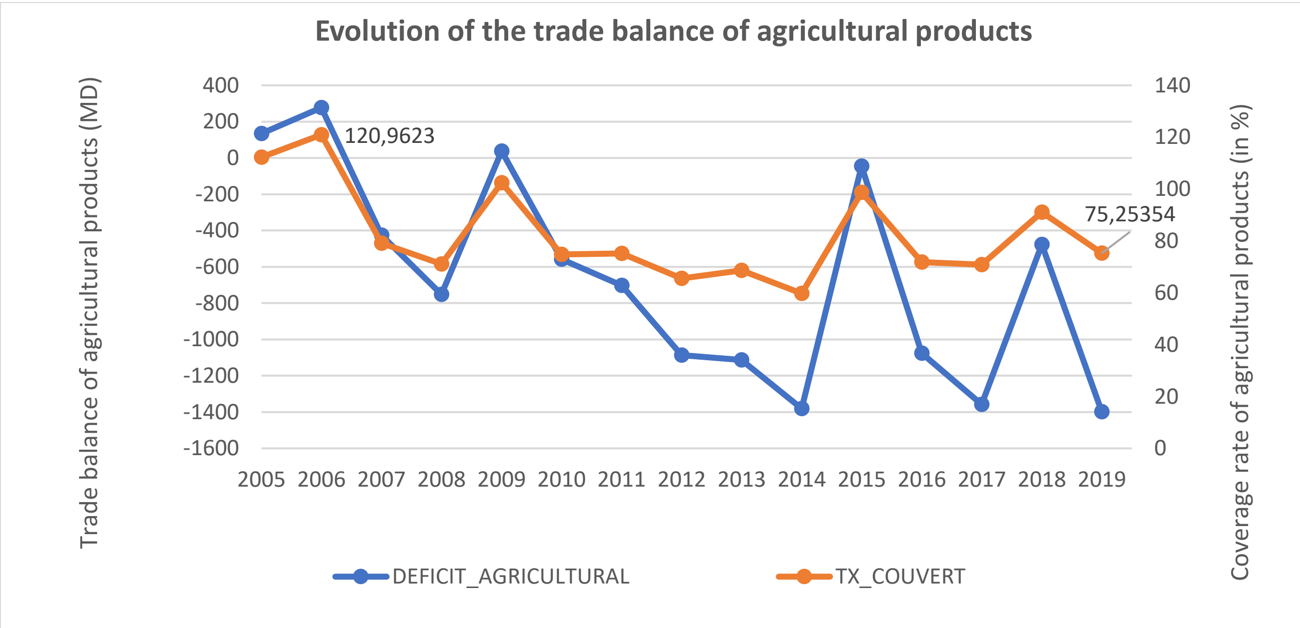
In Tunisia, the study of climate developments for the period (1961-1990) shows an upward trend in the annual average temperatures starting in 1975. This trend is also observed for annual minimum and maximum within regions. In addition, water resources are largely dependent on the variability of climate and precipitation. The average volume of surface water available annually in Tunisia is about 2700 Million Cubic meters per year (Mm^3/year). This availability is conditioned by the rainfall and the agricultural sector remains the main user of water resources (80% demand in 2010) followed by manufacturing and tourism.

Over the period (2005-2019), the deficit in the Balance of agricultural products is growing more and more as shown in Fig (1), when the coverage rate was characterized by a downward trend in recent years. This balance is largely related to the two main trade products, cereals, and oil olive, that are particularly impacted by climate change.

However, the imported cereal is the main reason of increasing deficit since 2007, with exception of 2009 and 2015 where the agricultural food balance has witnessed a surplus.

Figure 1:

Balance of agricultural and food products deficit in Millions of Dinars



Author's Calculation (data source CBT).

While agricultural sector remains important, the weather shock has still received a little attention as a serious source of Business Cycle in Tunisia. Our object in this paper is to show how much do weather shocks matter in business cycle through the agricultural production?

We follow a two-step strategy. In the first, we analyze the transmission mechanism of weather shocks using an SVAR model, the impulse response functions calculated provide a benchmark for initiating a General Equilibrium Model. In the second step, we enrich a Dynamic Stochastic General Equilibrium (DSGE) model à la Gallic and Vermandel (2020) with a weather dependent agricultural sector and real activity facing exogenous weather shocks.

The paper is organized as follows: Section (2) describes the SVAR model Section (3) develop a DSGE model with weather dependent agricultural sector for a small open economy and Section (4) conclude.

2. SVAR Model

We develop a Structural Vector Autoregressive model (SVAR). The model is defined in the following way:

$$A_0 Y_t = C + \sum_{i=1}^{p} A_i Y_{t-i} + u_t \qquad (1)$$

Where Y_t is a (8×1) vector of K endogenous variables. A_i is a (8×8) matrix of coefficients of endogenous variables and u_t is a (K×1) vector of error terms and A_0 is the lower triangular matrix which imposes restrictions on the contemporaneous relationships between variables, these restrictions on the A_0 identify the orthogonal structural disturbances in vector u_t.

The restrictions on the matrix are the weather variable and foreign economy which are contemporaneously affected by themselves only and not caused by the other domestic variables.

2.1 *Data description*

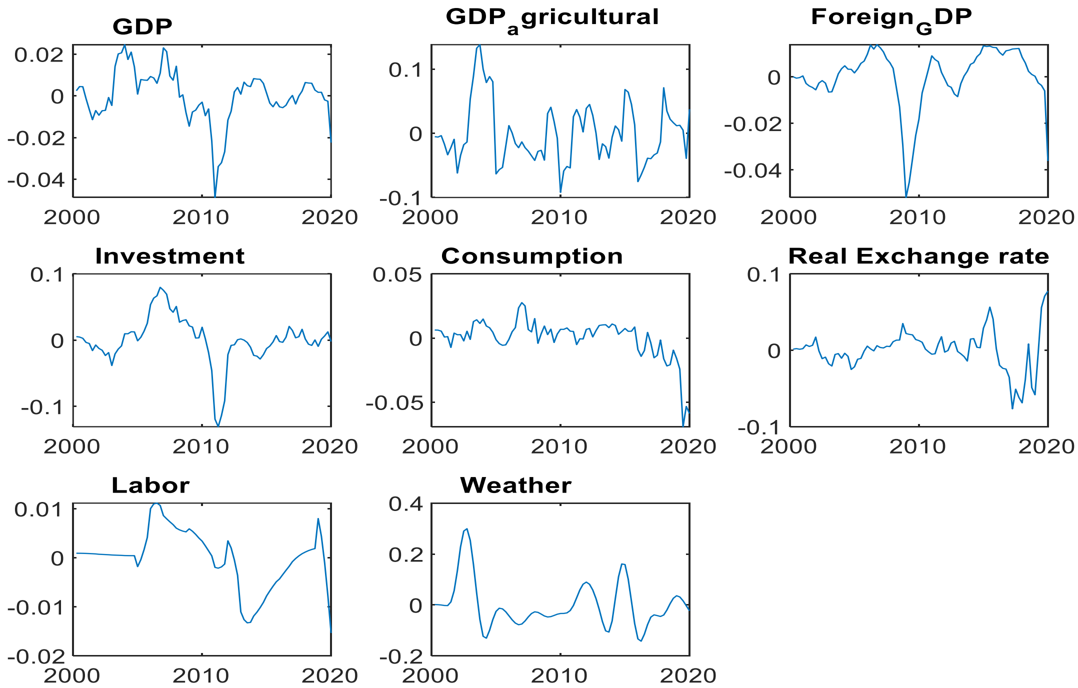
The sample period begins in 2000Q1 and extends to 2020Q1. All data are log deviations from their trend except of the weather. Frequency of the variables is quarterly.

- Gross Domestic Product. (Data source, INS)
- Rest of the World Domestic Product: RGDP of Euro Area, seasonally adjusted. (Data source, Eurostat)
- Agricultural output: real agriculture, seasonally adjusted. (Data source, INS).
- Consumption: households final consumption expenditure, seasonally adjusted. (Data source, INS)
- Real Exchange rate: source ((Data source, IFS)
- Investment: Gross Fixed Capital Formation, seasonally adjusted. (Data source, INS)
- Employment, Labor Force. (Data source, INS)
- Weather? (Data source, CBT)

Gallic and Vermandel (2020) reported that in environmental economics, weather and climate measurements are based on temperatures records. These measures are supplemented by rainfall observations in agricultural economics, to characterize agricultural returns patterns. They used the soil moisture deficit which depict the balance ratio between rainfalls and temperatures. Rainfalls boost the productivity lands by favoring crop growth, and conversely the evapotranspiration process induced by high temperatures reduces land productivity.

In Tunisia we have an annual series of land productivity for cereal sector. So, in our empirical study, we proxy the weather variable by the productivity of cereals which was mainly affected by temperatures and rainfall. We build a macroeconomic index of weather shocks from this series of cereal land productivity. Figure (2) illustrates dynamic of macroeconomic variables gap detrended by the Hodrick-Prescott filter from 2000Q1 to 2020Q1.

Figure 2: Observable detrended variables used in the model



Source: calculations by authors of CBT.

Two constraints on the VAR's equations are necessary to consider the Tunisian specificity situation.

- We impose an exogenous climate change (CC) which is not Granger caused by any other variables.
- We force domestic variables to have no effect on foreign variables.

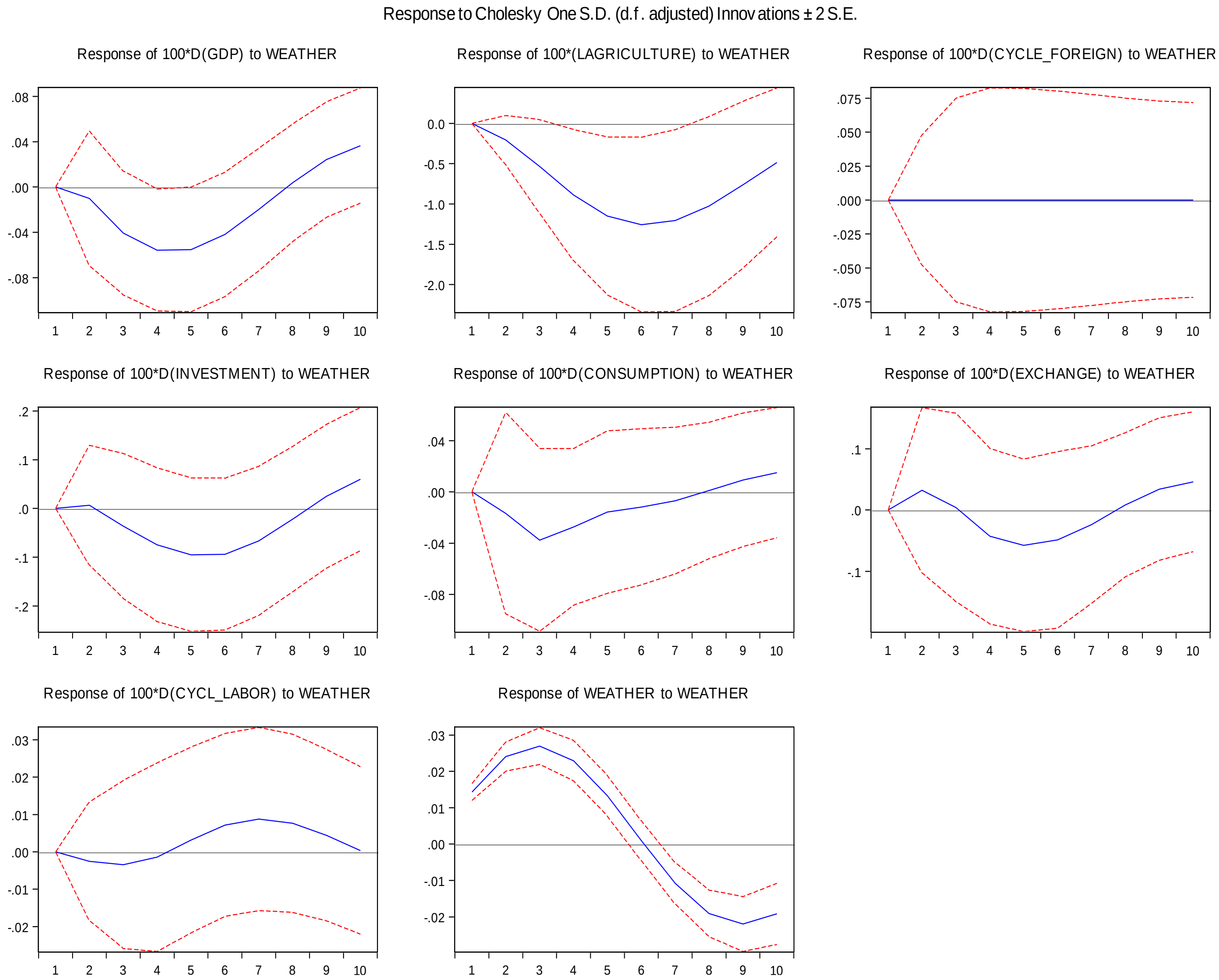
2.2. Empirical results

Results report multiple channels affecting the business cycle after a weather shock which acts as a negative supply shock. It creates a significant decline of GDP. The contractionary is triggered by the large fall in agricultural production accompanied by a decrease in investment, followed by the weaker demand for capital goods from farmers.

Figure (3) sets the IRF where each graphic represents the response to the macroeconomic variables to a weather shock. This graph represents the impulse responses to a one standard deviation shock to the weather.

Figure 3: SVAR impulse response to standard deviation of weather shock in Tunisia

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



The weather shock has an important and significant impact on economic activity:

- A one standard deviation shock to the weather variable (the drought indicator to assess the macroeconomic response following this shock) generates a contraction of Tunisian's economy which follows a contraction of agricultural production by 1.26%,
- The downturn in agricultural production reaches a peak after six periods.
- It is simultaneously followed by a 0.04% decline in consumption and a 0.1% decline in investment which the adjustment of investment is slow and materialize through a contraction in investment, followed by a late rise occurring 7 quarters after realization of the weather shock.

- The adjustment of labor market is slow, and the impact of weather shock is persistent of a TFP shock. The weather shock vanishes seven periods after its realizations.

3. DSGE Model, Weather Shocks, and the Agricultural Sector

To explain the mechanism of transmission of the weather shock, we estimate a structural general equilibrium model for Tunisia with a weather dependent agricultural sector using Bayesian approach. We follow the DSGE model developed by Gallic & Vermandel (2020) for a small open economy.

3.1 The Model

The model is for a small open economy with two sectors and two-goods. The home economy is populated by households and firms. Firms operate in the agricultural and non-agricultural sectors. Workers from agricultural sector face an unexpected weather conditions that affect productivity of their land. Households consume both home and foreign varieties of goods, thus creating a trading channel adjusted by the real exchange rate.

3.1.1 <u>Households</u>

Economy is populated by a continuum $j \in [0,1]$ of identical households that consume, save and work in two productions sectors. The model is described in terms of representative consume which maximizes the welfare index expressed as the expected sum of utilities discounted by $\beta \in [0,1]$:

$$E_t \sum_0^{\infty} \beta^{\tau} \left[\frac{1}{1-\sigma}(C_{jt+\tau} - bC_{t-1+\tau})^{1-\sigma} - \varkappa \, \frac{\varepsilon_{t+\tau}^{H}}{1+\sigma_H} h_{jt+\tau}^{1+\sigma_H}\right] \quad (1)$$

Where the parameter $b \in [0,1]$ accounts for external consumption habits, $\sigma > 0, \sigma_H > 0,$ represent respectively consumption aversion and labor disutility coefficients, h_{jt} is a labor effort for the agricultural and non-agricultural sectors.

Labor supply is affected by a shift parameter $\varkappa$ pinning down the steady state of hours worked and a labor supply shock ε_t^H that makes hours worked more costly in terms of welfare. The assumption of imperfect substitutability of labor supply between the agricultural and non-agricultural sectors is allowed as Horvath (2000):

$$h_{j,t} = [({h_{jt}}^{N})^{1+\iota} + \left(h_{jt}^{A}\right)^{1+\iota} \quad]^{\frac{1}{1+\iota}} \qquad (2)$$

Reallocating labor across sectors is costly and is governed by the substitutability parameter $\iota \geq 0$. If $\iota = 0$, hours worked across the two sectors are perfect substitues, leading to a negative correlation between the sectors. Positive values of ι capture some degree of sector specificity and imply that relative hours respond less to sectorial wage differential.

Consumers maximize their utility subject to their real budget constraint:

$$\sum_{s=N,A} w_t^s h_{jt}^s + r_{t-1}\, b_{j,t-1} - T_t \geq C_{jt} + b_{jt} \qquad (3)$$

The income of households is made up of labor income with a real wage w_t^s in each sector. Domestic bonds are remunerated at a domestic rate r_{t-1}. T_t are the government charges lump sum taxes.

The CES consumption bundle is determined by:

$$C_{jt} = \left[(1-\varphi)^{\frac{1}{\mu}}(C_{jt}^N)^{\mu-1/\mu} + (\varphi)^{1/\mu}(C_{jt}^A)^{\mu-1/\mu}\right]^{\mu-1/\mu} \quad (4)$$

Where $\mu \geq 0$ denotes the substitution elasticity of the two types of consumption goods and $\varphi \in [0,1]$ is the fraction of the agricultural goods in the household's total consumption basket.

Each C_{jt}^N and C_{jt}^A is also a composite consumption composed of domestically and foreign produced goods:

$$C_{jt}{}^{s} = \left[(1-\alpha_s)^{\frac{1}{\mu_s}}\left(C_{jt}^s\right)^{\mu_s-1/\mu} + (\alpha_s)^{1/\mu_s}\left(C_{jt}^{s*}\right)^{\mu_s-1/\mu}\right]^{\mu_s-1/\mu_s} \qquad (5)$$

For s=N, A.

where μ_s is the elasticity of substitution between home and foreign goods. In this context the consumption price index for each sector s, are given by:

$$P_{C,t}^s = [(1-\alpha_s)\,(P_t^s)^{1-\mu_s} + \alpha_s(e_t^* P_t^{s*})^{1-\mu_s}]^{1/(1-\mu_s)} \quad (6)$$

Finally, demand for each type of good is a fraction of the total consumption adjusted by its relative price:

$$C_{jt}^N = (1-\rho)(\frac{P_{C,t}{}^N}{P_t})^{-\mu} C_{jt} \quad \text{and } C_{jt}^A = \rho\left(\frac{P_{C,t}^A}{P_t}\right) C_{jt} \qquad (7)$$

$$c_{jt}^s = (1-\alpha_s)\left(\frac{P_t^s}{P_{C,t}^s}\right)^{-\mu_s} C_{jt}^s \qquad (8)$$

$$c_{jt}^{s*} = (\alpha_s)\left(e_t^* \frac{P_t^{s*}}{P_{C,t}^s}\right)^{-\mu_s} C_{jt}^s \qquad (9)$$

3.1.2 Non-Agricultural Firms

The firms in non-agricultural sector produce goods using inputs capital and labor which their technology does not require land inputs then they are not directly affected by weather.

Each representative non-agricultural firm has the following Cobb-Douglas technology:

$$y_{it}^{N} = \varepsilon_t^{Z}\left(k_{it-1}{}^{N}\right)^{\alpha}(h_{it}^{N})^{1-\alpha} \qquad (10)$$

Where the law of motion of physical capital is:

$$I_t^N = K_t^N - (1-\delta_K)K_{t-1}^N \qquad (11)$$

Technology is characterized as an AR (1) shock process:

$$\log(\varepsilon_t^Z) = \rho_z \log(\varepsilon_{t-1}^Z) + \sigma_Z \eta_t^Z \qquad (12)$$

The real profits are defined as:

$$d_{it}^N = p_t^N y_{it}^N - p_t^N(i_{it}^N + K\left(\varepsilon_t^i \frac{i_{it}^N}{i_{it-1}^N}\right) - w_t^N h_{it}^N \qquad (13)$$

Firms maximizes the discount sum of profits:

$$\max E_t\left\{\sum_{\tau=0}^{\infty} n_{t,t+s} d_{it}^N\right\} \qquad (14)$$

Under technology and capital accumulation constraints.

3.1.3 Farmers

Each farmer $i \in [n, 1]$ require land, physical capital and labor as inputs to his production function. As Mundlak (1961), the agricultural output is Cobb-Douglas in land, capital inputs and labor inputs:

$$y_{it}^A = [\Omega(\varepsilon_t^W) l_{it-1}]^{\omega}\left[\varepsilon_t^Z (k_{it-1}^A)^{\alpha}(\kappa_A h_{it}^A)^{1-\alpha}\right]^{1-\omega} \qquad (15)$$

The damage function is defined as $\Omega(\varepsilon_t^W) = (\varepsilon_t^W)^{-\theta}$,where θ is the elasticity of land productivity respect to the weather.

The Law of motion of physical capital in the agricultural sector is given by:

$$I_t^A = K_t^A - (1-\delta_K)K_{t-1}^A \qquad (16)$$

Assumption of fixed land in agricultural sector is relaxed by allowing time-varying efficiency of the land which follow an endogenous law of motion:

$$l_{it} = [(1-\delta_l) + v(x_{it})] l_{it-1} \Omega(\varepsilon_t^W) \qquad (17)$$

$v(x_{it})$ is the land costs, (cost of land maintenance to maintain the farmland productivity). The production is subject to an economy technology shock following an autoregressive AR (1):

$$log(\varepsilon_t^Z)=\rho_w \, log\,(\varepsilon_{t-1}^Z) + \sigma_w \mu_t^Z \quad (18)$$

And the weather shock as follows:

$$log(\varepsilon_t^W)=\rho_w \, log\,(\varepsilon_{t-1}^W) + \sigma_w \mu_t^W \quad (19)$$

The law of motion of physical capital in the agricultural sector:

$$i_t^A = k_t^A - (1-\delta_K)k_{t-1}^A \qquad (20).$$

Equation of the real profits is defined as:

$$d_{it}^A = p_t^A y_{it}^A - p_t^N \left(i_{it}^A + S\left(\varepsilon_t^i \frac{i_{it}^N}{i_{it-1}^N}\right) i_{it-1}^A \right) - w_t^A h_{it}^A - p_t^N x_{it} \quad (21)$$

Where $S\left(\varepsilon_t^i \frac{i_{it}^N}{i_{it-1}^N}\right)$ is the cost of investment. In fact, profit maximization consisted in choosing the input levels under land efficiency capital motions as well as technology constraint.

First order conditions give the optimal demand of intermediate expenditures:

$$\frac{p_t^N}{v'(x_{it}) l_{it-1} \Omega(\varepsilon_t^W)} = \boldsymbol{E}_t \left\{ \boldsymbol{\Lambda}_{t,t+1} \left(\boldsymbol{\omega} \frac{y_{it+1}^A}{l_{it}} + \frac{p_{t+1}^N}{v'(x_{it+1}) l_{it}} + \frac{p_{t+1}^N}{v'(x_{it+1}) l_{it}} \left[(\mathbf{1} - \boldsymbol{\delta}_l) + \boldsymbol{v}(\boldsymbol{x}_{iy+1}) \right] \right\} \quad (22)$$

The left-hand side of the equation (22) captures the current marginal cost of land maintenance, while the right-hand side corresponds to the sum of marginal product of land productivity with the value of land in the next period. A weather shock deteriorates the expected marginal benefit of lands and rise the current cost of land maintenance.

3.1.4 Foreign sector

The foreign country is only affected by its own consumption shocks but not by shocks of the home economy:

$$\log(c_{jt}^*) = (1-\rho_c) log(\overline{c_j^*}) + \rho_c \log(c_{jt-1}^*) + \sigma_C \eta_t^C \quad (23)$$

Where ρ_c and σ_C are the parameters to capture variations of the foreign demand. The objective function is defined as:

$$\max_{c^*_{jt}, b^*_{jt}} E_t \left\{ \sum_{0}^{\infty} \beta^\tau \varepsilon^E_{t+\tau} log\ (c^*_{jt+\tau}) \right\} \qquad (24)$$

Under constraint $\quad r^*_{t-1} b^*_{jt-1} = c^*_{jt} + b^*_{jt}$.

3.1.5 Government authority

The public authority consumes some non-agricultural output G_t, issues debt b_t at real interest rate and chargesT_t. Public spending is assumed to be exogenous, and the government demand shock follows an AR (1):

$$\log(\varepsilon^G_t) = \rho_G \log(\varepsilon^G_{t-1}) + \sigma_G \varepsilon^G_t \quad (25)$$

The government budget constraint is defined as:

$$G_t + r_{t-1} b_{t-1} = b_t + T_t \qquad (26)$$

3.2 Empirical results

3.2.1 *Calibration and priors' parameters*

We combined different data sources to achieve the calibration as well as the estimation of the model parameters. First, following Cooley and Prescott (1995), we calibrate the capital depreciation δ_k. Starting from the law of motion of capital:

$$K_{t+1} = I_t + (1 - \delta_k) K_t \qquad (27).$$

We identify $\frac{Y_{t+1}}{Y_t} \frac{K_{t+1}}{Y_{t+1}} = \frac{I_t}{Y_t} + (1 - \delta_k) \frac{K_t}{Y_t}$. If $\frac{Y_{t+1}}{Y_t}$=g equals GDP growth rate arranging the expression, we get $(g - 1 + \delta_k) = \frac{I_t}{Y_t} \Big/ \frac{K_{t+1}}{Y_{t+1}}$. By using the average ratios in expressions over the period 2000Q1-2020Q1, it follows that $\delta_k = 0.025$.

The parameter of public expenditures is calibrated to the average ratio of government expenditure (% of GDP).

We fix the small number of parameters that are commonly used in the literature of the Real Business Cycle models, including β=0.998. The steady state of hours worked per day $\overline{H_N} = \overline{H_A}$ =1/3. In addition, the land to employment ratio $\bar{l} = 0.27$ is based on the hectares of arable land (hectares per person) in Tunisia (data provided by the Bulletin of Financial Statistics of the CBT). The share of capital in output is fixed to 0.33 (empirical studies).

The remainder of the parameters are estimated using Bayesian methods.
Table (1) reports calibrated parameters,
Table (2) reports priors and distribution of structural parameters
Figure (4) reports posterior distributions of parameters for Tunisia.

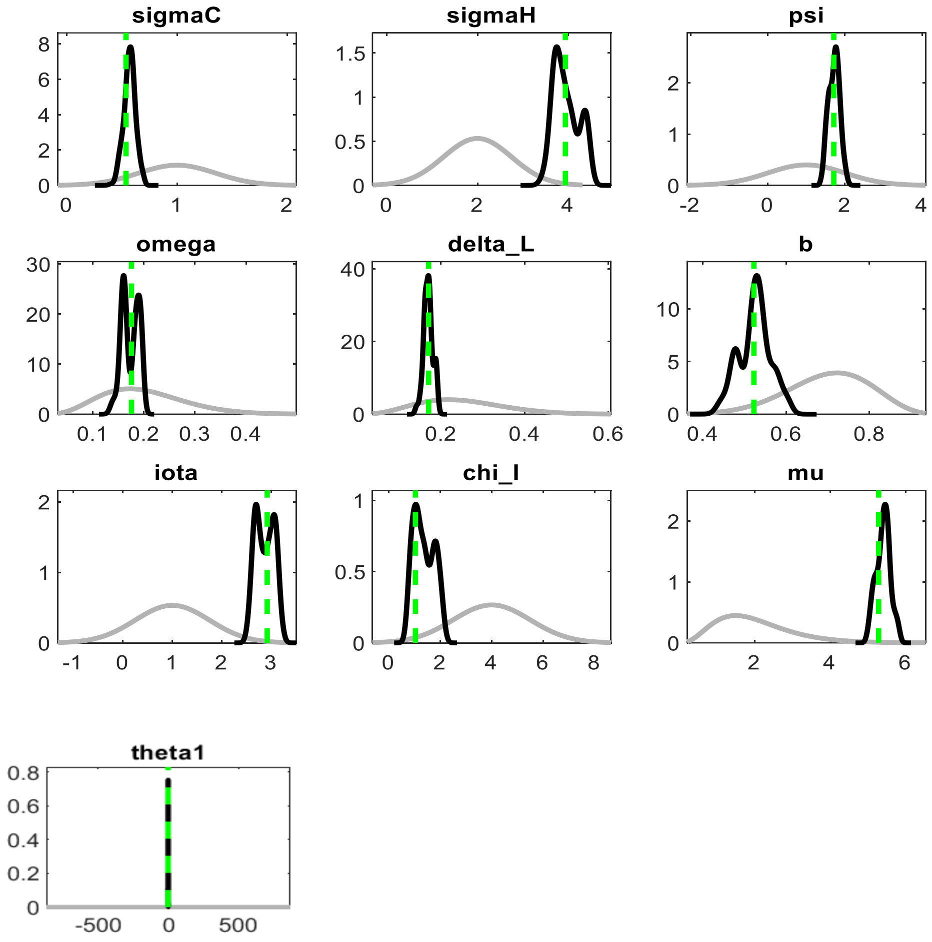
<u>Table (1): Calibrated parameters on a quarterly basis</u>

Variable	*Interpretation*	*Value*
$\boldsymbol{\beta}$	Discount factor	0.998
$\boldsymbol{\delta_k}$	Capital depreciation rate	0.025
$\boldsymbol{\alpha}$	Share of capital in output	0.6
g	Share of spending in GDP	0.20
$\overline{\boldsymbol{H_N}} = \overline{\boldsymbol{H_A}}$	Hours worked	1/3
$\bar{\boldsymbol{l}}$	Land per capita	0.27

<u>Table (2): Priors and distributions of structural parameters</u>

Variable	*Distribution*
Labour desutility:$\boldsymbol{\sigma_H}$	$N\sim(2,0.35)$
Land expenditure cost:φ	$N\sim(1,1)$
Risk consumption: $\boldsymbol{\sigma_c}$	N~(2,0.75)
Share of land in agricultural production ($\boldsymbol{\omega}$*)*	$\beta eta\sim(0.3,0.1)$
Labor sectorial cost (i)	$\boldsymbol{N(1,0.75)}$
Land weather elasticity ($\boldsymbol{\theta}$*)*	$U\sim(0,500)$
Land efficiency decay (*$\boldsymbol{\delta_l}$*)	$Beta(0.3\ ,0.1)$

<u>Figure 4: Posterior distributions of the parameters</u>



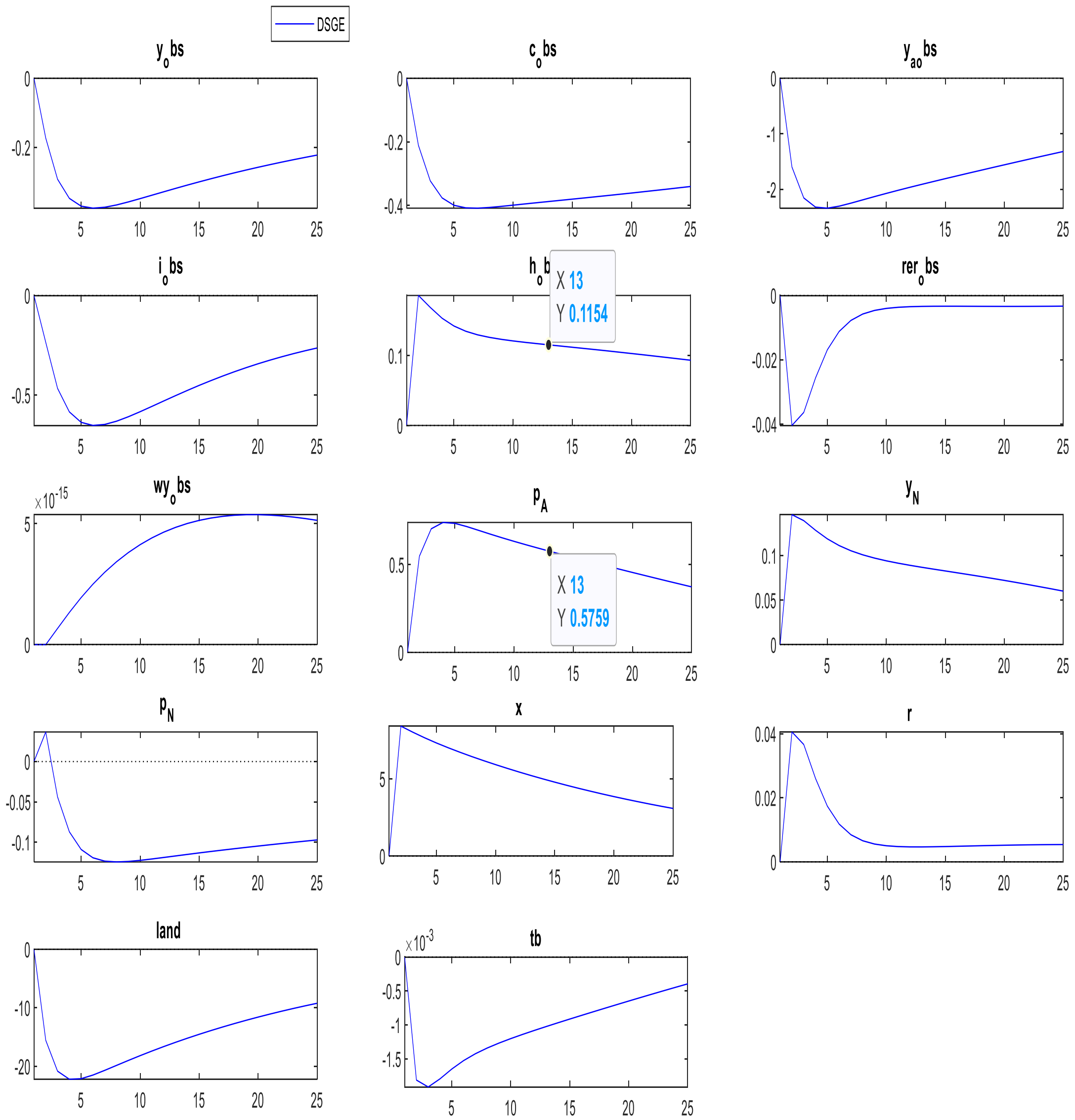
3.2.2 ***<u>Results</u>***

The data are informative as their posterior distributions did not stay very close to their priors. The structural parameter theta (θ) (land weather elasticity) has a posterior value that is different from zero equals to 0.47, which implies that weather variables conditions matter for generating business cycle.

To investigate the effects of an adverse weather shock, we simulated the impulse response functions to a one standard deviation of the weather variable. Figure (5) reports the response of each variables to weather shocks:

Overall, a shock to the weather generates a contraction of Tunisian Economy through a persistent decline of agricultural production which is simultaneously followed by a persistent decline in consumption and investment.

Figure 5: Impulse response function of the weather shock



4. Conclusion

The research indicate that weather shock has an important impact on the Tunisian Economy through the agricultural sector. Precisely, a significant spillover mechanism from agricultural sector to the rest of the economy allows the weather to propagate and generate a business cycle.

To mitigate the impact of the global warming in Tunisia. The adaptation strategy should include the following measures:

- Appointment of Inter-ministerial National Climate Council to improve coordination of measures for adaptation to climate change.
- Introduction of insurance services for climate related damage in agriculture with a particular focus on small farmers.
- Assistance with a restricting a farmer that are affected by climate change.
- Development of climate label for agricultural products which are particularly resilient to the impacts of climate change.
- Counter-cyclical fiscal policy
- Rescheduling and/or smoothing farmers debt

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