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Climate shock versus productivity shock: an assessment using a RBC models from Benin

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Abstract

Mankind has experienced many upheavals in recent decades. These changes have marked developed economies as well as developing economies under the hegemony of globalization. These shocks can be of different shapes, different natures and with several rhythms. Some economists have been successful in using DSGE models to assess the effects of these shocks on different macroeconomic variables. This intention has been deepened since the 2008-2009 financial crisis, which economists saw nothing coming. The concerns were not only focused in the financial field, but all the random phenomena (environmental, health, social) that can influence the real economy. It is in this sense that we have oriented our study and especially towards climate change which has not spared developing economies, in particular the Beninese economy. Our DSGE model which will be used is the real cycle model (RBC) which takes into account the hypothesis of representative agent with infinite horizon. The central question of this study is to assess the climatic shocks on the Benin economy. We will delay to discover this model from its history and present in detail its characteristics as the first DSGE model. This is a first attempt applied to the case of Benin, especially how to integrate the climate shock into the structure of an RBC model. Modeling this type of model requires macroeconomic variables and borrowed and calibrated parameters. This consistency is especially important in order to be able to simulate three types of scenarios, in two different behavioral situations of the Benin household. The first situation is an improvement in living and working conditions while the second will consist of a maximum value, explained by the arduous working conditions. These various simulations were carried out with the Matlab-Dynare software. The first scenario will consist in determining the impact of a productivity shock on the Benin economy, the second will present the impact of a climate shock and then the last scenario will combine the two shocks in order to be able to compare them. This comparison will lead us to determine which shock will prevail over the other? The results show that the productivity shock has a positive effect on growth and well-being in Benin, while the climate shock has a negative effect. Moreover, when there is the presence of these two shocks, it is the climatic effects that prevail.

Keywords: DSGE model, growth, well-being, RBC model, technological shock, climate shock, Benin.

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1. INTRODUCTION

Dynamic stochastic general equilibrium (DSGE) models are extensions of general equilibrium theory. These models contain optimization behaviors of economic agents, namely the consumer and the firms, whose each objective is to maximize utility and profit respectively. In addition to its agents, there are also fiscal and monetary institutions which are analyzed via budget constraints and a policy rule (Breuss. (2016)). There are basically two types of DSGE such as New Keynesian models and Real Cycle (or RBC) models. This article will focus on the real cycle model. These models are built on the neoclassical general equilibrium theory. The full RBC model includes: households, businesses, fiscal and monetary authorities, the external sector and financial institutions. The existing literature constantly emphasizes that these models help predict shocks and they often encounter forecasting errors. In RBC models, the main shock on which the interpretations are based is the productivity shock which we consider as an innovation or a technological shock (total factor productivity (TFP) or total factor productivity (TFP)) and which we try to to assess on the economy as a whole. Through these models, the modeler in question will be able to make the inter-temporal arbitration between work and leisure, since each agent reacts according to this shock.

But in our case, in addition to the productivity shock, another shock will be integrated. It is about the climatic shock because the objective behind this study is quite different. This objective is to analyze the impact of climate change on the Beninese economy. It will be a question of seeing if the climatic shock, that is to say an increase in temperature, will have a positive or negative impact on the Beninese economy and therefore on the well-being of the population. From a simple RBC model, as a first attempt, we consider only two agents: the household and the firm and do not take into account the State or financial institution. Thus the use of the RBC model for the various simulations (the case of the presence of the productivity shock, the case of the climatic shock and the case of the presence of the two shocks at the same time) would clearly make it possible to see the nature of the impact of the rise in temperature on the Beninese economy. Now the results could show that the productivity shock acts positively on the economy while the temperature increase has a negative impact. Moreover, if in the presence of the two shocks, the negative effect of the climatic shock prevails over the productivity shock, this would simply mean that the increase in temperature seriously affects the Beninese economy and therefore the well-being of the population.

To provide answers to these different points, we have divided our study into three sections. The first will deal with the generality of RBC models via the different literatures. The second section will help us to understand how climate change can be inserted into CBR models but also to understand the structure of the Beninese CBR model. And the third section will discuss the results of the different simulations performed.

2. HISTORY OF DSGE MODELS: A REVIEW OF THE LITERATURE

RBC (Real Business Cycle) models are models built from the neoclassical theory of general equilibrium. These models are based on the assumption that there is no presence of governments, no adjustment costs (since each agent conforms to the same market price for all), pure and perfect competition and finally the price flexibility (prices are free to reach their equilibrium value). According to Blanchard (2017), RBC models are “microfounded general equilibrium models” and seek “to analyze the effect of productivity shocks”. Some economists assume two important characteristics which are the micro-foundation and the presence of financial frictions.

The first success of DSGE models was done with RBC models. The latter with a neoclassical approach, they have been used by the majority of researchers in their theoretical research and especially used as easily explained academic models for bachelor's and master's students. RBC models are models generally used to analyze the impact of random shocks related to productivity using macroeconomic aggregates. These models may also contain other random disturbances that affect demand (e.g. falling interest rates), market imbalances and policies (Epaulard et al. (2008)). The aggregates that RBC models make up, such as the real aggregates (consumption, production, etc.), the nominal sphere (inflation and interest rates), and the international aspects (development aid) make it possible to explain a large part of the aspects of the economic cycle (Naoussi and Tripier. (2012)). RBC models seek to combine uncertainty shock and economic cycle. The surest way to combine uncertainty shocks with economic cycles would require the agents available to the model to have precautionary behaviors (Fernández-Villaverde and Guerron-Quintana. (2020)).

The empirical literature has also grown for these RBC models since they do not require a very extensive database or a large number of values for its variables. We can present this empirical richness from a few examples that were close to our problem.

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Liu and Gupta. (2007), with a view to analyzing the South African economy, used several models for the period 1970-2000 such as Dynamic Stochastic General Equilibrium (DSGE), Vector Autoregressive (VAR), Bayesian Vector Autoregressive (BVAR). Several results were identified: the first result showed that the response functions present all the aggregated variables whose investment is the variable that responds the most to the shock (increases by more than 10% following the shock). As for the second result, it shows that the productivity shock acts on consumption, investment and working time at different periods. But according to the reference model, the effect occurs at the same time. While the third result, which is rather a comparison of DSGE models to VAR and BVAR, proves that DSGE models have significant forecasting errors.

Caraiani. (2008), tried to evaluate with the DSGE model, the Romanian data and also tried to predict the Romanian quarterly GDP. The analysis was carried out over the period 2000-2007 using the posterior averages to calculate the impulse response functions. The results show that the productivity shock acts significantly on total factor productivity and GDP for more than 16 quarters and 12 quarters respectively. As for consumption and capital, they have a response function in the form of an inverted U and the "peak" is reached after 3 quarters and 5 quarters respectively. The results also show that the model predicts better for medium-term horizons. The model can provide a good representation of real GDP except for some quarters of 2004 (where real GDP was higher than potential GDP). The model also predicts an annual growth rate of 6% for the period from 2007 to 2010.

Vasilev. (2018) analyzed the impact of pollution on Bulgaria over the period 1999-2016 using standard RBC models. The results show that a productivity shock (total factor productivity) increases macroeconomic variables. Capital increases and households devote more hours to work. But over time all the variables reach their stationary state except that capital and consumption take an inverted U-shape before reaching the stationary state. This technological shock lowers the quality of the environment. The results also show that a pollution shock increases pollution and lowers the quality of the environment, production remains unchanged as well as reduction expenditure. Over time, the decrease in the pollution shock causes the improvement of the quality of the environment but the other variables are not affected.

Pham et al. (2020) analyzed the economy of Vietnam. They compared it to ASEAN-5 economies (Indonesia, Malaysia, Philippines, Singapore and Thailand). The study covered a period from 1986-2015 using the DSGE-RBC model.

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There have been several studies that have been done using the RBC model for developing economies. We will focus on using this kind of model for the case of the Beninese economy.

3. MODELING: STRUCTURE OF THE BENIN RBC MODEL

3.1. How to integrate climate change into RBC models?

Consider the production function Y of the Cobb-Douglas type, combining two production factors (t is the year, K is the capital factor, L is the labor factor, α is the elasticity of production with respect to capital and A Technical progress). It looks like this:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \qquad (1)$$

For this, it would be necessary to incorporate in this function, the cost of climate change that Nordhaus named it Ω_t. This cost includes: a damage function and a total emission reduction cost function. It looks like this (from Kendrick et al. (2005)):

$$\Omega_t = \frac{1-TC(t)}{1+D(t)} \qquad (2)$$

These authors considered that D(t) is the damage function. According to Fremstad et al. (2019), the damage function shows the impact of temperature increase on production (i.e. the damages caused by climate change on Benin in terms of production) with increasing marginal costs. This equation is:

$$\frac{D(t)}{Y(t)} = \Theta_1 T(t)^{\Theta_2} \qquad (3)$$

With :

D(t): The damage function

Y(t): The production function

T(t): Temperature

Θ_1 and Θ_2: Parameters of the damage function

The function of the total cost of emission reductions, on the other hand, shows the cost that the reduction of emissions could entail. It is followed by increasing marginal costs. This function looks like this:

$$\frac{TC(t)}{Y(t)} = b_1 \mu(t)^{b_2} \qquad (4)$$

With :

TC(t): The total cost

b_1 *and* b_2: The parameters of the reduction total cost function

μ(t): The fractional emission reduction

So the new production function looks like this:

$$Y_t = A_t \Omega_t K_t^{\alpha} L_t^{1-\alpha} \quad (5)$$

With: Ω_t which follows an autoregressive process of order 1 (AR(1)).

3.2. Source and Database

This section will be devoted solely to the determination of the structural parameters (the long-term parameters) and the steady-state variables. The analysis period is from 2017 to 2037. Some parameters will also be calibrated, others estimated and others taken from the literature. As for the steady-state variables, they will be determined by inserting the structural parameters into the equilibrium equation.

Calibration of production function parameters

Consider the last production function for activity j (5) : : $Y_{j,t} = A_t \Omega_t \, K_{j,t}^{\alpha} L_{j,t}^{1-\alpha}$

Table 1 presents the value added of Benin during the year 2017 in billions of constant FCFA taken from the national accounts of the country. Thus during 2017, all the sectors of the country, namely the primary, secondary and tertiary sectors, created as wealth 6607.145 billion FCFA (i.e. 11.377 billion dollars) for the country.

Table n° 1: Benin value added of all sectors in 2017

Nature	Added value of the primary sector	Added value of the secondary sector	Added value of the tertiary sector	Total added value
Values	1893,26	1138,289	3575,596	6607.145
Unit	Billion FCFA			
Source	National Institute of Statistics, BCEAO			

Note: The value added of the economy is found through the sum of the value added of the three sectors of the economy. This value will be subject to the exchange rate FCFA 2017 dollars (580.7) taken from the World Bank to be converted into US dollars and three digits will be considered after the decimal point without rounding.

During the year 2017, the value of EBITDA amounted to 38.597 billion FCFA (i.e. 66.466 million dollars).

The last point for this component concerns the MS (Mass Salariale). It can be defined as the total annual amount of wages paid to state workers.

$$VA = EBE + MS \qquad (6)$$

This means that the share of production devoted to the payment of wages amounts to 6568.548 billion FCFA (i.e. 11.311 billion dollars).

The elasticity of the level of production with respect to capital and labor has been calibrated. These two respectively show the share of capital and labor in the production function. Thus capital represents 0.5% of production and labor 99.5%.

Calibration of productivity shock parameters

We will use the OLS (Ordinary Least Squares) method to estimate the production function over a period from 1990-2017. Table 2 presents the results relating to the estimation of the production function by OLS (see Appendices A and B).

Table n° 2: estimation by OLS of the productivity of Benin

Settings	Values	Sources
Autoregressive productivity parameter (ρ_A)	0.374	Static output
Standard deviation of productivity (ε_A)	0.186	
Alpha (α)	0.0049≅ 0.005	

Note : See Appendices A and B for the output file. These values were considered three decimal places. And note in the stata output that lA_{t1} will be considered as lA_{t-1}.

It is important to note that there is no difference between the calibrated alpha value and that resulting from the stata output. Not only is the coefficient positive (0.005) but also significant at the 5% threshold (p>|t|=0.000 which is less than 5%). This confirms the positive relationship between production and capital, an increase or decrease in capital of 1% leads to an increase or decrease in production of 0.05%.

Calibration of parameters relating to the climatic shock

To assess the impact of climate change, we can use several factors but here we focus only on temperature. The temperature taken is that of Benin, for monthly data during 2009 to 2019 (i.e. 132 observations). The table below shows the different results (see also Annex D).

The model used for the estimation is as follows:

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$$T_t = \rho T_{t-1} + \epsilon_t \qquad (7)$$

Then, it is necessary to log-linearize it and estimate the autoregressive parameter of the temperature and its error term from the following formula:

$$logT_t = \rho \; logT_{t-1} - \epsilon_t \qquad (8)$$

Table n° 3: estimation of the temperature of Benin by the OLS

Parameters	values	Source
Autoregressive temperature parameter (ρ_Ω)	0.792	Static output
Standard deviation of temperature (ϵ_Ω)	0.054	

Note : See appendix D for stat outputs. The average temperature in °C was considered and comes from historique-meteo.net. The values of the table are taken three digits after the decimal point. The ltt is considered lT_t and the $ltt1$ is considered lT_{t-1}.

Calibration from existing literature

We mean by the coefficient of risk aversion, the behavior of the consumer in the face of uncertainty to reduce the risk. That is to say, the consumer does not like the risk and wants to reduce it. Thus, the risk aversion coefficient reflects the degree to which the consumer does not like risk. The value of this coefficient is equal to 2 from the study by Gandelman and Hernàndez-Murillo (2014). The following table presents this parameter. In other words, Beninese are risk averse, that is to say they are wary of risk.

For the values of the discount factor and the depreciation rate are equal respectively to 0.009 and 0.1 from the article by Naoussi and Tripier (2012).

The last parameter is the marginal disutility of the labor supply whose value is equal to 2.5 (at 1.43). Its value was calculated from the Frisch coefficient of Reichling and Whalen (2012) (Frisch coefficient is equal: from micro-data to 0.4 and from macro-data to 0.7).

Thus the various parameters used were calibrated. The table below can group together all the values of the different parameters of our model.

Table 4: summary of the structural parameters of the model

Parameters	Names	Values	Source
σ	Coefficient of risk aversion	2	Gandelman et Hernàndez-Murillo. (2014)
φ	Marginal disutility of labor supply	2.5 et 1.43	Calculate using the Frisch coefficient

α	Factorial elasticity of the capital factor	0.005	Calibrate and also estimate using STATA software
β	discount rate (inter-temporal preference coefficient)	0.009	Naoussi et Tripier. (2012)
δ	Depreciation rate (or capital depreciation coefficient)	0.1	Naoussi et Tripier. (2012)
ρ_A	Autoregressive productivity parameter	0.374	Estimate using STATA software
σ_A	Standard deviation of productivity	0.186	Estimate using STATA software
ρ_Ω	Autoregressive temperature parameter	0.792	Estimate using STATA software
σ_Ω	Standard deviation of temperature	0.054	Estimate using STATA software

Notes : As mentioned, the parameters come from several sources: literature review, calibration and OLS estimation using STATA software (see Appendices B and D).

Determination of Steady State Values

The detail of the determination of the steady-state equations will be carried out in the next section. In this section, we content ourselves with presenting the values of the different variables and parameters of our model at steady state, in the following table:

Table n° 5: values of the variables at steady state

Variables	Names	Values
A	Technological shock	1
Ω	Climate shock	1
R	Return on capital	110.211
W	salary	0.946
Y	production	0.963
I	Capital supply	0
C	consumption	0.963
L	Work request	1.012
K	Capital demand	0
Source: calibration from steady state equations		

Note: the different values have been calculated by hand. But they will be verified using Matlab-dynare. And for decimal numbers, three digits without rounding have been retained.

3.3. Structure of the CBR model: Case of Benin

The RBC model is inspired by that of Celso (2018) and it has been applied in Benin. The particularity of our RBC model applied to Benin, with technological shocks accompanied by climatic shocks, to respond well to our problem. The full RBC model includes households, businesses, fiscal and monetary authorities, the external sector and financial institutions. But this case takes into account two economic agents such as representative households and representative companies. Firms do not incur adjustment costs (costs related to the change in factors of production).

The representative household

The model considers a large number of identical households. It is the representative household that consumes or saves goods and services. The household welfare function is a separable additive function. In addition, population growth is ignored. The labor market is in pure perfect competition.

The maximization of this utility function is as follows:

$$\underset{C_{j,t},L_{j,t},K_{j,t+1}}{Max} \quad E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{C_{j,t}^{1-\sigma}}{1-\sigma} - \frac{L_{j,t}^{1+\varphi}}{1+\varphi} \right) \qquad (1)$$

With,

E_t : The mathematical expectation

C: consumption of goods and services

L: the number of working hours

β: inter-temporal discount factor

σ: the risk aversion coefficient

φ: loss of marginal utility with respect to labor supply (or disutility)

Household utility meets the following conditions: $U_C > 0$, $U_L < 0$ et $U_{CC} < 0$ et $U_{LL} < 0$

The household budget constraint equation that gives an idea of the resources available to them and how these resources are allocated is as follows:

$$P_t\left(C_{j,t} + I_{j,t}\right) = W_t L_{j,t} + R_t K_{j,t} + \prod\nolimits_t \qquad (2)$$

With,

P: the general price level

I: investment

W: salary

K: capital stock

R: return on capital

∏: corporate profit

The final element that would solve the household program is capital accumulation and is as follows:

$$K_{j,t+1} = (1 - \boldsymbol{\delta})K_{j,t} + I_{j,t} \qquad (3)$$

With,

δ: capital depreciation rate

The first-order conditions come from Lagrange derivatives with respect to consumption, labor, and capital accumulation. They look like this:

$$\frac{\partial \mathcal{L}}{\partial C_{j,t}} = C_{j,t}^{-\sigma} - \lambda_{j,t}P_t = 0 \qquad (4)$$

$$\frac{\partial \mathcal{L}}{\partial L_{j,t}} = -L_{j,t}^{\varphi} + \lambda_{j,t}W_t = 0 \qquad (5)$$

$$\frac{\partial \mathcal{L}}{\partial K_{j,t+1}} = -\lambda_{j,t}P_t + \beta E_t\lambda_{j,t+1}[(1-\delta)E_tP_{t+1} + E_tR_{t+1}] = 0 \qquad (6)$$

Let's look at equations (4) and (5). By trying to derive the Lagrange multiplier in the two equations, and after transformation, we will have the household labor supply equation. This equation explains that the relative price of consumption-leisure must be equal to the marginal rate of consumption-leisure substitution. This equation is:

$$-C_{j,t}^{\sigma}L_{j,t}^{\varphi} = -\frac{W_t}{P_t} \qquad (7)$$

With,

$-C_{j,t}^{\sigma}L_{j,t}^{\varphi}$: MSR (Marginal Substitution Rate) of consumption-leisure

$-\frac{W_t}{P_t}$: Relative price of consumption-leisure which is still the real wage

Economically, when the household works more, its leisure time is reduced. But he uses his extra income to increase consumption. This increases the marginal rate of substitution of consumption-leisure. In other words, when the real wage increases, the household consumes more without giving up its leisure. It is the arbitration between leisure and work: the intra-temporal choice of the household. That is to say, during the same period, the household wonders whether it will work or devote its time to leisure.

The last household equation is the inter-temporal Euler equation which comes from the Lagrange derivative with respect to consumption combined with that with respect to investment. It makes it possible to highlight today's consumption in relation to future consumption, i.e. the household's decision to save (its purchase of investment goods). Here the household wonders if it will consume at the present moment or consume in the future (saving at the present moment). Its equation is:

$$\left(\frac{E_t C_{j,t+1}}{C_{j,t}}\right)^{\sigma} = \beta\left[(1-\delta) + E_t\left(\frac{R_{t+1}}{P_{t+1}}\right)\right] \qquad (8)$$

The representative firm

Like the representative household, the representative firm is a large number of firms that the model considers to be identical. This agent produces goods and services that the household consumes. The fundamental assumption of the RBC model applied to Benin is that the main cause of climate change is the company, although the consumer also participates. In other words, whatever the nature of the product (polluting or not), the consumer consumes.

The production function of the firm as mentioned above also takes into account the stock of capital, labour, the technological shock and the climatic shock. It is a Cobb-douglas function and it looks like this:

$$Y_{j,t} = A_t \Omega_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha}$$

This production function has certain conditions which are: F_K>0, F_L>0 , F_{KK}<0 et F_{LL}<0

It is a production function at constant returns to scale and it satisfies the Inada conditions: : $lim_{K \to o} F_K = \infty$; $lim_{K \to \infty} F_K = 0$; $lim_{L \to 0} F_L = \infty$; $lim_{L \to \infty} F_L = 0$

As mentioned above, the climate shock follows an autoregressive process of order 1, as does the productivity shock: AR(1) which is a stationary process

For the productivity shock, we have:

$$logA_t = (1-\rho_A)logA_{SS} + \rho_A logA_{t-1} + \varepsilon_t \quad (9)$$

With :

A_{SS} : The value of productivity at steady state

ρ_A : The autoregressive parameter of productivity

$|\rho_A| < 1$: This condition ensures the stationarity of the model

$\varepsilon_t \rightarrow N(0, \sigma_A)$: The error term or white noise follows a normal law

For the climatic shock, we have:

$$log\Omega_t = (1-\rho_\Omega)log\Omega_{SS} + \rho_\Omega log\Omega_{t-1} + \epsilon_t \quad (10)$$

With :

Ω_{SS} : Steady state climate change value

ρ_Ω : The autoregressive parameter of climate change

$|\rho_\Omega| < 1$: This condition ensures the stationarity of the model

$\epsilon_t \rightarrow N(0, \sigma_\Omega)$: The error term or white noise follows a normal law

The program of the firm goes through the maximization of its profit function where it must choose the quantity of factors (labor and capital) to use. These are the two control variables available to the firm. The maximization is as follows knowing that the firms are in perfect competition with $\prod_t = 0$ for all t:

$$\underset{L_{j,t},K_{j,t}}{max}\prod_{j,t} = A_t\Omega_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} P_{j,t} - W_t L_{j,t} - R_t K_{j,t} \quad (11)$$

The first-order conditions are as follows:

$$\frac{\partial \prod_{j,t}}{\partial K_{j,t}} = \alpha A_t \Omega_t K_{j,t}^{\alpha-1} L_{j,t}^{1-\alpha} P_{j,t} - R_t = 0 \quad (12)$$

$$\frac{\partial \prod_{j,t}}{\partial L_{j,t}} = (1-\alpha) A_t \Omega_t K_{j,t}^{\alpha} L_{j,t}^{-\alpha} P_{j,t} - W_t = 0 \quad (13)$$

From solving the equations, we have:

$$\frac{R_t}{P_{j,t}} = \alpha \frac{Y_{j,t}}{K_{j,t}} \qquad (14)$$

This is the equation is the demand for capital.

$$\frac{W_t}{P_{j,t}} = (1-\alpha)\frac{Y_{j,t}}{L_{j,t}} \qquad (15)$$

This is the equation is the demand for labor

Firms choose their inputs so that the marginal product of those inputs equals their actual marginal costs. The marginal cost equation is as follows:

$$CM_{j,t} = \frac{1}{A_t\Omega_t}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t}{\alpha}\right)^{\alpha} \qquad (16)$$

Economically it depends on the two shocks, and on the prices of the factors of production. It is the same for all companies (i.e. $CM_{j,t} = CM_t$).). In the Benin RBC model, the condition of equality between the price level (P_t) and the marginal cost was maintained:

$$CM_t = P_t = \frac{1}{A_t\Omega_t}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_t}{\alpha}\right)^{\alpha} \qquad (17)$$

The balance of the model

On the market, households are masters of three things while taking prices as given, namely: the quantity to consume (C), the quantity to save (I) and the labor supply that allows them to maximize their utility. As for the companies, they decide on the quantity to produce (Y) by using the available technology and by choosing the factors of production while taking their price as given. Excluding the government and the Rest of the World agent, we have the following equilibrium condition: $Y_t = C_t + I_t$ (18).

The stationary state

The system of equations cannot be solved without being made stationary For an endogenous variable x_t , in the stationary state for all t, we have this condition: $E_t x_{t+1} = x_t = x_{t-1} = x_{ss}$.

In the basic RBC models, it is productivity that is at the origin of the shocks, but in the RBC model applied to Benin, the origin of the shocks will be productivity but also climate change. Generally the value of $A_{ss} = 1$and that of $\Omega_{ss} = 1$at steady state. Thus the remainder of the steady-state model is determined as follows:

$$C_{ss}^{\sigma} L_{ss}^{\varphi} = \frac{W_{ss}}{P_{ss}} \qquad (19)$$

$1 = \beta\left[1 - \delta + \frac{R_{ss}}{P_{ss}}\right]$ (20)

$I_{ss} = \delta K_{\boldsymbol{ss}}$ (21)

$Y_{ss} = K_{ss}^{\alpha} L_{ss}^{1-\alpha}$ (22)

$K_{ss} = \alpha \frac{Y_{ss}}{\frac{R_{ss}}{P_{ss}}}$ (23)

$L_{ss} = (1-\alpha)\frac{Y_{ss}}{\frac{W_{ss}}{P_{ss}}}$ (24)

$P_{ss} = \left(\frac{W_{ss}}{1-\alpha}\right)^{1-\alpha}\left(\frac{R_{ss}}{\alpha}\right)^{\alpha}$ (25)

$Y_{ss} = C_{ss} + I_{ss}$ (26)

The log-linear model

It is important to log-linearize the model, to facilitate solving and finding exact values. Celso (2018) used the linearization method taken from the literature in the basic RBC model, a method that log-linearizes our model around its stationary state. This method consists of replacing X_t by $X_{ss}e^{\tilde{X}_t}$with $\tilde{X}_t = logX - logX_{ss}$the log of the deviation of the variable from its stationary state and X_{ss} the variable in the stationary state.

Some theorems deriving from this method that would help to solve the equations:

$e^{(\tilde{X}_t + a\tilde{Y}_t)} \approx 1 + \tilde{X}_t + a\tilde{Y}_t$; $\tilde{X}_t\tilde{Y}_t \approx 0$; $E_t\left[ae^{\tilde{X}_{t+1}}\right] \approx a + aE_t[\tilde{X}_{t+1}]$

Our Beninese log linear RBC model looks like this:

$\sigma\tilde{C}_t + \varphi\tilde{L}_t = \tilde{w}_t$ Labour supply (27)

$\frac{\sigma}{\beta}\left(E_t\tilde{C}_{t+1} - \tilde{C}_t\right) = \frac{R_{ss}}{P_{ss}}E_t\left(\tilde{R}_{t+1} - \tilde{P}_{t+1}\right)$ Euler equation (28)

$\tilde{K}_{t+1} = (1-\delta)\tilde{K}_t + \delta\tilde{I}_t$ Accumulation of capital (29)

$\tilde{Y}_t = \tilde{A}_t + \tilde{\Omega}_t + \alpha\tilde{K}_t + (1-\alpha)\tilde{L}_t$ Production function (30)

$\tilde{K}_t = \tilde{Y}_t - \tilde{r}_t$ Capital demand (31)

$\tilde{L}_t = \tilde{Y}_t - \tilde{w}_t$ Labour demand (32)

$Y_{ss}\tilde{Y}_t = C_{ss}\tilde{C}_t + I_{ss}\tilde{I}_t$ Equilibrium condition (33)

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$\tilde{A}_t = \rho_A \tilde{A}_{t-1} + \varepsilon_t$ Productivity shock (34)

$\tilde{\Omega}_t = \rho_\Omega \tilde{\Omega}_{t-1} + \epsilon_t$ Climate shock (35)

The Blanchard-Kahn Condition (1980) of the Beninese RBC model

The Blanchard-Kahn (1980) condition is applied only to the linear model with coefficients that do not depend on time and where the exogenous variables can be considered constant from a certain period. This condition allows us to verify the existence and uniqueness of the equilibrium of our Beninese RBC model.

The 1st step: we must simplify the linear system to facilitate the Blanchard-Kahn analysis.

To do this, we will substitute equation (32) into equation (27):

According to (32) : $\tilde{L}_t = \tilde{Y}_t - \widetilde{W}_t$, equals $\widetilde{W}_t = \tilde{Y}_t - \tilde{L}_t$

According to (27) :$\sigma\tilde{C}_t + \varphi\tilde{L}_t = \widetilde{W}_t$, equals $\sigma\tilde{C}_t + \varphi\tilde{L}_t = \tilde{Y}_t - \tilde{L}_t$

So, $\sigma\tilde{C}_t + (1 + \varphi)\tilde{L}_t = \tilde{Y}_t$ (36)

Substitute equation (31) in equation (28):

According to (31) : $\widetilde{K}_t = \tilde{Y}_t - \tilde{R}_t$, $\tilde{R}_t = \tilde{Y}_t - \widetilde{K}_t$, $\tilde{R}_{t+1} = \tilde{Y}_{t+1} - \widetilde{K}_{t+1}$

According to (28) : $\frac{\sigma}{\beta}\left(E_t\tilde{C}_{t+1} - \tilde{C}_t\right) = R_{ss}E_t\tilde{R}_{t+1}$,

$\frac{\sigma}{\beta}\left(E_t\tilde{C}_{t+1} - \tilde{C}_t\right) = R_{ss}E_t(\tilde{Y}_{t+1} - \widetilde{K}_{t+1})$ (37)

Substitute equation (33) in equation (29):

According to (33) : $Y_{ss}\tilde{Y}_t = C_{ss}\tilde{C}_t + I_{ss}\tilde{I}_t$, $\tilde{I}_t = \frac{1}{I_{ss}}\left[Y_{ss}\tilde{Y}_t - C_{ss}\tilde{C}_t\right]$

According to (29) : $\widetilde{K}_{t+1} = (1-\delta)\widetilde{K}_t + \delta\tilde{I}_t$,

$\widetilde{K}_{t+1} = (1-\delta)\widetilde{K}_t + \delta\left[\left(\frac{Y_{ss}}{I_{ss}}\right)\tilde{Y}_t - \left(\frac{C_{ss}}{I_{ss}}\right)\tilde{C}_t\right]$ (38)

We keep the equation (30) :

$\tilde{Y}_t = \tilde{A}_t + \tilde{\Omega}_t + \alpha\widetilde{K}_t + (1-\alpha)\tilde{L}_t$ (39)

We also keep the equations (34) et (35) :

$\tilde{A}_t = \rho_A \tilde{A}_{t-1} + \varepsilon_t$ (40)

$$\widetilde{\Omega}_t = \rho_\Omega \widetilde{\Omega}_{t-1} + \epsilon_t \qquad (41)$$

In this system, there are two forward-looking variables$E_t\tilde{C}_{t+1}$ et $E_t\tilde{Y}_{t+1}$ and three predetermined variables $\tilde{A}_t, \widetilde{\Omega}_t \; et \; \widetilde{K}_{t+1}$.

This type of system can be represented as a state space:

$$E \begin{bmatrix} \widetilde{\Omega}_t \\ \tilde{A}_t \\ \widetilde{K}_{t+1} \\ E_t\tilde{C}_{t+1} \\ E_t\tilde{Y}_{t+1} \end{bmatrix} = A_0 \begin{bmatrix} \widetilde{\Omega}_{t-1} \\ \tilde{A}_{t-1} \\ \widetilde{K}_t \\ \tilde{C}_t \\ \tilde{Y}_t \end{bmatrix} + DL_t + G \begin{bmatrix} \epsilon_t \\ \varepsilon_t \end{bmatrix} \qquad (42)$$

It is better to write the system in a consistent form of the state space:

$$\Omega\text{: } \widetilde{\Omega}_t = \rho_\Omega \widetilde{\Omega}_{t-1} + \epsilon_t$$

$$\text{A: } \tilde{A}_t = \rho_A \tilde{A}_{t-1} + \varepsilon_t$$

$$\text{K: } \widetilde{K}_{t+1} = (1-\delta)\widetilde{K}_t + \delta\left[\left(\frac{Y_{ss}}{I_{ss}}\right)\tilde{Y}_t - \left(\frac{C_{ss}}{I_{ss}}\right)\tilde{C}_t\right]$$

$$\text{C: } \frac{\sigma}{\beta}E_t\tilde{C}_{t+1} - R_{ss}E_t\tilde{Y}_{t+1} + R_{ss}E_t\widetilde{K}_{t+1} = \frac{\sigma}{\beta}\tilde{C}_t$$

Since the variable$E_t\tilde{Y}_{t+1}$ appears only in the previous equation, it is necessary to use a dummy equation to represent it:

$$YY\text{: } R_{ss}E_t\tilde{Y}_{t+1} = R_{ss}E_t\tilde{Y}_{t+1}$$

$$Y\text{: } \tilde{Y}_t = \tilde{A}_t - \widetilde{\Omega}_t + \alpha\widetilde{K}_t + (1-\alpha)\tilde{L}_t$$

$$L\text{: } \sigma\tilde{C}_t + (1+\varphi)\tilde{L}_t - \tilde{Y}_t = 0$$

The next step will be to find the matrices E,A_0, D et L_t :

$$E = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & R_{ss} & \frac{\sigma}{\beta} & -R_{ss} \\ 0 & 0 & 0 & 0 & R_{ss} \end{bmatrix}$$

$$A_0 = \begin{bmatrix} \rho_\Omega & 0 & 0 & 0 & 0 \\ 0 & \rho_A & 0 & 0 & 0 \\ 0 & 0 & (1-\delta) & -\delta\frac{C_{ss}}{I_{ss}} & \delta\frac{Y_{ss}}{I_{ss}} \\ 0 & 0 & 0 & \frac{\sigma}{\beta} & 0 \\ +1 & -1 & \alpha & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ (1-\alpha) \end{bmatrix}$$

$$L_t = \begin{bmatrix} 0 & 0 & 0 & \frac{\sigma}{1+\varphi} & -\frac{1}{1+\varphi} \end{bmatrix} * \begin{bmatrix} \tilde{\Omega}_{t-1} \\ \tilde{A}_{t-1} \\ \tilde{K}_t \\ \tilde{C}_t \\ \tilde{Y}_t \end{bmatrix} = K * \begin{bmatrix} \tilde{\Omega}_{t-1} \\ \tilde{A}_{t-1} \\ \tilde{K}_{t-1} \\ \tilde{C}_{t-1} \\ \tilde{Y}_{t-1} \end{bmatrix}$$

DK is obtained:

$$DK = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ (1-\alpha) \end{bmatrix} * \begin{bmatrix} 0 & 0 & 0 & \frac{\sigma}{1+\varphi} & -\frac{1}{1+\varphi} \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{(1-\alpha)\sigma}{1+\varphi} & \frac{(1-\alpha)}{1+\varphi} \end{bmatrix}$$

The next step will be to determine the matrix A:

$$A = A_0 + DK = \begin{bmatrix} \rho_\Omega & 0 & 0 & 0 & 0 \\ 0 & \rho_A & 0 & 0 & 0 \\ 0 & 0 & (1-\delta) & -\delta\frac{C_{ss}}{I_{ss}} & \delta\frac{Y_{ss}}{I_{ss}} \\ 0 & 0 & 0 & \frac{\sigma}{\beta} & 0 \\ +1 & -1 & \alpha & 0 & 1 \end{bmatrix}$$

$$+ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{(1-\alpha)\sigma}{1+\varphi} & \frac{(1-\alpha)}{1+\varphi} \end{bmatrix}$$

$$
= \begin{bmatrix} \rho_\Omega & 0 & 0 & 0 & 0 \\ 0 & \rho_A & 0 & 0 & 0 \\ 0 & 0 & (1-\delta) & -\delta\frac{C_{ss}}{I_{ss}} & \delta\frac{Y_{ss}}{I_{ss}} \\ 0 & 0 & 0 & \frac{\sigma}{\beta} & 0 \\ +1 & -1 & \alpha & \frac{(1-\alpha)\sigma}{1+\varphi} & 1-\frac{(1-\alpha)}{1+\varphi} \end{bmatrix}
$$

Finally, the objective is to analyze eigenvalues of the matrix $\bar{A}$ with:

$\bar{A} = E^{-1}A$

When we determine the eigenvalues of the matrix $\bar{A}$, it is possible to analyze whether the system has a unique and stable solution. According to the condition of Blanchard and Kahn (1980), the results show that the matrix $\bar{A}$ contains an eigenvalue greater than 1. Therefore the Blanchard-Kahn condition is verified.

4. Economic interpretations of the different shocks: productivity and climate

Like any other model, our Benin RBC model has advantages and disadvantages. Let's start with the weak points, the RBC models fail to reproduce the essential characteristics of the product market, the labor market, and the asset market. These models generally focus on fluctuations in factors of production. The representative agent character combined with the infinite horizon means that these models explain in an approximate way the economic reality of Benin. Moreover, the fact that these models do not take into account the imbalance (no market failure) and that they consider that the agents behave in a rational way cast doubt on their effectiveness.

Despite these drawbacks, our study is considered one of the first attempts to assess climate change on the Beninese economy. This analysis is enriched by a comparison with a technological shock, which is always overestimated compared to not taking into account a climate shock. This shock which is generally ignored or marginalized by other studies applied to Benin, by economists, when using an RBC model which is oriented to always confirm the technological shock as a positive externality for developing countries and in a specific way for the case of Benin. RBC models which are still considered as very successful academic models within academia. These models make it possible to measure the impact of any macroeconomic variable on the economy as a whole. They are based on an uncertain framework to analyze the different simulations in relation to the problem in question. These simulation-based models help decision-makers understand and assess the various shocks faced by their economy. As is the case for our Beninese economy.

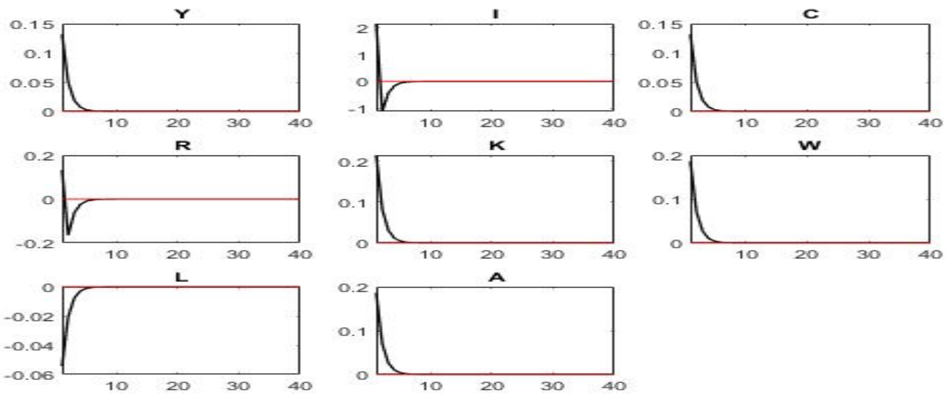
The different stochastic shocks: technological shock and climatic shock

In our article, we will discuss the effect of two exogenous shocks (productivity shock and climate shock) on the endogenous variables of the model. The simulation will be on three parts, namely: one part with the technological shock, a 2nd part with the climatic shock and a 3rd part with the two shocks at the same time. We will proceed to the use of two values of the marginal disutility of the supply of labor (phi), resulting from the literature and the calibration (a minimum value: 1.43 and a maximum value: 2.5). This parameter is important in our explanation, because it will allow us to distinguish two behaviors of the Beninese household. The first value consists of a low marginal disutility, explained by an improvement in living and working conditions (see the improvement in life expectancy) and the second value will consist of a maximum value, explained by the harshness of working conditions work (or reduced life expectancy). The various simulations were performed using Matlab-Dynare software version 4.5.7. We present the various results in the following paragraphs.

The results of the three simulations for the case phi=1.43

Figure 1 shows the effects of the productivity shock on the various macroeconomic variables. From this figure, we see that the majority of the macroeconomic variables tend towards their stationary state, from the period (10). This means that before period 10, these different variables vary over time, in a monotonous way.

Figure 1: Effect of the productivity shock



Source : made by the authors (using Matlab-dynare software)

The productivity shock has a positive effect on production and consumption in the short term before they reach their steady state. This positive effect led to a negative effect on investment.

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This explains why technology has boosted production oriented more towards consumption than investment in Benin. This production which was shared between two factors of production. A positive effect on the capital factor accompanied by a drop in capital remuneration (R) while we observe a negative effect on the labor factor accompanied by an increase in wages (W). This technical progress has been in favor of the phenomenon of capitalization of the Beninese economy compensated by a decline in the labor factor. Despite this decline in the number of workers, wages have been increased, which explains the continued motivation of Beninese households to consume more and maintain a high level of well-being. In other words, the improvement of living and working conditions among Beninese also contributed to this increase in their consumption, accompanied by technical progress, which continued to have a positive influence on their production.

Our figure 2 is devoted to the effects of the climatic shock (increase in temperature) on the various macroeconomic variables of our model. The macroeconomic variables converge towards their stationary states at a delayed period (the period 20) compared to that of the technological shock (the period 10). The climate shock has a negative effect on production, consumption and investment. It is considered an expected impact. The negative effect affected production, which also led to a drop in consumption. In the short term, we also observe a negative effect on investment, but which was accompanied by a positive effect from the fourth period to converge towards its steady state.

The negative effect on production was caused by the negative effect on the capital factor, on the other hand the climatic shock was in favor of a positive effect for the labor factor. This positive effect of labor can be explained by the improvement of living and working conditions among Beninese (the assumption of the value of phi was maintained equal to 1.43). this increase led to a drop in wages following this climatic shock, on the other hand to a positive effect on the return on capital, following a reduction in the quantity of the capital factor. Despite the improved working conditions that have been maintained in Benin, this has not prevented Beninese households from lowering their consumption, leading to a drop in production. In other words, the climatic shock has a detrimental effect on Beninese economic growth accompanied by a drop in the well-being of Beninese consumers explained by the drop in their wages.

Figure n° 2 : effect of the climatic shock

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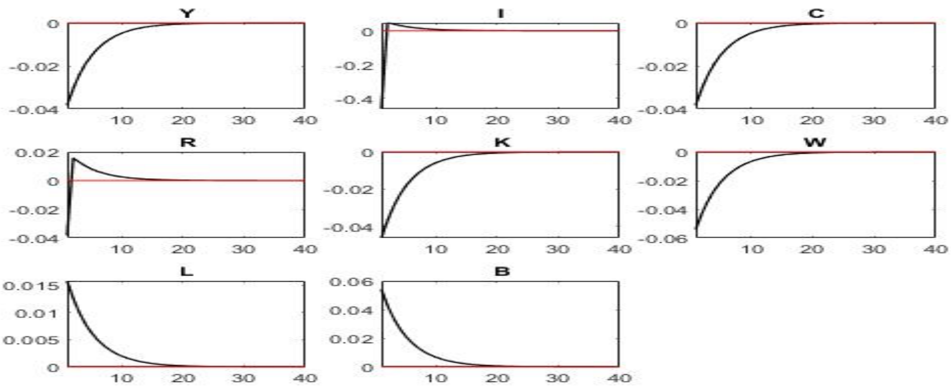
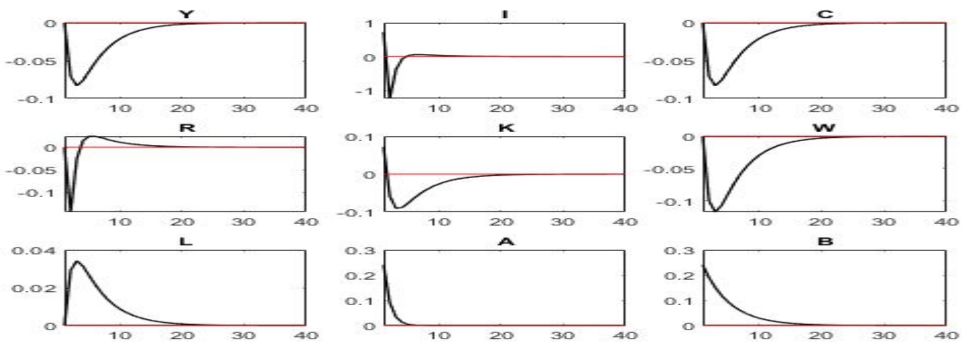


<u>Figure n° 2</u> : effect of the climatic shock

<u>Source</u> : made by the authors (using Matlab-dynare software).

We noticed that the two shocks: productivity shock and climatic shock, influenced differently the macroeconomic aggregates of the Beninese economy. What prompts our investigation, which shock will prevail over the other and what are the impacts on the macroeconomic variables of our model, if we carry out the two shocks at the same time?

In this context, we will devote Figure 3 which represents the effects of the two shocks on the various macroeconomic variables of the Beninese economy.



<u>Figure 3</u> : Effect of productivity shock and climate shock

<u>Source</u> : made by the authors (using Matlab-dynare software)

With two shocks, an increase in both temperature and total factor productivity, Beninese production was affected in the medium and long term and then reached its steady state in period 20. We notice in this scenario, there there is a significant movement in the short term for the majority of macroeconomic variables. The impact of these two shocks negatively affected production and consumption. This negative effect is different from the climatic shock alone

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(around 40%), on the one hand on the intensity side and on the other hand on the rhythm side. With the two shocks, we have an abrupt decrease in production (more than 5%) followed by consumption then a slow increase to converge towards the stationary state, from period 20. This same movement was followed by the consumption. In other words, the climate shock prevailed over the productivity shock, since we are witnessing a negative effect with a slow pace and less intensity than the climate shock alone. In the short term, we are witnessing a sudden increase in investment, accompanied by a sharp drop to converge after less than the fifth period towards its steady state. This phenomenon also explains a drop in the consumption of Beninese following a negative impact on their wages. This decline occurred during a positive effect on the number of workers following these two shocks. On the other hand, we are witnessing a sudden drop in the short-term interest rate accompanied by a sudden increase during the first ten periods. This evolution affected the quantity of capital in Benin, in the form of a negative effect until it converged at the end of the first twenty periods. We note the negative effect on production is explained exclusively by the negative effect on capital, which prevailed despite a positive effect on the labor factor.

From these results, we confirm the presence of a climatic shock alongside a productivity shock better reflects reality. Above all, climate change has given rise in recent years to reflections in scientific research, it is for this reason in our study, we have introduced this phenomenon as a shock. This shock confirms that it has effects on a small economy, including the Beninese economy. Alongside the productivity shock, this climatic shock can intensify or even slow down the harmful effects on Beninese growth and on the well-being of Beninese. We studied in a positive framework explained by a low marginal disutility, in other words under a context where there is an improvement in the living and working conditions (see the improvement in life expectancy) of Beninese. The next paragraph we will devote ourselves to a more pessimistic context.

The results of the three simulations for the case phi=2.5

In this section, we will devote ourselves to evaluating the effects of our three scenarios in the case of a maximum value of marginal disutility, explained by the harshness of working conditions (or by the reduction in life expectancy). Figures 4, 5 and 6 present almost the same results as the previous three figures. This means that under different values of phi (1.43 or 2.5), the effects of the productivity shock, the effects of the climatic shock and the effects of the two shocks have this does not change the same response functions: the intensities of the effects and

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the rhythms to converge towards stationary states. In other words, the two optimistic and pessimistic behaviors of the Beninese do not change the external effects of each of the shocks or even the two shocks at the same time. These results also show the importance of climate shocks as externalities that should not be overlooked when we assess the macroeconomic impacts of the Beninese economy or any developing economy.

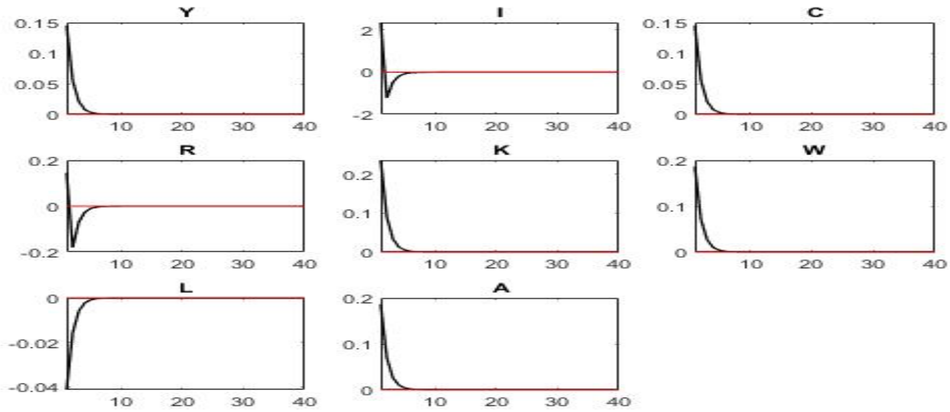


Figure n° 4: effect of the productivity shock

Source : made by the authors (using Matlab-dynare software)

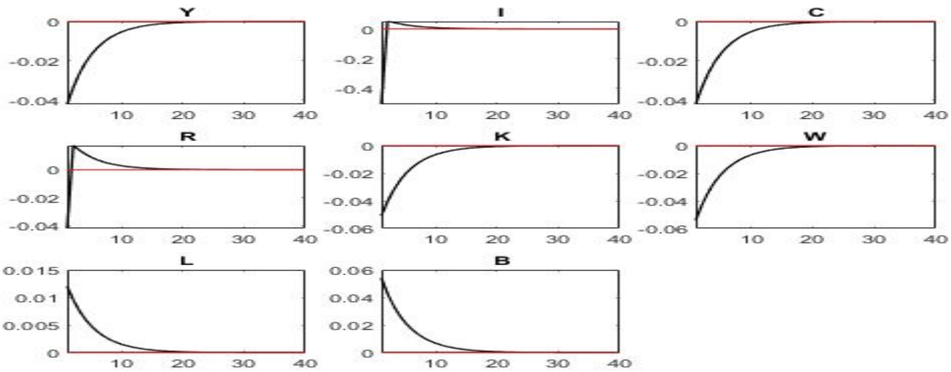
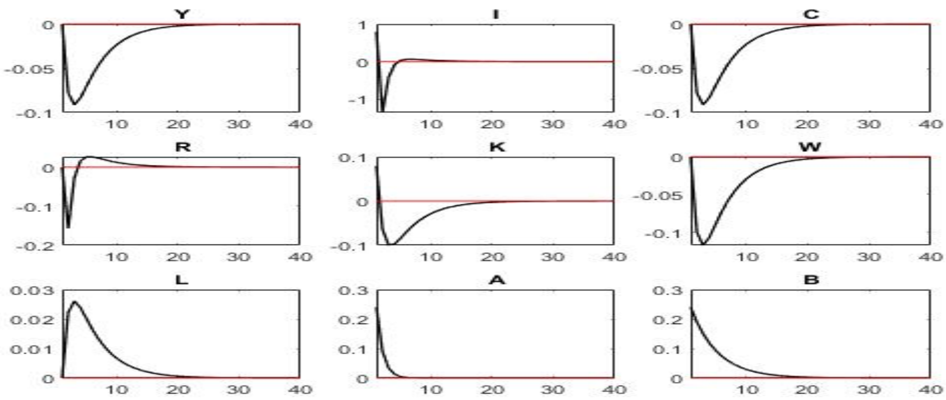


Figure n° 5: effect of the climatic shock

Source : effectuée par les auteurs (à l'aide du logiciel Matlab-dynare).



<u>Figure n° 6</u>: effect of the productivity shock and the climate shock

<u>Source</u> : made by the authors (using Matlab-dynare software)

Thus each macroeconomic variable has a very different reaction to each of these shocks. But we can argue that when we are in the case of two shocks, the effects of the climatic shock will also outweigh the effects of the technological shock. Here, we mention that the Beninese economy must face these climatic shocks that are more important than the productivity shock. The labor factor is the only beneficiary of these two shocks, while we notice that there is a deterioration in well-being (lower consumption) and a lower production. This deterioration is caused both by the single climatic shock and by both shocks at the same time. This explains why climate change does not spare developing countries, even a small country like Benin. But to deal with these negative effects, the Beninese government must adopt a sustainable technological strategy to be able to counter these adverse climatic effects.

5. CONCLUSION

RBC models seek to construct general equilibrium models in a flexible price economy based on a mode of perfect competition. These models generally incorporate real shocks arising from fluctuations in the business cycle. These models take into account the calibration of certain numbers of parameters, some possible adjustments, as well as forecast errors that may be possible. It is important to emphasize the standard RBC models which have little interpretation of economic fluctuations relative to the stationary path following technological shocks. Moreover, we can add that the structure of these models does not consider either fiscal or monetary policy to act on macroeconomic conditions. Following our three simulations carried out with our Benin RBC model, we note that the productivity shock remains the only shock that has a positive impact on production, consumption, capital and wages. On the other hand, the climatic shock, only, has negative effects on the same macroeconomic variables. We can point out that the effects of these two shocks are contradictory. These results led us to propose a third scenario that combines the two shocks at the same time. From this third scenario, we notice that there were negative effects on production, consumption, capital and wages. These can be explained by the weight of the impact of the climate shock on the Beninese economy compared to the weight of the productivity shock. These evolutions were noticed in the two possible behavioral situations of Beninese households. The optimistic situation as well as the pessimistic situation which offered us almost the same effects of the two shocks on the various macroeconomic variables of the Beninese economy. This modest study gives us an approximate idea of the role played by climatic shocks, but we can improve our Beninese CBR model by integrating the government, which can also intervene to regulate this negative situation through its various economic policies (budgetary, tax, etc.). As, we can also evaluate in future research the impact of climatic shocks on the international trade of Benin, let us introduce, the Rest of the World.

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Appendices

Appendix A: Production Function Regression

Source	SS	df	MS			
				Number of obs	=	28
				F(2, 25)	>	99999.00
Model	6.65795283	2	3.32897642	Prob > F	=	0.0000
Residual	.000024087	25	9.6347e-07	R-squared	=	1.0000
				Adj R-squared	=	1.0000
Total	6.65797692	27	.246591738	Root MSE	=	.00098

lgdp	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lcapital	.0049326	.0004516	10.92	0.000	.0040025	.0058627
llabor	.9951654	.0008479	1173.63	0.000	.993419	.9969117
_cons	.0310365	.005646	5.50	0.000	.0194083	.0426647

Source: compiled by the authors (using STATA software)

Appendix B: Productivity shock regression

Source	SS	df	MS			
				Number of obs	=	27
				F(1, 25)	=	4.05
Model	3.3279e-06	1	3.3279e-06	Prob > F	=	0.0550
Residual	.000020536	25	8.2144e-07	R-squared	=	0.1395
				Adj R-squared	=	0.1050
Total	.000023864	26	9.1785e-07	Root MSE	=	.00091

lAt	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lAt1	.3744855	.1860549	2.01	0.055	-.0087017	.7576727
_cons	.0201275	.0059906	3.36	0.003	.0077896	.0324653

Source: compiled by the authors (using STATA software)

Appendix C: Stochastic characteristic of the productivity shock

Variable	Obs	Mean	Std. Dev.	Min	Max
lAt	28	.0321614	.0009453	.031479	.0348976

Source: compiled by the authors (using STATA software)

Appendix D: Climate shock regression

Source	SS	df	MS			
				Number of obs	=	131
				F(1, 129)	=	214.82
Model	.441359371	1	.441359371	Prob > F	=	0.0000
Residual	.265038014	129	.002054558	R-squared	=	0.6248
				Adj R-squared	=	0.6219
Total	.706397385	130	.005433826	Root MSE	=	.04533

ltt	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ltt1	.7920975	.0540433	14.66	0.000	.6851716	.8990235
_cons	.6910817	.1794032	3.85	0.000	.336128	1.046035

Source: made by the authors (using STATA software)