Macroeconomic Fluctuations Under Natural Disaster Shocks in Central America and The Caribbean

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Abstract

This paper examines the role of disaster shock in a one-sector, representative agent dynamic stochastic general equilibrium model. Firstly, we estimate a panel vector autoregresive (VAR) model for output, investment, trade balance, consumption and country spread to capture the economic effects of output, country risk and exogenous natural disaster shocks. We determined the empirical dynamic responses of 10 countries of Caribbean and 7 countries in Central America. Secondly, by taking into account rare events and trend shocks this paper also provides a baseline framework of the dynamic interactions between the macroeconomic effects of rare events and financial friction. The findings show that Caribbean countries are better prepared for natural disaster shocks and Central America countries have long-run negative effects. Disaster shock have no significant effects impact on long run growth

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1 Introduction

The aim of the study is to determine the short-run and long-run dynamics of macroeconomic fluctuations within an exogenous disaster shock for 10 Caribbean countries (Antigua and Barbuda, Bahamas, Barbados, Dominica, Granada, Jamaica, St. Kitts and Nevis, St.Lucia, St.Vincent and Grenadines, and Trinidad and Tobago) and 7 Central America countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Panama and Nicaragua). To achieve this goal, firstly we use a panel Vector Autoregressive (VAR) model to capture the dynamic responses of a variety of shocks and secondly, we consider a small open economy in the spirit of Aguiar and Gopinath (2007).

Aggregate supply and demand fluctuations have been well documented for developed and emerging markets (Blanchard 1989, Cushman and Zha 1995, Agnor et al 1999, Uribe and Yue 2006). However, only few literature research has tried to explain macroeconomic fluctuation for small open economies as Central America and the Caribbean countries (Watson (1996), Borda, Manioc and Montauban (2000), Sosa and Cashin (2013)). We extends the discussion to the case of small open economies and particularly the case of Caribbean countries and Central America by introducing disaster risk in a panel VAR model and a dynamic stochastic general equilibrium (DSGE) model. However less attention has been paid to disaster risk in general equilibrium model. Understanding the fiscal policy and the monetary policy facing to disaster risk is of interest.

The goal of this paper is to estimate the responses of macroeconomic quantities of the region under an exogenous natural disaster shock. Given their geographical location, Central America and the Caribbean countries are vulnerable to a variety of natural phenomenons. For example, both economies suffered several times a year the stroke of hurricane,storms and earthquakes (But only Central America countries suffered significant impact of earthquakes). The consideration of disaster shocks in the analysis is twofold. Firstly, it allows us to analyze some of potential driving forces of business cycles beyond the productivity and foreign shocks. Secondly, and most importantly, this is a first step to test the role of rare events in the business cycles. The main results of the paper show that Central America and Caribbean countries have different responses for aggregate supply and demand shocks. We find that Caribbean countries are better prepared for natural disaster shocks. Impulse response function to a disaster shock show that output, consumption, investment and trade balance ratio fairly adjust in the short-run to their pre-shock level. But Central America countries have negative long-run effects for disaster shocks on output and trade balance ratio mainly.

The paper is organized as follows. Section 2 contains a brief review of the related literature on macroeconomic fluctuations and natural disaster shocks. In section 3, we start with some stylized facts of selected countries. Section 4 presents the empirical model specification with the data and estimation issues. The empirical results are also discussed. Section 5 develops the general frame work. In Section 6, we describe the data and introduce our parametrization and estimation technique. Estimation results are presented in Section 7, while Section 6 discusses the dynamics of our model in greater detail. Some concluding remarks appear in Section 7. Section 8 offers concluding remarks.

2 Literature Related

In this section we make a brief review on the related empirical literature. Several authors have studied macroeconomic fluctuations in the existing literature. Their approach has focused in explaining the sources of fluctuations in the business cycle for a variety of developed and developing countries. It is known that developing countries are more likely to prone sudden crisis and their business cycles are significantly affected by negative external shocks. With this idea in mind, literature has evolved in order to understand the sources of fluctuation in developing economies as Africa (Hoffmaister et al. (1998)) and the Caribbean (Watson (1996), Borda, Manioc and Montauban (2000)).

Blanchard (1989) studies the dynamic behaviour of U.S output, unemployment, prices, wages and nominal money under the effects of demand and supply innovations. His results are consistent with the traditional interpretation of macroeconomic fluctuations. Movements of output are dominated by demand shocks in the first quarters and by supply shocks in the long-run.

Agenor et al (1999) examine how business cycles conditions in developed economies could affect macroeconomic fluctuations in 12 developing countries. They measure the relationship between economic fluctuations with an index of industrial country output and a measure of the world real interest rate. Their main findings suggest that output volatility is much higher than developed countries and government expenditure in developing countries is countercyclical.

A series of studies have focused in studying macroeconomic fluctuations in specifically developing countries. Hoffmaister et al. (1998) studied the sources of macroeconomic fluctuations in Africa by dividing the study group in two sub-sample groups of sub-Saharan countries: CFA franc and non-CFA franc. Using a structural VAR model to explain the fluctuations effects under different exchange rate regimes and address the role of domestic versus external shocks. Their results show that supply shocks are the main source of output fluctuation in both group of countries. In relationship with Caribbean countries, Watson (1996) investigate the impact of a monetary policy shocks on real sector variables in Trinidad and Tobago. With a VAR model he calculate the impulse response functions from a one standard deviation shock to policy innovations.

The main findings of his work tell us that the monetary shock works more through the transmission mechanism of loans in the Caribbean country.

Borda Manioc and Montauban (2000) estimate a panel VAR model for GDP, real exchange rate, consumer price index and world real interest rate to understand the importance of US monetary policy in 12 Caribbean countries. Same as Hoffmaister et al (1998) they divided the study in two groups of countries to see the effects of different exchange rate regimes. Their results show that for both groups, domestic supply shocks have important effects on the long-run.

World interest rates and country spreads interrelationship are studied with a first-order Panel VAR system in Uribe and Yue (2006). They explain the movements in aggregate variables under different identified shocks. Their conclusion suggest that country spreads have an important role in propagating shocks to emerging markets business cycles.

In the Caribbean countries there are a few papers that study mainly the effects of hurricanes. Using a VAR model with block exogeneity restrictions Cashin and Sosa (2013) analyze the effect exogenous factors in the ECCUs business cycle. They find that rare shocks lead to a significant drop in output in the short run, but the effects do not appear to be persistent in the long run. Strobl (2012) uses an innovative[1] index of potential local destruction of hurricanes in the Caribbean basin. He finds that the disaster shock (average hurricane) reduces growth by 0.8 percentage points. However, the Strobl results could overestimating the effects of hurricanes on output because of the interaction between rare shocks and macroeconomic quantities. Recently, Acevedo (2014) has used Fomby, Ikeda, Loayza (2013) methodology by modeling the impacts of natural disasters on economic growth and debt growth for 12 Caribbean countries. They find that storms have persistent effect on debt in short and long run.

[1] Strobl used the wind field model on hurricane proposed by Emanuel (2005).

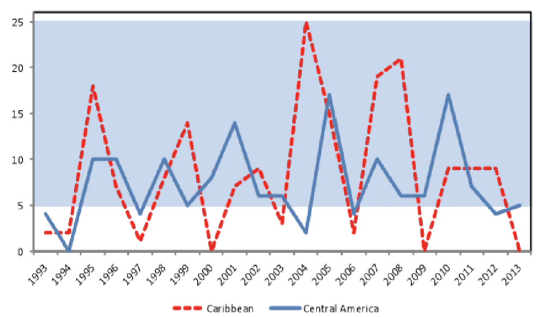
There are few studies attempting to take into account the interaction of natural disaster and business cycles. Keen and Pakko (2007) determined the optimal monetary policy under a natural disaster shock with a DSGE model as they incorporate nominal rigidities with sticky price and wage models. They find that the optimal response is an increase in the nominal interest rate target. Gourio (2012), has analyzed the effect of rare events and time-varying risk of disaster in a standard Real Business Cycles (RBC) framework. He especially focus on the responses of macroeconomic quantities to a sudden rise in the probability of disaster.

3 Caribbean and Central America Stylized Facts

As mentioned before, the Caribbean and Central America countries are vulnerable to a variety of natural phenomenons given their geographical location. Figure 1. presents the occurrence of natural disasters in both regions. In particular, Eastern Caribbean countries stand out as among the most disaster-prone in the world (Rasmussen 2004). We use the EM-DAT database compiled by the Centre for Research on the Epidemiology of Disasters (CRED) to analyze the incidence of different natural disasters (Local Storm, Tropical Cyclone and Earthquake) in the region (See Table A1.) Over the past twenty years, the Caribbean has suffered 142 storms with 7 earthquakes. Meanwhile, Central America has suffered 98 storms with 28 earthquakes. Tropical cyclones are the major source of disaster in the region. Earthquakes play an important role only in Central American countries.

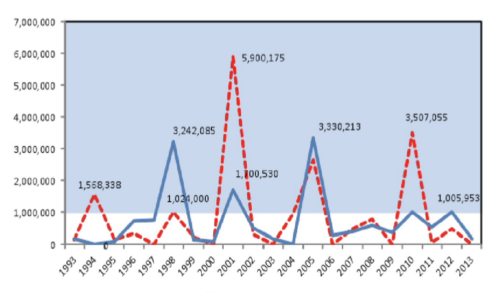
Major natural disaster events have negative macroeconomic implications. Figure 2. shows the estimates of the number of people affected by natural phenomenons from 1993 to 2013, the events which surpass one million people affected are shown. We count 5 major natural disasters in each region. In the whole sample period, a total of 34 million people was affected by disasters. Approximately 18 million and 15 million people in the Caribbean and Central America respectively. Given the high frequency of events each year, it should be expected to translate into relatively high levels of damage that affect some key macroeconomic variables and therefore their business cycle. Natural disasters represent a negative supply shock that affect macroeconomic fluctuations. Next section will address the dynamic response of these external shocks in order to understand the impact of natural disasters in the Caribbean and Central America.

Figure 1: INCIDENCE OF NATURAL DISASTERS



Note: Include local storms, tropical cyclones and earthquakes.
Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be – Université catholique de Louvain – Brussels – Belgium.

Figure 2: MILLIONS OF PEOPLE AFFECTED BY NATURAL DISASTERS



Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be – Université catholique de Louvain – Brussels – Belgium.

4 An Empirical model of shocks: a Panel VAR

In this section, we present the specification of the panel var estimated in this paper. In the usual case, panel data is used to exploit the heterogeneous information in cross-country data. We begin with a discussion of the variables included in the model followed by a discussion of the structure of the Panel Var model and how we resolve the identification problem.

4.1 Econometric Specification

Our model contains 5 variables: output, investment, trade balance ratio, consumption and country spread. These variables should capture the economic relationship that determines the dynamic of small open economies. As Caribbean Small islands and Central America countries are strongly vulnerable to climatic conditions, it is necessary to incorporate the effects of disasters variable on economic performance. Thus, we include as exogenous variable a disaster shock (or a rare shocks). The baseline specification of the model corresponds to :

$$x_{i,t} = x_0 + \sum_{k=1}^{n} A_k x_{i,t-k} + \sum_{k=0}^{n} B_k d_{i,t-k} + e_{i,t}, \quad i = 1, ...N; t = 1, ...T \tag{1}$$

where i denotes the country and t the time. $x_{i,t}$ is an $m \times 1$ vector of endogenous variables. In our case, $x_{i,t} = \begin{pmatrix} y_{i,t}, & i_{i,t}, & c_{i,t}, & tb_{i,t}, & r_{i,t} \end{pmatrix}'$ are respectively GDP *per capita*, investment *per capita*, consumption *per capita*, trade balance ratio and a measure of country risk. The previous variables include the traditional macroeconomic variables typically used in works of Uribe et Yue (2006). $d_{i,t}$ is vector of exogenous variables which differ across countries and includes variables capturing the occurrence of natural disasters[2], $d_{i,t} = \left(\begin{array}{cc} storm_{i,t}, & earth_{i,t} \end{array} \right)^{'}$. The use of a natural disaster variable in the empirical model may be controversial and can raise some questions. For instance, is natural disaster shocks is exogenous or endogenous regarding the externality caused by economic activity? To answer to this question we suggest that natural disaster variable is strongly exogenous to the system.

A_k is an $m \times m$ matrix of slope coefficients. $e_{i,t}$ is the vector of components errors including unobserved individual fixed effects and an error term :

$$e_{i,t} = \mu_i + \epsilon_{i,t},$$

subject to the usual conditions :

$$E(e_{i,t}) = 0 \text{ and } E(e_{i,t}e^{'}_{i,t}) = \sum = \sigma_{ij}. \tag{2}$$

Once the parameters of A_k are estimated is useful to get the reduced form of the Panel Var for implementing dynamic simulations (the *IFRs* and *FEVDs*). This involves impulse response analysis that allows one to examine the effect of innovations to any particular variable to other variables in the system. For this, we need to solve the identification issue. The traditional way to deal with the identification issue is to choose a causal ordering. However, we deliberately, don't use any special causal ordering, then we suggest to use the Generalized Impulse Responses (Pesaran and Shin (1998)), which is invariant to the ordering of the variables in the system. The main idea is to understand the impulse response as the difference between the expected value of the variable at time $t + j$ after a shock at time t, and the expected value of the same variable at time $t + j$ given the observed history of the system.

[2] Large sudden natural disasters such as earthquakes and hurricanes in Central America or hurricanes in Caribbean Bassin.

4.2 Data and estimation issues

Our model contains a panel of 10 Caribbean countries[3] and 7 Central America countries. Data are annual and cover the period from 1993 to 2011 for Caribbean Countries and 1993 to 2012 for Central America countries. Most of data and comes from the International Financial Statistics and the World Bank data base. As we mentioned above, the Panel Var contains 5 endogenous variables that are the real output *per capita*, investment *per capita*, consumption *per capita*, trade balance ratio and country spread (or country risk) and one exogenous variable, a disaster index. The nature of disaster measure use in this paper is the economic damage of the hurricane (or the earthquake) experience by an economy for a given period. The data on economic damage are obtained from EM-DAT (Emergency Disaster Data Base). Data on macroeconomic variables come various data base. We measure the country spread (or country risk) as the sum of the JP Morgan's EMBI+ strippe spread and the US real interest rate. All variables are expressed as log deviation from linear trend. As we have seen, the main assumption is the strong exogeneity of disaster shock: disaster shocks are assumed to be unrelated to any macroeconomics variables. We have the following d_0[4] matrix structure for the Caribbean States :

$$d_0 = \begin{pmatrix} d_{1,1} \\ 0 \\ d_{3,1} \\ 0 \\ 0 \end{pmatrix}$$

and the following one for Central America :

[3] For Caribbean countries: Antigua and Barbuda, Bahamas, Barbados, Dominica, Granada, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, and Trinidad and Tobago. For Central America countries : Belize, Costa Rica, El Salvador, Guatemala, Honduras, Panama and Nicaragua.

[4] d_0 is the contemporaneous effect of a disaster shock on endogenous variables.

$$d_0 = \begin{pmatrix} d_{1,1} & d_{1,2} \\ 0 & 0 \\ d_{3,1} & d_{3,2} \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$$

The d_0 matrix of contemporaneous means that output and consumption respond contemporaneously to disaster shocks (*storms* for Caribbean states and *storms* and *Earthquake* for Central America countries). The equation (1) is a system of dynamic panel data equations. It is known that the fixed effects are correlated with the regressors' due to lags of the endogenous variables, then within transformations would generate biased coefficients. The model is estimated using the SURE technique. We have estimated the previous with two lags for the first sample one and one lag for the second one. The lags length is chosen following the AIC and BIC criteria.[5]

4.3 Empirical results

We begin with a discussion of the relative importance of Disaster shocks and output shocks followed by the analyze of forecast error variance decompositions.

4.3.1 Impulse responses functions

In this section we analyze impulse responses to output, country risk and natural disaster shocks for each of the five endogenous variables. As we mentioned before, storm shocks affect both group of countries and earthquakes shocks only Central America economies. In Figure 3. and 6. the respectively empirical responses to a storm shock

[5]For lags lengths, k=1, 2, 3, 4, 5 the BIC criterions for the first sample is 2611.30, 2513.38, 2572.49, 2646.52, 2708.84 and for the second one (Central America) the BIC 4504.47, 4609.91, 4725.90, 4838.80, 4941.1.

for Caribbean and Central America countries are shown. During the first year, in both group of countries: output, investment, trade balance ratio and consumption decrease and country risk increase. As the figures support, it seems that Caribbean countries are better prepared for storm shocks than Central America countries. In the Caribbean, output decline is lower and it recovers to pre-shock levels up to the fifth year. These results are consistent with Sosa and Cashin (2009), they found that output contractions in the region do not appear to be persistent in the long-run. Trade balance ratio and consumption levels decreases in the short-run to then increase significantly to positive levels in about one year and in later periods the effects in the long-run are close to zero. Meanwhile, investment never reaches its pre-shock levels and country risk increases in the first year to slightly decrease until the effects get close to zero. In Central America, output, investment, trade balance ratio and consumption levels decrease and their negative effects remain in the long-run. Country risk level increases by approximately 2 percent in the whole sample period. Keen and Pakko (2007) estimated the Taylor rule response to a disaster shock for the U.S and find that after Hurricane Katrina hit the U.S Golf coast in 2005, output and investment fall in the short-run to stabilize in the long-run. In this meaning, our results are in line with the existing literature.

The empirical responses to an earthquake shock for Central America countries are shown in Figure 7. They behave similarly to storm shock effects only they seem to have a greater impact in output and trade balance ratio. Again, the shock negative effects remain in the long-run. Surprisingly, investment and consumption levels fall significatively less than storm shocks and country risk declines rather than increase.

Significant differences appear in the dynamic responses for both group of countries with an output shock. In Figure 4. and 8. the respectively empirical responses to a one standard deviation output shock for Central America and the Caribbean are shown. In

Caribbean countries, the positive effect deteriorates rapidly in output, investment, trade balance ratio and consumption. Approximately, in the fifth year all variables reach its pre-shock level, after a slight decline in their levels. Country risk diminishes by little to surprisingly increase and maintain in the long-run. In the case of Central America, output, investment, trade balance ratio and consumption levels increase in the short run, to gradually decrease in the long-run and reach it pre-shock levels. In the Caribbean, supply shocks dominate the movement of output in the short-run, while in Central America dominate in the long-run. This results differ from the traditional interpretation of macroeconomic fluctuations (Blanchard 1989, Borda and Montauban 2000).

The empirical responses to a country risk shock for both Caribbean and Central America countries are show in Figure 5. and 9. respectively. Caribbean countries response varies. Investment and trade balance ratio decreases in the short-run, but the effects last in the long-run. Meanwhile, output and consumption level increases in the short-run. Unlike, Central America countries, the country risk level increase significantly and stays around 1 percent in the whole sample period. As expected, the shock effects in Central America economies initially decreases the level for output, investment, trade balance and consumption; to then recover its pre-shock level in the ninth quarter. Country risk effect last only for two years.

4.3.2 The variance decompositions

To better understand the contribution of the different shocks to the empirical model, we realize a forecast error variance decomposition of the variables at eleventh periods for the Caribbean countries. Our results are in line with the natural disaster literature, as the external climatic shocks represent a dominant factor driving output fluctuations in the short-run (Sosa and Cashin, 2009). Disaster shocks explain about 80 percent of the output fluctuations in the very short-run (one year) while consumption shock explain almost the 90 percent of the fluctuations in the long-run. For an overall view of the decomposition of variance of trade balance and country risk (see Figure 10).

5 The General Frame Work

In this section we describe the economic framework we use to deal with the empirical results established in the previous section. As pointed above, we introduce a risk disaster realization on Gourio (2012) methodology in a standard neoclassical small open economy initially developed by Mendoza (1991) and extended by Schmitt-Grohe and Uribe (2003), Aguiar and Gopinath (2007), Garcia-Cicco et all (2010) and Chang and Fernandez (2010).

5.1 The Technology

Let us consider an small open economy which is endowed with only one sector in which firms produce a final good denoted Y_t with two inputs K_t and L_t according to a Cobb-Douglas technology :

$$Y_t = e^{z_t} K_t^{\alpha} (A_t L_t)^{1-\alpha}, \quad \text{with } 0 < \alpha < 1 \tag{3}$$

in which t stands for time index, z_t and A_t are respectively the transitory and trend productivity shocks. Notice that trend shocks is specific to labor and define as $A_t = e^{g_t} A_{t-1}$ which is similar to Solow Residual. Transitory and trend productivity shocks are captured by the following the auto-regressive processes :

$$z_t = \rho_z z_{t-1} + \epsilon_{z,t}, \text{ with } |\rho_z| < 1 \ , \epsilon_{z,t} \rightarrow iid(0, \sigma_z) \tag{4}$$

and

$$g_t = \rho_g g_{t-1} + (1 - \rho_g)\mu_g + \epsilon_{g,t}, \text{ with } |\rho_g| < 1 \ , \epsilon_{g,t} \rightarrow iid(0, \sigma_g) \tag{5}$$

where the random term has a normal distribution with zero mean. μ_g is the long run growth. A realization of g_t permanently influences A_t, output is then non stationary with a stochastic trend. We introduce the following transformation to denote its de-trended variables :$\hat{x}_t = \frac{x_t}{A_{t-1}}$.

In a our model, capital stock is considered as a risky asset because it may be randomly hit by a *natural disaster*. The natural disaster realization may be an earthquake or an hurricane which destroys an important part of the physical capital stock. We assume that the disaster destroys a share d_k of the physical capital stock if realized. However, contrary to Gourio (2012), we relax the assumption that total factor productivity (hereafter TFP) is affected by the natural disaster realization because of its ambiguous effects on productivity. While some author argue that some natural disasters were associated with a fall in TFP (see Gourio (2012)), other papers find, on the contrary, that TFP may rise in recessions (Petrosky-Nadeau, 2010). The law of capital accumulation is given by

:

$$K_{t+1} = (1 - \bar{\pi} h_{t+1} d_k) \{(1 - \delta) K_t + I_t - \Phi(K_{t+1}, K_t)\} \tag{6}$$

where I_t is the investment flow, $\beta \in [0, 1]$ denotes the rate of depreciation, and $\Phi(K_{t+1}, K_t)$ is the capital adjustment cost function assumed to verify $\Phi(0) = 0$ and $\Phi'(0) = 0$. ϕ is the parameter that governs the capital adjustment costs. The capital adjustment cost function takes a usual functional form : $\Phi(.) = \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - e^{\mu_g}\right)^2 K_t$. One important element of this paper is the introduction of a natural disaster shock. Clearly some natural disaster like Luis and Marylin (1995) in Dominica and Georges (1999) in St. Kitts led in many small countries to large physical capital destruction. Given that, natural disaster is captured in the equation (6) by an indicator, h_{t+1} which is one if there is a natural disaster realization with a probability $\overline{\pi}$ and 0 otherwise with a probability $1 - \bar{\pi}$. $\bar{\pi}$ is a time invariant transition probability.

5.2 The household

The representative household consumes the final goods and maximizes the following utility function :

$$U = E_0 \sum_{t=0} \beta^t u(C_t, L_t) \tag{7}$$

where C_t and L_t are consumption at time t and labor at time t respectively and $\beta \in [0, 1]$ is the subjective discount factor. $u(.)$ is the current utility function while $E(.)$ is the expectations operator. While most of papers (Mendoza (1991), GarciaCicco et al (2009) and Chang and Fernandez (2009) among others) use the greenwood-Hercowitz-Huffman preference (hereafter GHH) because of their ability to improve the performances of small open economy models in reproducing some stylized facts, we adopt the following Cobb-Douglas utility function :

$$U(C_t, L_t) = \frac{(C_t^{\gamma} L_t^{1-\gamma})^{1-\sigma}}{1-\sigma} \tag{8}$$

where $\gamma > 0$ determines the utility elasticity of labor supply. We can later show that the main results do not qualitatively change if we use the GHH preference. The representative households supply labor and decides the levels of consumption in a competitive market and purchase one period bonds so by maximizing the lifetime utility (8) subject to the production function and the resource constraint :

$$\frac{B_{t+1}}{q_t} = B_t - Y_t + C_t + \frac{K_{t+1}}{1 - \bar{\pi} h_{t+1} d_k} - (1-\delta)K_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - e^{\mu_g}\right)^2 K_t \tag{9}$$

and to some non-Ponzi-game constraint. In the above equation B_t and q_t denote respectively the external debt and the price of net external debt due at time t.

Furthermore, net exports, tb_t can be easily calculated as the difference between output, consumption and investment:

$$tb_t = \frac{Y_t - C_t - I_t}{Y_t} \tag{10}$$

5.3 Financial friction and disaster shocks

As Uribe an Yue (2003) and Neumeyer and Perri (2005), we assume that the small open economy faces a debt-elastic interest-rate premium, such that the gross interest rate paid is given by :

$$\frac{1}{q_t} = 1 + r^\star + \psi \left[e^{\frac{B_{t+1}}{A_t} - \bar{b}} - 1 \right] + e^{(s_t - 1)} - 1 \tag{11}$$

In the previous expression, $r^\star$ and $\bar{b}$ are respectively the world interest rate (assumed to be constant) and the steady-state of normalized debt. ψ capture the elasticity of the borrowing interest rate to changes in indebtedness. s_t captures an exogenous stochastic country premium shock. We assume that the rest of the world is willing to lend to the domestic country any amount of credit at rate r_t . Bond to this economy is risky because of default risk on payments and disaster realization. As noted above, the existence of natural disaster on physical capital could affects the country specific spread. An alternative approach is to allow the country specific spread to respond negatively to transitory productivity shocks and positively to disaster shock. We then assume that the country spread, s_t is driven by two exogenous process : the TFP shocks, $z_t + 1$ and the disaster shocks, h_{t+1}. Combining transitory shocks and disaster shock, the country spread evolves according to the following process :

$$s_t = -\eta_z (1 - \bar{\pi} h_{t+1} d_k) E_t z_{t+1} + \epsilon_{s,t+1} \tag{12}$$

and $\epsilon_{s,t+1}$ captures the country spread shock with zero mean and variance σ_s^2. η_z is a positive parameter describing the sensitivity of spreads to future productivity and disaster realization.

6 Parametrization and Estimation

As our data sample does not allow us to estimate all the underlying parameters of the model, we choose a combination of calibration and estimation. Formally, we divide the parameter vector, noted by Θ in two parts : Θ_1=[β, γ, δ, $\overline{\pi}$, d_k, $\overline{b}$, μ_g] contains the parameters which are calibrated and Θ_2=[ψ, ϕ, α, ρ_z, ρ_g, η, σ_z, σ_g, σ_s] contains the parameters, which are to be estimated. Then, instead of impose the value of the debt adjustment parameter, we choose to estimate, ψ and the other exogenous variables. We estimate the model for two economies : Barbados and Belize. This choice is motivated by Belize$'$ s status as both a Caribbean and Central American country. Compared to some Central American countries, Belize has been a growth star, starting 1960 as the one of poorest countries in the region, but now among the growing countries with a GDP per capita near that of Panama.

6.1 The Data

The time unit t in the theoretical model is considered as year. To estimate general frame work, we use annual data on real per capita GDP and consumption per capita : $[y_t, c_t]$. This choice of sample period is motivated by data availability. Our observables variables are taken from previous data base and are detrended prior to estimation. To compute per capita variables, we divide the respective nominal series by population and deflate output using the GDP deflator and consumption using the CPI.

6.2 Calibration

As noted, the other parameters values are calibrated. Some calibrated parameters common for the two countries, and assign conventional values are borrowed from the business cycle literature (De jong, Dave (2007)). The calibration strategy adopted here is similar to the one in Aguiar and Gopinath (2007) that we modify only to account for the presence of the regional specificity component. By doing so, we could retain a comparability with previous work. The structural parameters of the model are reported in tables 1 and 2.

Table 1: COMMON STRUCTURAL PARAMETERS

Parameter	Description	Value
β	discount factor	0.99
γ	consumption weight in utility	0.50
δ	depreciation rate	0.05
σ	curvature of utility	2.00

Table 2: COUNTRY SPECIFIC VALUES

	$\overline{\pi}$	d_k	$\overline{b}$	μ_g
Barbados	$\frac{1}{30}$	0.43	0.90	1.0027
Belize	$\frac{1}{25}$	0.50	0.80	1.0021

The discount factor is β is set to 0.99. The parameter γ takes the value 0.50. As in Aguiar and Gopinath (2007), the depreciation rate is set to 5% per year. In addition, we set the curvature of utility at 2.00. Another decision we need to make concerns the choice of specific parameters for the two countries (see table 2). One important element of the calibration is the calibration of $\overline{\pi}$. Since there are no previous studies for for Barbados and Belize , we set the probability of a disaster realization at 0.033 and 0.040 per year on average respectively for Barbados and Belize. We assume that the size of disaster for capital, d_k is set at 0.40 and 0.50 for Barbados and Belize. Capital stock, then decreases to 40 % if there is a disaster shock, for instance in Barbados. We set the steady-state of normalized debt, $\bar{b}$ equal to the average debt ratio for each country in the data. The steady state growth rate, μ_g is also equal to the average output growth rate.

6.3 Priors Distributions and Estimation

Following the procedure detailed in An and Schorfheide (2007), the Bayesian methodology is used to estimate the other parameters of the model. As noted, there are two observables, y_t and c_t for the two countries : Barbados and Belize.

6.3.1 Priors

The priors selection is a very important step in Bayesian estimation. In our case, we have a limited set of information to base the priors. This could explains why some of DSGE modeling for Caribbean and Central America economies use calibration method instead. The prior concerning the estimated parameters are summarized in tables 3 and 4. Some of our priors are choose from Uribe and Yue (2006) studies. As Garca-Cicco et al. (2010) noted, the importance of the size of the debt sensitivity, ψ, entails important implications for the dynamics in the model. Consequently, our priors, ψ, allows to take on values that are substantially greater than zero and follows an uniform distribution on the respective interval $[0, 10]$ and $[0, 15]$ for Barbados and Belize with a mean of 5 for Barbados and 7.5 for Belize (see tables 3 and 4). Similarly, capital stock cost, ϕ in small open economies may be very high because of after sale service cost. Consequently, we use an uniform distribution for capital adjustment cost with the respective value of 6 and 7.5 for Barbados and Belize. The production elasticity is assumed to follow a normal distribution with a prior mean of 0.70 and a standard deviation of 3% for the two economies. In line of calibrated model, the persistence parameter, ρ_z, of the temporary productivity shock follows a beta distribution with prior mean of 0.95 and standard deviation of 1.2%. For Belize, we impose also beta distribution with mean .95 and variance 1.10 on ρ_z. Priors on autoregressive coefficient, ρ_g, is also rely on the beta distribution with a mean of 0.71 and a standard deviation of 2.25% for Barbados and 0.75 and 2.25 for Belize. Furthermore, for Barbados economy, the elasticity of spreads to expected technology shocks, η is assumed to follow a gamma distribution with a unit mean and a standard deviation of 10%. Standard deviation σ_z, σ_g, σ_s also rely on the gamma distribution for priors with respective mean 0.90, 0.80 and 0.98 and standard deviations 0.88, 0.78, 0.98 for Barbados economy. Finally, for Belize economy, we impose the priors mean of stand deviation, 0.75, 0.72 and 0.98 with a respective standard deviation 0.55, 0.55 and 0.10.

Table 3: PRIORS DISTRIBUTION-FOR BARBADOS

Parameters	Priors mean	Prior std in %	Distribution	Domain
ψ	0.05	2.00	Uniform	$[0, 5]$
ϕ	5.00	2.00	Uniform	$[0, 10]$
α	0.70	3.00	Normal	$[0, 1]$
ρ_z	0.95	1.20	Beta	$(0, 1]$
ρ_g	0.71	2.25	Beta	$(0, 1]$
η	1.00	0.10	Gamma	$\mathbb{R}^+$
$100\sigma_z$	0.90	0.88	Gamma	$\mathbb{R}^+$
$100\sigma_g$	0.80	0.78	Gamma	$\mathbb{R}^+$
$100\sigma_s$	0.98	0.98	Gamma	$\mathbb{R}^+$

Table 4: PRIORS DISTRIBUTION-FOR BELIZE

Parameters	Priors mean	Prior std in %	Distribution	Domain
ψ	0.01	2.00	Uniform	$[0, 5]$
ϕ	7.50	4.00	Uniform	$[0, 10]$
α	0.70	3.00	Normal	$[0, 1]$
ρ_z	0.95	1.10	Beta	$(0, 1]$
ρ_g	0.75	2.25	Beta	$(0, 1]$
η	2.00	0.10	Gamma	$\mathbb{R}^+$
$100\sigma_z$	0.75	0.55	Gamma	$\mathbb{R}^+$
$100\sigma_g$	0.72	0.55	Gamma	$\mathbb{R}^+$
$100\sigma_s$	0.98	0.10	Gamma	$\mathbb{R}^+$

6.3.2 Estimation

Table 5. and 6. report the results statistics of the posterior modes, means and the 90% confidence intervals for the two economies. Several facts can be noted. Firstly, the data base seems to be informative because of the closeness of the confidence intervals of most of estimates parameters. Secondly, the ratio of transitory with respect to permanent productivity shocks (i.e, for example for Barbados (σ_z/σ_g)=0.003), assigns an important role to permanent productivity shocks for the two country. Aguiar and Gopinath (2007) suggest the necessity of a high standard deviation of the permanent relative to transitory productivity shock in their model in order to account for business cycle phenomena in developing economies. Such a process places a premium on permanent productivity shocks in macrofluctuations in the Caribbean countries and Central America. Another result worth emphasizing is the parameter of the elasticity of spreads, η. The posterior mean of the estimated, η with respect to the transitory shocks and disaster shock is equal to 0.829 for Barbados. Furthermore, our estimate for Belize indicate a higher spread elasticity of the disaster shocks compared to Barbados. Our result is consistent on one hand with the existing literature and the other hand with the findings empirical

result. A higher value of η implies that an adverse supply shock like a disaster shock, can be amplified through the increase in cost of borrowing because of higher debt default probability (see the panel var results). Interestingly, the exogenous propagation parameters, ρ_z, ρ_g which tend to be relatively high for both economies.

Table 5: POSTERIORS-FOR BARBADOS

Parameters	**Priors mean**	**Post mode**	**std**	**Post mean**	**Conf. interval**	**Distribution**
ψ	0.050	0.054	1.343	0.060	$[0.042, 0.075]$	Uniform
ϕ	6.000	4.284	0.204	4.021	$[2.904, 4.947]$	Uniform
α	0.680	0.770	0.006	0.763	$[0.732, 0.785]$	Normal
ρ_z	0.950	0.952	0.002	0.956	$[0.946, 0.967]$	Beta
ρ_g	0.710	0.711	0.009	0.712	$[0.711, 0.708]$	Beta
η	1.000	0.453	0.177	0.829	$[0.305, 1.517]$	Gamma
σ_z	0.090	0.010	0.011	0.011	$[0.006, 0.017]$	Gamma
σ_g	0.080	2.721	0.284	2.690	$[1.901, 3.625]$	Gamma
σ_s	0.010	0.004	0.005	0.006	$[0.003, 0.009]$	Gamma

Table 6: POSTERIORS-FOR BELIZE

Parameters	**Priors mean**	**Post mode**	**std**	**Post mean**	**Conf. interval**	**Distribution**
ψ	0.100	0.065	0.014	0.079	$[0.065, 0.100]$	Uniform
ϕ	7.500	7.430	0.030	7.490	$[7.430, 7.549]$	Uniform
α	0.700	0.756	0.009	0.765	$[0.750, 0.780]$	Normal
ρ_z	0.950	0.953	0.009	0.952	$[0.936, 0.967]$	Beta
ρ_g	0.750	0.770	0.019	0.773	$[0.740, 0.806]$	Beta
η	2.000	3.877	2.250	4.456	$[0.698, 8.051]$	Gamma
σ_z	0.007	0.005	0.003	0.007	$[0.002, 0.012]$	Gamma
σ_g	0.007	1.0950	0.253	1.234	$[0.825, 1.637]$	Gamma
σ_s	0.010	0.004	0.004	0.008	$[0.003, 0.009]$	Gamma

7 Simulation Analysis

In this section we examine the results of the simulations from the Bayesian estimation of our small open economy RBC model. We begin with the impulse responses analysis of the four structural shocks. We then, finally turn to the forecast error variance decomposition to shed light the relative importance of the structural shocks in the business cycles.

7.1 Impulse Response Functions

One of main objective of this paper is to shed light on the importance of disaster shocks (and all the potential leading forces) in driving macroeconomic fluctuations in a very small open economy.

7.1.1 The effect of a disaster shock

Figures 11. and 15. plot selected impulse responses to a disaster which hits Barbados and Belize economies. The disaster shock leads capital to fall by the factor d_k (not reported here). As argued in the theoretical framework, output and investment drop on impact by the same factor, and consumption tend to increase. The increase of the country risk leads to a reduction in the future investment. Hence, low investment decreases output. Simultaneously, consumption increases since agents want to invest less in a more risky capital. Due to an intertemporal substitution mechanism, consumption then progressively decrease over time with a persistence effect on Belize economy (see figures 11. and 15.). It seems that such an outcome suggests that disaster shock is not a major determinant of consumption volatility. This result could be explained by the fact that rare shock have low occurrences in the Barbados economy. Regarding the trade balance ratio response, we notice that a natural disaster shock is associated to a deterioration of the trade balance ratio in the short run. This negative effect may be explained by the fact that a natural disaster led to an increase in imports growth to compensate for output loss and a reduction of exports growth. The shock impact tend to decline progressively over time, for both countries. As the figures support, it seems that Barbados are better prepared for storm shocks than Belize. Overall, disaster shock have no significant effects impact on long run growth.

7.1.2 The effect of a Spread Shock

Figures 12. and 16. show the response a one standard-deviation spread shock. The responses to a spread shock in the model with disaster risk are very close to the responses in a standard small open economic model. Impulses response functions do not vary substantially across countries. A spread shock reduces output, investment and consumption.

7.1.3 *Trend* versus *Cycle*

A positive trend shock (a permanent productivity shock) leads to an increase in consumption and investment (see figure 13. and 17.). However, output has opposite response. In the first period of the shock, we notice a positive effect on income (for Barbados) and then decline over time. It is worth noting that trend shock has a permanent effect on income for both economies. On the contrary, a temporary productivity shock increases income but income increase much more. Due to the substitution effect consumption rise less. Following these outcomes, we find the well-known consumption-smoothing.

7.2 Variance Decomposition

As noted below, we compute the long run variance decomposition techniques to determine the relative contribution of each shock in explaining macroeconomics fluctuations in the economies (see table 7. and 8). Some outcomes are worth emphasizing. Firstly, in both countries, trend shocks are the driving force behind output in the longrun. Secondly, disaster shocks play a minor role for the output dynamics. Thirdly, financial frictions in our model, play also an important role in explaining business cycle variations in these economies.

Table 7: VARIANCE DECOMPOSITION-FOR BARBADOS

Variables	$\epsilon_{z,t}$	$\epsilon_{g,t}$	x_{t+1}	$\epsilon_{s,t}$
Y_t	0.14	90.75	0.15	8.96
C_t	0.01	85.00	0.06	14.93
I_t	0.00	31.92	1.68	66.40
tb_t	0.00	46.20	0.82	52.98
ΔY_t	-	-	-	-

Table 8: VARIANCE DECOMPOSITION-FOR BELIZE

Variables	$\epsilon_{z,t}$	$\epsilon_{g,t}$	x_{t+1}	$\epsilon_{s,t}$
Y_t	0.12	97.73	0.08	2.07
C_t	0.07	98.14	0.00	1.78
I_t	0.76	57.56	7.74	33.93
tb_t	0.57	80.71	0.82	17.91
ΔY_t	0.15	83.90	0.05	15.90

8 Conclusion

In this paper, we develop a small open economy DSGE model featuring a non-stationary productivity process and financial frictions to analyze the importance of disaster shocks (rare events) on macroeconomics quantities. In the empirical part of the paper, in order to evaluate the impact of a disaster shock, we estimate a panel vector autoregresive model for output, investment, trade balance, consumption and country spread to capture the economic effects of output, country risk and exogenous natural disaster shocks for Caribbean and Central America Countries. Our results show that Caribbean countries are better prepared for natural disaster shocks and Central America countries have persistent effects. We also estimate a DSGE model using Bayesian techniques respectively for Barbados and Belize. Our results show that the coexistence of disaster shock, financial frictions and permanent productivity shock (trend shock) shocks can explain macroeconomic fluctuations in these countries. Introducing a disaster shock in a standard DSGE improves the model fit. Such a result can find support for the well-known Aguiar, Gopinath (2007) hypothesis that the *cycle* is the *trend*. Our theoretical model provides a baseline framework that could be used to compare the effectiveness of several economic policy (monetary and fiscal policies, aid policy and optimal reserve policy...) under a disaster risk.

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Table A1. Occurrence of Local Storm, Tropical Cyclone or Earthquake (1993 – 2013)

	Caribbean			Central America		
Year	Local storm	Tropical cyclone	Earthquake	Local storm	Tropical cyclone	Earthquake
1993	1	1	…	1	1	2
1994	…	2	…	…	…	
1995	1	17	…	…	7	3
1996	…	7	…	…	10	…
1997	…	…	1	…	2	2
1998	…	8	…	…	9	1
1999	…	14	…	…	1	4
2000	…		…	2	4	2
2001	…	7	…	…	11	3
2002	…	9	…	…	6	…
2003	…	2	1	…	2	4
2004	…	23	2	…	1	1
2005	…	15	…	…	16	1
2006	…	2	…	…	3	1
2007	…	16	3	…	9	1
2008	…	21	…	…	6	…
2009	…	…	…	…	4	2
2010	1	7	1	…	16	1
2011	…	9	…	…	6	1
2012	…	9	…	…	2	2
2013	…	…	…	…	4	1
TOTAL	3	169	8	3	120	32

Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be – Université catholique de Louvain – Brussels – Belgium.

Figure 3: Empirical Responses to a Storm Shock for Caribbean Countries

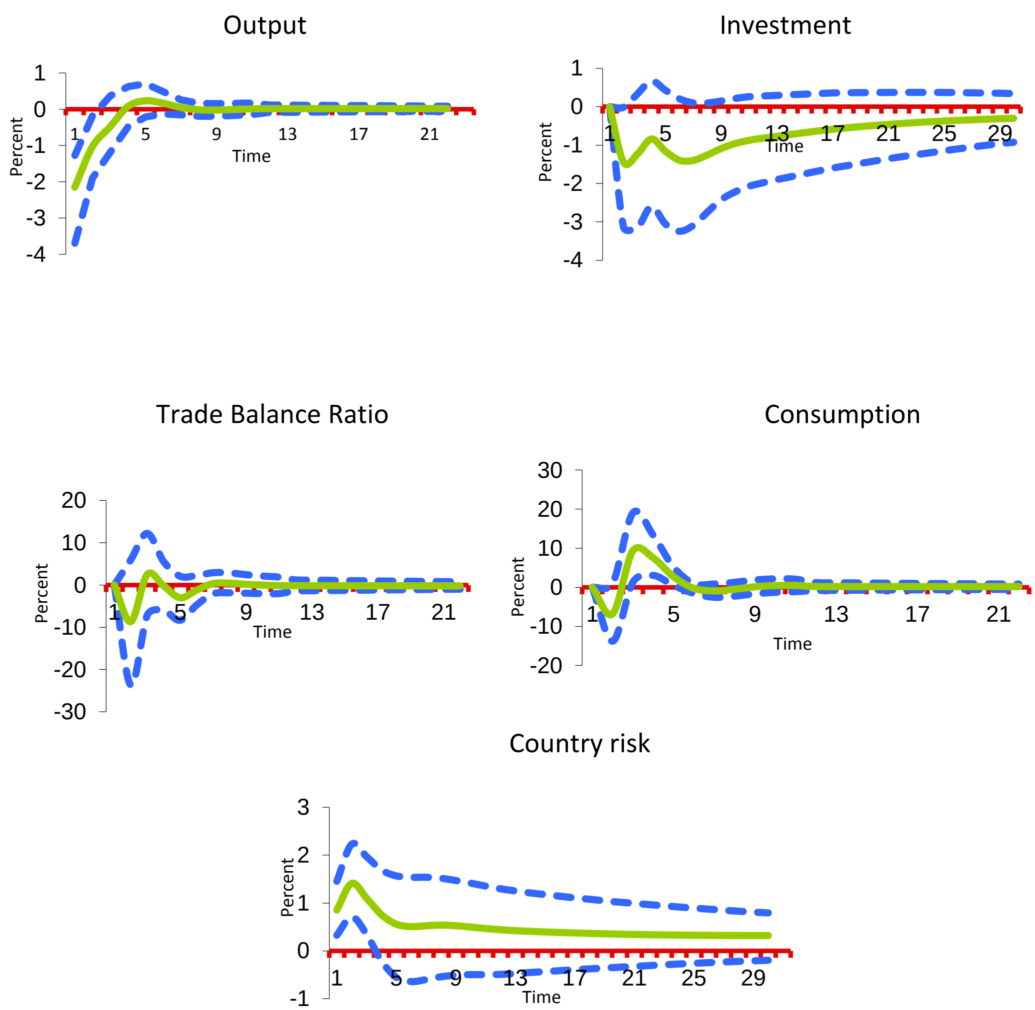

Figure 4: Empirical Responses to an Output Shock for Caribbean Countries

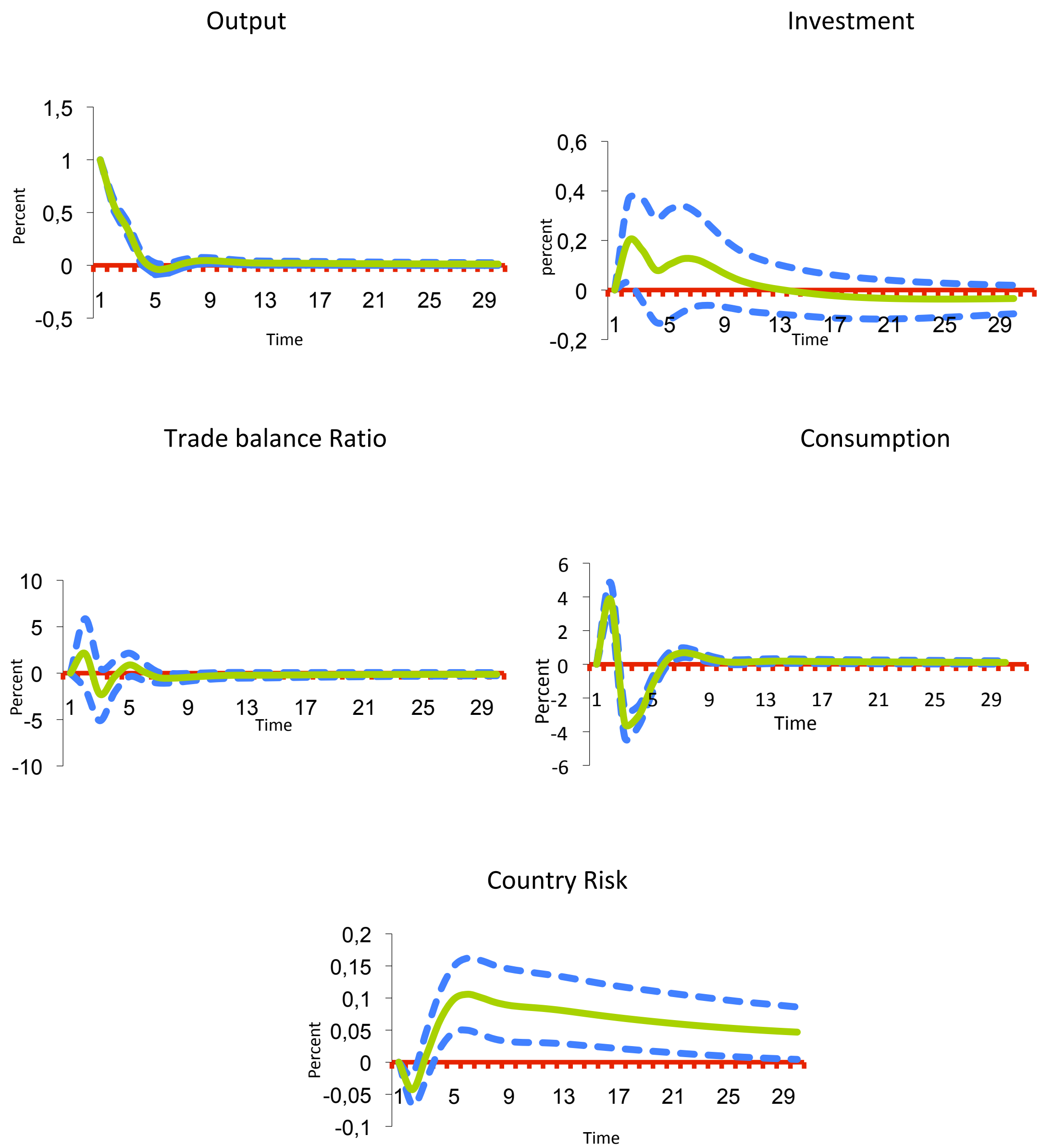

Figure 5: Empirical Responses to an Spread Shock for Caribbean Countries

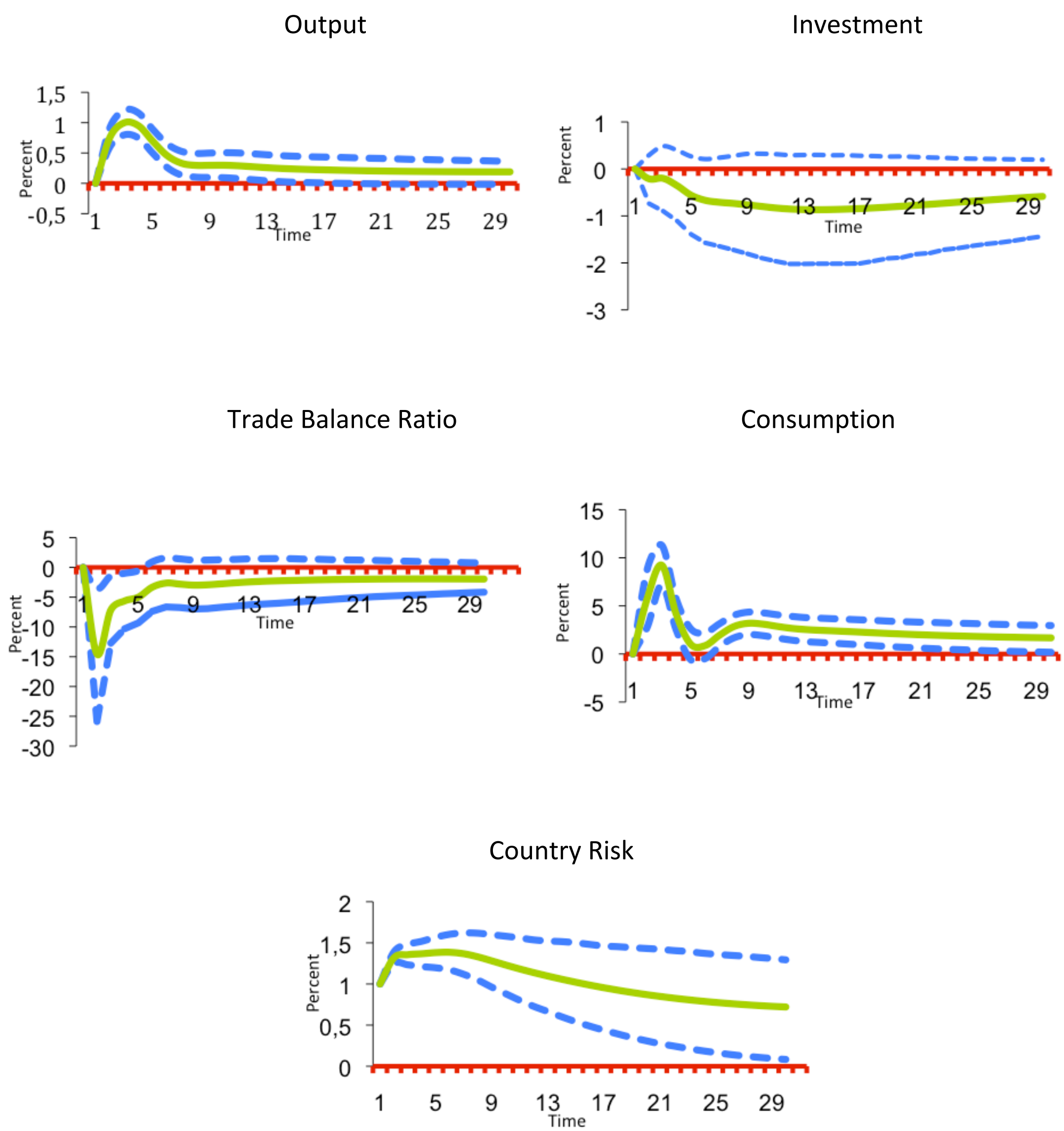

Figure 6: Empirical Responses to an Storm Shock for Central America Countries

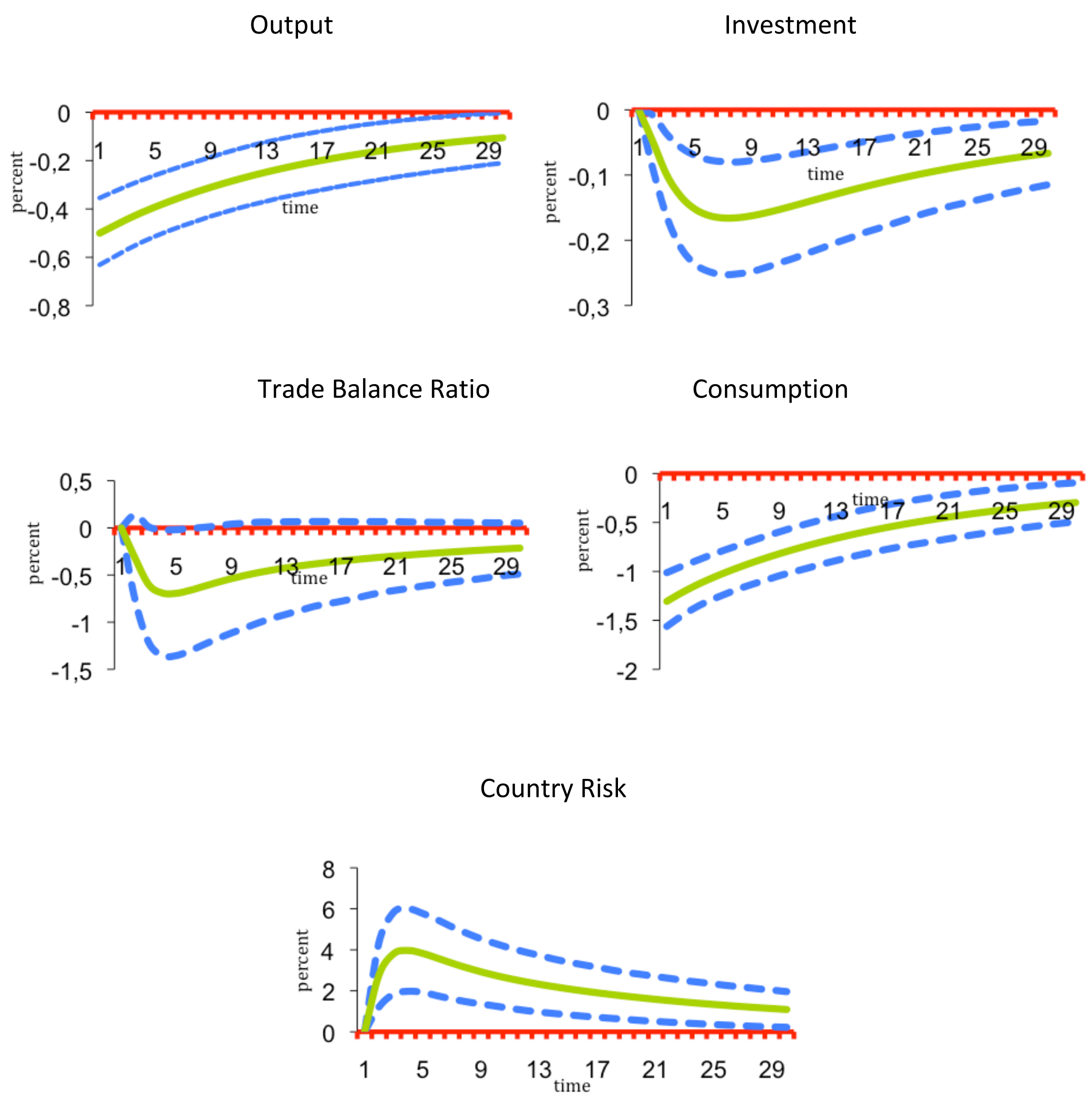

Figure 7: Empirical Responses to an Earthquake Shock for Central America Countries

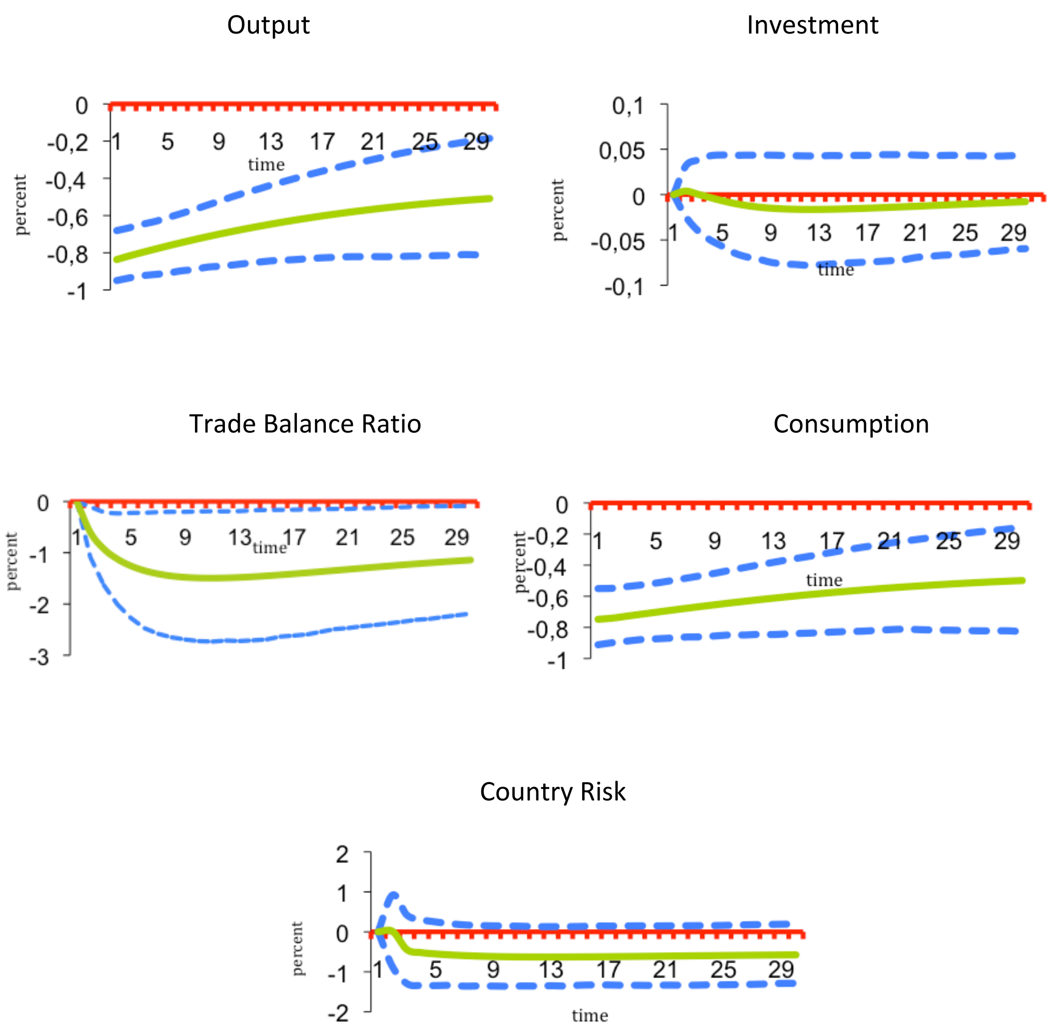

Figure 8: Empirical Responses to an Output Shock for Central America Countries

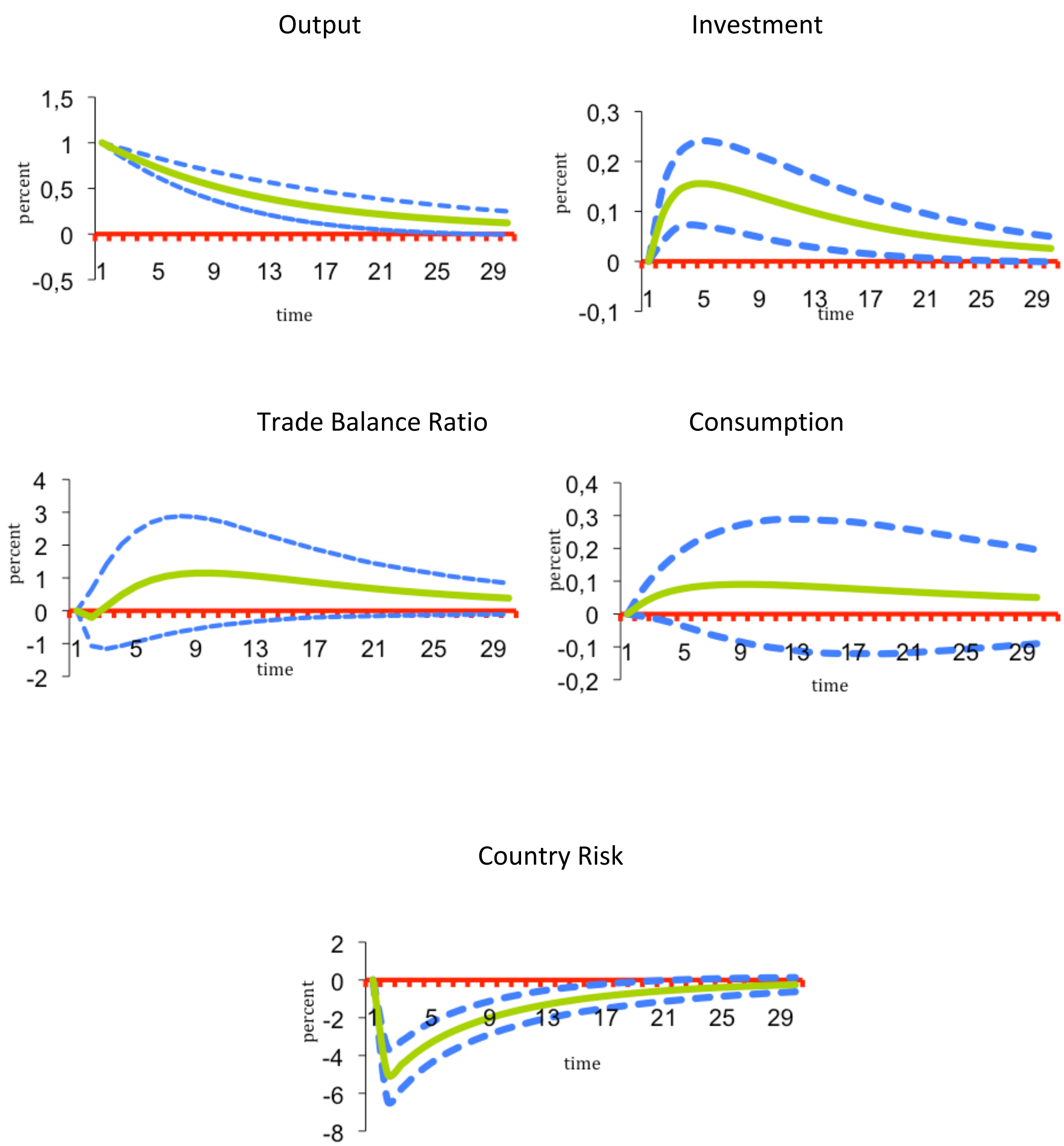

Figure 9: Empirical Responses to an Spread Shock for Central America Countries

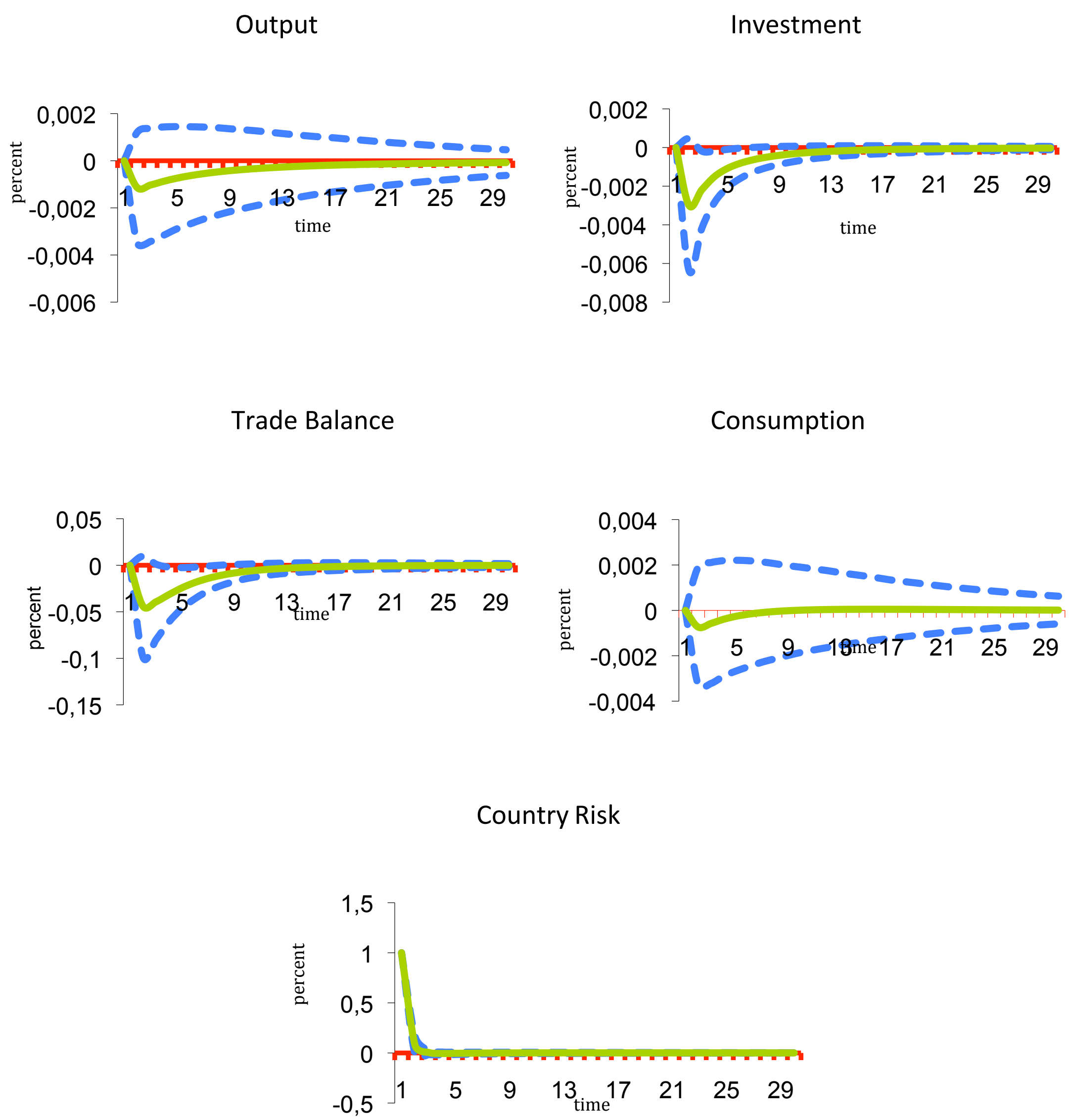

Figure 10: Forecast Error Variance Decompositions for Caribbean Countries

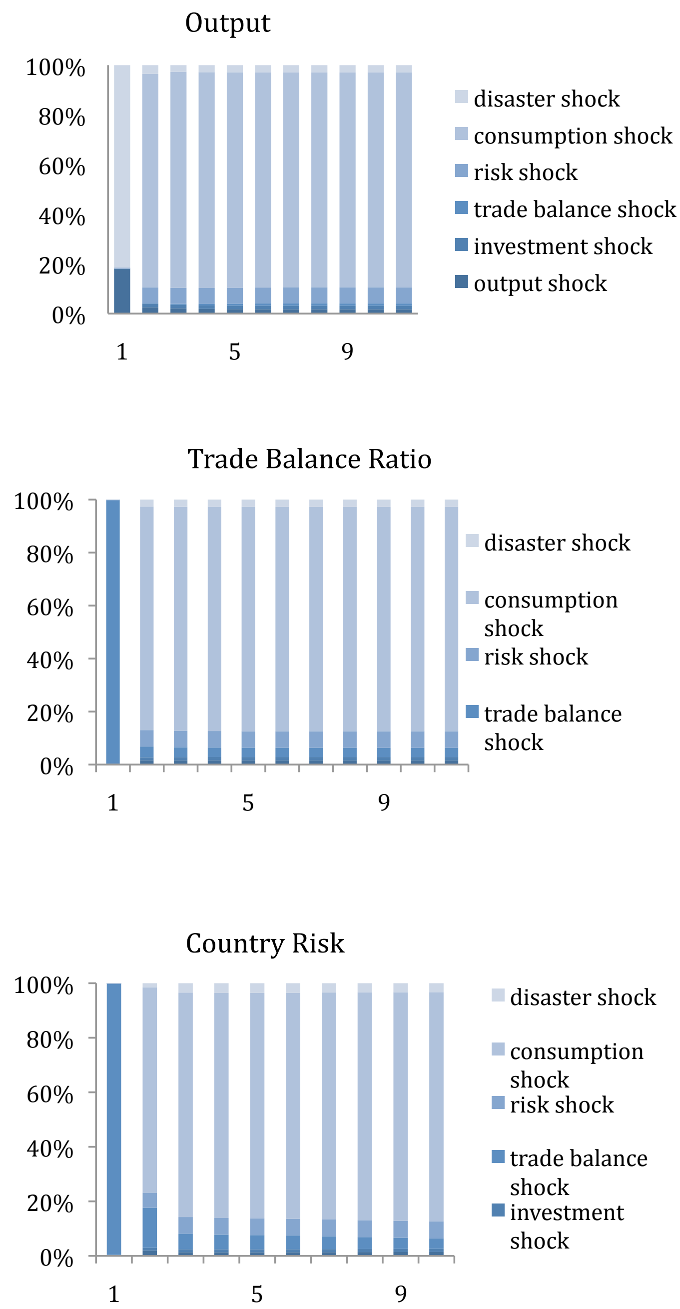

Figure 11: Impulse Responses to a Disaster Shock for Barbados

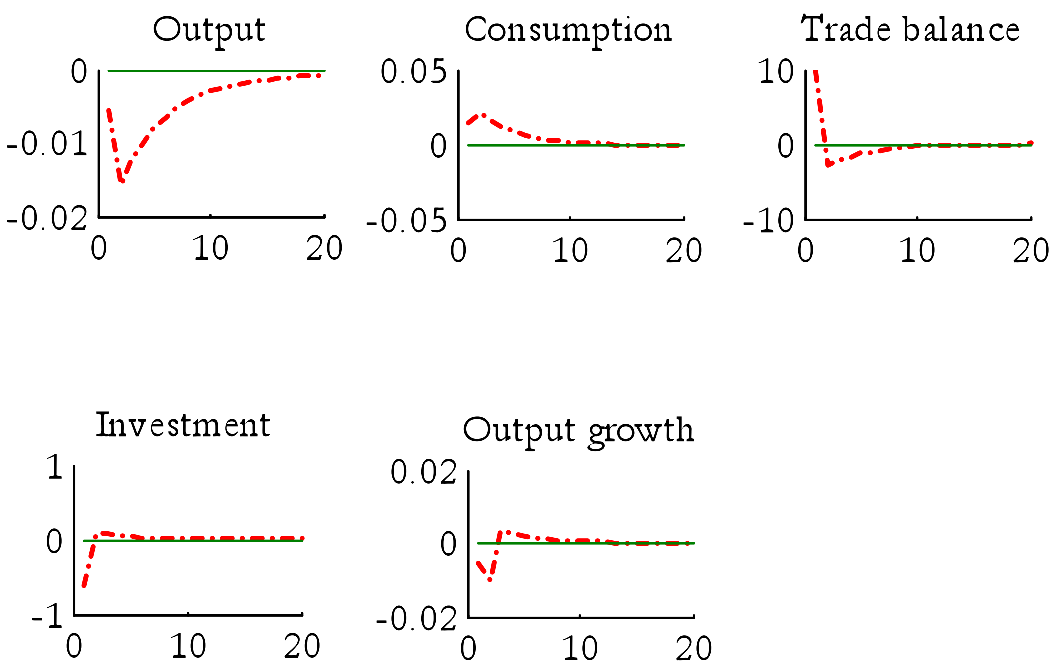

Figure 12: Impulse Responses to a Spread Shock for Barbados

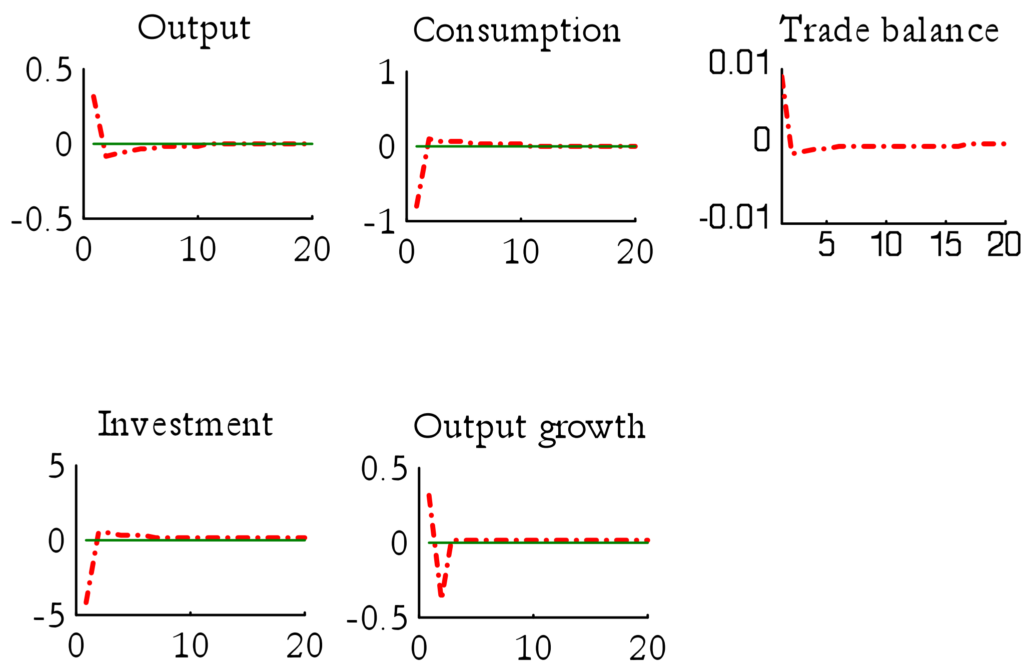

Figure 13: Impulse Responses to a permanent productivity Shock for Barbados

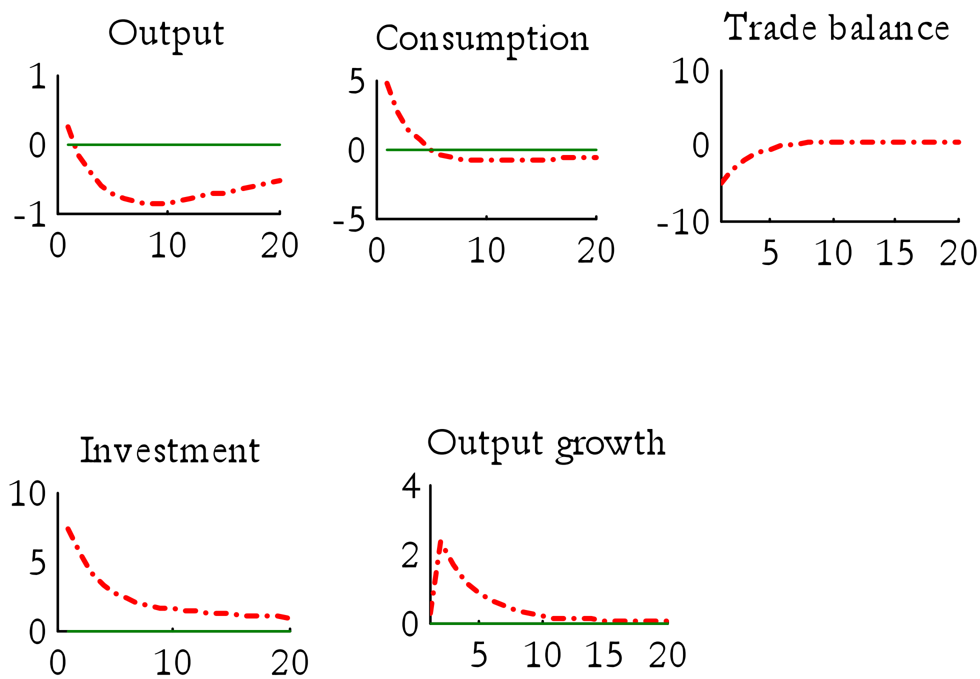

Figure 14: Impulse Responses to a Transitory productivity Shock for Barbados

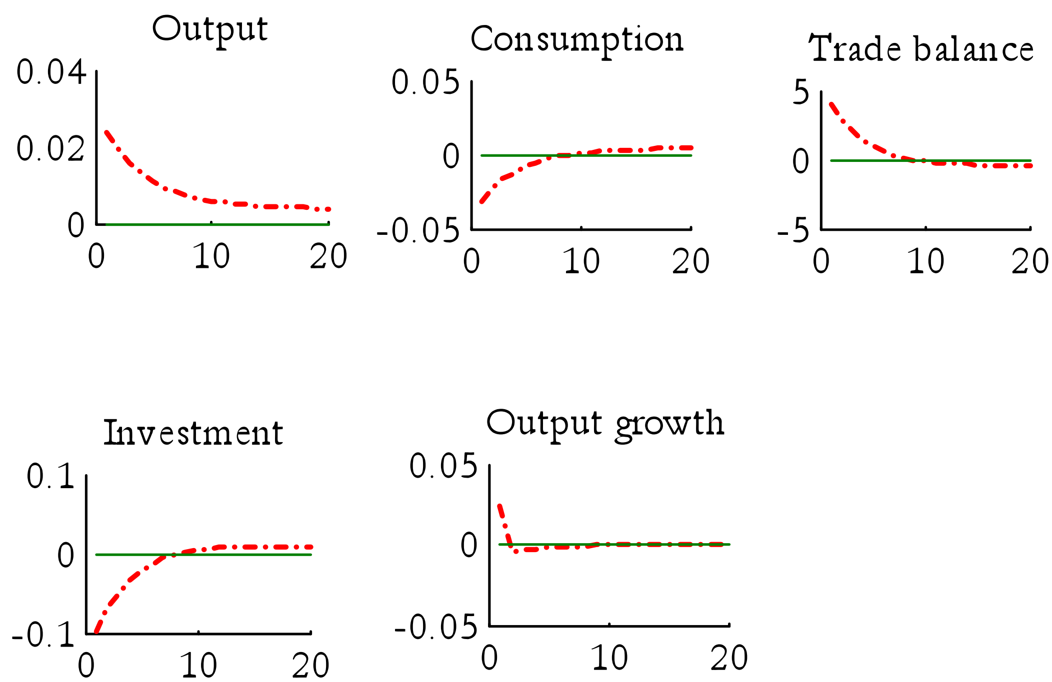

Figure 15: Impulse Responses to a Disaster Shock for Belize

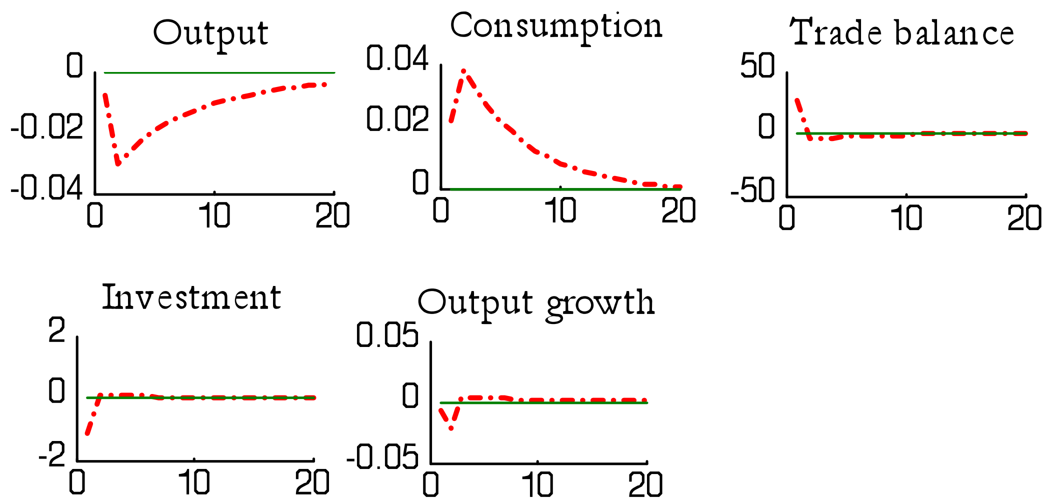

Figure 16: Impulse Responses to a Spread Shock for Belize

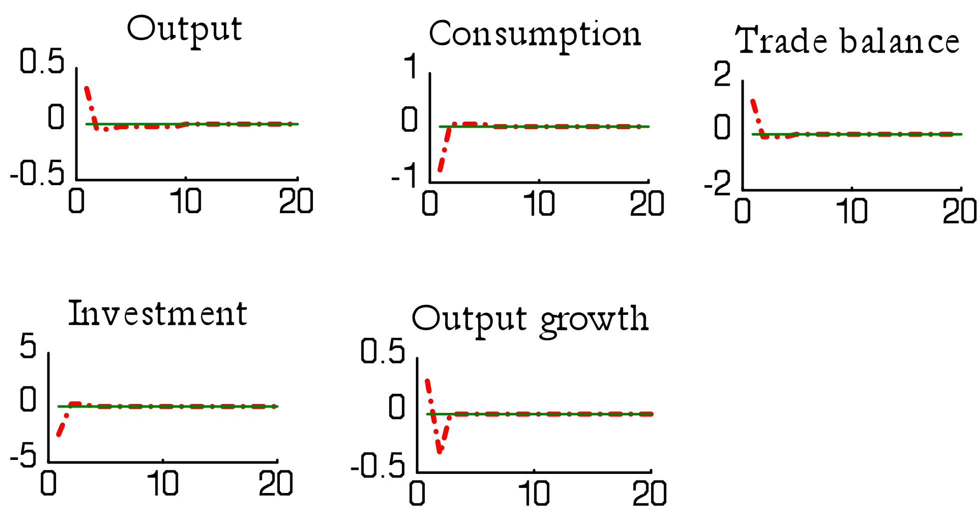

Figure 17: Impulse Responses to a Permanent Productivity Shock for Belize

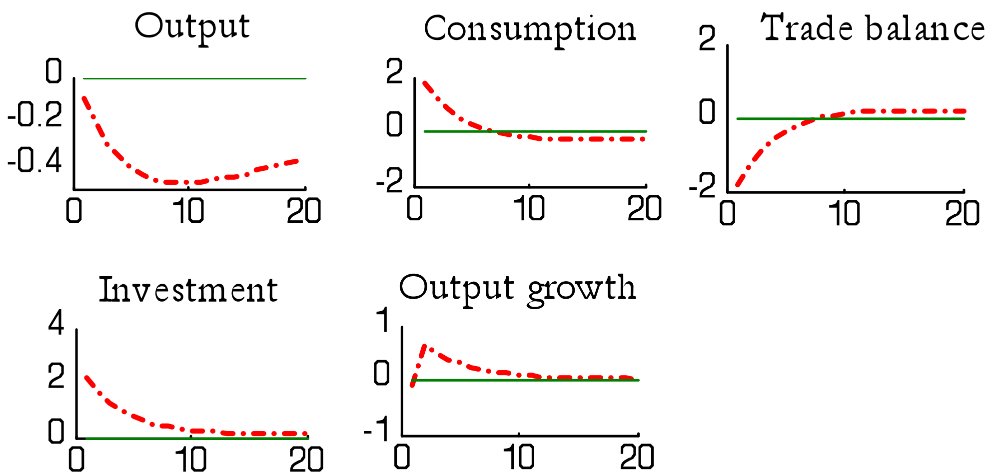

Figure 18: Impulse Responses to a Temporary Productivity Shock for Belize