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Allan Wright
Patrice Borda

Inter-American Development Bank
Country Department Caribbean Group

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Allan Wright*
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Inter-American Development Bank*
Université des Antilles et de la Guyane and CREDDI**

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http://www.iadb.org

CET@iadb.org

Allan Wright: allanw@iadb.org; Patrice Borda: patrice.borda@univ-ag.fr

Abstract[1]

This paper examines the role of disaster shock in a one-sector, representative agent dynamic stochastic general equilibrium model (DSGE). First, it estimates 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. The study determines the empirical dynamic responses of ten Caribbean countries and seven countries in Central America. Second, 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 for two specific countries: Barbados and Belize. Similar findings between empirical and general frameworks show that disaster shocks in Central America and the Caribbean have only a significative impact in the short-run regional business cycle. The findings show that Caribbean countries are better prepared for natural disaster shocks.

JEL Classification: E32, F41
Key Words: Panel VAR, Business Cycles, DSGE, Small Open Economy.

[1] Patrice Borda, CREDDI and Universite des Antilles, e-mail: patrice.borda@univ-ag.fr. Allan Wright, Economics – Senior Specialist, IDB: allanw@iadb.org.

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This paper presents preliminary findings and is being distributed to economists and other institutions solely to stimulate discussion and comments. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the IDB.

1. Introduction

The aim of this study is to determine the short- and long-run dynamics of macroeconomic fluctuations within an exogenous disaster shock for ten Caribbean countries (Antigua and Barbuda, Bahamas, Barbados, Dominica, Grenada, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, and Trinidad and Tobago) and seven Central American countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama). To achieve this goal, first we use a panel vector autoregressive (VAR) model to capture the dynamic responses of a variety of shocks, and second, 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 (Agenor et al., 1999; Blanchard, 1989; Cushman and Zha, 1995; Uribe and Yue, 2006). However, very little research has attempted to explain macroeconomic fluctuation for small open economies such as Central America and the Caribbean countries (Borda, Manioc, and Montauban, 2000; Sosa and Cashin, 2013; Watson, 1996). We extend the discussion particularly to the case of small open economies in the Caribbean and Central America by introducing disaster risk in a Panel VAR model and a DSGE model. However, less attention has been paid to disaster risk in a general equilibrium model. Understanding the fiscal policy and the monetary policy facing disaster risk is of interest. The novelty in this paper concerns the introduction of disaster shocks in a small open DSGE framework.

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 locations, Central American and Caribbean countries are vulnerable to a variety of natural phenomena. For example, both economies experience hurricanes, storms, or earthquakes several times a year. But only Central American countries suffer a significant impact from earthquakes.

The consideration of disaster shocks in the analysis is twofold. First, it allows us to analyze some of the potential driving forces of business cycles beyond productivity and foreign shocks. Second, and most importantly, this is a first step to test the role of rare events in business cycles. From the dynamic response to the several shocks, our main results are the following: first, Central American and Caribbean countries have different responses for aggregate supply and demand shocks; second, Caribbean countries are better prepared for natural disaster shocks; third, Panel VAR empirical impulse response functions to disaster shocks show that output, consumption, investment, and trade balance ratios fairly adjust in the short run to their pre-shock levels, and Central American countries have negative long-run effects only for earthquake disaster shocks—mainly on output and trade balance ratios.

Meanwhile, DSGE response functions compliment the results obtained in the empirical model: disaster shocks in Central America and the Caribbean have only a significative impact in the short-run regional business cycle.

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 Panel VAR model specification with the data and estimation issues. The empirical results and variance decompositions are also discussed. Section 5 develops the DSGE general model framework. Section 6 presents the parametrization and estimation of two representative countries: Barbados and Belize. Priors distributions and posteriors are also reported. Impulse response functions and variance decompositions from the Bayesian estimations are presented in Section 7. Section 8 offers concluding remarks.

2. Related Literature

In this section, we briefly review the related empirical literature. Several authors have studied macroeconomic fluctuations in the existing literature. Their approach has focused on 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 prone to sudden crisis and their business cycles are significantly affected by negative external shocks. With this idea in mind, literature has evolved to understand the sources of fluctuation in developing economies, such as Africa (Hoffmaister et al., 1998) and the Caribbean (Borda, Manioc, and Montauban, 2000; Watson, 1996).

Blanchard (1989) studied 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) examined how business cycle conditions in developed economies may affect macroeconomic fluctuations specifically in 12 developing countries. They measured 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 for developed countries, and government expenditure in developing countries is countercyclical.

A series of studies have focused on 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 subsample groups of sub-Saharan countries: CFA franc and non-CFA franc. Their results show that supply shocks are the main source of output fluctuation in both groups of countries. With regard to the Caribbean countries, Watson (1996) investigated the impact of monetary policy shocks on real sector variables in Trinidad and Tobago. The main findings of his work suggest that the monetary shock works more through the transmission mechanism of loans in the Caribbean country.

Borda, Manioc, and Montauban (2000) estimated 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. Like Hoffmaister et al. (1998), they divided the study into 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 in the long run.

The relationship between world interest rates and country spreads was studied with a first-order Panel VAR system in Uribe and Yue (2006). They explained the movements in aggregate variables under different identified shocks. Their conclusion suggests 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 mainly study the effects of hurricanes. Using a VAR model with block exogeneity restrictions, Cashin and Sosa (2013) analyzed the effect of exogenous factors in the ECCUs business cycle. They found 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) used an innovative[2] index of potential local destruction of hurricanes in the Caribbean basin. He found that the disaster shock reduces growth by 0.8 percentage points. However, the Strobl results could be overestimating the effects of hurricanes on output because of the interaction between rare shocks and macroeconomic quantities. Recently, Acevedo (2014) has used the Fomby, Ikeda, Loayza (2013) methodology by modeling the impacts of natural disasters on economic growth and debt growth for 12 Caribbean countries. They found that storms have a persistent effect on debt in the short and long run.

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 found that the optimal response is an increase in the nominal interest rate target. Gourio (2012) analyzed the effect of rare events and time-varying risk of disaster in a standard Real Business Cycles (RBC) framework. He focused especially on the responses of macroeconomic quantities to a sudden rise in the probability of disaster.

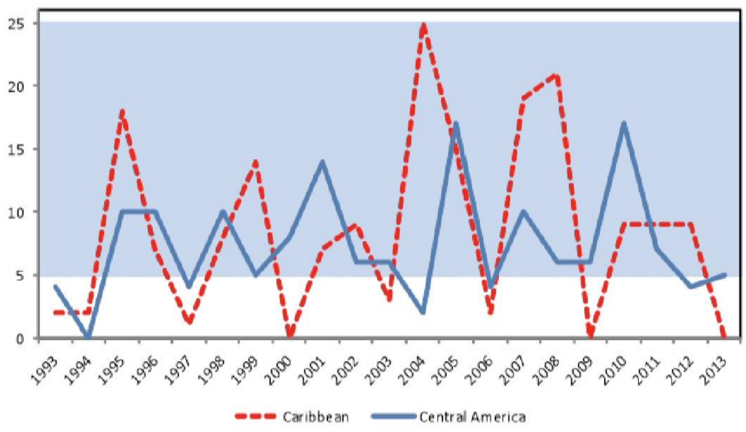
[2]Strobl used the wind field model on hurricane proposed by Emanuel (2005).

3. Caribbean and Central American Stylized Facts

As mentioned before, the Caribbean and Central American countries are vulnerable to a variety of natural phenomena 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 20 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 in Central American countries only.

Major natural disaster events have negative macroeconomic implications. Figure 2 shows estimates of the number of people affected by natural phenomena from 1993 to 2013. The events which surpass one million people affected are shown. We count five major natural disasters in each region. In the whole sample period, a total of 34 million people were 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, this should be expected to translate into relatively high levels of damage that affect some key macroeconomic variables and therefore their business cycles. Natural disasters represent a negative supply shock that affects macroeconomic fluctuations. The next section will address the dynamic response of these external shocks to understand the impact of natural disasters in the Caribbean and Central America.

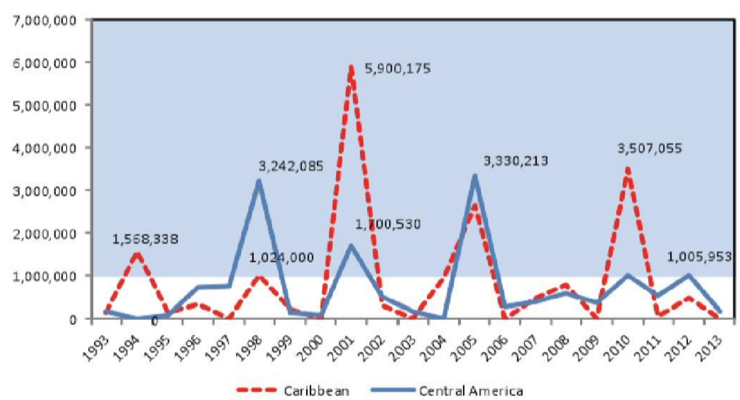
Figure 1: Incidence of Natural Disasters



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 five variables: output, investment, trade balance ratio, consumption, and country spread. These variables should capture the economic relationship that determines the dynamics of small open economies. As Caribbean small islands and Central American countries are very 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 shock). The baseline specification of the model corresponds to :

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

where i denotes the country and t the time. $x_{i,t}$ is an $m \times 1$ vector of endogenous variables. In our case, $x_{i,t} = \left(y_{i,t}, \quad i_{i,t}, \quad c_{i,t}, \quad tb_{i,t}, \quad r_{i,t} \right)'$ 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 and Yue (2006). $d_{i,t}$ is vector of exogenous variables which differ across countries and includes variables capturing the occurrence of natural disasters[3], $d_{i,t} = \left(storm_{i,t}, \quad earth_{i,t} \right)'$. The use of a natural disaster variable in the empirical model may be controversial and can raise some questions. For instance, are natural disaster shocks exogenous or endogenous regarding the externality caused by economic activity? To answer this question, we suggest that a 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 :

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

subject to the usual conditions :

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

Once the parameters of A_k are estimated, it 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 on 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 do not use any special causal ordering, and then we suggest use of 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**.**

4.2 Data and Estimation Issues

Our model contains a panel of ten Caribbean countries[4] and seven Central American countries. Data is annual and covers the period from 1993 to 2011 for Caribbean countries and 1993 to 2012 for Central American countries. Most of the data comes from the International Financial Statistics and the World Bank database. As we mentioned above, the Panel VAR contains five 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) experienced by an economy for a given period. The data on economic damage are obtained from EM-DAT (Emergency Disaster Database). Data on macroeconomic variables come from various database. We measure the country spread (or country risk) as the sum of the JP Morgan's EMBI+ stripped 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[5] matrix structure for the

[3] Large sudden natural disasters such as earthquakes and hurricanes in Central America or hurricanes in the Caribbean Basin.

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

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

Caribbean States :

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

and the following one for Central America :

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

The d_0 matrix of contemporaneous coefficients means that output and consumption respond contemporaneously to disaster shocks (*storms* for Caribbean states and *storms* and *earthquakes* for Central American 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.[6]

4.3 Empirical results

This section is devoted to the computation of the responses of some key variables (output, investment, trade balance, consumption, and country risk) to disaster shock, output shock, and country risk shock. We begin with a discussion of the relative importance of disaster shocks and output shocks followed by the analysis of forecast error variance decompositions. For recall, storm shocks affect both groups of countries and earthquake shocks only affect Central American economies.

[6] For lags lengths, k=1, 2, 3, 4, 5 the BIC criteria 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.

4.3.1 The effect of natural disaster shocks

The dynamic response to disaster shocks is depicted in Figures 3, 5, 6, and 7. The different panels of these figures show the Generalized-Impulse-Response Functions (GRF) of the five endogenous variables to disaster shock or to a storm shock for Caribbean and Central American countries. In the short run, as can be seen, a storm shock seems to have a significant impact on output in both countries. This type of shock leads to a rapid and large reduction of output (Figures 3, 5, and 6). This occurs because such a shock damages or destroys part of physical capital. The decline in output is accompanied by an immediate decrease in trade balance ratio (exports decline and imports increase). During the first year, in both groups of countries, investment and consumption decrease and country risk increases. In the long run, the disaster shock can affect economic outcomes through several channels, including the destruction of capital stock and worsening of fiscal balance. The destruction of capital stock has persistent effects on investment (Figures 3, 6, and 7). Country spreads respond strongly to disaster shock because of indebtedness, which raises real interest rates.

The effects of storms in Central America seem to be more persistent than for the Caribbean. As the figures show, it seems that Caribbean countries are better prepared for storm shocks than Central American countries. In the Caribbean, output decline is lower and it recovers to pre-shock levels up to the fifth year. This suggests that the dynamics of output are associated with higher reconstruction activity. These results are consistent with Sosa and Cashin (2009), who found that output contractions in the region do not appear to be persistent in the long run. Trade balance ratios and consumption levels decrease in the short run, and then increase significantly to positive levels in about one year. In later periods, the long-run effects 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 ratios, and consumption levels decrease in the short run, and their negative effects slightly remain in the long run. Nevertheless, we conclude that storm shocks have no significant impact on long-run growth. Country risk level increases by approximately 2 percent in the whole sample period. The empirical responses to earthquake shock for Central American countries are shown in Figure 7—they behave similarly to storm shocks, but they seem to have a greater impact only on output and trade balance ratio. Again, the shock's negative effects remain in the long run. Surprisingly, investment and consumption levels fall significantly less than for storm shocks, and country risk declines rather than increases. Unlike storm shocks, earthquake shocks have a significant effect on output and consumption in the long run.

4.3.2 The effect of other shocks

Significant differences appear in the dynamic responses for both groups of countries with an output shock. In Figures 4 and 8, the respective 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. In approximately the fifth year all variables reach their pre-shock levels, after a slight decline. Country risk diminishes slightly 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 pre-shock levels. In the Caribbean, supply shocks dominate the movement of output in the short run, while in Central America they dominate in the long run. These 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 American countries are shown in Figures 5 and 9, respectively. Caribbean countries' response varies. Investment and trade balance ratios decrease in the short run, but the effects last in the long run. Meanwhile, output and consumption levels increase in the short run. Unlike Central American countries, the country risk level increases significantly and stays around 1 percent in the whole sample period. As expected, the shock effects in Central American economies initially decrease the level for output, investment, trade balance, and consumption, then recover to their pre-shock levels in the ninth quarter. Country risk effects last only for two years.

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

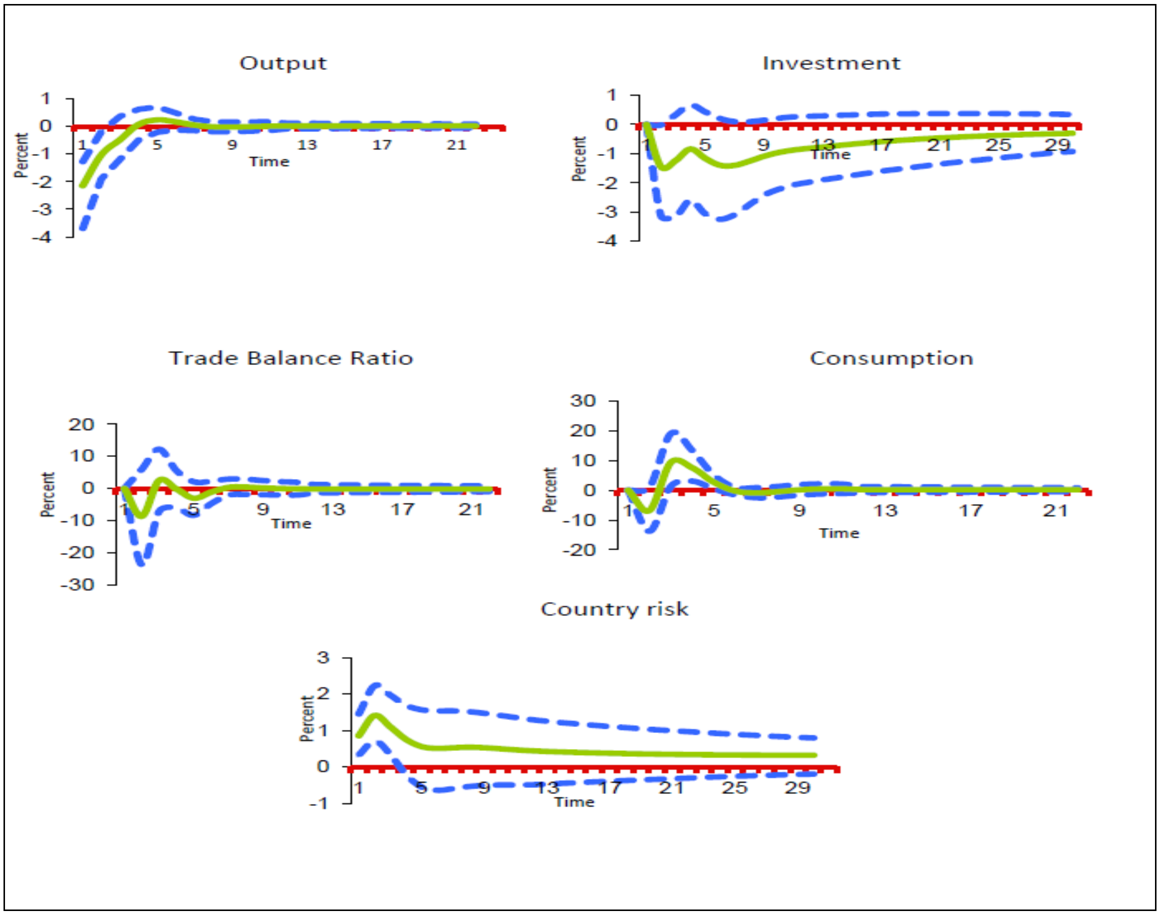


Figure 4: Empirical Responses to an Output Shock for Caribbean Countries

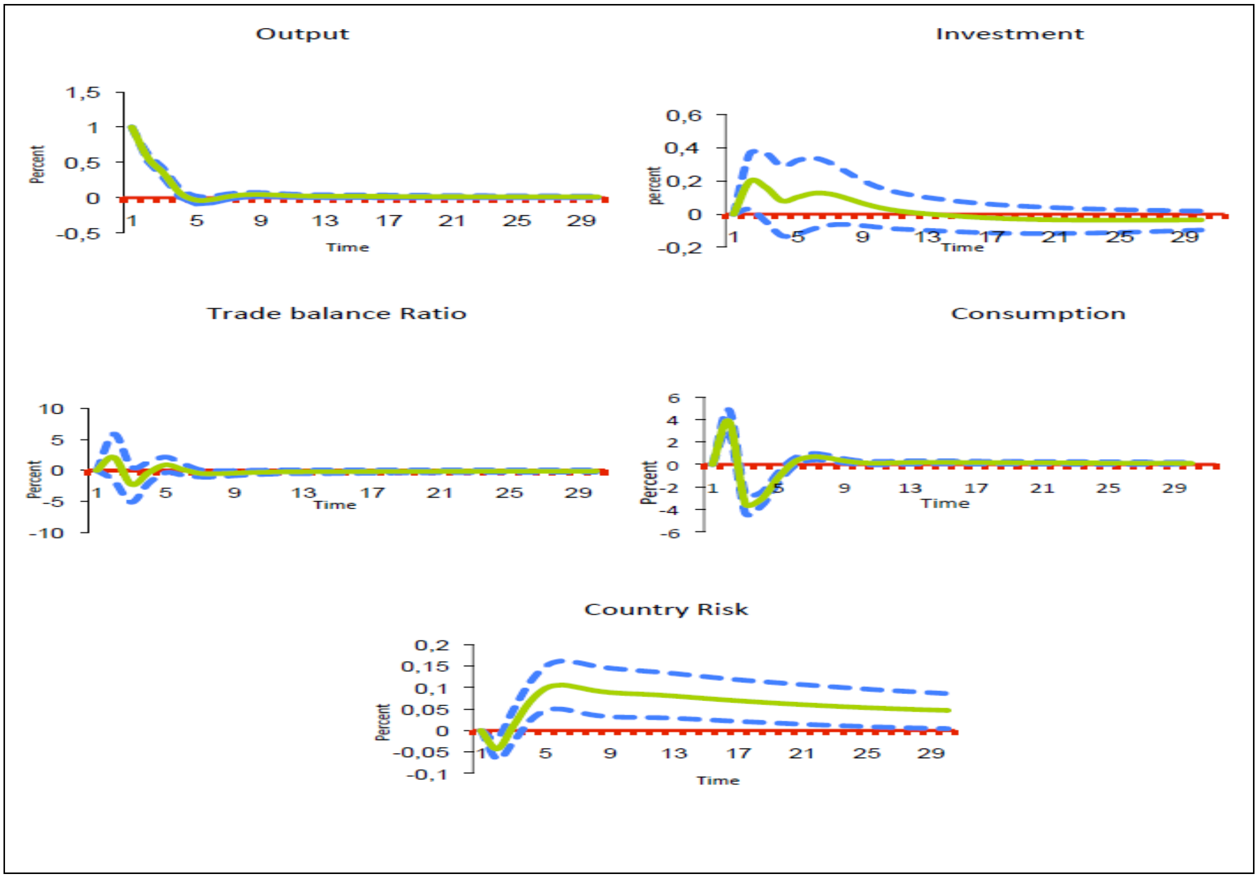


Figure 5: Empirical Responses to a Spread Shock for Caribbean Countries

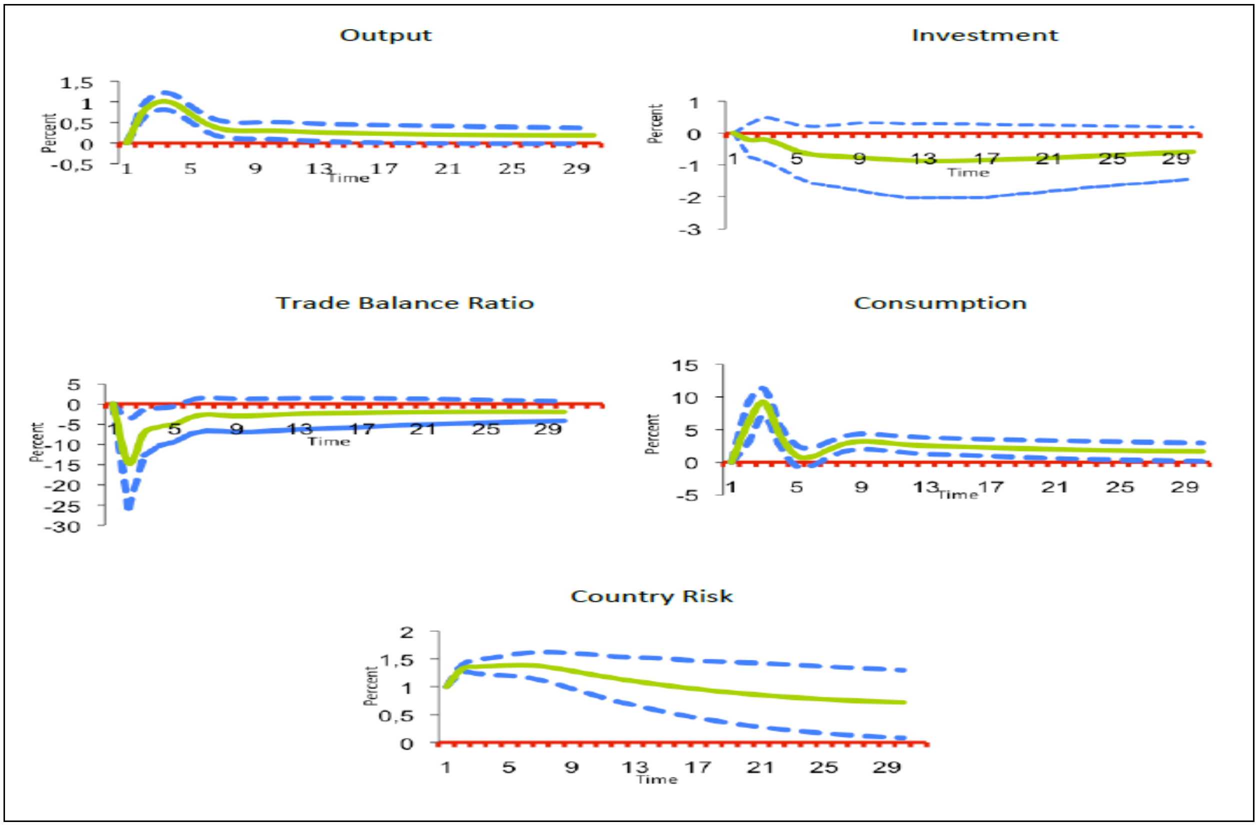


Figure 6: Empirical Responses to an Storm Shock for Central American Countries

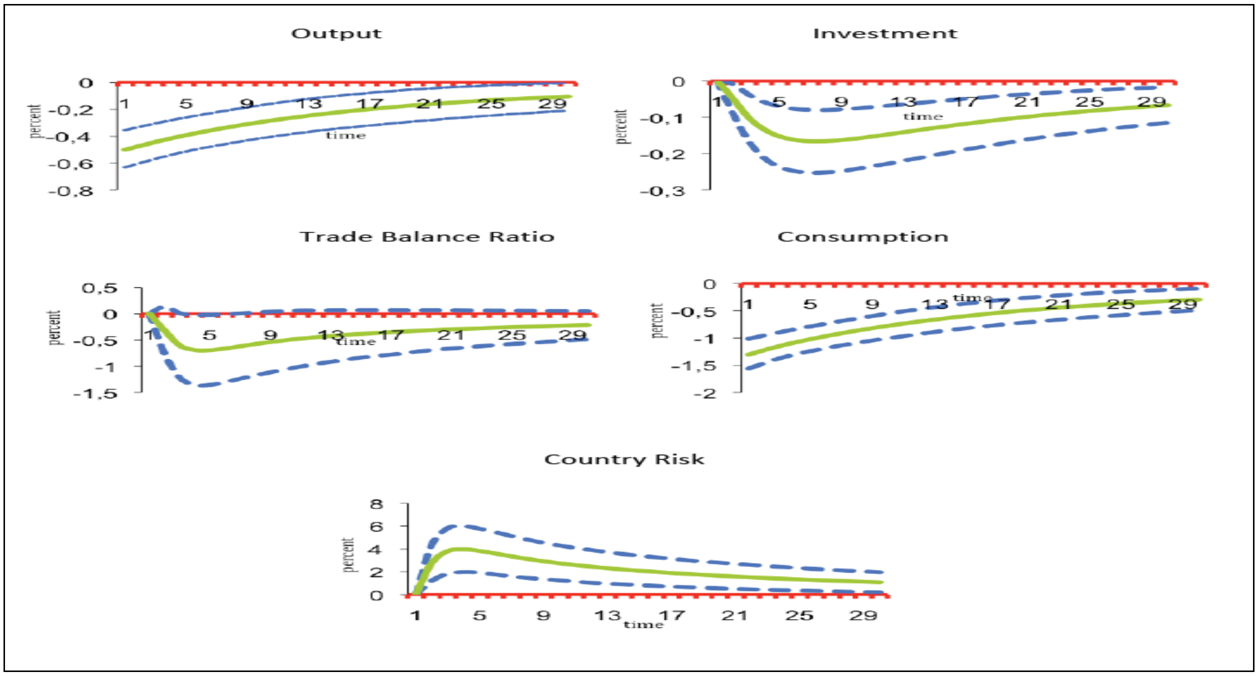


Figure 7: Empirical Responses to an Earthquake Shock for Central American Countries

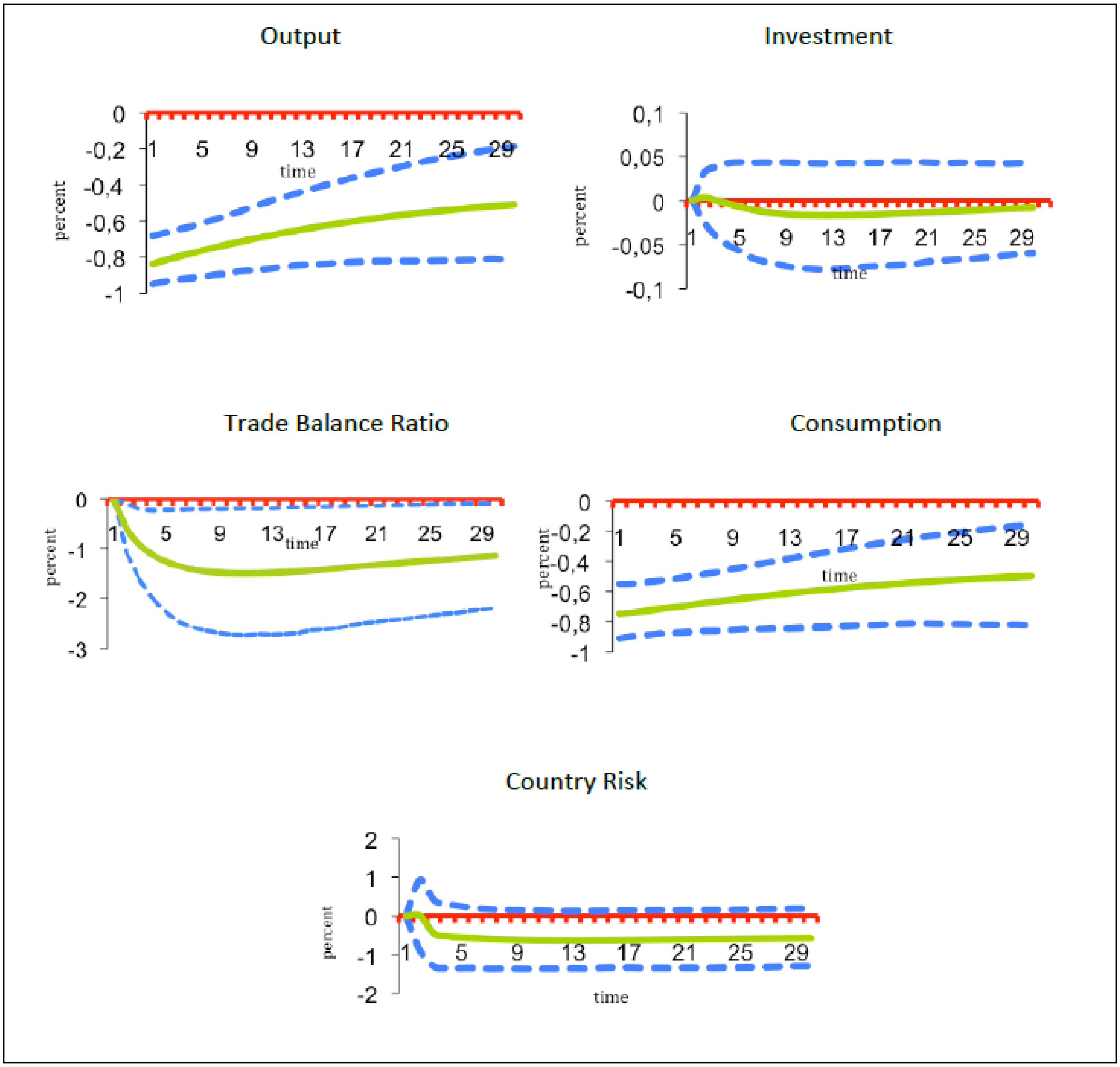


Figure 8: Empirical Responses to an Output Shock for Central American Countries

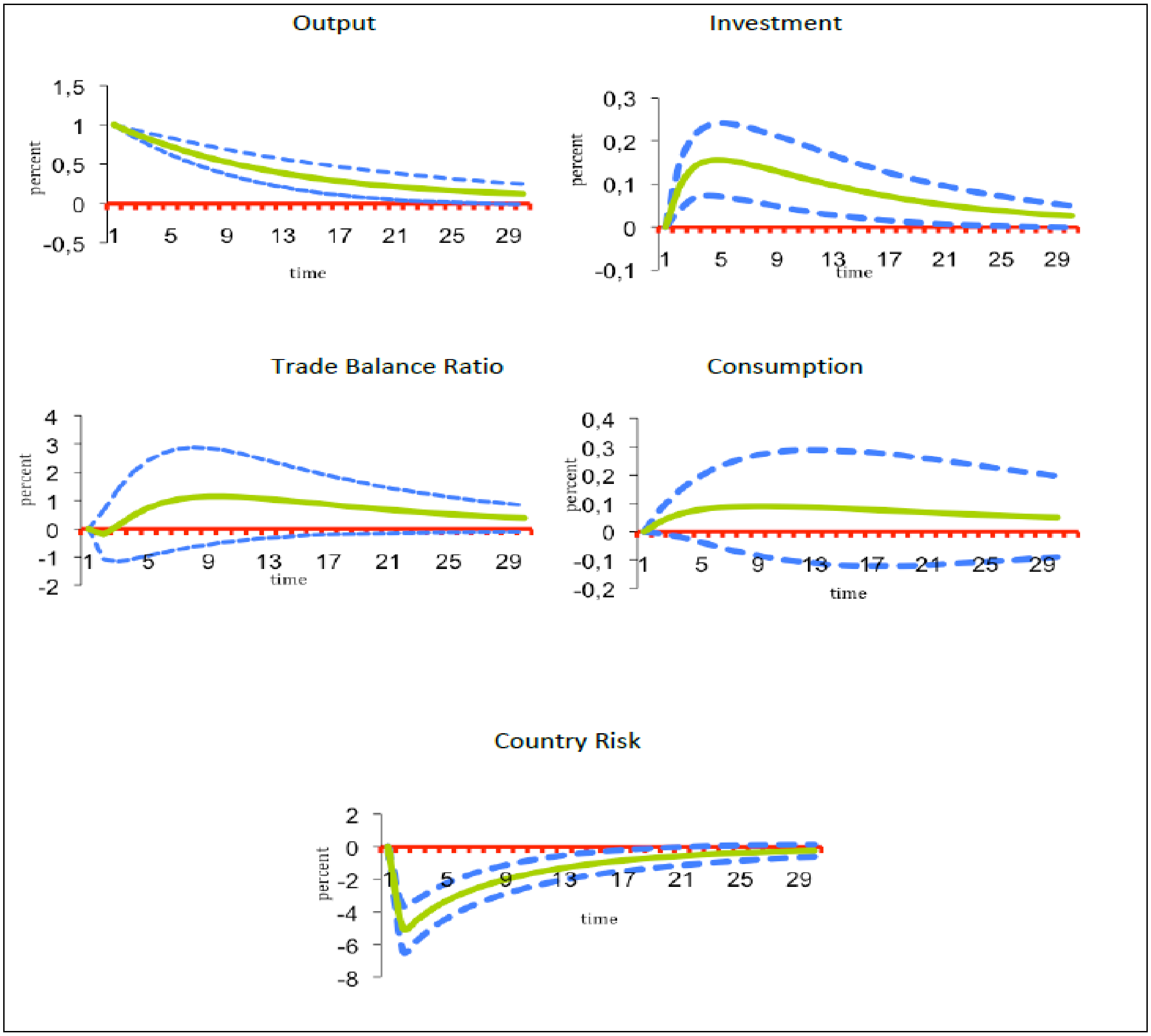
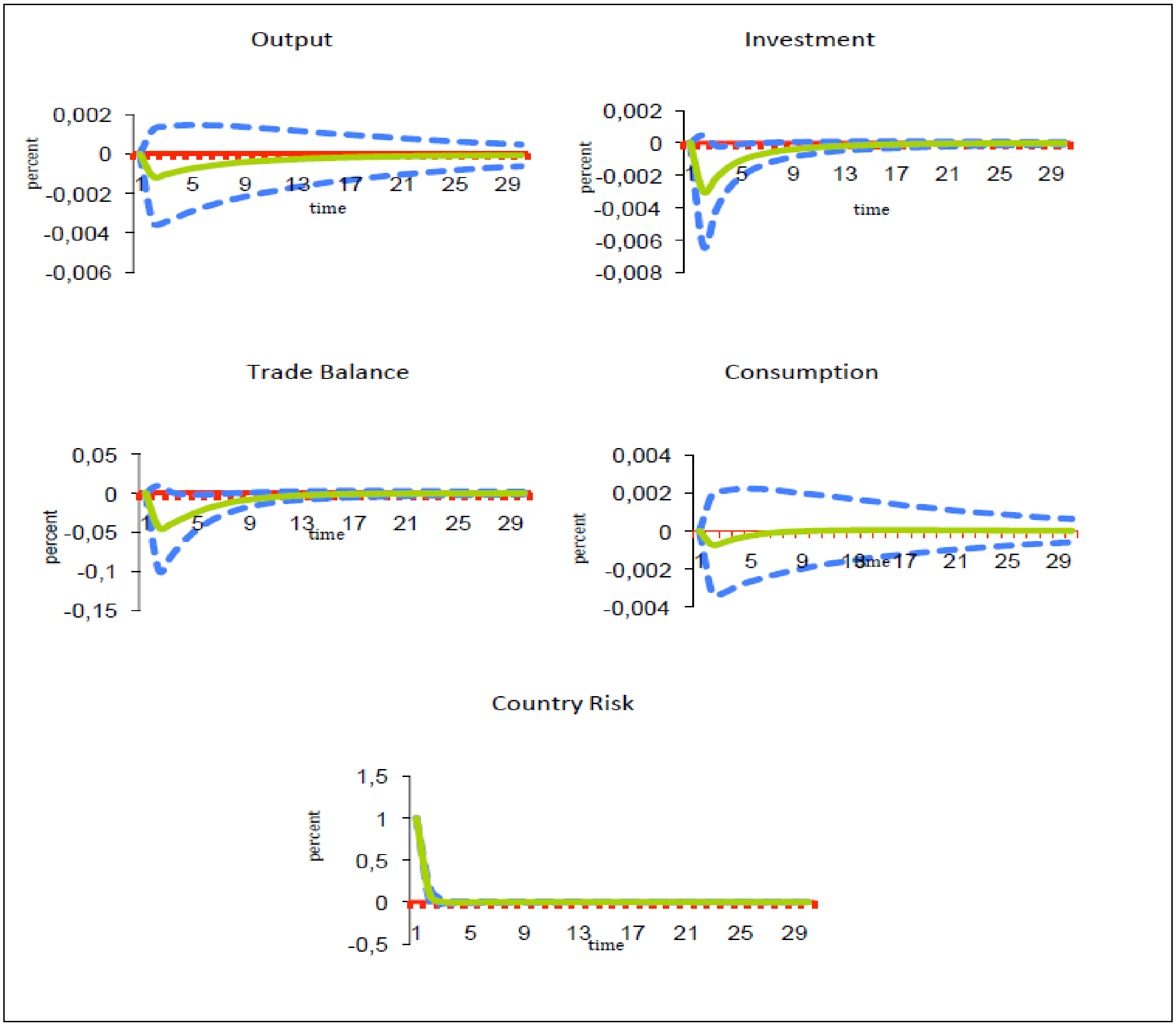


Figure 9: Empirical Responses to a Spread Shock for Central American Countries

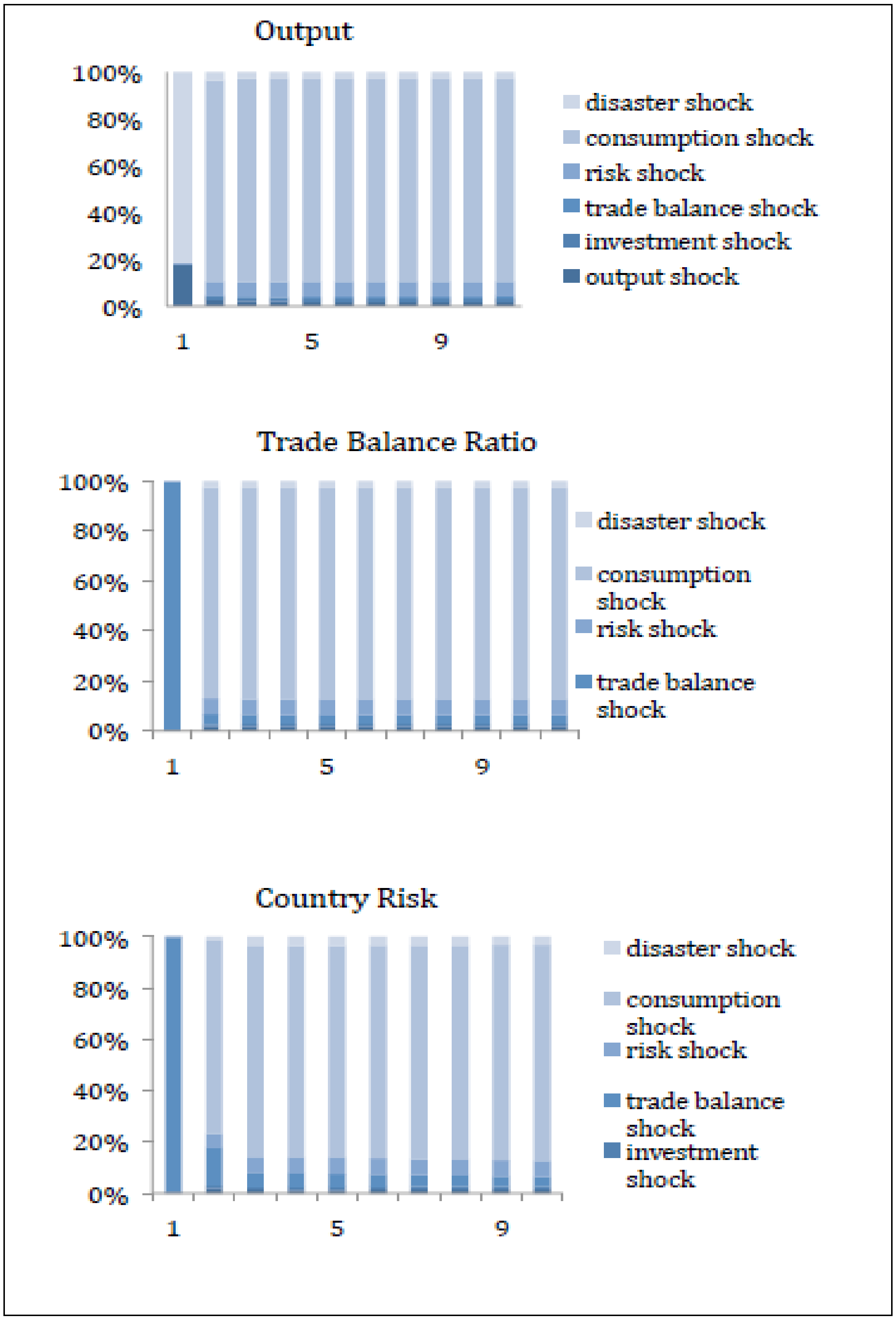


4.3.3 The variance decompositions

Figure 10 shows the variance decompositions derived from the structural VAR for Caribbean countries. We notice that the errors variance for output is dominated by productivity shocks at all horizons. As the horizon lengthens, the contribution of disaster shocks to the variance of output decrease while the contribution of consumption shock increases mostly for Caribbean countries. However, disaster shock plays a marginal role in explaining macroeconomics movements in the long run. Our results are in line with the natural disaster literature, as the external climatic shocks represent a dominant factor driving output fluctuations in the very 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 explains almost 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.

Figure 10: Forecast Error Variance Decompositions for Caribbean Countries



5. The General Framework

In this section, we describe the economic framework we use to deal with the empirical results established in the previous section. As indicated 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 al. (2010), and Chang and Fernandez (2010).

5.1 The Technology

Let us consider a 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 are 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 :

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

and

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

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 nonstationary with a stochastic trend. We introduce the following transformation to denote its detrended variables : $\hat{x}_t = \dfrac{x_t}{A_{t-1}}$.

In 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 a 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 authors argue that some natural disasters were associated with a fall in TFP (Gourio, 2012), other papers find, on the contrary, that TFP may rise in recessions (Petrosky-Nadeau, 2013). The law of capital accumulation is given by :

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

where I_t is the investment flow, $\delta \in [0,1]$ 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 disasters like Luis and Marylin in 1995, in Dominica and Georges in 1999, and in St. Kitts led to large physical capital destruction in many small countries. 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 $\bar{\pi}$ 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 :

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

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 papers (Chang and Fernandez, 2009; Garcia-Cicco, et al., 2009; Mendoza, 1991; among others) use the Constant Relative Risk Aversion (CRRA) because of their ability to improve the performances of small open economy models in reproducing some stylized facts, we adopt the following utility function :

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

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 decide 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

Consistent with Uribe and 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 :

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

In the previous expression, $r^{å}$ and $\bar{b}$ are respectively the world interest rate (assumed to be constant) and the steady-state of normalized debt. ψ captures 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 affect 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:

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

and $\varepsilon_{s,t+1}$ 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 imposing 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 in 1960 as one of the 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 framework, 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 database 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 are common for the two countries and assigned conventional values are borrowed from the business cycle literature (Dejong, 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

	$\bar{\pi}$	d_k	$\bar{b}$	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 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 percent 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 (Table 2). One important element of the calibration is the calibration of $\bar{\pi}$. Since there are no previous studies 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 percent 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 on which to base the priors. This could explain why some of DSGE modeling for Caribbean and Central American economies use the calibration method instead. The priors concerning the estimated parameters are summarized in Tables 3 and 4. Some of our priors are chosen from the Uribe and Yue (2006) studies. As Garcia-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 a 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 (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 a 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 percent 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 percent. For Belize, we also impose beta distribution with mean 0.95 and variance 1.10 on ρ_z. Priors on autoregressive coefficient, ρ_g, also relies on the beta distribution with a mean of 0.71 and a standard deviation of 2.25 percent 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 percent. 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	R^+
$100\sigma_z$	0.90	0.88	Gamma	R^+
$100\sigma_g$	0.80	0.78	Gamma	R^+
$100\sigma_s$	0.98	0.98	Gamma	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	R^+
$100\sigma_z$	0.75	0.55	Gamma	R^+
$100\sigma_g$	0.72	0.55	Gamma	R^+
$100\sigma_s$	0.98	0.10	Gamma	R^+

6.3.2 Estimation

Tables 5 and 6 report the results statistics of the posterior modes, means, and the 90 percent confidence intervals for the two economies. Several facts can be noted. First, the database seems to be informative because of the closeness of the confidence intervals of most of the estimates parameters. Second, the ratio of transitory to permanent productivity shocks (i.e, for

Barbados (σ_z / σ_g)=0.003), assigns an important role to permanent productivity shocks for the two countries. 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 indicates a higher spread elasticity of the disaster shocks compared to Barbados. Our result is consistent on the one hand with the existing literature, and, on 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 (Panel VAR results). Interestingly, the exogenous propagation parameters, ρ_z, ρ_g 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.Then, we finally turn to the forecast error variance decomposition to shed light on the relative importance of the structural shocks in the business cycles. We can address three central questions: First, how do disaster shocks affect macroeconomics quantities such as output, investment, consumption, and the trade balance? Second, how country spread shocks affect domestic variables? Third, how does long-run growth respond to disaster shock?

7.1 Impulse Response Functions

One main objective of this paper is to highlight 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 the 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 tends to increase. Households substitute consumption for investment in the first period, while lower output leads consumption to fall in the next periods. Investment in capital is riskier, so that the country risk raises. The increase of the country risk leads to a reduction in 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 decreases over time with a persistent effect on Belize's economy (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 shocks 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 tends to decline progressively over time for both countries. As the figures support, it seems that Barbados is better prepared for storm shocks than Belize. We must emphasize the similar results obtained from the Panel VAR and DSGE response functions under a disaster shock. We can conclude that disaster shocks in Central America and the Caribbean have only a significative impact in the short-run regional business cycle.

The majority of the studies support the idea that the net effect of a disaster shock on long-run growth is ambiguous. The short-run impact of a disaster shock on growth rate is negative. In the long run, disaster shocks have no significant effects impact on long-run growth. Such a result is in accordance with traditional Ramsey-Cass-Koopman class of growth models, which predict that the destruction of capital will therefore not affect the rate of technological progress and will only enhance short-run growth rate.

7.1.2 The effect of a spread shock

Figures 12 and 16 show the response to a one standard deviation spread shock. Output, investment, and trade balance react as expected. 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. In the periods following the country-spread shock, output and investment fall, and recover their pre-shock levels. The country-spread shock produces a larger contraction in investment and consumption in output. This effect can be explained by the fact that the effect on the trade balance remains positive following the shock. The trade balance ratio recovers quickly and after two periods returns to its pre-shock level (for Barbados and Belize). Our results are in line with Uribe and Yue (2006), as the spread shock reduces output, investment, and consumption for Barbados and Belize. In our Panel VAR results, the impulse response to a country spread shock for Central American countries follows the expected response. However, the Caribbean countries' results differ as output and consumption initially increase until the fourth period.

7.1.3 Trend versus cycle

A positive trend shock (a permanent productivity shock) leads to an increase in consumption and investment (Figures 13 and 17). However, output has the opposite response. In the first period of the shock, we notice a positive effect on income for Barbados and then a 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. Due to the substitution effect, consumption rises 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 macroeconomic fluctuations in the economies (Tables 7 and 8). Some outcomes are worth emphasizing. First, in both countries, trend shocks are the driving force behind output in the long run. Second, disaster shocks play a minor role for the output dynamics. Third, financial frictions in our model also play an important role in explaining business cycle variations in these economies.

Table 7: Variance Decomposition-for Barbados

Variables	$\varepsilon_{z,t}$	$\varepsilon_{g,t}$	h_{t+1}	$\varepsilon_{s,t}$
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	$\varepsilon_{z,t}$	$\varepsilon_{g,t}$	h_{t+1}	$\varepsilon_{s,t}$
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, to evaluate the impact of a disaster shock, we estimate a Panel 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 for Caribbean and Central American countries. Our results show that Caribbean countries are better prepared for natural disaster shocks and Central American countries have persistent effects in the long run only when the disaster shock corresponds to an earthquake. 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) 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*. We must highlight the similar results obtained from the Panel VAR and DSGE response functions under a disaster shock. We can conclude that disaster shocks in Central America and the Caribbean have only a significative impact in the short-run regional business cycle. Our theoretical model provides a baseline framework that could be used to compare the effectiveness of several economic policies (monetary and fiscal policies, aid policy, and optimal reserve policy) under a disaster risk.

Figure 11: Impulse Responses to a Disaster Shock for Barbados

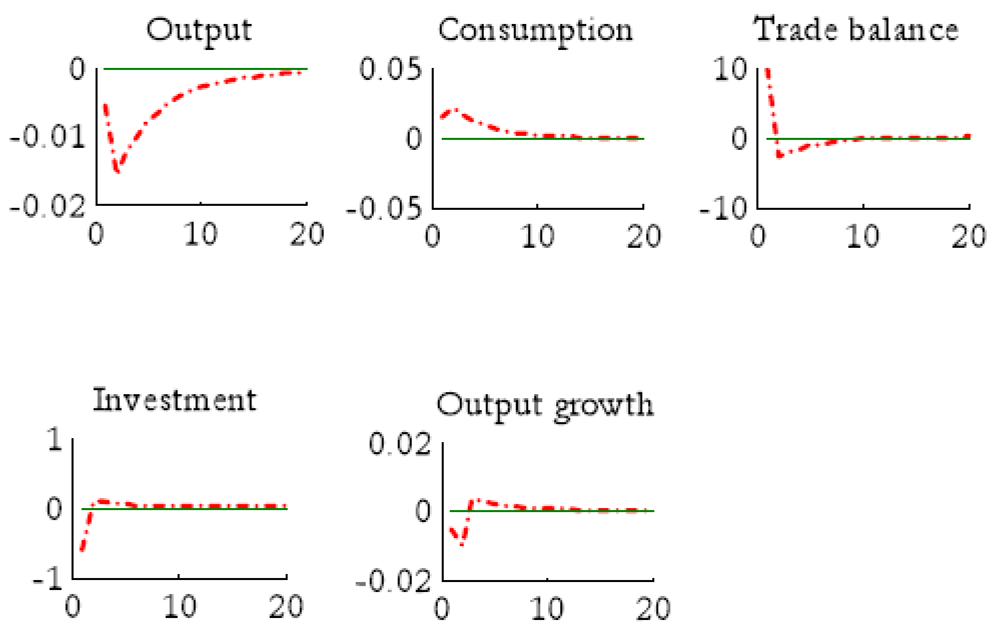


Figure 12: Impulse Responses to a Spread Shock for Barbados

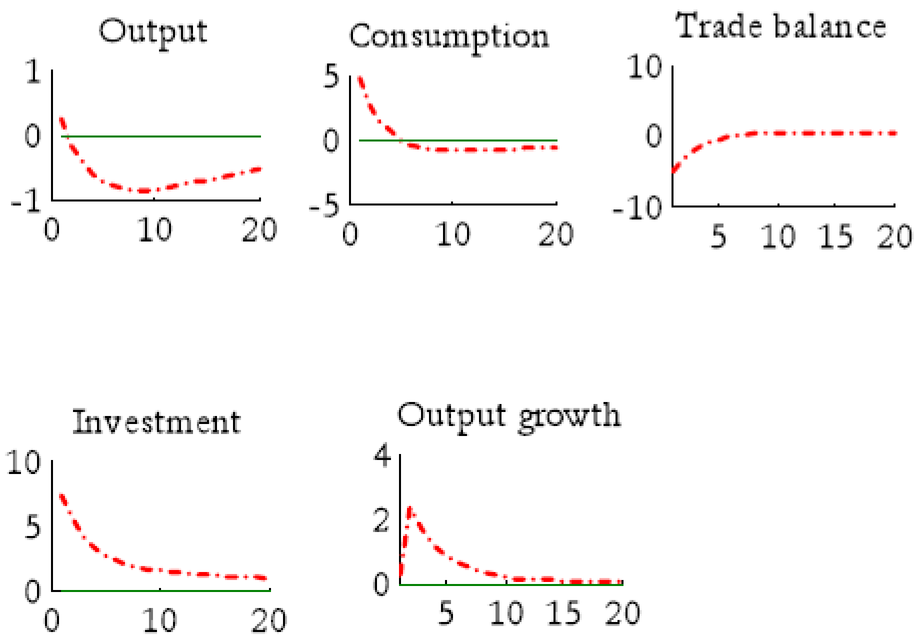


Figure 13: Impulse Responses to a Permanent Productivity Shock for Barbados

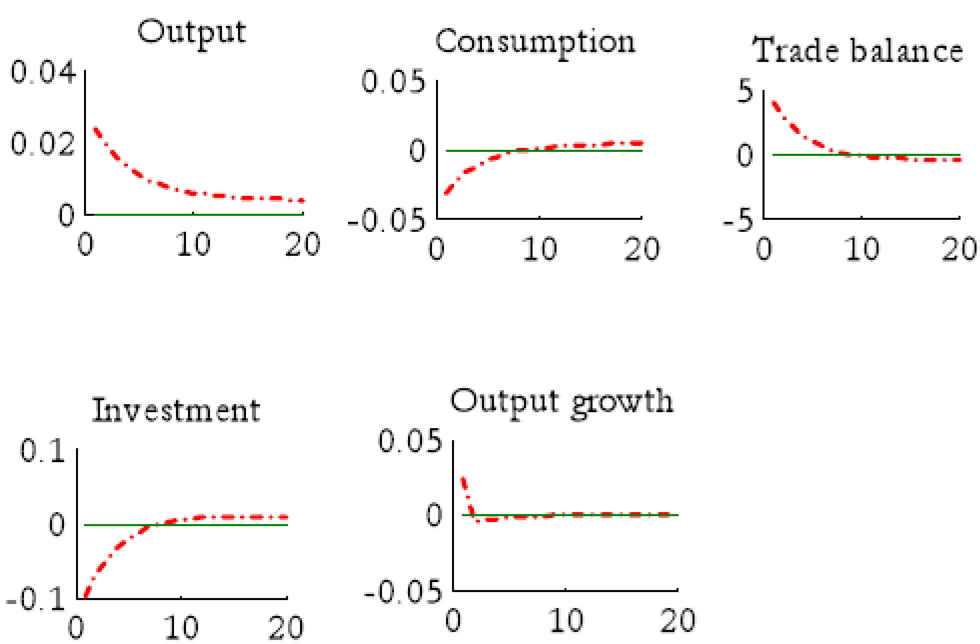


Figure 14: Impulse Responses to a Transitory Productivity Shock for Barbados

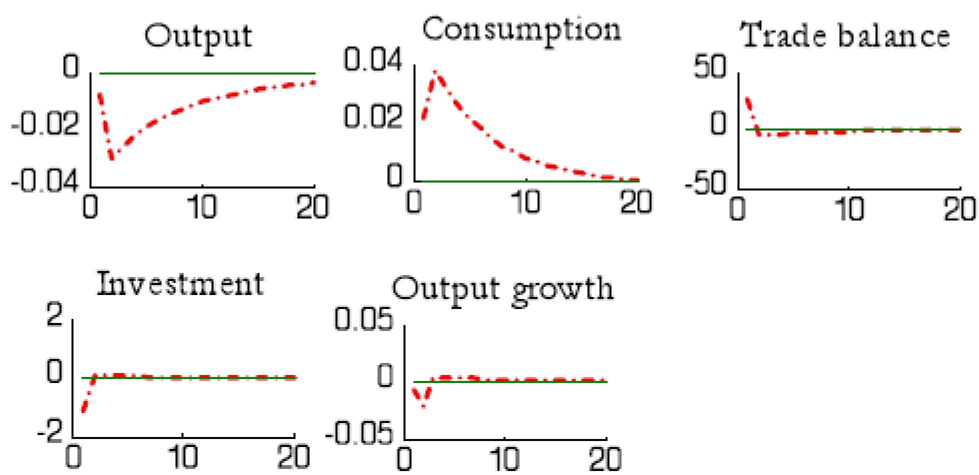


Figure 15: Impulse Responses to a Disaster Shock for Belize

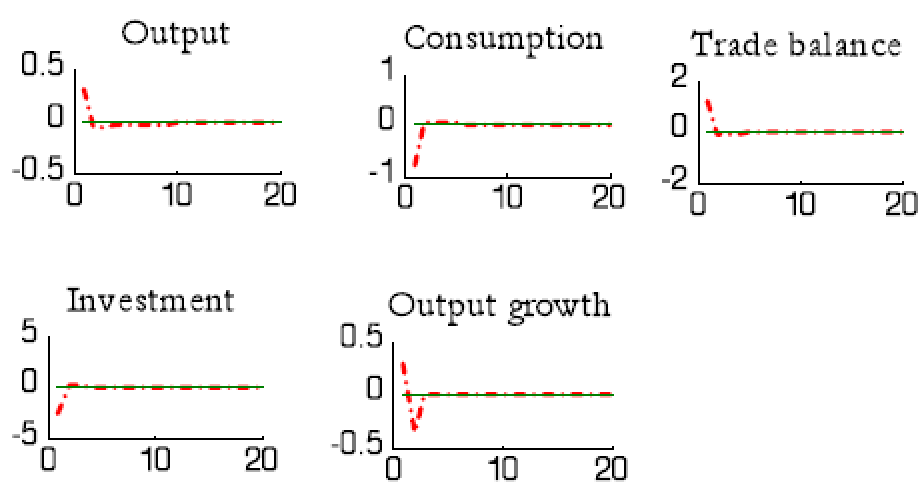


Figure 16: Impulse Responses to a Spread Shock for Belize

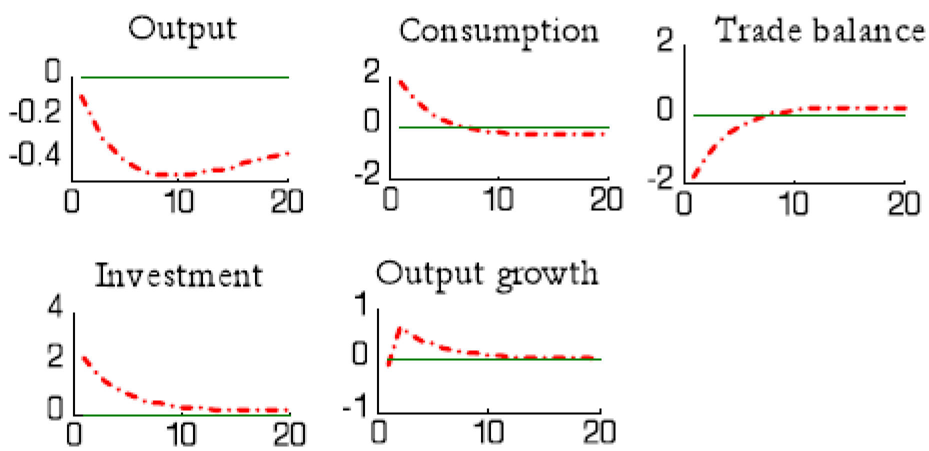


Figure 17: Impulse Responses to a Permanent Productivity Shock for Belize

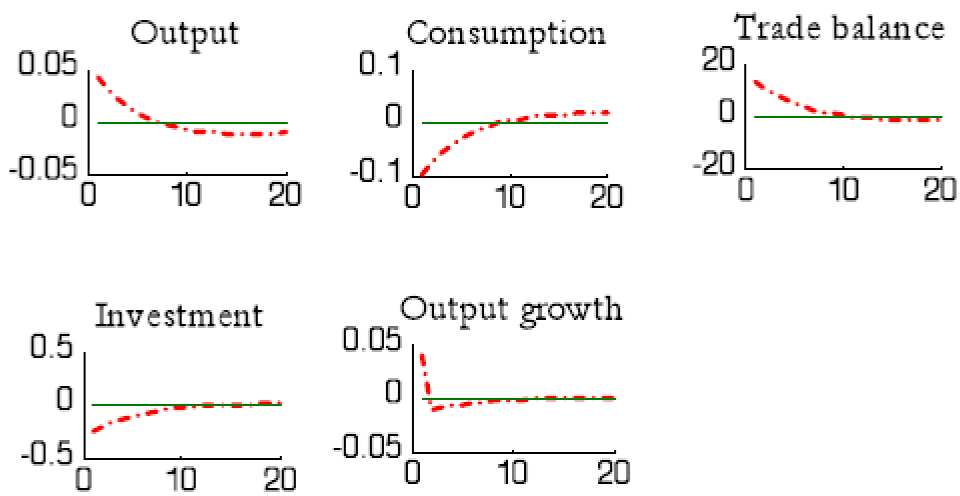
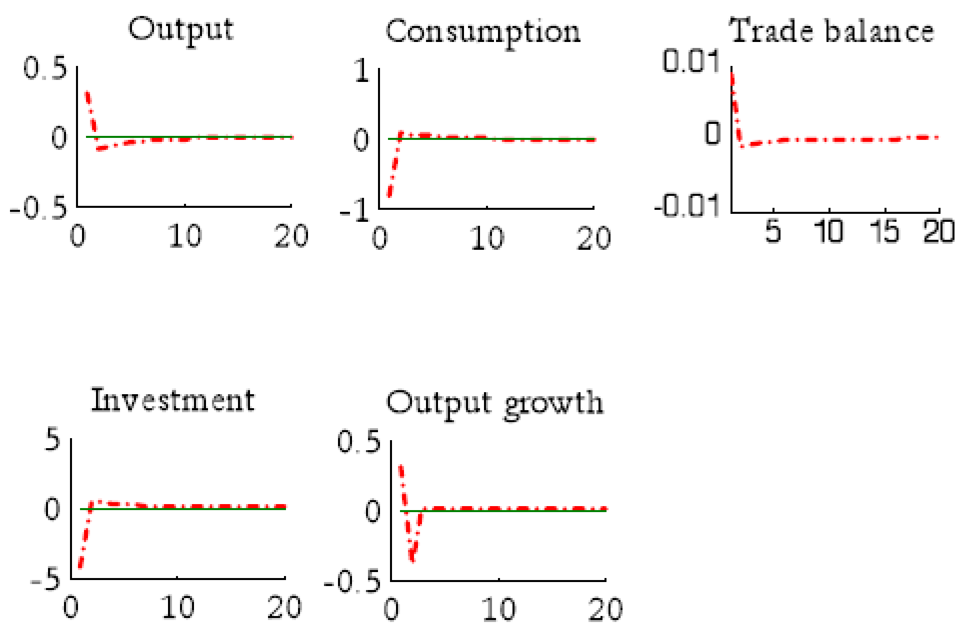


Figure 18: Impulse Responses to a Temporary Productivity Shock for Belize



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