Regime - Switching and Fiscal Policy: Evidence from Selected Economies

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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 are not necessarily reflective of views at the Central Bank of Barbados, Central Bank of the Dominican Republic, Caribbean Centre for Money & Finance.
Abstract

This paper explores the effects of changes in tax regime and fiscal policy among selected economies of Central America and the Caribbean. The results show how agents respond to changes in tax regimes and the impact upon investment, consumption and output growth. The findings will assist in determining allocation of income, consumption and investment as agents make inference regarding regime-switching of tax regimes.

Keywords: Regime-switching, Fiscal Policy, Developing Economies
1. Introduction

This paper uses a standard business cycle model to study the effects of income allocation between gross domestic product (GDP), investment and consumption as a result of changes in debt-to-GDP ratios and tax regimes for developing economies of Central America and the Caribbean. Our model assumes that given the stochastic nature of tax changes and regimes, agents must make a probabilistic inference whether changes in tax rates are intra–regime (temporal) or inter-regime (regime shift) given the known parameter values of debt-to-GDP ratios.

The income allocation mechanism for consumption and investment to GDP ratios in a regime-switching (RS) model depends on the ability of agents, which do not observe the current tax regime, to formulate expectations over future taxes as government decide to finance its deficit with debt. As the regime shifts from low to high debt/GDP ratio, consumption/GDP is expected to decline until agents believe future taxes will fall. Meanwhile, investment/GDP ratio is expected to behave the other way; i.e. until taxes are expected to rise to finance higher levels of debt.

Variable movements behave as expected, the results show for Antigua and Barbuda, Dominica, Dominican Republic, Panama, Saint Lucia, Saint Vincent and the Grenadines and Trinidad and Tobago, that changes in income allocation for GDP, investment and consumption vary as these economies moved from a low to high debt regime.

The understanding of this change in income allocation is critical for these developing economies of Central America and the Caribbean, which currently face expanding levels of debt-to-GDP ratios, and limiting ability to enact expansionary fiscal policy changes due to reducing fiscal space (Wright and Ramirez, 2014).

A simple relationship analysis of changes in debt-to-GDP against government revenue-to-GDP over the past decade among economies of Central America and the Caribbean show a negative relationship, as governments’ revenues as a percentage of GDP are increased to seemingly finance higher debt to GDP ratios (Figure 1). However as these economies continue to accumulate levels of debt and attempt to finance debt by adjusting fiscal policy, what exactly is the impact on income allocation, especially on GDP, investment and consumption within these economies? It is this question, our paper attempts to answer for the developing economies of Central America and the Caribbean.

Using the Davig (2004) model our paper analyzes the impact of agents’ probabilistic inference on regime changes as tax rates are allowed to continuously vary for economies not previously studied. The structure of the paper is as follows: section 2 briefly reviews the literature. Section 3 discusses the model, data and the parameters
used in deriving our results on income allocation, which is analyzed and discussed in section 4 and 5 after showing the variations of transition probabilities and its impact on the regime switching model. Sections 6 and 7 discuss the policy implications and conclusions.

Figure 1: Revenue-to-GDP vs Debt-to-GDP in Central America and the Caribbean, 2003-2012

2. Literature Review

Our analysis is related to other studies that explore the effects of a debt-financed tax cut in a model with income taxation and the impact it has on macroeconomic aggregates. Coleman (1989) studied an intertemporal stochastic production economy in which income is taxed, proving the existence of a unique equilibrium. The solution methodology allows the comparison of equilibrium under tax-rate smoothing and tax-revenue smoothing in their model, but in general can be used to realize a variety of tax-policy experiments. This methodology allowed us to quantify the best decision rule response to a specific set of variables.
In the existing literature of fixed-regime fiscal policy, Judd (1987) has shown that a temporary substitution of debt followed by a tax increase in the future to keep government budget balanced, has a short-run negative impact on consumption, but a positive impact on investment. Their results are in line with ours, as agents reduce their consumptions/GDP levels to recover with future expectation that taxes will fall in line with future debt.

In a general equilibrium model with inelastic labor supply, Dotsey (1994) demonstrates that deficit-financed income tax cut, and in consequence future distortionary taxation, will reduce investment and output. Meanwhile Ludvigson (1996) extend the analysis with an elastic labor supply model, the main results show that a deficit-financed tax cut may increase investment and output. The varying results are driven by two main factors: the elasticity of labor supply and the degree of permanence in government debt shocks.

The specification of the fixed-regime model implies an abrupt change in fiscal policy due to the incapacity of the government to smooth the policy intervention reaction, i.e. given a tax reduction brought by one-period shock to debt, higher taxes will be expected on the next period.

More recently, regime-switching literature has incorporated agents’ perception of policies in two categories: inter-regime or intra-regime. According to some authors, agents’ beliefs about the prevailing policy regime and the possibility of switching to a different regime may shift the projected paths and probability distributions of macro variables. The framework created by Leeper and Zha (2003) allows the analysis of direct and expectation-formation effects in modest policy interventions within an environment where policy can switch regime and evolves randomly according to a Markov chain. The results from U.S postwar data analysis in the paper show that intervention can generate large direct effects without producing important expectations-formation effects.

Following an estimated regime-switching process for the debt-to-GDP ratio within a standard growth model, Davig (2004) studied the effects of changes to the tax rate as agents incorporate the possibility of switching to different fiscal regimes. He finds that regardless future fiscal policy; agents’ beliefs have a great impact on income allocation as their actions generate important nonlinear effects in their consumption and investment responses. Again, Davig results follow the same pattern of ours, nonlinear impulse responses to a regime change (inter-regime) show that consumption diminishes in the short-run as investment increases is levels in the long-run.
3. The Model, Data and Parameters

This section describes the theoretical model, data and parameters used in the simulations. The model is taken from Davig (2004) and it is a standard business cycle model with a government facing a debt-to-GDP rule subject to regime switches. It is assumed that the economy is populated by three agents: households, firms and government.

3.1 Households

Following Davig (2004), the household sector is modeled by a representative agent that maximizes its lifetime utility function subject to a budget constraint.

$$\max \{c_t, l_t, k_{t+1}, b_{t+1}\}_{t=0}^{\infty} E_t \sum_{t=0}^{\infty} \beta^t u(c_t, l_t), 0 < \beta < 1$$

Subject to

$$c_t + k_{t+1} + b_{t+1} \leq (1 - \tau_t)(w_t n_t + r_t k_t) + (1 - \delta) k_t + (1 + r_t^b) b_t + h_t$$

Where $c_t$ is private consumption, $l_t$ is leisure, household investment is given by the equation $i_t = k_{t+1} - (1 - \delta)$, $k_{t+1}$ is the stock of capital at the beginning of period that follows and $b_{t+1}$ is the stock of bonds at the beginning of period. Also, $\tau_t$ is the income tax rate, $n_t$ is the time allocation to production, subject the constraint $n_t + l_t = 1$. $w_t, r_t, r_t^b$ are the real wage, the real rental of capital and the real return of government bonds, respectively. All variables are in per-capita terms.

3.2 Firms

Firms maximize profits subject to technology and factor prices. They solve the following problem every period:

$$\max_{k_t, n_t} f(k_t, n_t) - r_t k_t - w_t n_t$$

Where $Y_t = f(k_t, n_t)$ is real output and denotes a constant return to scale production function, concave and twice differentiable ($f'(.) > 0$ and $f''(.) < 0$). In addition it is assumed that markets for production factors are competitive, so firms and households are price takers.
3.3 Fiscal policy

Following Davig (2004), fiscal variables are determined by a policy rule stating the evolution of debt-to-GDP in terms of a regime switching process, specified as a first order Markov chain:

\[ x_t = \mu(S_t) + \phi x_{t-1} + \epsilon_t \]

Where \( x_t \) is the debt-to-GDP ratio at the end of period \( t \) and \( \epsilon_t \) is a shock with probability distribution \( N \sim (0, \sigma^2) \) and \( E[\epsilon_t \epsilon_s] = 0 \) for \( s \neq t \). The intercept varies randomly between two regimes, \( S=1 \) and \( S=2 \).

\[ \mu(S_t) = \begin{cases} 
\mu_1 & \text{for } S_t = 1 \\
\mu_2 & \text{for } S_t = 2 
\end{cases} \]

Where \( \mu_1, \mu_2, \) and \( \mu_2 \) are the debt ratios for each regime. The economy switch between regimes according the following stochastic process:

\[ \Pi = \begin{bmatrix} p_{11} & 1 - p_{11} \\
1 - p_{22} & p_{22} \end{bmatrix} \]

With \( P[S_t = j | S_{t-1} = i] = p_{ij} \) where \( i,j = 1,2 \). The matrix \( \Pi \) is known as the transition matrix.

The specification proposed by Davig (2004) allows the analysis of the economic implications of two types of shocks. The first one, \( \epsilon_t \), is inferred as an intra-regime shock. The second one, \( S_t \), represent an inter-regime shock, or regime change. These changes are interpreted as results of changes in the tax rate, so intra-regime shock is a temporal shift in tax rate, compare to the inter-regime change.

As the purpose is the study of the dynamic response to shifts in taxes that induces a regime change in the behavior of debt-to–GDP ratio, it is assumed that government purchases and lump-sum transfers are constant (\( G_t = \bar{G} \) and \( H_t = \bar{H} \)). Given that assumptions, the tax rate adjust to satisfy the flow constraint for government debt,

\[ B_{t+1} = (1 + \tau_t^b)B_t + \bar{G} + \bar{H} - \tau_t Y_t \]

Where \( B_t \) is the aggregate government bond maturing at time \( t \) and \( Y_t \) is the real output. In equilibrium, the quantity of bonds willingly to be held by the agent must equal the aggregate level of government debt. In relation to the transversality condition (the existing debt is equal to the expected discounted future surpluses), as the model does not has long run growth and the real interest rate is positive, this condition is satisfy when debt does not grow faster than the real interest.
It is worth noting that, a regime change is not equal to a permanent change in the tax rate. This is important to stress, because in this model spending and lump sum transfers are held constant, so the government cannot adjust these variables when a reduction in tax rate delivers a rise in public debt. Then, to meet the transversality condition, the government must raise future taxes.

3.4 Solving the signal extraction problem

Given the stochastic nature of tax regimes, agent do not observe directly the current regime so they need to makes a probabilistic inference about it. This inference is based in the information set $\Omega_t = \{k_t, x_t, B_t, G_t, H_t, \omega_t\}$ where $\omega_t \equiv P[S_t = 1| \Omega_{t-1}]$ is the probability that agents give to being in the low debt-output regime. In addition, agents know the parameter values governing the process for the debt–output ratio.

As new data is incorporated in the information set, agents actualize their prior belief of being in a low debt-to-output regime, meaning they behave as a Bayesian updaters, where the rule for the updating process is:

$$
\theta_t = \frac{\theta_{t-1}p_{11}\eta(1) + (1 - \theta_{t-1})p_{12}\eta(1)}{\sum_{i=1,2}(\theta_{t-1}p_{1i}\eta(i) + (1 - \theta_{t-1})p_{2i}\eta(i))}
$$

Where

$$
\eta_t(1) = \varphi(x_t - \mu_1 - \phi x_{t-1})
$$
$$
\eta_t(2) = \varphi(x_t - \mu_2 - \phi x_{t-1})
$$

And $\theta_t \equiv P[S_t = 1| \Omega_t]$ is the updated inference, and $\varphi$ is the normal density with variance $\sigma^2$.

3.5 Functional forms and solution

The solution of the model requires the specification of the utility and production functions. As in Davig (2004), we use a log-utility and Cobb-Douglas production function:

$$
u(c_t, 1 - n_t) = \ln(c_t) + \gamma \ln(1 - n_t)
$$
$$
f(k_t) = k_t^\alpha n_t^{1-\alpha}
$$

The first order conditions are:

$$
c_t^{-1} = \beta E[(1 - \tau_t)r_{t+1} + 1 - \delta]c_{t+1}^{-1} \quad (1)
$$
\[ [1 - n_t]^{-1} = (1 - \tau_t)w_t c_t^{-1} \quad (2) \]

\[ r_t = \alpha k_t^{\alpha-1} n_t^{1-\alpha} - \delta \quad (3) \]

\[ w_t = (1 - \alpha)k_t^{\alpha} n_t^{-\alpha} \quad (4) \]

Equations (1) and (2) are the optimizing conditions for households. The first relation is the Euler equation establishing the evolution of consumption. Equation (2) is the labor supply function. Finally, equation (3) and (4) are the firm’s demand for labor and capital.

In equilibrium the budget constraint satisfy:

\[ c_t = k_t^{\alpha} n_t^{1-\alpha} + (1 - \delta)k_t - k_{t+1} - G_t \]

The tax rate is given for agents and is derived as:

\[ \tau_t = \frac{(1+r_t)B_t+G_t+H_t-B_{t+1}}{Y_t} \quad \text{and} \quad B_{t+1} = Y_t x_t \]

### 3.6 Solution method

The solution method is based on Coleman (1991) and follows the steps:

1. Give a conjecture candidates decision rules: \( r_t = h^r(t), n_t = h^n(t), k_{t+1} = h^k(t + 1) \) and \( w_t = h^w(t) \).
2. Substitute this candidates decision rules and the aggregate resource constraint into the first order conditions for the representative agent and firm. The results are the decision rules and pricing functions.
3. Treat the decision rules as unknowns and obtain the solution for a given state by solving the four equations (the first order conditions) in the four unknowns.
4. Discretize the state space and solve the system for every set of state variables. The expectations are evaluated using numerical quadrature.
5. Repeat the procedure until iteration improves the current decision rule at any given vector given same \( \epsilon \).

### 1. Data and parameters

The model is calibrated for seven economies from the Caribbean and Central America where we found evidence of increasing levels of debt-to-GDP ratios: Antigua and Barbuda, Dominica, Dominican Republic, Panama, St. Lucia, St. Vincent and the Grenadines and Trinidad and Tobago. There are two types of parameters: structural...
parameters associated with the utility and production functions and the factors of the
debt-to-output dynamics.

Relative to the structural parameters, the elasticity of capital in the production function
($\alpha$) is set to 0.5, the depreciation rate of capital, $\delta$, is equal to 0.1, that is 10% per year.
The elasticity of substitution of labor in the utility function is calibrated to 2, as is
standard in the literature. These parameters are common across countries, because of
the lack of information. Finally, the discount rate is computed through the average real
interest rate observe in these countries. Table 1 shows these parameters.

Table 1: Preference and technology parameter values

<table>
<thead>
<tr>
<th>Countries</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\delta$</th>
<th>$\gamma$</th>
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</thead>
<tbody>
<tr>
<td>Antigua and Barbuda</td>
<td>0.5</td>
<td>0.93</td>
<td>0.1</td>
<td>2</td>
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<tr>
<td>Dominica</td>
<td>0.5</td>
<td>0.86</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>0.5</td>
<td>0.92</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Panama</td>
<td>0.5</td>
<td>0.94</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>St. Lucia</td>
<td>0.5</td>
<td>0.94</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>St. Vincent and the Grenadines</td>
<td>0.5</td>
<td>0.94</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>0.5</td>
<td>0.95</td>
<td>0.1</td>
<td>2</td>
</tr>
</tbody>
</table>

For the calibration of the debt-to GDP rule, we estimate for each country univariate
regime switching model, as it was specify in the last section. Parameters estimates are
reported and its standard errors (s.d.) are reported in Table 2. The sample for
estimation varies across countries due to data availability. Despite of it, we identify two
regimes in each country considered in the study. The low debt-to-GDP ($\mu_1$) goes from a
conditional mean of 6% in the case of Trinidad and Tobago to 80% in the case of
Antigua and Barbuda. Relative to the high debt-to-GDP regime, the interval consist in a
conditional mean of 33% for the Dominican Republic through 123% for Antigua and
Barbuda. As can be seen in Table 2, heterogeneity in terms of conditional mean of debt-
to-GDP ratios across countries is considerable. Finally the same pattern is noticed in
terms of the probabilities of staying in one of the regimes.

Table 2: Estimated fiscal policy parameter values

<table>
<thead>
<tr>
<th>Countries</th>
<th>$p_{11}$</th>
<th>$p_{22}$</th>
<th>$\mu_1$</th>
<th>s.d.</th>
<th>$\mu_2$</th>
<th>s.d.</th>
<th>$\varphi$</th>
<th>s.d.</th>
<th>$\sigma_2b$</th>
<th>s.d.</th>
</tr>
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<tbody>
<tr>
<td>Antigua and Barbuda</td>
<td>0.6</td>
<td>0.6</td>
<td>0.4</td>
<td>0.0</td>
<td>0.6</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td></td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Dominica</td>
<td>0.8</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.8</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>0.8</td>
<td>0.7</td>
<td>0.1</td>
<td>0.0</td>
<td>0.2</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
4.0 Transition Probabilities and Impact on Income Allocation

Based on the stochastic nature of tax regime changes, agents within our model will make probabilistic inferences on the changes in the regimes, given the known parameter values of the debt-to-GDP ratio.

The transition probabilities that agents placed on being within a particular regime are based on the following information set $\Omega_t = \{k_t, x_t, B_t, G_t, H_t, \omega_t\}$ where $\omega_t = P[S_t = 1|\Omega_{t-1}]$ the probability in the low debt-output regime. For the economies studied, our paper examine variations in the transition probabilities through the use of varying the level of persistence in a low debt-to-GDP regime and the impact this will have on income allocation. Figures 2 and 3 below; show the effects of alternative values or transition probabilities for p11, with differing degrees of probabilities of staying in the low debt-to-GDP regime for investment and GDP respectively. At higher transition probabilities with more persistence, agents believe they will remain in the low debt-to-GDP regime and changes are temporal or intra-regime shift.

The results show at values of p11 closer to 1, with persistence in transition probabilities, agents believe changes are temporal, and investment response remain almost fixed (when compared to other probabilities) after period 5 when the regime changes to the high debt/output state.

For transition probabilities further away from 1 (p11 closer to 0), agents believes that there will be an inter-regime shift given the parameter values of debt-to-GDP after a tax change, and that governments will soon raise taxes to help finance higher debt-to-GDP ratios, resulting in a fall in both investment-to-GDP ratio and GDP after period 5.

Figure 2: Effects of alternative values of p11 on Investment/GDP ratio.
Figure 3: Effects of alternative values of $p_{11}$ on GDP.
Figure 4, shows a similar impact of persistence in transition probabilities, however this time we examine the impact on consumption. At the highest transition probability, agents believe that changes are intra-regime and therefore believe that tax changes are temporal. This results in consumption changing but at a lower level than demonstrated by probabilities with less persistence among the economies studied. For agents who believe the changes are inter-regime shift, reduced their consumption/GDP ratio at the perceived period of regime shift (period 5) and recover their consumption levels as regime changes to the high debt/output.

**Figure 4: Effects of alternative values of p11 on Consumption/GDP ratio.**
With agents acting as Bayesian updaters and making probabilistic inferences on the stochastic nature of regime changes, transition probabilities closer to 1 (for low debt/out regime) will believe changes are temporal and intra-regime, hence income allocation changes to investment/GDP ratio, GDP and consumption/GDP ratio are expected to be lower when compared to the actions of agents who are making inferences with less persistence in transition probabilities.

5.0 Results and Discussion on Income Allocation

Using the estimated fiscal policy parameters values (see Table 2) our paper shows the changes in investment/GDP ratio against debt-to-GDP as agents make probabilistic inferences with less transition persistence about the stochastic nature of regimes.

The results shows in Figure 5, investment/GDP ratio initially rises as agents believe tax changes will remain low as the economy transition through a low debt-to-GDP regime, however this changes towards lowers levels of investment/GDP ratios as the economy moves into a high debt-to-GDP regime, and taxes are expected to rises to finance higher levels of debt for most of the economies studied. The slight exception appears to be Trinidad and Tobago which respond sooner than the other economies, with investment/GDP ratio falling at levels of debt-to-GDP ratios above 39%.

Trinidad and Tobago with a debt-to-GDP ratio of approximately 38.7% as at 2012, and historically operating within a low debt-to-GDP regime for several years, agents have formed the probabilistic inference that taxes will be rising to finance higher levels of debt-to-GDP and hence lowering their Net investment/GDP allocation.
Figure 5: Income Allocation of Investment/GDP vs Debt/GDP

Antigua and Barbuda

Dominica

Dominican Republic

Panama

St. Lucia

St. Vincent and the Grenadines

Trinidad and Tobago
Again, agents acting as Bayesian updaters, and forming inferences about the nature of regime changes will reduced their consumption/GDP ratio as the regime shifts from low debt/GDP to high and recover their levels at higher debt-to-GDP ratios with the future expectation that taxes will fall in line with future debt. This is evident in all economies, with the recovery in consumption/GDP ratios appearing to be quicker for Trinidad and Tobago, Dominican Republic, Saint Lucia and Saint Vincent and the Grenadines.

Figure 6: Income Allocation of Consumption/GDP vs Debt/GDP
6.0 Policy Implications

For the economies of Central America and the Caribbean studied in our paper, the allocation of income across GDP, investment/GDP and consumption/GDP can be seen as economies moved across regimes as agents form inferences on the nature of these regime changes. The results show investment/GDP ratios rising initially on lower tax changes, but falling at higher debt/GDP ratios as taxes are expected to be increased to finance higher debt. The opposite results are obtained for consumption/GDP which initially falls and recovers at higher debt/GDP levels as taxes are expected to fall in line with future debt levels.

Policy makers will observed the evolution of these changes as regimes shifts, with some economies experiencing a quicker decline in investment/GDP as regimes shifts to the higher level. Trinidad and Tobago shifted at approximately 39% of Debt/GDP level, while Saint Lucia, Saint Vincent and the Grenadines at 90%, Dominican Republic at 100%, and while Panama, Dominica, and Antigua and Barbuda were slightly higher.
7.0 Conclusions

Looking to our analysis results in a small closed economy Real Business Cycle (RBC) model developed by Davig (2004), our model estimation offers significant policy implications in term of income allocation for several economies with Central America and the Caribbean. We realized that agents form inferences on the stochastic nature of regimes based on the existing parameter values of debt to GDP which is imbedded in the model and transition probabilities with higher persistence, assumes that changes are temporal or intra-regime when compared with probabilities with less persistence which show regime switching or inter-regime shifting properties.

In Figures 5 and 6, the changes in income allocation for investment/GDP and consumption/GDP as regimes shifts are displayed, with investment/GDP rising at lower levels of debt/GDP but falling thereafter as expectations of taxes become higher to finance higher debt/GDP levels. The opposite is observed in Figure 6 for consumption/GDP against changing levels of debt/GDP.

Some economies show changes in income allocation at lower levels of debt/GDP (Trinidad and Tobago 39%) while the majority experience these changes at levels closer to 100% or slightly higher of debt/GDP.
References


