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Output Collapse, Growth and Volatility in Sub-Saharan Africa: A Regime-Switching Approach

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Abstract: A Markov-switching model with time-varying transition probabilities is applied to sub-Saharan African data to examine the link between output collapses and growth. In the model, the growth rate moves discretely between two regimes; one characterised by a stable positive average growth rate, and a collapse regime characterised by negative and volatile growth rate. The aim is to derive plausible estimates of the transition probabilities for the Markov chain component. These estimates are then included in a vector of time-varying country-specific variables for the Markov-switching estimation. The results show that the probability of an economy remaining in a stable growth regime increases with institutional quality, education, improving terms of trade and increased concentration on manufacturing industries. The analysis takes into account the fact that the dynamics of output following a large collapse differs significantly from the dynamics of output during more stable time periods by taking a non-linear approach.

I INTRODUCTION

The failure of most sub-Saharan African economies to conform to economic growth theory is a puzzle that remains largely unanswered. One unwanted characteristic that most sub-Saharan African economies share is the prevalence and magnitude of output collapses. Research into output

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collapses remains largely unexplored. Much of the focus of growth econometrics has been on cross-country analysis, ignoring the volatility of growth patterns. Concentrating on average growth rates gives little insight into the growth patterns of an individual country or how the growth rates evolve over time. Economic growth, particularly in developing economies, undergoes frequent episodes in which the behaviour of the series changes significantly. The growth path of such economies are often characterised by large swings and fluctuations. In these periods the application of linear models seems inappropriate because the changes in regime can alter the long-run growth path of an economy.

In this paper, a Markov-switching model with time-varying transition probabilities is applied to sub-Saharan African data to examine the link between output collapses and growth. In the model, the growth rate moves discretely between two regimes; one characterised by a stable positive average growth rate, and a collapse regime characterised by a negative and volatile growth rate. The Markov-switching model with time varying transition probabilities developed by Diebold *et al.* (1994) is the key component of the analysis. While some authors have postulated various transition probabilities and assessed the different choices, 'real world' estimates are preferable. Therefore, the initial aim is to derive plausible estimates of the transition probabilities for the Markov chain component. These estimates are then included in a vector of time-varying country-specific variables for the Markov-switching estimation. The results show that the probability of an economy remaining in a stable growth regime increases with institutional quality, education, improving terms of trade and increased concentration on manufacturing industries. The analysis takes into account the fact that the dynamics of output following a large collapse differs significantly from the dynamics of output during more stable time periods by taking a non-linear approach.

An output collapse is defined as a fall in the level of output in an economy that is in excess of 10 per cent over a three-year period (Durlauf *et al.,* 2004). Output collapses occur far more frequently in sub-Saharan Africa than in the developed world or emerging economies (Becker and Mauro, 2006). No single factor provides a satisfactory answer as to why this is the case. The most common explanation offered is that these collapses take place during periods of intense civil war, but civil war only partially explains the extent of such collapses among sub-Saharan African nations. To illustrate how dramatic collapses are, Table 1 shows the ten largest real output drops for OECD countries and African countries between 1980 and 2000.[1] It is clear from

[1] Each country is included once showing its largest output drop.

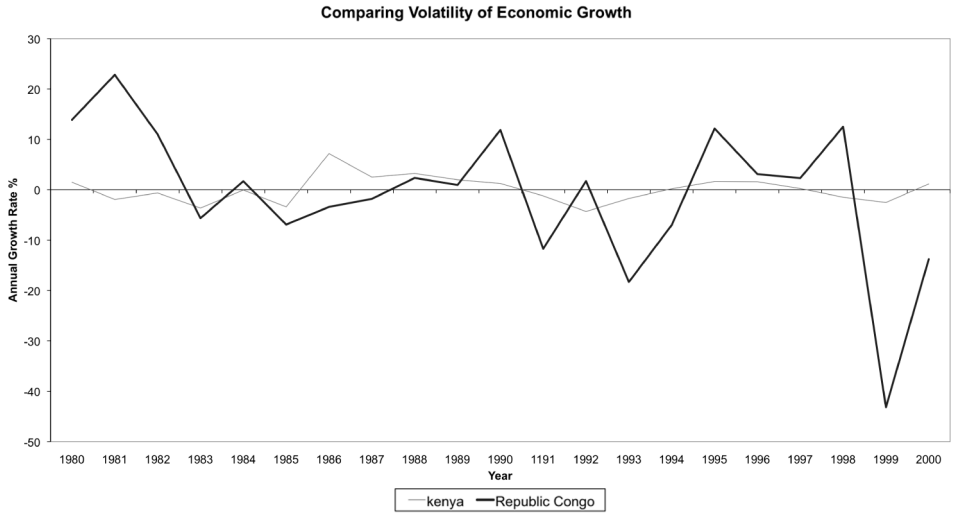
examining the timing of output drops among the OECD countries that a distinct pattern emerges. The largest output drops among this group of countries are all consistent with worldwide external shocks. The world oil shock in 1979 led to a fall in world oil production of 8.9 per cent while the Persian Gulf War in 1990 generated a fall in world oil production of 8.8 per cent. Finland was also contending with the fall of communism in the neighbouring Soviet Union. There is no such consistency among the output drops of the African nations.

Table 1: *Top Ten Output Drops for OECD and African Countries Between 1980 and 2000*

OECD Country	*Output Drop (%)*	*Time Period*	*African Country*	*Output Drop (%)*	*Time Period*
Finland	13.11	1990-1993	Chad	49.85	1980-1983
Switzerland	9.92	1990-1993	Rwanda	46.70	1991-1994
Greece	7.62	1991-1994	Angola	41.27	1990-1993
Iceland	7.17	1990-1993	DR Congo	36.27	1992-1995
Sweden	7.12	1990-1993	Mauritania	34.48	1985-1988
Spain	6.80	1990-1993	Tanzania	34.43	1987-1990
Netherlands	5.86	1990-1993	Mali	33.94	1985-1988
Canada	5.79	1980-1983	Cameroon	33.50	1987-1990
USA	5.37	1980-1983	Nigeria	32.04	1997-2000
UK	3.59	1980-1983	Togo	29.55	1994-1997

Countries that endure output collapses display a high level of volatility around their average growth rate. Unless periods of large drops in output are accounted for, little can be inferred through standard econometric analysis because the dynamics of output following a large collapse can differ significantly from the dynamics of output during stable time periods. Pritchett (2000) observed that comparing countries with similar long-run growth rates but vastly differing volatility levels can lead to biased results. Following the identification of the variables to be used in determining the transition probabilities, the time-varying, two-state Markov-switching model is applied to test the hypothesis that an output collapse causes an economy to switch regimes, thus altering its long run growth path. Two distinct regimes are identified – one characterised by relatively stable positive growth rates, the other a collapse regime characterised by volatile negative average growth rates.

Figure 1: *The Dangers of Ignoring Growth Volatility*



The graph above illustrates the growth experiences of Kenya and The Republic of Congo. Over a twenty year period, the average annual growth rates of these countries were 0.65 per cent and 0.68 per cent respectively. Although the average growth rates are almost identical, it is clear that the growth experiences of the two countries were very different. Higher frequency growth regressions mix the determinants of long-term growth and abrupt shorter-term movement, so including these two countries in such a regression will not take into account how differently growth has evolved. The fact that economic variables behave differently depending upon the stage of the business cycle also needs to be considered in any meaningful analysis.

The remainder of the paper proceeds as follows. Section II provides further motivation for this study and reviews the related literature; real world estimates of the transition probabilities for the Markov chain component are defined and estimated using ordinary least squares analysis in Section III. The two-state time-varying Markov-switching model is defined in Section IV. Section V presents the results and Section VI concludes.

II FURTHER MOTIVATION AND RELATED STUDIES

A substantial body of literature has emerged regarding convergence. Barro and Sala-I-Martin (1992) and Mankiw *et al.* (1992) examine β-convergence, where there is a negative partial correlation between growth in income over

time and its initial level. Sala-I-Martin (1996) concludes that the estimated speeds of β-convergence are so similar across cross-sectional data sets that economies converge at a rate of 2 per cent per year. Quah (1993) notes that b-convergence is uninformative for distribution dynamics because cross-section regressions only capture average behaviour. He describes a theoretical model of ideas and growth where convergence clubs form endogenously. Alternative empirics based on studying the dynamics of evolving distributions are suggested. σ-convergence is viewed as the reduction of the differences in per capita incomes across time, usually measured by the standard deviation of the regional income distribution. Quah (1997) argues in favour of analysing the distribution dynamics directly.

A cursory glance at countries around the world shows vastly differing levels of volatility. Table 2 shows the growth rates and standard deviations of a sample of 89 countries from around the world from 1960 to 2003. The countries with the most volatile growth rates are mainly found in sub-Saharan Africa, the region with the most frequent and catastrophic output collapses.

Empirical studies have found that over one hundred variables significantly contribute towards determining the economic growth rate. Besides raising serious endogeneity issues, it would be counter-productive to include each of these variables in our vector of country-characteristics, so I focus instead on those variables most likely to significantly contribute to the poor growth performance of sub-Saharan African economies.

Empirical evidence finds a strong link between terms of trade and economic growth. Hausmann, Pritchett and Rodrik (2004) find that increases in investment and trade, real exchange rate depreciation and changes to political regimes help explain the reasons behind periods of economic acceleration, while Becker and Mauro (2006) find that adverse changes in the terms of trade are the most costly type of shock for developing countries. They also find that the duration and magnitude of output drops is approximately twice as large for developing countries as it is for emerging countries. One reason for this may be the reliance of most sub-Saharan African economies on primary commodity or extractive industries. The concentration of many nations on particular industries, especially agriculture contributes to output collapses. Prices of primary commodities are falling relative to prices of manufactured commodities contributing to slow economic growth while drought and crop disease often lead to large falls in crop yield. Primary commodity production has been found to be one of the most robust determinants of slow economic growth (Sala-I-Martin, 1997).

Extractive industries are also a primary source of revenue for many sub-Saharan African economies. Of sub-Saharan Africa's total exports 57 per cent are comprised of mining products yet these products make up only 13 per cent

Table 2: *Growth Rates and Standard Deviations of Countries Around the World*

Country	*Growth Mean*	*SD*	*Country*	*Growth Mean*	*SD*
Africa			*Asia*		
Algeria	1.62	8.44	Afghanistan	–2.27	11.62
Botswana	6.19	6.72	Bangladesh	0.51	5.93
Ghana	2.38	9.18	Hong Kong	5.23	5.00
Kenya	0.27	3.72	India	2.91	2.95
Lesotho	3.01	7.44	Iran	1.94	7.84
Liberia	–2.68	18.55	Iraq	1.86	22.92
Malawi	1.39	5.84	Israel	2.58	4.36
Mauritius	3.29	4.45	Japan	3.85	3.83
Mozambique	1.51	6.33	Jordan	–0.27	6.64
Niger	–0.67	6.58	Korea (South)	6.12	4.22
Senegal	–0.34	4.85	Malaysia	4.60	3.64
Sierra Leone	–0.90	5.83	Nepal	1.49	3.14
South Africa	1.28	2.01	Pakistan	2.81	2.70
Sudan	1.43	4.33	Philippines	1.35	3.58
Swaziland	3.06	5.51	Singapore	4.60	4.74
Tanzania	2.02	9.44	Sri Lanka	3.68	3.04
Togo	–0.21	5.79	Syria	2.52	9.66
Tunisia	3.18	3.93	Taiwan	6.39	3.19
Uganda	0.87	5.52	Thailand	4.71	3.77
DR Congo	–1.79	9.19			
Zambia	0.37	8.54			
Zimbabwe	0.47	9.03			
North America, Central America and Caribbean			*Europe*		
Barbados	1.91	4.25	Austria	2.76	2.19
Canada	2.36	2.32	Belgium	2.66	2.15
Costa Rica	1.73	3.12	Cyprus	4.93	7.63
Dominican Republic	3.14	5.34	Denmark	2.05	2.52
El Salvador	1.16	2.88	Finland	2.59	3.62
Guatemala	0.96	2.28	France	2.57	1.90
Haiti	0.72	5.47	Germany	2.25	2.14
Honduras	0.78	3.71	Greece	3.03	4.00
Jamaica	0.66	3.94	Iceland	2.92	4.69
Mexico	1.89	3.58	Ireland	3.99	3.19
Nicaragua	–0.55	5.44	Italy	2.64	2.28
Panama	2.78	4.15	Malta	5.90	5.22
Trinidad and Tobago	2.66	8.03	Netherlands	2.24	2.11
United States	2.41	2.28	Norway	2.97	1.79
			Portugal	3.68	3.82

Table 2: *Growth Rates and Standard Deviations of Countries Around the World (contd.)*

Country	*Growth Mean*	*Growth SD*	*Country*	*Growth Mean*	*SD*
South America			Spain	3.25	2.75
Argentina	0.69	5.40	Sweden	1.98	2.14
Bolivia	0.54	3.67	Switzerland	1.41	2.61
Brazil	2.24	3.91	Turkey	2.25	3.90
Chile	2.23	5.48	United Kingdom	2.21	1.96
Colombia	1.81	1.81			
Ecuador	1.55	4.70	*Pacific*		
Paraguay	1.46	3.16	Australia	2.33	1.90
Peru	0.82	5.44	Fiji	1.59	6.49
Uruguay	1.02	5.37	New Zealand	1.42	3.10
Venezuela	0.20	5.21	Papua New Guinea	3.76	10.65

of the world's trade in merchandise. Sachs and Warner (2001) find that countries with an abundance of natural resources have lower levels of GDP per capita and are characterised by stagnation of growth, while Busby *et al.* (2003) show that different types of natural resource endowments lead to differing capacities to respond to economic shocks. Van der Ploeg and Poelhekke (2009) find that the negative indirect effect of natural resources on growth performance through increased volatility outweigh the beneficial direct effects of natural resource abundance on economic growth. Of the 168 incidences of output collapses in this study, 113 occurred in countries where output is predominantly from the agricultural sector. Fifty-three occurred in countries where fuel and mining products are the main source of output and just two in countries where output is primarily from the manufacturing industry.

Previous studies have also shown that trade is a crucial determinant of economic growth. Crespo-Cuaresma and Worz (2003) find a positive correlation between high-end technology intensive exports and growth. Blattman *et al.* (2003) show that terms of trade movements is an important determinant of economic performance and that less developed countries at the periphery are more sensitive to terms of trade volatility.

Prior to the most recent research, the explanation most often offered to explain output collapses is that they occur during periods of intense civil war. Civil wars cause increasing levels of uncertainty in relation to economic conditions, which in turn lead to increased risk to investment and subsequent capital flight. In sub-Saharan Africa, twenty-nine of the thirty-nine countries

in the sample have experienced civil war during the period examined. The conventional wisdom is to halt development efforts during periods of conflict and redirect aid towards immediate relief programmes. Undoubtedly, there are complex interactions between events associated directly with war and the economy that contribute toward falling output. Rodrik (2000) argues that domestic social conflicts are the main reason behind growth collapses because internal conflict reduces a country's ability to deal with the impact of external shocks. Collier (1999) finds that civil war reduces annual growth by approximately 2.2 per cent. In a comprehensive study of growth econometrics, Durlauf *et al.* (2004) point out that although civil war is most likely a contributing factor to an output collapse, the collapses are too common an occurrence and too significant in magnitude for civil war to be the only factor. Including a variable for civil war in the regression analysis is problematic. Estimating the causal effect of economic growth and civil war is extremely difficult. Does civil war lead to lower growth or does low growth cause civil war? Estimating the impact through an instrumental variables technique ultimately leads to the same issue of multi-collinearity. It is, however, reasonable to assume that countries with low levels of institutions are more prone to civil war because institutions can lead to a better management of conflicts and ethnic diversity. The quality of institutions reflect the extent of social divisions. Easterly *et al.* (2006) find that societies with lower initial inequality and more linguistic homogeneity have more social cohesion and thus a better quality of institutions.

Institutional quality is a central factor to economic activity (Rodrik, 2004), Aron, (2000). Foreign firms are much more likely to invest in countries that have a good legal system which allows for legal contracts to be defined and enforced, thus giving stability to their investment. By attracting foreign investment, countries can accumulate capital and knowledge and thus enjoy long-term growth. Barro (1999) estimated the effect of an improvement of the rule of law on growth. Using figures from the *Economic Freedom Index*, he found that an improvement by one category in the political risk section increases growth by 0.5 per cent per annum and that most of this increase occurs through an increase in investment. Institutions have both a direct effect on growth and an indirect effect. Improving institutional quality can indirectly affect growth through increased investment, increased integration and trade, increased stock of social capital, improved management of conflicts and increased political stability.

Research has also shown that education plays an important role in determining the growth rate in an economy Barro, 1991, Hanushek and Woessman (2009). A group of models (for example, Lucas, 1988; Mankiw *et al.,* 1992) views human capital as an input in the production function that can be accumulated by investment in schooling, or learning by doing. In such models,

investment in human capital stimulates growth. Therefore, a measure for education will be included in the initial analysis.

Following the identification of the causes of an output collapse, the focus of the paper changes to concentrate on capturing the effect these collapses have on the long-run growth path. In order to achieve this, a two-regime Markov-switching model with time-varying transitional properties is applied. Initially explored by Hamilton (1989), the Markov-switching model is widely used as it allows for non-linearities in the economic growth process. One limitation of Hamilton's model is that the transition properties are fixed. The use of a regime-switching model that allows for probabilities to change over time can yield more accurate estimates of the process. Filardo (1994) and Diebold *et al.* (1994) developed the Markov-switching model with time-varying transition probabilities in order to capture the systematic changes in the transition probabilities before and after turning points. By applying the time-varying model, underlying economic fundamentals and policy shocks can affect the transition probabilities. Markov-switching models have been used to analyse business cycle fluctuations (Diebold *et al.,* 1994; Engel and Hakkio, 1996; Moolman, 2004), risk-return tradeoffs in emerging markets (Chang and Ho, 2007) and Colombian economic growth (Misas and Ramirez, 2006).

The main advantage of regime switching models is their ability to model series that have irregular cycles. Regime switching models are characterised by a number of distinct and discrete regimes within which different model parameters apply. The model will periodically switch from one regime to another and these switches represent structural changes occurring in the process that is being modelled. The hypothesis here is that the economic growth process of sub-Saharan African economies can be thought of as switching between two regimes; one a relatively stable growth regime, the other characterised by volatile and negative growth.

III TIME-SERIES ANALYSIS

The first stage of the analysis focuses on the causes of an output collapse. The ordinary least squares analysis is conducted in order to give some idea of the variables to be included in the vector of country-characteristics for the Markov-switching model. The initial model regresses the fall in output on the variables discussed in the previous section – education, terms of trade, institutions and the composition of output. The literature suggests that growth regressions may be subject to endogeneity issues, leading to biased results. For example, the results can be biased because the quality of institutions may be endogenous to the level of development of a country. It

may be the case that only relatively wealthy countries can afford to implement good institutions. A solution often used is to apply an instrumental variables approach to account for this bias (Acemoglu *et al.*, 2008). In this case, however, the dependent variable is the fall in output as opposed to output levels. Therefore, it is possible that variables such as institutions and education levels are less likely to be determined by a change in output than they are by output levels.

Data

The period examined is 1960 to 2004[2] and includes all sub-Saharan economies for which there is available data. The measure of output collapse is the percentage drop in GDP per worker over each three-year period. Data for GDP/Worker is taken from the Heston *et al.*, dataset.[3] GDP per worker is used because it is a more accurate measure of productivity than GDP per capita. Terms of Trade data is taken from the World Trade Organisation *International Trade Statistics*, and the measure of institutional quality comes from the *Country Indicators for Foreign Policy* (CIFP). Data on educational attainment is obtained from the Lee and Barro (2001) dataset.

The Model

The model takes the following form:

$$Y_t = \begin{array}{l} \beta_0 + \beta_1(Edu) + \beta_2(T.O.T) + \beta_3(Inst.) + \beta_4(Manuf) \\ + \beta_5(Agr.) + \beta_6(Fuel) + u_i \end{array} \quad (1)$$

These variables are explained in more detail in Table 3.

Table 3: *Notation and Explanation of Variables in Model*

Notation	*Explanation*
y_t	Percentage drop in output in country i between time t and time t+3.
Edu	Level of education in country i at time t.
TOT	Terms of trade in country i at time t (1980=100).
Inst	Quality of institutions in country I at time t.
Manuf	Dummy variable that takes on the value of 1 if <50 per cent of output is made up of manufacturing products and 0 otherwise.
Agr	Dummy variable that takes on the value of 1 if <50 per cent of output is made up of agricultural products and 0 otherwise.
Fuel	Dummy variable that takes on the value of 1 if <50 per cent of output is made up of fuel and mining products and 0 otherwise.

[2] For some countries, the sample period is shorter due to data availability.
[3] The Penn World Tables Version 6.2 is used in this analysis.

Results

The results from the model are presented below.

Table 4: *Results from OLS Model*

Variable	*Coefficient*	*P-Value*
Constant	2.86	0.168
Education	–1.73	2.1E-04***
Terms of Trade	–0.048	0.001***
Institutions	–1.546	5.5E-05***
Agriculture Dummy	2.82856	0.0689*
Fuel Dummy	–2.1710	0.2134
Manufacturing Dummy	–6.3639	0.0037**
R^2	0.432	
Observations	1,609	

*Denotes significance at 10 per cent level, **denotes significance at 5 per cent level, *** denotes significance at 1 per cent level.

All variables except the dummy fuel variable are found to be statistically significant and of the expected sign. Deterioration in terms of trade and poor institutional quality both contribute to a collapse in output. The finding that predominantly agricultural economies are more volatile than predominantly manufacturing economies conforms to previous findings. The coefficient on the manufacturing dummy is high. This fits in with the data because only two of the collapses in the sample occur in countries where output comes from predominately manufacturing industries.

The variables that have been found to be statistically significant in this analysis will be included in the transitional probability vector for the Markov-switching analysis.

IV MARKOV SWITCHING ANALYSIS

As mentioned previously, output collapses are more prevalent and of longer duration in sub-Saharan Africa than any other region of the world. In the preceding section I established the causes of these collapses. The issue I address now is the effect such output collapses have on the long-run growth prospects of an economy. The growth path of a country displays different behaviour during periods of stable growth and periods of collapse. In order to capture this asymmetry, I apply a two-state Markov-switching model with time-varying transition probabilities. The regime-switching model combines

two or more sets of model parameters into one system. The regime the system is likely to be in at a certain time determines which set of parameters (coefficients) should be applied. For example, a two-state switching model takes the form:

$$Y_t = \begin{cases} x(t) \times b_1, \; s(t) = 1 \\ x(t) \times b_2, \; s(t) = 2 \end{cases} \tag{2}$$

Where $s(t)$ denotes the state the economy is in at time t. The first set of parameter estimates apply to the observed independent variables when the system is in state 1; the second set apply when the system is in state 2. This system can be extended to incorporate any number of regimes. $s(t)$ is determined by a Markov chain which itself depends on a transition matrix. The transition matrix gathers the probabilities that one particular state is followed by another particular state. In modelling the regime changes, it is assumed that at some point in the sample, the mean value of the growth rate will shift to another value. In this study, this will occur when a country moves from a stable to a collapse regime. The probability of being in a particular regime is inferred from the data. The two-state Markov-switching model is estimated using annual data on real GDP per worker for the period 1960-2004. The variables included in the transition probability vector are the variables that were identified as the main causes of output collapses – terms of trade, institutional quality, output composition, and education.

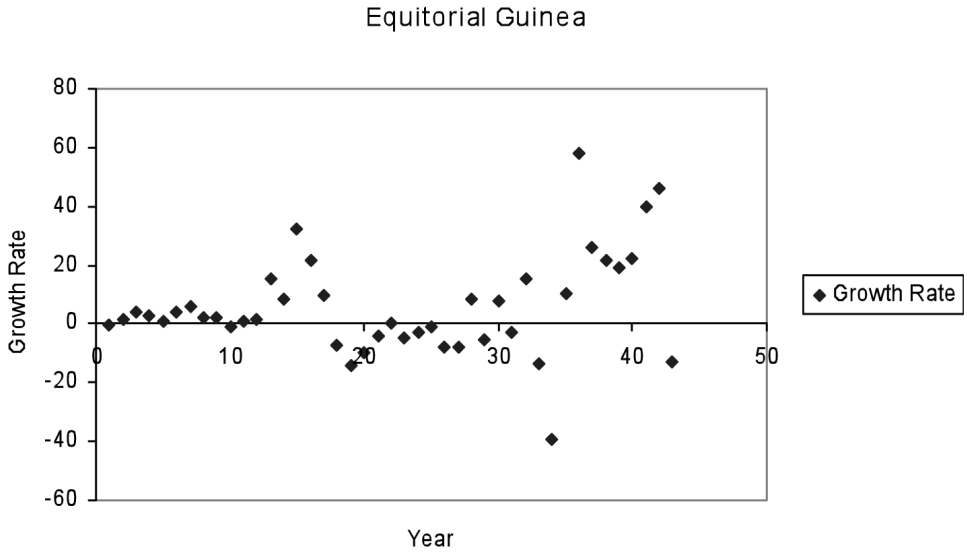
The Model

In using Markov-switching models, the first challenge is to determine the true number of regimes. The idea behind regime switching models is that the parameters of the underlying data generating process of the observed time series vector depends on an unobservable regime variable , the probability of being in a certain state. If there is insufficient information in the series, the regime classification will be weak. Badly parameterised switching models may not be an improvement over models that do not allow for switching.

Looking for the number of regimes is equivalent to looking for the number of regression lines that will best fit the data. Figure 2 shows the graph of the growth rate of Equatorial Guinea. It is clear from the graph that two regression lines are a better fit to the data than one.

I begin by assuming two regimes, then adding an additional regime. I find that a two-regime model captures the series appropriately. The finding of two regimes can be confirmed by a further test. I apply a regime classification measure (RCM) introduced by Ang and Bekaert (2002). The RCM provides a measure of the information of regime switches available in the data. The measure relies on the estimated filtered probabilities of the states from the

Figure 2: *Choosing the Number of Regimes*



model that indicate the likelihood of a particular regime. The RCM is given by the following:

$$RCM = 400X\frac{1}{T}\sum_{t=1}^{T} ps_{1,\,t}\,(1 - ps_{1,\,t}),$$

where $ps_{1,\,t}$ is the smoothed probability of being in regime 1 at time t, and the constant normalises the statistic to between 0 and 100. The same method can be applied to $ps_{2,\,t}$. In the case of a perfect regime classification, the inferred state probability for a particular data point would be 0. A statistic of 100 indicates no regime classification. Here, the RCM for state 1 is 19.58 and for state 2 is 36.48 indicating that both regimes are well defined.

To apply a regime-switching model, I must first consider how growth evolves. S.I.C. and A.I.C. criterion both choose an AR(1) model of growth. Therefore, I assume there are 2 possible states of nature and that in each state, growth follows an AR(1) process.

$$\begin{aligned} y_{it} &= \alpha_{st} + \beta_{1st} y_{t-1i} + \varepsilon_{it}^{st}, \\ \varepsilon_{it}^{st} &\sim i.i.d.N(0,\, \sigma_{st}^2) \end{aligned} \tag{3}$$

y_{it} is the growth rate of country i in period t.
s_t is the state that is in effect at time t.

In the time invariant model, the regime follows a first order Markov-chain:

$$\begin{aligned} &p[s_t = 1 \mid s_{t-1} = 1] = p_{11} \\ &p[s_t = 2 \mid s_{t-1} = 2] = p_{22} \\ &p[s_t = 2 \mid s_{t-1} = 1] = p_{12} \\ &p[s_t = 1 \mid s_{t-1} = 2] = p_{21} \end{aligned} \tag{4}$$

P_{11} is the probability of an economy remaining in regime 1 at time t, given that the economy was in regime 1 at time t – 1; $1 - P_{11}$ is the probability of an economy switching from regime 1 to regime 2. P_{22} is the probability of remaining in regime 2 at time t, given that the economy was in regime 2 at time t – 1; $1 - P_{22}$ is the probability of switching from regime 2 to regime 1.

To allow the transition probabilities to depend on the macroeconomic variables obtained in Section II in order to explain the probability of switching from one regime to another, we follow the method of Diebold *et al.* (1994). In this case, Equation (4) becomes:

$$\begin{aligned} &p[s_t = 1 \mid s_{t-1} = 1] = p_{11}(\psi_t) \\ &p[s_t = 2 \mid s_{t-1} = 2] = p_{22}(\psi_t) \\ &p[s_t = 2 \mid s_{t-1} = 1] = p_{12}(\psi_t) \\ &p[s_t = 1 \mid s_{t-1} = 1] = p_{21}(\psi_t) \end{aligned} \tag{5}$$

where ψ_t is the country-specific vector of exogenous variables.

The transition probabilities are modelled as a logistical functional form

$$\begin{aligned} p_{11} &= \frac{\exp\,(\beta_{11}(1) + \beta_{11}(2) * \psi_t)}{(1 + \exp\,\beta_{11}(1) + \beta_{11}(2)\psi_t + \exp\,(\beta_{12}(1) + \beta_{12}(2) * \psi_t)} \\ p_{12} &= 1 - \frac{\exp\,(\beta_{11}(1) + \beta_{11}(2) * \psi_t)}{(1 + \exp\,\beta_{11}(1) + \beta_{11}(2)\psi_t + \exp\,(\beta_{12}(1) + \beta_{12}(2) * \psi_t)} \\ p_{21} &= 1 - \frac{\exp\,(\beta_{21}(1) + \beta_{21}(2) * \psi_t)}{(1 + \exp\,\beta_{21}(1) + \beta_{22}(2)\psi_t + \exp\,(\beta_{22}(1) + \beta_{22}(2) * \psi_t)} \\ p_{22} &= \frac{\exp\,(\beta_{21}(1) + \beta_{21}(2) * \psi_t)}{(1 + \exp\,\beta_{21}(1) + \beta_{22}(2)\psi_t + \exp\,(\beta_{22}(1) + \beta_{22}(2) * \psi_t)} \end{aligned} \tag{6}$$

To estimate the model, the complete data likelihood function must be specified. The conditional density depends on both current and past regimes. The state variable S_t is unobservable so it is not possible to construct the

complete likelihood in practice. It can be obtained by using the EM algorithm applied by Hamilton (1990).

V RESULTS

The results of the model for the entire sample of countries are presented below.

Table 5: *Markov-Switching Model with Time-Varying Transition Probabilities Within Regime Estimates of* $y_{it} = \alpha_{st} + \beta_{1st} y_{t-1t} + \varepsilon_{it}^{st}$

	Constant	*AR Coefficient*	σ_s	*Implied LR Growth*
State 1	0.00527*	0.095***	0.0320	0.71%
State 2	–0.0105*	0.065*	0.0551	–1.31%
$p_{11} = 0.89$				
$p_{22} = 0.76$				

***denotes significance at 1 per cent level, **denotes significance at 5 per cent level, *denotes significance at 10 per cent level.

State 1 has a low positive growth rate, relatively low autocorrelation and quite a large standard deviation of growth rates. State 2 has a negative growth rate, lower autocorrelation and a much larger standard deviation. The transition probabilities show that the level of persistence in each regime is quite high indicating that when a country is in a particular regime in one period, it is highly likely to remain there in the next period. State 1 is a more stable regime than state 2. However, the volatility levels associated with regime 1 are high. This would seem to indicate that the levels of volatility associated with output in sub-Saharan Africa, are higher than elsewhere, even for countries that are performing relatively well. This confirms the results shown in Table 2. Increasing volatility stems mostly from external shocks. The probability of an economy remaining in a stable growth regime increases with education, institutional quality, improving terms of trade and increased concentration on manufacturing industries. Countries with good quality institutions, terms of trade, and diversity of output spend a higher proportion of time in the stable regime. When these countries do end up in the collapse regime, they are unlikely to remain there as they are in a better position to recover from shocks to output. In contrast, predominantly agricultural economies, with deteriorating terms of trade and poor institutional quality are much more likely to spend a significant amount of time in state 2, the

"collapse" regime. This regime is characterised by negative annual growth of –1.31 per cent on average and extremely high levels of volatility. The probability of remaining in a collapse regime, given that an economy was in a collapse regime at time t-1 is 0.76. Thus, an economy that is in a collapse regime is likely to remain there. This is in all probability because these economies are poorly equipped to deal with a shock thus precluding the possibility of stable and sustainable growth. It is important to note that every country in the sample visits each regime at some point in time.

It is the amount of time spent in each regime that is crucial in determining economic growth performance of an individual country.

The expected duration of remaining in a particular regime is given by:

$$E(D_j) = \sum_{k=0}^{\infty} kP(D_j = k) = \frac{1}{1 - P_{jj}}, \tag{7}$$

While the expected duration for the entire sample of countries is 9.47 years for state 1 and 4.25 years for state 2, the expected durations differ substantially across countries. A higher proportion of time spent in state 2 corresponds to being more susceptible to, and slower to recover from, adverse shocks. Table 6 shows the probabilities associated with, and the expected duration of remaining in, each regime for every country in the sample. The higher the probability associated with a regime, the longer the expected duration of remaining in that regime.

For example, the countries with the longest expected durations of remaining in regime 1 include Botswana, Malawi, Equatorial Guinea and Lesotho. The average long-term growth rates of these countries are all positive- 6.45 per cent, 1.67 per cent, 6.95 per cent and 3.24 per cent respectively. These countries also spend a relatively short amount of time in regime 2. Conversely, the countries with the longest expected duration of remaining in regime 2 include Democratic Republic of Congo, Somalia, Niger, and Liberia. The average long-term growth rates are –4.16 per cent, –1.92 per cent, –0.70 per cent and –2.61 per cent respectively. The results imply that some countries recover from shocks relatively quickly, while others such as Liberia and Somalia are much slower to emerge

Neither of the regimes identified are particularly desirable. Although state 1 is more desirable than state 2, it is worth noting that this is a regime that is characterised by very low, almost stagnant growth rates. The results lend support to the notion that many sub-Saharan African economies are stuck in a poverty trap and are just too poor to achieve sustainable positive growth. The results also confirm that an output collapse can trigger an economy to switch regimes, thus altering its long-run growth path.

Table 6: *Probabilities and Expected Durations of Each Regime*

	P_{11}	*Duration State 1*	P_{22}	*Duration State 2*
Botswana	0.96	25 years	0.61	2.56 years
Burkina Faso				
Burundi	0.88	8.33 years	0.86	7.14 years
Cameroon	0.78	4.54 years	0.92	12.5 years
Central African Republic				
Chad	0.90	10 years	0.88	8.33 years
Congo, Democratic Republic	0.71	3.44 years	0.94	16.67 years
Congo, Republic	0.74	3.85 years	0.93	14.29 years
Cote d'Ivoire	0.91	11.11 years	0.83	5.88 years
Equatorial Guinea	0.92	12.5 years	0.85	6.67 years
Ethiopia	0.88	8.33 years	0.66	2.95 years
Gabon	0.89	9.09 years	0.77	4.35 years
Gambia, The	0.96	25 years	0.49	1.96 years
Ghana	0.67	3.03 years	0.37	1.59 years
Guinea	0.88	8.33 years	0.86	7.14 years
Guinea Bissau	0.70	3.33 years	0.72	3.57 years
Kenya	0.91	11.11 years	0.85	6.67 years
Lesotho	0.93	14.29 years	0.75	4 years
Liberia	0.83	5.88 years	0.95	20 years
Madagascar	0.62	2.63 years	0.95	20 years
Malawi	0.94	16.67 years	0.81	5.26 years
Mali	0.90	10 years	0.85	6.67 years
Mauritania	0.86	8.33 years	0.84	6.25 years
Mauritius	0.92	12.5 years	0.64	2.77 years
Mozambique	0.51	2.04 years	0.69	3.23 years
Namibia	0.61	2.56 years	0.74	3.85 years
Niger	0.21	1.27 years	0.90	10 years
Nigeria	0.87	7.69 years	0.78	4.55 years
Rwanda	0.87	7.69 years	0.38	1.61 years
Senegal	0.73	3.7 years	0.865	7.41 years
Somalia				
South Africa	0.90	10 years	0.35	1.54 years
Tanzania	0.78	4.54 years	0.89	9.09 years
Togo	0.95	20 years	0.84	6.25 years
Uganda	0.84	6.25 years	0.915	11.76 years
Zambia	0.83	5.88 years	0.91	11.11 years
Zimbabwe	0.91	11.11 years	0.86	7.14 years

Policy Implications

The findings here have important policy implications. Growth and development in sub-Saharan Africa have stagnated over the last four decades. In order for these economies to achieve sustained economic growth, the

frequencies of output collapses, which drive economies into regime 2, must be substantially reduced. There appear to be a number of factors that has constrained the growth and development process in sub-Saharan Africa.

Sub-Saharan African economies are largely dependent on volatile primary commodities for export due to limited diversification. Africa has an abundance of natural resources but the opportunities to maximise the contribution they can make to an economy are not being taken. Many sub-Saharan African economies have a comparative advantage in natural resources but poor governance means they cannot exploit this advantage. Improving natural resource management through improved institutional quality, increasing participation in decision-making and improving social protection for workers could help these economies increase revenues. Improving land rights and governance could enhance agricultural production, and the potential for an expansion of agricultural trade through increased diversification should be considered. Moving away from primary industries to manufacturing industries can also increase market access opportunities and leave economies less vulnerable to deteriorating terms of trade. Major investments in infrastructure will enhance the supply side capacity, improving output. This approach may depend on increased donor grants. Another way to limit their vulnerability to price volatility is to form new international commodity associations.

One of the most frequently cited reasons that sub-Saharan African economies stagnate is their poor quality of institutions. In order to use public and private resources, and financial aid effectively, an improvement of public financial management is essential. Improved transparency and accountability is required if sub-Saharan African economies are to attract foreign investment. Currently, potential external investors overestimate the risk associated with investing in African countries.

VI CONCLUDING REMARKS

Although the typical cross-section approach to understanding economic growth has yielded many important results, this approach ignores the different paths an individual country may take. Further analysis of this kind is unlikely to add considerably to our current understanding of the growth process. The regime-switching model gives an important understanding of output collapses in sub-Saharan Africa and their subsequent impact on the long-term growth performance of an economy. Both of the regimes identified in the analysis displayed high levels of volatility around the mean, confirming that the sub-Saharan region as a whole is more volatile in terms of output.

This conforms to the fact that output collapses are more frequent an occurrence in sub-Saharan Africa than elsewhere. The incidences of output collapses could be reduced by increasing institutional quality or improving the terms of trade by switching away from agricultural industries to focus more on manufacturing or service-based industries. However, the question remains as to whether these countries have the ability to make such a switch. It is likely that significant infrastructural investment in education, transport, telecommunications etc. would be required to make this a feasible policy. Nations at the G8 summit in 2009 have pledged US$20 billion over the next three years to promote sustainable agricultural development in developing countries. The money is to be used to provide emergency food aid and to implement a comprehensive strategy focused on sustainable agricultural development.

Although the processes of improving institutional quality and terms of trade would be difficult and slow-moving policies to implement in practice, lower volatility levels should encourage foreign investment, further enhancing economic growth prospects and limiting output collapses. Through these mechanisms, sub-Saharan Africa may gradually emerge from the poverty trap and begin to conform to economic growth theory and converge with other economies. One possible extension of this analysis is to include emerging and industrialised countries in the model and allow for a greater number of regimes to be identified. This would allow for a direct comparison of volatility levels and long-term growth paths of different kinds of economies while allowing for non-linearities of the process.

REFERENCES

ACEMOGLU, D., S. JOHNSON, J. ROBINSON and P. YARED, 2008. "Income and Democracy". *American Economic Review,* Vol. 98, No. 3, pp. 808-842.

ALVAREZ-PLATA, P. and M. SCHROOTEN, 2006. "The Argentinean Currency Crisis: A Markov-Switching Model Estimation", *The Developing Economies,* Vol. 44, No. 1, pp 79-91.

ARON, J., 2000. "Growth and Institutions: A Review of the Evidence", *World Bank Research Observer,* Vol. 15, No. 1, pp. 99-135.

BARRO, R. J., 1991. "Economic Growth in a Cross-section of Countries", *Quarterly Journal of Economics*, Vol. 106, No. 2 (May), pp. 407-443.

BARRO, R. J. and X. X. SALA-I-MARTIN, 1992. "Convergence", *Journal of Political Economy,* Vol. 100, pp. 223-251.

BECKER, T. and MAURO, P., 2006. "Output Drops and the Shocks That Matter," IMF Working Papers 06/172.

BLATTMAN, C., J. HWANG and J. WILLIAMSON, 2003. "The Impact of the Terms of Trade on Economic Development in the Periphery, 1870-1939: Volatility and Secular Change". NBER Working Paper No. 10600.

BLOOM, D. and J. SACHS, 1998. "Geography, Demography, and Economic Growth in Africa", *Brookings Papers on Economic Activity*.

BUSBY, G., J. ISHAM, L. PRITCHETT and M. WOOLCOCK, 2003. "The Varieties of Resource Experience: How Natural Resource Export Structures Affect the Political Economy of Economic Growth", Middlebury College Discussion Paper No. 2003-08, Middlebury College, Vermount.

C.I.A. *World Factbook 2002*. United States Central intelligence Agency.

COLLIER, P. and A. HOEFFLER, 1998. "On Economic Causes of Civil War", *Oxford Economic Papers,* Vol. 4, pp. 563-573.

COUNTRY INDICATORS FOR FOREIGN POLICY (C.I.F.P.). www.Carleton.ca/cifp

CRESPO-CAURESMA, J. and J. WORZ, 2003. "On Export Composition and Growth". *Vienna Economics Papers 0309*, University of Vienna.

DIEBOLD, F., J. H. LEE and G. WEINBACH, 1994. "Regime Switching with Time-varying Transition Probabilities" in Colin P. Hargreaves (ed.), *Non-stationary Time Series Analysis and Cointegration,* pp. 283-302. Oxford University Press.

DIEBOLD, F. and G. RUDEBUSCH, 1999. "Measuring Business Cycles: A Modern Perspective", *Business Cycles: Durations, Dynamics and Forecasting,* Princeton University Press.

DURLAUF, S., P. JOHNSON and J. TEMPLE, (2004. "Growth Econometrics", Vassar College Department of Economics Working Paper Series 61, Vassar College Department of Economics.

ELBADAWI, I and H. HEGRE, 2004. "Globalization, Economic Shocks, and Armed Conflict". Paper presented at conference on 'Globalization, Territoriality and Conflict', University of California, San Diego.

ENGEL, C. and C. HAKKIO, 1996. "The Distribution of Exchange Rates in the EMS", *International Journal of Finance and Economics,* John Wiley and Sons Ltd., Vol. 1, No. 1, pp 55-67.

FEARON, J. and D. LAITIN, 2003. "Ethnicity, Insurgency, and Civil War", *American Political Science Review*, Vol. 97, pp. 75-90.

FILARDO, A., 1994. "Business-cycle Phases and their Transitional Dynamics", *Journal of Business and Economic Statistics,* Vol. 12, No. 3, pp. 299-308.

HAMILTON, J., 1989. "A New Approach to the Economic Analysis of Non-stationary Time Series and the Business Cycle", *Econometrica,* Vol. 57, pp. 357-384.

HAMILTON, J., 1990. "Analysis of Time Series Subject to Changes in Regime", *Journal of Econometrics,* Vol. 45, pp. 39-70.

HAMILTON, J., 1994. *Time Series Analysis*, Princeton University Press.

HAUSMANN, R., L. PRITCHETT and D. RODRIK, 2004. "Growth Accelerations". NBER Working Paper No. 10566, June, MA: National Bureau of Economic Research, Cambridge.

HANUSHEK, E. and L. WOESSMANN, 2009. "Do Better Schools Lead to More Growth? Cognitive Skills, Economic Outcomes, and Causation", NBER Working Paper No. 14633, National Bureau of Economic Research.

HESTON, A., R. SUMMERS and B. ATEN, 2006. "Penn World Tables Version 6.2", Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania (CICUP).

KIM, C. J., 1994. "Dynamic Linear Models with Markov-Switching", *Journal of Econometrics,* Elsevier, Vol. 60, Nos. 1-2, pp 1-22.

LEE, J. W. and R. J. BARRO, 2001. "Schooling Quality in a Cross-section of Countries", *Economica*, London School of Economics and Political Science, Vol. 68, No. 272, pp. 465-488.

LUCAS, R., 1988. "On the Mechanics of Economic Development", *Journal of Monetary Economics,* Vol. 22, pp. 3-42.

MANKIW, N. G., D. ROMER and D. WEIL, 1992. "A Contribution to the Empirics of Economic Growth", *The Quarterly Journal of Economics,* Vol. 107, (May), pp. 407-437.

MISAS, M. and M. T. RAMIREZ, 2006. "Colombian Economic Growth under Markov Switching Regimes with Endogenous Transition Probabilities", *Borradores,* 425, Banco de la Republica de Colombia.

MOOLMAN, E., 2004. "A Markov-Switching Regime Model of the South African Business Cycle", *Economic Modelling,* Vol. 21, No. 4, pp. 631-646.

PRITCHETT, L., 2000. "Understanding Patterns of Economic Growth: Searching for Hills among Plateaus, Mountains, and Plains", *World Bank Economic Review,* Vol. 14, No. 2, pp. 221-250.

QUAH, D. T., 1993. "Galton's Fallacy and Tests of the Convergence Hypothesis", *Scandinavian Journal of Economics,* Blackwell Publishing, Vol. 95, No. 4, p. 427-443.

QUAH, D. T., 1997. "Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs", *Journal of Economic Growth,* Vol. 2, pp. 27-59.

RODRIK, D., 2000. "Where Did All the Growth Go?: External Shocks, Social Conflict, and Growth Collapses"*, Journal of Economic Growth*, Vol. 4, pp. 385-412.

RODRIK, D., 2004. "Getting Institutions Right", *CESifo DICE Report,* Harvard University, April.

ROMER, P., 1986. "Increasing Returns and Long Run Growth", *Journal of Political Economy,* Vol. 94, pp 1002-1037.

ROMER, P., 1990. "Endogenous Technological Change", *Journal of Political Economy,* Vol. 98, No. 5, pp. s71-s102.

ROS, J., 2005. "Divergence and Growth Collapses: Theory and Empirical Evidence" in Jose Antonio Ocampo (ed.), *Beyond Reforms, Structural Dynamics and Macroeconomic Vulnerability*, New York: Stanford University Press.

SACHS, J. D., and A. WARNER, 2001. The Curse of Natural Resources*", European Economic Review,* Vol. 45, No. 4, pp. 827-838.

SALA-I-MARTIN, X., 1996. "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence", *European Economic Review,* Vol. 40, pp. 1325-1352.

SALA-I-MARTIN, X., 1997. "I Just Ran Two Million Regressions*", American Economic Review, Papers and Proceedings,* Vol. 87, No. 2, pp. 178-183.

UNCTAD: United Nations Conference on Trade and Development. *www.unctad.org*

VAN DER PLOEG, R. and S. POELHEKKE, 2009. "Volatility and the Natural Resource Curse", *Oxford Economic Papers*, Vol. 61, Issue 4, pp. 727-760.