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Abstracts of recent postgraduate theses and dissertations at South African universities

Essays on statistical economics with applications to financial market instability, limit distribution of loss aversion and harmonic probability weighting functions.
By Godfrey-Charles Cadogan for Ph.D in Behavioural Finance (Economics and Actuarial Science) at University of Cape Town, 2016

This dissertation is comprised of four essays. It develops statistical models of decision making in the presence of risk with applications to economics and finance. The methodology draws upon economics, finance, psychology, mathematics and statistics. Each essay contributes to the literature by either introducing new theories and empirical predictions or extending old ones with novel approaches.

The first essay (Chapter II) includes, to the best of our knowledge, the first known limit distribution of the myopic loss aversion (MLA) index derived from micro-foundations of behavioural economics. That discovery predicts several new results. We prove that the MLA index is in the class of a-stable distributions. This striking prediction is upheld empirically with data from a published meta-study on loss aversion; published data on cross-country loss aversion indexes; and macroeconomic loss aversion index data for the US and South Africa. The latter results provide contrast to Hofstedes cross-cultural uncertainty avoidance index for risk perception. We apply the theory to information-based asset pricing and show how the MLA index mimics information flows in credit risk models. We embed the MLA index in the pricing kernel of a behavioural consumption-based capital asset pricing model (B-CCAPM) and resolve the equity premium puzzle. Our theory predicts: (1) stochastic dominance of good states in the B-CCAPM Markov matrix induce excess volatility; and (2) a countercyclical fourfold pattern of risk attitudes.

The second essay (Chapter III) introduces a probability model of 'irrational exuberance' and financial market instability implied by index option prices. It is based on a behavioural empirical local Lyapunov exponent (BELLE) process we construct from micro-foundations of behavioural finance. It characterises stochastic stability of financial markets, with risk attitude factors, in fixed point neighbourhoods of the probability weighting functions implied by index option prices. It provides a robust early warning system for market crash across different credit risk sources. We show how the model would have predicted the Great Recession of 2008. The BELLE process characterises Minsky's financial instability

hypothesis that financial markets transit from financial relations that make them stable to those that make them unstable.

The third essay (Chapter IV) introduces an outcome-dependent harmonic probability weighting function (HPWF) based on an information theory of stochastic choice. We use the HPWF to resolve the preference reversal (PR) puzzle, which is observed in economics and psychology experiments when a decision maker's (DM's) preferences over the same items change depending upon how she is subsequently asked to construct a preference. We use the principle of maximum entropy to synthesise information processing, probabilistic choice, and momentary fluctuation hypotheses proposed by various researchers to explain intransitivity implied by PR phenomenon. The HPWF theory is illustrated via simulation. Additionally, we show how the HPWF decomposes regret theory, and rank dependent utility (RDU), into core expected utility theory (EUT) plus functionally equivalent stochastic error addends. This theoretical prediction finds support in Hey and Orme's (1994) seminal experiments on the difference between generalised EUT and core EUT models.

We also prove that experimenter interference with the probability cycle of the DM's HPWF causes them to observe preference reversal in stochastic choice experiments even though the true state is transitive and there is no violation of procedure invariance.

The fourth essay (Chapter V) shows that Bernoulli's (1738) original utility function is alive and well. For example, several papers reexamine Bernoulli's (1738) expected utility resolution of the St Petersburg Paradox in the context of cumulative prospect theory (CPT). We go a step further. We reexamine the geometry of Bernoulli's original sketch of his utility function. We prove that contrary to received literature, which alleges that Bernoulli's utility function is unable to generate a loss aversion index (ULA), the geometry of Bernoulli's original sketch accommodates a ULA index with smooth reference dependent utility functions. In fact, it provides a solution to the open problem of a closed-form global ULA index formula in prospect theory. Like in the first essay, the ULA index predicted by Bernoulli's utility function is a-stable. Under fairly mild assumptions, we show how it supports a Fisher z-transform statistical test for the loss aversion index and we show how the test can be applied.

Compound Lévy random bridges and credit risky asset pricing

By Dennis Ikpe for Ph.D Financial Mathematics (Mathematics and Actuarial Science) at University of Cape Town, 2016

In this thesis, we study Random Bridges of a certain class of Lévy processes and their application to credit risky asset pricing. In the first part, we construct the compound random bridges (CLRBs) and analyse some tools and properties that make them suitable models for information processes. We focus on the Markov property, dynamic consistency, measure changes and increment distributions. Thereafter, we study their applications in credit risky asset pricing. We generalise the information-based credit risky asset pricing framework to incorporate prematurity default possibilities. Lastly we derive closed-form expressions for default trend and intensities for a randomly-timed cash flow with a CLRB as the background partial information process. We obtain analytical expressions for specific CLRBs. The

second part looks at the application of stochastic filtering in the current information based asset pricing framework. First, we formulate our information-based framework as a filtering problem under incomplete information. We derive the Kalman–Bucy filter in one dimension for bridges of Lévy processes with a given finite variance.

On improving the forecast accuracy of the hidden Markov Model

By Thomas Rooney for M.Com (Actuarial Science) at University of Cape Town, 2016

The forecast accuracy of a hidden Markov model (HMM) may be low due first, to the measure of forecast accuracy being ignored in the parameter estimation method and, second, to overfitting caused by the large number of parameters that must be estimated. A general approach to forecasting is described which aims to resolve these two problems and so improve the forecast accuracy of the HMM. First, the application of extremum estimators to the HMM is proposed. Extremum estimators aim to improve the forecast accuracy of the HMM by minimising an estimate of the forecast error on the observed data. The forecast accuracy is measured by a score function and the use of some general classes of score functions is proposed. This approach contrasts with the standard use of a minus log-likelihood score function. Second, penalised estimation for the HMM is described. The aim of penalised estimation is to reduce overfitting and so increase the forecast accuracy of the HMM. Penalties on both the state-dependent distribution parameters and transition probability matrix are proposed. In addition, a number of cross-validation approaches for tuning the penalty function is investigated. Empirical assessment of the proposed approach on both simulated and real data demonstrated that, in terms of forecast accuracy, penalised HMMs fitted using extremum estimators generally outperformed unpenalised HMMs fitted using maximum likelihood.

Evaluating the adequacy of the method of using vital registration and census data estimating adult mortality when applied sub-provincially

By Chido Chinogurei for MPhil (Centre for Actuarial Research) at University of Cape Town, 2017

In developing countries, vital registration is the best source of death data that can be used to estimate adult mortality provided they are sufficiently complete. However, they are usually insufficient for estimating mortality sub-nationally due to incomplete registration. This research adapts a method used by Dorrington, Moultrie and Timæus at the provincial level to determine whether it is adequate for estimating adult mortality at the district municipality level in the year prior to the 2001 census. The method uses registration data adjusted for completeness of registration to scale (up or down) the deaths reported by households in the census by age group for each sex.

The process of correcting the registered deaths in the year prior to the 2001 census involves estimating intercensal completeness for each population group and each sex between 1996 and 2001 using the average of results from the GGB and the SEG+δ methods. Thereafter,

the results are used to estimate the completeness in each of the years within the intercensal period. Thus, an estimate of completeness is obtained in the year prior to the 2001 census for correcting the registered deaths at the population group level. These registered deaths are then used to obtain population group specific adjustment factors to correct the deaths reported by households at the district level, and thereafter to estimate adult mortality rates.

Most districts in KwaZulu-Natal have amongst the highest rates of adult mortality, while most districts in the Western Cape have amongst the lowest rates. Results show the Buffalo metropolitan municipality to have higher mortality than that expected for most of the district metropolitan municipalities for both sexes. The same is true for women in Mangaung metropolitan district. It is suspected that HIV prevalence had a significant impact on different levels of adult mortality in the districts, although some adults in the more urban provinces may have died in other provinces. At the provincial level, the method produces marginally higher estimates of adult mortality than the other sources. Provinces that reflect a higher level of mortality appear to deviate more from other research findings than those reflecting lower mortality. In conclusion, the method produces district estimates of that are consistent with provincial estimates from other sources and with estimates of HIV prevalence at the district level.

Stable processes: theory and application to finance

By Michael Kateregga for Ph.D in Financial Mathematics (Actuarial Science) at University of Cape Town, 2017

This thesis is a study on stable distributions and some of their applications in understanding financial markets. Three broad problems are explored: first, we study a parameter and density estimation problem for stable distributions using commodity market data. We investigate and compare the accuracy of the quantile, logarithmic, maximum likelihood (ML) and empirical characteristic function (ECF) methods. It turns out that the ECF is the most recommendable method, challenging literature that instead suggests the ML. Secondly, we develop an affine theory for subordinated random processes and apply the results to pricing commodity futures in markets where the spot price includes jumps. The jumps are introduced by subordinating Brownian motion in the spot model by an alpha-stable process, alpha in (0; 1] which leads to a new pricing approach for models with latent variables. The third problem is the pricing of general derivatives and risk management based on Malliavin calculus. We derive a Bismut–Elworthy–Li (BEL) representation formula for computing financial Greeks under the framework of subordinated Brownian motion by an inverse alpha-stable process with alpha in (0; 1]. This subordination by an inverse alpha-stable process allows zero returns in the model rendering it fit for illiquid emerging markets. In addition, we demonstrate that the model is best suited for pricing derivatives with irregular payout functions compared to the traditional Euler methods.

Estimating the risks in defined benefit pension funds under the constraints of PF117
By Ra'ees Mahmood for MBusSc (Actuarial Science) at University of Cape Town, 2017

With the issuing of Pension Funds circular PF117 in 2004 in South Africa, regulation required valuation assumptions for defined benefit pension funds to be on a best-estimate basis. Allowance for prudence was to be made through explicit contingency reserves, in order to increase reporting transparency. These reserves for prudence, however, were not permitted to put the fund into deficit (the no-deficit clause). Analysis is conducted to understand the risk that PF117 poses to pension fund sponsors and members under two key measures: contribution rate risk and solvency risk. A stochastic model of a typical South African defined benefit fund is constructed with simulations run to determine the impact of the PF117 requirements. Findings show that a best-estimate funding basis, coupled with the no-deficit clause, results in significant risk under both contribution rate and solvency risk measures, particularly in the short-term. To mitigate these risks, alternative ways of introducing conservatism into the funding basis are required, with possible options including incorporating margins into investment return assumptions or the removal of the no-deficit clause.

Old age mortality in South Africa, 1985–2011
By Ronald Richman for MPhil (Centre for Actuarial Research) at University of Cape Town, 2017

Estimating the level and trend in population mortality rates at advanced ages in South Africa is complicated by problems with both the population and death data. Population and death data, particularly in developing countries, often suffer from age misreporting—age exaggeration and digit preference. Also, censuses may under- or overestimate the population and registration of deaths is usually incomplete in developing countries (Dorrington, Moultrie & Timæus, 2004). To avoid these problems, the research in this dissertation relies on the method of extinct generations and its extensions (Thatcher, Kannisto & Andreev, 2002) to re-estimate the population using only the death data, which is often recorded more accurately than the population data.

Since deaths are not reported completely in South Africa, the death data must be corrected before use. Death Distribution Methods (Moultrie, Dorrington, Hill et al., 2013) are used to correct the death data for incomplete registration of deaths. After correction, Near Extinct Generation methods (NEG) are used to re-estimate the population by projecting future deaths of nearly extinct cohorts. After showing that mortality rates produced using the original NEG methods are biased because of age and year of birth heaping present in the South African death data, the NEG methods are adapted to the South African context. The adapted NEG model smooths the age and year of birth heaping in the death data and produces mortality rates that are less biased than the original NEG methods. This model—referred to as the NEG-GAM model in this research—is used to re-estimate the population at each age from 70 and above and to calculate mortality rates since 1985.

The population estimates aged 70+ produced using the NEG-GAM model match those from the 2011 census well. It is found that both the population and death data suffer from the

same pattern of heaping, that the population and death data are affected by age exaggeration and that the death data are less affected by age exaggeration than the population data. The level and trend in mortality rates calculated using the NEG-GAM model are discussed and compared to the mortality rates in the Human Mortality Database and other studies of South African mortality. The mortality rates produced for the African and coloured population groups appear too low at the older ages due to age exaggeration in the death data, while those for the Indian and white population groups appear to be reasonable over the entire age range. Mortality appears to be improving in the age range 70–79 for the coloured, Indian and white population groups and deteriorating slowly for the African population group.

Exotic equity derivatives: A comparison of pricing models and methods with stochastic volatility and interest rates

By Jaundré Scheltema for MSc (Actuarial Science) at the University of the Free State, 2017

The traditional Black–Scholes methodology for exotic equity option pricing fails to capture the features of latent stochastic volatility and observed stochastic interest rate factors exhibited in financial markets today. The detailed study presented here shows how these shortcomings of the Black–Scholes methodology have been addressed in literature by examining some of the developments of stochastic volatility models with constant and stochastic interest rates. A subset of these models, notably with models developed within the last two years, are then compared in a simulated study design against a complex Market Model. Each of the select models were chosen as 'best' representatives of their respective model class. The Market Model, which is specified through a system of Stochastic Differential Equations, is taken as a proxy for real-world market dynamics. All of the select models are calibrated against the Market Model using a technique known as Differential Evolution, which is a globally convergent stochastic optimiser, and then used to price exotic equity options. The end results show that the Heston–Hull–CIR Model (H2CIR) outperforms the alternative Double Heston and 4/2 Models respectively in producing exotic equity option prices closest to the Market Model. Various other commentaries are also given to assess each of the select models with respect to: parameter stability, computational run times and robustness in implementation, with the final conclusions supporting the H2CIR Model in preference over the other models. Additionally a second research question is also investigated that relates to Monte Carlo pricing methods. Here the Monte Carlo pricing schemes used under the Black–Scholes and other pricing methodologies is extended to present a semi-exact simulation scheme built on the results from literature. This new scheme is termed the Brownian Motion Reconstruction scheme and is shown to outperform the Euler scheme when pricing exotic equity derivatives with relatively few monitoring or option exercise dates. Finally, a minor result in this study involves a new alternative numerical method to recover transition density functions from the characteristic functions and is shown to be competitive against the popular Fast Fourier Transform. It is hoped that the results in this thesis will assist investment and banking practitioners to obtain better clarity when assessing and vetting different models for use in the industry, and extend the current range of techniques that are used to price options.

Path-dependent volatility and the preservation of PDEs

By M Light for MSc (Financial Mathematics) at University of Pretoria, 2017

We examine so-called Markovian path-dependent volatility models, in particular those of David Hobson and Chris Rogers as well as Paolo Foschi and Andrea Pascucci. A link between these models and the local volatility framework is derived via the representation of local volatility as the conditional expectation of some, more complicated, process. Julien Guyon used this link as a tool in fitting a large class of models to the market. We use the technique to propose a fitted, complete and Markovian market model, which incorporates past asset levels in future volatility levels. The numerical implementation of such a model is addressed through a Monte Carlo scheme incorporating Guyon's particle method.

An augmented Basel II capital requirement formula: applications for Africa

By S Nowosenetz for MSc (Actuarial Science) at University of Pretoria, 2017

This research investigates the use of an augmented, country-specific capital requirement in African countries that is based on the Basel II capital requirement. Although the Basel regulations are considered to be the globally accepted standard of banking regulations, such regulations may not be appropriate for use in developing countries such as those in Africa. Few African countries have implemented the most current Basel regulations and so the financial regulations across the continent are very diverse. If a single set of globally accepted banking regulations was to be implemented across Africa, this could aid the process of financial and economic integration across the continent. The approach taken to derive an augmented, country-specific capital requirement makes use of the Basel II capital requirement formula for credit risk and a systemic factor that is dependent on the business cycle and net worth variances of counterparties. The KMV model is also utilised to determine the probabilities of default of a Ghanaian company to illustrate the capital requirements in a practical setting. It was found that, under certain assumptions, the augmented, country-specific capital requirement is larger than the Basel II capital requirement for most of the African countries investigated, which may indicate the need of African banks to hold more capital. Furthermore, these results are compared to results obtained for developed countries, where the augmented capital requirements are smaller than the Basel II capital requirement.

Model uncertainty and risk aggregation of extreme losses

By MO Okolosi for MSc (Actuarial Science) at University of Pretoria, 2017

In recent times, regulators, researchers, and practitioners have been interested in estimating the 99.9% Value-at-Risk for an aggregate portfolio of extreme losses, in line with the Basel regulatory framework. One critical issue that has arisen is how to model the uncertainty resulting from obtaining the Value-at-Risk for a portfolio where there is little or no information about the dependence structure between individual risk components. Several methods have been proposed which include a rearrangement algorithm. The rearrangement algorithm, based on a 'worst case' and 'best case' approach for model uncertainty, is used to

compute bounds for the Value-at-Risk of an aggregate portfolio given all possible dependence structures. We provide several examples which shows how the different parameter estimates and distributional and dependence assumptions could affect on the Value-at-Risk bounds. Applying the rearrangement algorithm to an operational risk loss dataset, we obtained estimates for the Value-at-Risk bounds using the lognormal and generalised Pareto distributions. By means of a Kolmogorov–Smirnov fitting test result and QQ-plots, the lognormal distribution is seen to provide the best fit to the dataset. Compared to the lognormal, the generalised Pareto distribution analysis produced significantly higher estimates thus illustrating the effect of model uncertainty resulting from distributional assumptions.

The use of risk measures and its applications to portfolio optimisation

By S Resham for MSc (Financial Engineering) at University of Pretoria, 2017

In this dissertation, we study the application of risk measures to portfolio optimisation. A risk measure is a functional over the set of random portfolio returns mappings. We present the various risk measures in this dissertation within an axiomatic framework. Although Value-at-Risk (VaR) has been widely used, the Conditional-Value-at-Risk (CVaR) has become the more popular risk measure since it is a coherent and convex risk measure. We solve a CVaR based optimisation model that is used for portfolio optimisation and hedging a target portfolio. Further, we include alternative risk measures such as distortion, spectral, drawdown and coherent-distortion risk measures (CDRM) and develop optimisation problems for each risk measure. We present a case study where a portfolio is optimised using CVaR, spectral and CDRM risk measures.

A finite element approach to pricing barrier options

By M Richards for MSc (Financial Mathematics) at University of Pretoria, 2017

In this dissertation we consider the valuation of discretely monitored barrier options under the infinite element method. The infinite element method is an extension to the standard finite element method that accepts problems with unbounded spacial domains (such as the Black–Scholes PDE), without resorting to domain truncation. The degeneracy of the Black–Scholes PDE when the underlying asset reaches zero, requires that the method be formulated within the context of weighted Sobolev spaces. We will demonstrate the convergence of the proposed method and provide a rigorous investigation into the underlying weighted Sobolev spaces in which the convergence is to be demonstrated.

Pricing Options under Lévy models using spectral methods

By F Youbi for MSc (Financial Engineering) at University of Pretoria, 2017

Spectral methods have been actively developed in the last decades. The main advantage of these methods is to yield exponential order of accuracy when the function is smooth. However, for discontinuous functions, their accuracy deteriorates due to the Gibbs phenomenon.

When functions are contaminated with the Gibbs phenomenon, proper workarounds can be applied to recover their accuracy. In this dissertation, we review the spectral methods and their convergence remedies such as grid stretching, discontinuity inclusion and domain decomposition methods in pricing options. The basic functions of Lévy processes models are also reviewed. The main purpose of this dissertation is to show that high order of accuracy can be recovered from spectral approximations. We explored and designed numerical methods for solving PDEs and PIDEs that arise in finance. It is known that most standard numerical methods for solving financial PDEs and PIDEs are reduced to low order accurate results due to the discontinuity at strike prices in the initial condition. Firstly the Black–Scholes (BS) PDE was solved numerically. The computation of the PDE is done by using barycentric spectral methods. Three different payoffs call options are used as initial and boundaries conditions. It appears that the grid stretching, the discontinuity inclusion and the domain decomposition methods provide efficient ways to remove Gibbs phenomenon. On the other hand, these methods restore the high accuracy of spectral methods in pricing financial options. The spectral domain decomposition method appears to be the most accurate workaround when we solve a BS PDE in this dissertation. Secondly, a financial PIDE was discretised and solved by using a barycentric spectral domain decomposition method algorithm. The method is applied to two different options pricing problems under a class of infinite activity Lévy models. The use of barycentric spectral domain decomposition methods allows the computation of ODEs obtained from the discretisation of the PIDE. The ODEs are solved by exponential time integration scheme. Several numerical tests for the pricing of European and butterfly options are given to illustrate the efficiency and accuracy of this algorithm. We also show that the option Greeks such as the Delta and Gamma sensitivity measures are computed with no spurious oscillation. The methods produce accurate results.

Extreme Value-based Novelty Detection

By Matthys Lucas Steyn for MComm (Mathematical Statistics) at the University of Stellenbosch, 2017

This dissertation investigates extreme value-based novelty detection. An in-depth review of the theoretical proofs and an analytical investigation of current novelty detection methods are given. It is concluded that the use of extreme value theory for novelty detection leads to superior results. The first part of this dissertation provides an overview of novelty detection and the various methods available to construct a novelty detection algorithm. Four broad approaches are discussed, with this dissertation focusing on probabilistic novelty detection. A summary of the applications of novelty detection and the properties of an efficient novelty detection algorithm are also provided. The theory of extremes plays a vital role in this work. Therefore, a comprehensive description of the main theorems and modelling approaches of extreme value theory is given. These results are used to construct various novelty detection algorithms based on extreme value theory. The first extreme value-based novelty detection algorithm is termed the Winner-Takes-All method. The model's strong theoretical underpinning as well as its disadvantages are discussed. The second method reformulates

extreme value theory in terms of extreme probability density. This definition is utilised to derive a closed-form expression of the probability distribution of a Gaussian probability density. It is shown that this distribution is in the minimum domain of attraction of the extremal Weibull distribution. Two other methods to perform novelty detection with extreme value theory are explored, namely the numerical approach and the approach based on modern extreme value theory. Both these methods approximate the distribution of the extreme probability density values under the assumption of a Gaussian mixture model. In turn, novelty detection can be performed in complex settings using extreme value theory. To demonstrate an application of the discussed methods a banknote authentication dataset is analysed. It is clearly shown that extreme value-based novelty detection methods are extremely efficient in detecting forged banknotes. This demonstrates the practicality of the different approaches. The concluding chapter compares the theoretical justification, predictive power and efficiency of the different approaches. Proposals for future research are also discussed.

Examining the relationships between socio-economic status and hypertension: an application of structural equation modelling

By Racquel Morgan for MSc (Statistics) at the University of the Witwatersrand, 2017

Over the years, epidemiological research has seen differing levels of the prevalence of hypertension across socio-economic strata. However in Sub-Saharan Africa, the patterns of association and underlying risk factors have often been poorly understood. In this study, we examined the extent to which socio-economic factors affect systolic and diastolic blood pressure across gender. Furthermore we explored whether certain risk factors associated with hypertension such as resting heart rate, smoker status, alcohol consumption, body mass index, emotional well-being and physical exercise mediate the relationship between socio-economic status and blood pressure. We used data from the third phase of the National Income Dynamic Study conducted in South Africa in 2012 on more than 18 000 adult individuals.

Structural equation modeling was first analysed in order to assess the effects of socio-economic status on systolic and diastolic blood pressure and to determine whether certain bio-behavioural risk factors can explain the observed relationships.

Multiple linear regression was then used to estimate the relationship between the systolic or diastolic blood pressure and various behavioural, demographic and socio-economic variables. Structural equation modelling and multiple linear regression results were then compared to determine which technique provides more meaningful results. After the adjustment for the use of antihypertensive medication and age, a higher socio-economic status was independently associated with a higher systolic and diastolic blood pressure in both males and females. Furthermore, body mass index was a mediator of the indirect effect of socio-economic status on blood pressure for both males and females. Smoker status, alcohol consumption, physical exercise, emotional well-being and resting heart rate were also mediators in the relationship between SES and blood pressure; however their role was modest in comparison to BMI. One of the findings of this study is that a reduction in the BMI of an individual through a balanced

diet will have a substantial impact on lowering hypertension. Furthermore, the promotion of healthy behaviours and interventions that target higher income groups need to be established so that these groups can make rational decisions in choosing their behaviours. The long term consequences that arise from poor lifestyle choices have to be stressed to the population in general and to groups with higher SES in particular.

Country risk analysis: An application of logistic regression and neural networks
By Gugu Ncube for MSc (Statistics) at the University of the Witwatersrand, 2017

Country risk evaluation is a crucial exercise when determining the ability of countries to repay their debts. The global environment is volatile and is filled with macro-economic, financial and political factors that may affect a country's commercial environment, resulting in its inability to service its debt. This research report compares the ability of conventional neural network models and traditional panel logistic regression models in assessing country risk. The models are developed using a set of economic, financial and political risk factors obtained from the World Bank for the years 1996 to 2013 for 214 economies.

These variables are used to assess the debt servicing capacity of the economies as this has a direct impact on the return on investments for financial institutions, investors, policy makers as well as researchers. The models developed may act as early warning systems to reduce exposure to country risk.