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ENTREPRENEURIAL MATHEMATICS: REVISING THE MATH101 COURSE

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Abstract
The typical course in mathematics begins with the assumption that applications of mathematics in the manufacture and distribution of products are already known. It also assumes that mathematics is only concerned with symbolic manipulation and technical design. In reality, the best mathematics relies on creativity. Mathematics is a means for the expression and investigation of creative ideas. The only source of creativity must be human capital ideas of imagination and creativity, otherwise known as entrepreneurship. Entrepreneurship, where it succeeds, creates its own demand for products and services in the minds of people who do not know what they want until they are shown to them. Therefore, mathematics must be concerned with entrepreneurship education. A new CDR model is discussed for inclusion in the beginning university course in mathematics for students majoring in business administration.

Keywords: Mathematics; Entrepreneurship; Capitalist; Capitalism; Democracy; Rule of Law.

INTRODUCTION

The traditionally courses on entrepreneurship originated in business or management schools. Then, during the last decade many educational institutions began to introduce entrepreneurship education in engineering (Luryi et al., 2007) and other curricula. In developing countries the process has been slower, due in part to what is referred to as resource limitations, but especially due to the wrong mindset and culture of university administrators. Business courses are complemented with startup business development assistance and encouragement for filing patents. However, in many colleges and universities mathematics courses or lectures in general

Vol. 2, No. 05; 2018

ISSN: 2456-7760

are conducted in the traditional setting where students passively receive information from the instructor. In the traditional approach to college teaching, most class time is spent with the professor lecturing and the students watching and listening. The students work individually on assignments, and cooperation is limited. Such instructor-centered instructional methods have repeatedly been found inferior to instruction that involves active learning, in which students solve problems, answer questions, formulate questions of their own, discuss, explain, debate, or brainstorm during class (Hacisalihoglu et al, 2018). Active learning refers to activities that are introduced into the classroom. The core elements of active learning are student activity and engagement in the learning process.

The purpose of this paper is to acknowledge a new CDR index that is remarkable for explaining real gross domestic product adjusted for purchasing power parity (G) and use it to introduce the active learning in a beginning finite mathematics course and entrepreneurship theory to business administration students. It is best to introduce entrepreneurial mathematics at the earliest point in the curriculum so we refer to that point as the proverbial math 101. The actual name will vary from university to university. The CDR index = f(C,D,R) is a function constructed from capitalism (C), democracy (D) and rule of law (R). It epitomizes the role of science, technology, engineering and mathematics (STEM) in the true creation of wealth. Capitalism is measured by market capitalization, the value of outstanding stocks on the financial markets. Democracy is a method for creating new pathways that connect human capital ideas of imagination and creativity. Rule of law is the opposite of corruption, and promotes property rights and justice. The traditional introduction to economics assumes that wealth is produced by manufacturing goods at a factory and distributing them to customers. But, it does not answer the question: where do factories come from? The CDR model says that wealth is created solely from human ideas of creativity and imagination. These are the types of ideas that emerge from STEM personnel. That is, capital is embedded in the human being. And, said capital is embedded in the value of outstanding stocks sold on the capital markets. In the capital to wealth production mechanism, rule of law attracts capital and democracy deploys capital optimally.

The remainder of this paper is organized as follows. In section 2 we review the traditional pedagogy used in teaching Finite Mathematics. In section 3 we present a modern pedagogy that includes active learning techniques and entrepreneurship. Section 4 contains conclusion and recommendations for future research. Next, a nomenclature is given to help beginning students understand various terminologies used in economics, particularly the elements of the CDR index.

TRADITIONAL MATHEMATICS PEDAGOGY

The traditional college or university mathematics classroom is depicted in Figure 1. There is a front and centre lecture console where the instructor stands. Students sit in rows and face the instructor, whiteboard (or blackboard) and white screen. The instructor transmits information very efficiently via didactic lecture, with the aid of the whiteboard and writing implements and by projecting images onto the white screen. The students watch and listen passively and/or do

Vol. 2, No. 05; 2018

ISSN: 2456-7760

whatever else they choose to do. The students work independently on assignments if any. The instructor intentionally limits student interaction, concerned that it might distract from the lecture.

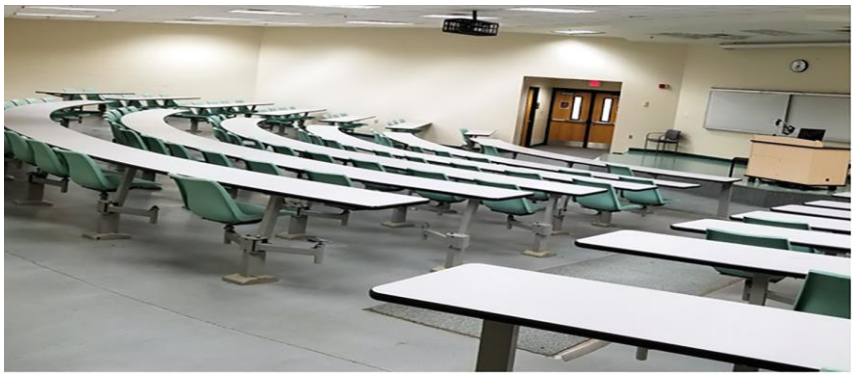

Figure 1: Traditional classroom setting

A MODERN MATHEMATICS PEDAGOGY FOR FINITE MATHEMATICS

Bonwell and Eison (1991) defined strategies that promote active learning as "instructional activities involving students in doing things and thinking about what they are doing." Approaches that promote active learning focus more on developing students' skills than on just transmitting information. Active learning requires that students do something—read, discuss, write, etc. Student activity requires higher order thinking beyond just listening. They also tend to place some emphasis on students' explorations of their own attitudes and values. Active learning techniques described by Brame (2016) are given as follows:

The Pause Procedure— Pause for two minutes every 12 to 18 minutes, encouraging students to discuss and rework notes in pairs. This approach encourages students to consider their understanding of the lecture material, including its organization. It also provides an opportunity for questioning and clarification and has been shown to significantly increase learning when compared to lectures without the pauses (Bonwell and Eison, 1991).

Retrieval practice—Pause for two or three minutes every 15 minutes, having students write everything they can remember from the immediately preceding class segment. Encourage questions. This approach prompts students to retrieve information from memory, which improves long-term memory, ability to learn subsequent material, and ability to translate information to new domains.

Demonstrations—Ask students to predict the result of a demonstration, briefly discussing the demonstration with their neighbor. After the demonstration, ask them to discuss the observed result and how it may

Vol. 2, No. 05; 2018

ISSN: 2456-7760

have differed from their prediction. Then, follow up with instructor explanation. This approach asks students to test their understanding of a system by reconciling their prediction with an actual outcome. If their prediction is incorrect, it helps them see the misconception and thus prompts them to restructure their mental model.

Think-pair-share—Ask students a question that requires higher order thinking (e.g., application, analysis, or evaluation levels within Bloom's taxonomy). Ask students to think or write about an answer for one minute, then turn to a peer to discuss their responses for two minutes. Ask groups to share responses and follow up with the instructor's explanation. By asking students to explain their answer to a neighbor and to critically consider their neighbor's responses, this approach helps students articulate newly formed mental connections.

Peer instruction with Concept Tests—This modification of the think-pair-share involves personal response devices (e.g., clickers). Pose a conceptually based multiple-choice question. Ask students to think about their answer and vote on a response before turning to a neighbor to discuss. Encourage students to change their answers after discussion, if appropriate, and share class results by revealing a graph of student responses. Use the graph as a stimulus for class discussion. This approach is particularly well-adapted for large classes and can be facilitated with a variety of tools (e.g., Poll Everywhere, TopHat, Turning Point).

Minute papers—Ask students a question that requires them to reflect on their learning or to engage in critical thinking. Have them write for one minute. Ask students to share responses to stimulate discussion or collect all responses to inform future class sessions. Like the think- pair-share approach, this approach encourages students to articulate and examine newly formed connections.

A particular advantage of the active learning comes from its unique classroom design (see Figure 2) that helps students to foster collaborations and increases interaction among students and instructor. Unlike the traditional classroom, this design directly facilitates overall student engagement.

Vol. 2, No. 05; 2018

ISSN: 2456-7760

Figure 2: Student-Centered Active Leaning environment classroom setting

The Source of Wealth: intangible versus tangible

The source of all wealth is intangible human capital ideas of imagination and creativity. Capital comprises both exogenous entrepreneurship capital and endogenous capital stock. The endogenous components of capital are knowledge from training, machines, computers, recording devices, etc., all related to prior entrepreneurship ideas. Endogenous capital is subject to depreciation and obsolescence. Therefore, the only source of growth is the entrepreneurship components of human capital. There are various manufacturing and other processes that convert intangible wealth (human capital) to tangible wealth of goods and services. In such processes C is converted to G. The CDR growth model for year 2014 is derived in the appendix as CDR index = 1.53C + 0.14D + 0.23R - 1.21C·D·R, where G = CDR index(highest G-lowest G) + lowest G, highest G=$83,066 and lowest G=$1,112. That is, a function that serves as an index that can be used to compute G in any year for any country where C, D and R are known, and the highest and lowest G in the world are known. The CDR model explains 83% of the variation in G with a straight line (Figure 4). The residuals (not shown) are random, implying that there is no omitted variables bias. There are other growth models (Solow, 1956, Gwartney, et, al., 1999, 2004, 2006). Solow's aggregate adaptation of the Cob-Douglas micro production function is a fallacy of composition (Ridley and Ngnepieba, 2018). Gwartney's model of growth as a function of economic freedom yields much lower values of R^2_{adj}. Neither of these explains growth in terms of policy variables that can be modified to create growth. The CDR model was re-estimated for years 1995 through 2016 for which data were available and the results were approximately the same. This establishes that after adjusting for country factors of production, the conversion of C to G is global time invariant. The conversion is governed by the laws of natural science. It is therefore the same in all countries. What is often thought of as high country productivity is actually its ability to attract capital. In the CDR model, R creates stability that attracts C and D is a virtue that creates additional pathways for the efficient allocation of C. Notice that natural resource explains only a negligible 6% of the variation in g. Also, unless well managed, natural resources (N) can create many economic and social problems known as the Dutch disease paradox (Ebrahim-zadeh, 2003, Auty, 1993, Sachs and Warner, 2001, Ross, 2001, Sala-i-Martin and Subramanian, 2003, Humphreys, 2005, Wadho, 2014, Ridley, 2017b). Geographical latitude explains only 4% of the variation in G. And, latitude can play no role in policy making. Government spending had no impact on the model. So, latitude and government spending were also dropped from the CDR model and the appellation CDR was adopted.

Vol. 2, No. 05; 2018

ISSN: 2456-7760

Entrepreneurship information theory of mathematics

Entrepreneurship is the process of starting a business, typically a startup company offering an innovative product, process or service. Such innovation is different from the normal business activities for which the outcomes are well known. Figure 3 depicts the conversion of capital to products via a production process. Gilder, 2013 and Romer, 1990 explain why quanta of new information must be detected before they can be acted on. A high noise environment is implied by low D and low R. A high noise environment blocks exogenous innovative C. On the other hand, allow noise environment is implied by high D and high R. A low noise environment will permit detection of human entrepreneurial ideas. Sometimes it is the people who no one imagines anything of, that do the things that no one can imagine. D and R are heterogeneous exogenous government catalysts that provide positive social equilibrium effects. D and R are catalysts and do not take part in the process (Berzelius, 1835). They are the same before and after the process. While one may discover N or invent methodology ε_{CDRN}, the ultimate resource is not N but scientific knowledge to detect N and the idea of what can be done with it.

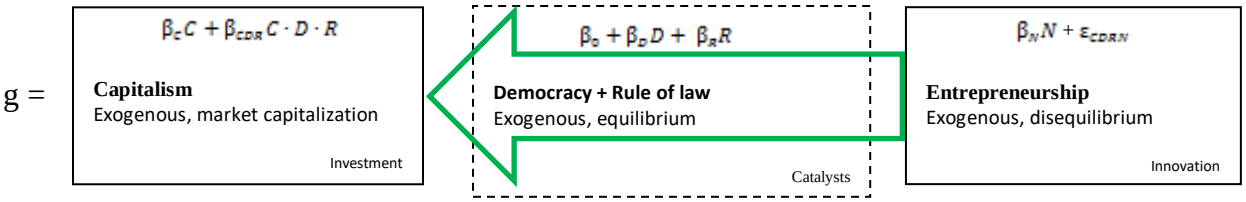

Figure 3. Conversion of exogenous innovation C to g through a DR channel. Process by which exogenous innovative C is converted to products. The variable g is the standardized version of G used to estimate the CDR model (see Appendix).

Revising the finite mathematics MAD 2120course

In order to incorporate the new discovery of the CDR model, it is necessary to revise the extant mathematics curricula in a small number of ways. Although only few, the implication of the revisions is profound. In order to fit the limited number of pages in this paper, only a single syllabus for an introductory course will be considered. Other courses can be revised similarly. The first item to include is the CDR model itself as the genesis of wealth. It is a prerequisite to business and growth. It provides the initial human capital that can be converted to tangible wealth. Without CDR, the creation of wealth will be negligible. Furthermore, there will be no growth. A few other topics are revised where appropriate to account for the CDR effects. The selected course is the Florida A&M University Department of Mathematics (MAD 2120) under the supervision of Professor Pierre Ngnepieba. The original topics in the syllabus are listed in the left column in Table 1. The center and right columns list descriptions and reasons for the revisions, respectively.

Vol. 2, No. 05; 2018

ISSN: 2456-7760

Table 1

Introductory Finite Mathematics Course: MAD 2120 (*changes in italics*)

Traditional Topics	***Proposed Topics/Pedagogy***	**Rationale for change/addition/removal**
1. Set operation, Probability and counting techniques -Set and set operations -Basic concepts of probability -Conditional Probability, independent events -Fundamental Counting Principle -Permutation and Combinations -Applications of Counting Principles	**1. Set operation, Probability and counting techniques** No change in topics. *Change in pedagogy:* *-Before class activities* *-In-class activities* *-After class activities*	
2. Logic and Matrix Arithmetic -Logical Statements, Basic Operators, Truth Tables -Truth Tables, Logical Equivalence -Conditional and Biconditional, More on Truth Tables -Arguments with Truth Tables - Arguments with Quantifiers	**2. Logic and Matrix Arithmetic** No change in topics. *Change in pedagogy:* *-Before class activities* *-In-class activities* *-After class activities*	
3. System of Linear equations and Linear programming - Systems of Linear Equations, Echelon Elimination Method - Systems of Linear Equations, Gauss-Jordan Method - Addition and Subtraction of Matrices - Multiplication of Matrices -Linear Programming, Graphical Solutions - Applications of Linear	**3. System of Linear equations and Linear programming** No change in topics. *Change in pedagogy:* *-Before class activities* *-In-class activities* *-After class activities*	

Vol. 2, No. 05; 2018

ISSN: 2456-7760

Programming - Linear Programming, Simplex Method - Linear Programming, Maximization Problems		
4. Statistics - Frequency Distributions, Measures of Central Tendency - Measures of Variation - Normal Distributions - Binomial Probability - Normal Approximation to a Binomial Distribution	**4. Statistics** - Frequency Distributions, Measures of Central Tendency - Measures of Variation - Normal Distributions *Mixed deterministic & stochastic systems.* *Per unit analysis* - Binomial Probability - Normal Approximation to a Binomial Distribution *Change in pedagogy:* *-Before class activities* *-In-class activities* *-After class activities*	Entrepreneurship is the process of starting a business, typically a startup company offering an innovative product, process or service (see also CDRindex.blogspot.com). Innovators possess capital (C) that is required for the production of tangible wealth. They require an environment of democracy (D) and rule of law (R). R attracts C and D creates additional pathway for the optimal deployment of C. *Mixed deterministic & stochastic systems* (see Figure 3) The deterministic components are $\beta_c C + \beta_{cDR} C \cdot D \cdot R$ and $\beta_0 + \beta_D D + \beta_R R$. The stochastic component is $\beta_N N + \varepsilon_{CDRN}$. The student must be taught how to apply the normal distribution to the understanding of the stochastic component. This will allow them to understand the genesis of entrepreneurship and how to place a confidence interval around estimates of g. *Per unit analysis* The standardized g model in the appendix comprises variables that have all been transformed such that their values range from 0 to 1. This permits easy interpretation and parametric computation of world average endogenous $\bar{g}$ and standard deviation $\bar{g}$+/-z$\sigma_{\bar{g}}$. GDP can be obtained from inverse transformation of g: $\hat{G}=\hat{g}$(highest *G*-lowest *G*)+lowest *G*. $\bar{g}=\beta_0 + (\beta_c - \beta_{\bar{c}}) + \beta_D + \beta_R + \beta_{cDR} + \beta_N$ (see Ridley and Khan, 2018 for calculation of $\beta_{\bar{c}}$).

The pre-class, in-class and after class activities as they apply to inferential statistics and the normal distribution are designed so as to foster student understanding of entrepreneurship principles of CDR.

Pre-class activities – The pre-class activities consist of textbook reading assignments and video assignments.

Vol. 2, No. 05; 2018

ISSN: 2456-7760

In-class activities – The in-class activities consist of group activities, mini lectures, one minutes paper, peer learning, clicker quizzes.

After class activities – The after class activities consist of additional video assignment, online homework and quizzes, Blackboard worksheets

CONCLUDING REMARKS

Adam Smith (1776) said that the real tragedy of the poor is the poverty of their aspirations. The CDR global time invariant growth model shows that economic growth is derived from the conversion of human capital to standard of living, dependent on capitalism, democracy and rule of law, and independent of government spending, country size, location, culture, and physical characteristics of the population. The impact of natural resources and latitude are negligible. See also Korovaykovskaya and Ridley, 2017, Ridley, 2016, Ridley, Davis and Korovykovskaya, 2017, Ridley, 2017c. Ridley and Khan (2018) is the first to compute the values of ideas.This paper reminds college and university mathematics professors that the true genesis of wealth is human ideas of imagination and creativity. Mathematics is an excellent tool for the derivation and storage of scientific facts that can be passed on to others. Stored knowledge constitutes endogenous human capital from which wealth can be produced. But, such wealth is associated with current technology and methodology. And, equipment and technology can and does depreciate. As technology depreciates, the relevant mathematics can become obsolete. Therefore, mathematics education must not be designed to stagnate in the individual. It must be designed to stimulate the mathematical thinking process for lifelong learning and the release of human capital ideas of imagination and creativity. It must also encourage the student to be democratic in their interaction with other people so as to create new pathways for the deployment of their human capital. This may also help the many students who lack family exposure to entrepreneurship (see also Celuch, Bourdeau, Winkel (2017), Tognazzo, Gubitta and Martina (2016)).

Nomenclature

Endogenous:	**Generated from within a system.**
Entrepreneurship:	**The process of starting a business, typically a startup company offering an innovative product, process or service.**
Epistemology:	**The investigation of what distinguishes justified belief from opinion.**
Exogenous:	**Generated from outside a system.**
Capitalist:	**A person who deploys his personal capital so as to maximize his benefit.**
Capitalism:	**Mechanism for the collection and assembly of capital.**
Catalysis:	**The creation of alternative pathways to enable a process.**
CDR index:	**The vector inner The vector inner product (dot product) of the global constant [1.53 0.14 0.23 -1.21] and the country [C D R C·D·R].**
Company:	**The instrument of capitalism for the profitable investment of capital.**
Democracy:	**Private workforce idea participation and periodic election of public representatives (catalyst for the process of generating G from capital).**
Gross domestic product:	**The monetary value of all the finished goods and services produced within a country's borders in a specific time period.**
Intrapreneurship:	**The employee practice of entrepreneurial activity inside a large business without incurring the**

Vol. 2, No. 05; 2018

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	associated risk.
Micro intrapreneurship:	**The low skill employee practice of micro entrepreneurship in variance reduction, quality improvement or customer relations at a business by virtue of proximity to a task.**
Natural resource rents:	**Surplus value of natural resources after all costs and normal returns are accounted for.**
Property rights:	**Property is a legal expression of an economically meaningful consensus by people about assets, how they should be held, used and exchanged.**
Rule of Law:	**Reverse of corruption (protection of shareholder and other property rights) (catalyst for the attraction of capital).**
Virtue:	**Self-governing human property that promotes fairness and justice without the need for central government.**

APPENDIX: The Source and Mechanism of Wealth

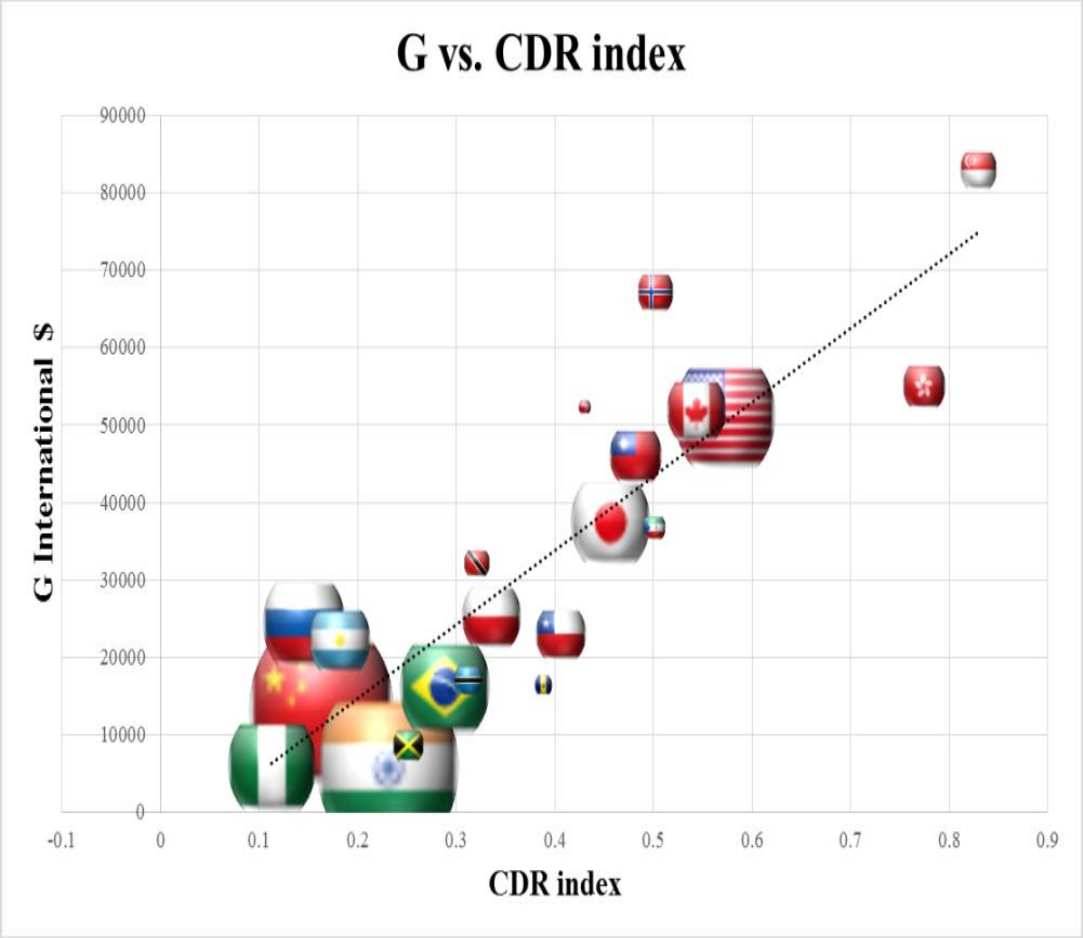

Figure 4. Year 2014 G vs CDR Index for 79 countries (line). Bubble size (21 countries) is the square root of population. This model was re-estimated for years 1995-2016 with similar results. For additional comments on the countries see Ridley (2017a, 2017b). (Spreadsheet data and Calculations will be available on request)

Vol. 2, No. 05; 2018

ISSN: 2456-7760

Standardized g model

The ordinary least squares *g* model is specified as follows:

$g = \beta_0 + \beta_C C + \beta_D D + \beta_R R + \beta_{CDR} C \cdot D \cdot R + \beta_N N + \varepsilon$

where, the intercept β_0 and the coefficients β_C,β_D, β_R, β_{CDR},β_N are all dimensionless,

ε is a random, normally distributed error with a mean of zero and constant standard deviation,

and where all model variables are standardized as follows:

$g = \frac{G - \text{lowest } G}{\text{highest } G - \text{lowest } G}$

G = per capita real gross domestic product per capita (PPP)

C(Capitalism) $= \frac{\text{per capita capitalization} - \text{lowest per capita capitalization}}{\text{highest per capita capitalization} - \text{lowest per capita capitalization}}$

D(Democracy) $= \frac{\text{lowest democracy rank} - \text{democracy rank}}{\text{lowest democracy rank} - \text{highest democracy rank}}$

R(Rule of law) $= \frac{\text{lowest corruption rank} - \text{corruption rank}}{\text{lowest corruption rank} - \text{highest corruption rank}}$

N(Natural resources) $= \frac{\text{per capita total natural resource rents} - \text{lowest per capita total natural resource rents}}{\text{highest per capita total natural resource rents} - \text{lowest per capita total natural resource rents}}$

These transformations standardize the variables and ensures upper and lower bounds on $0 \leq g,C,D,R,CDR,N \leq 1$.

Democracy and corruption are rank ordered, where the highest = 1 and the lowest = the number of countries. *G* is measured in $/capita/year.

$\hat{g} = 1.53C + 0.14D + 0.23R - 1.21C \cdot D \cdot R + 0.38N$

T = (6.60) (1.69) (2.60) (4.40) (5.59) F ratio = 81.

Partial correlations (contributions to R^2_{adj}):

59% 5% 10% 3% 6% R^2_{adj} = *83%.*

where ^ denotes estimated or fitted value and *G* can be estimated from

$\hat{G} = \hat{g}$ (highest *G*-lowest *G*) + lowest *G*.

Highest *G*=83,066. Lowest *G*=1,112.

The CDR index = 1.53C + 0.14D + 0.23R - 1.21C·D·R comprises positive C, D and R effects and a negative component due to friction from democracy that reduces G from what it might otherwise be if there were perfect agreement amongst decision contributors. The contribution from N is negligible and can be dropped from the model.

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Vol. 2, No. 05; 2018

ISSN: 2456-7760

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Vol. 2, No. 05; 2018

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Vol. 2, No. 05; 2018

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