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ENTREPRENEURIAL ENGINEERING: REVISING THE ENGINEERING 101 COURSE

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Abstract
The typical course in engineering begins with the assumption that manufacturing operations already exit. It also assumes that capital represented by facilities that produce final goods and services already exists, do not have to be created, and that engineering is only concerned with technical design execution, production and operations. In reality, all capital must have been previously created. The only source of capital must be human capital ideas of imagination and creativity, otherwise known as entrepreneurship. Entrepreneurship, where it succeeds, creates its own demand in the minds of people who do not know what they want until it is shown to them. Therefore, engineering must be concerned with entrepreneurship education. A new CDR model is discussed for inclusion in the beginning university course in engineering.

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

INTRODUCTION

Entrepreneurship has an important role in job creation and that has increased worldwide interest in the topic. In developing countries, entrepreneurial activities energize weak economies. Recent changes in the world present challenges and opportunities to engineering education. Market conditions, population demographics and employment dynamics, create different circumstances today than those existing a decade ago. Entrepreneurship is known as the creative destruction that leads to innovation. Entrepreneurial behaviour has a clear effect in increasing the economic wealth of a nation (Mueller, 2011).Entrepreneurship is also known as the process where the entrepreneur searches for new opportunities in the environment leading to a new venture. Others consider the entrepreneurial activity as an innovation process to exploit a business opportunity by applying entrepreneurial learning. In this process something new or different is created adding value to the society (Tung, 2011, Kao, 1993).
Traditionally, courses on entrepreneurship originated in business or management schools. This began to change during the last decade when many educational institutions began to introduce entrepreneurial education in the engineering curriculum (Luryi et al., 2007). 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 mind set and culture of university administrators. Often, resource limitations are actually resource suppression of talent and innovation capacity (see section 3.1

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below). This situation has been recognized by governments. And, several politically motivated plans are in place to overcome limitations and lack of funding. In Dominican Republic the Ministry of Higher Education prepared a strategic plan to implement entrepreneurship knowledge in engineering curricula. Business courses are complemented with start-up business development assistance and encouragement for filing patents.

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 entrepreneurship theory to engineering students. It epitomizes the role of science and engineering in the true creation of wealth. The CDR index = *f*(C, D, R) is a function constructed from capitalism (C), democracy (D) and rule of law (R). 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 engineers. 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 engineering pedagogy. In section 3 we present a modern engineering pedagogy that includes entrepreneurship. Section 4 contains conclusion and recommendations for future research. Next, a nomenclature is given to help beginning students understand various terminology used in economics, particularly the elements of the CDR index. A derivation of the new CDR index on which our theory of entrepreneurship (Ridley (2016), Korovyakovskaya and Ridley (2017), Ridley, Davis and Korovyakovskaya (2017), Ridley, (2017a, b, c), Ridley and Khan (2018), Ridley and Ngnepieba (2018)) is based is given in the appendix.

TRADITIONAL INDUSTRIAL ENGINEERING PEDAGOGY

In developing countries, a major concern is the poor quality of education and the lack of financing available to universities. This often results in insufficient capacity to join industry in innovation-related projects. Building effective university-industry linkages in this context takes time and sustained effort by college authorities. This is due in part to universities in developing countries generally having little experience in industry collaboration and limited managerial capacity in research (Guimon 2013). That is why universities concentrate on teaching, with low or no space for research, industry collaboration and joint venture. The research activity of these universities is less likely to lead to spin-offs or patents that can be commercially exploited. In many developing countries university-industry collaboration is constrained by historically based cultural and institutional barriers that take time to overcome.

Three university missions have given rise to the distinct concepts of *teaching university*, *Research University* and *entrepreneurial university*. Universities in developing countries have

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fostered the teaching activity over the other two. One possible way to incentivize the entrepreneurial spirit in college graduates is to promote university-industry collaboration. This collaboration may take place under all of these university missions, although it will have a distinct focus on training in the teaching university, on research and development in the research university, and on technology commercialization and spin-offs in the entrepreneurial university. In any case, complementarities exist among the different university-industry links (Guimon 2013).

A MODERN ENTREPRENEURIAL ENGINEERING PEDAGOGY

Entrepreneurship education is explained as the methods and approaches used to teach people to start new businesses successfully and operate such businesses profitably. Entrepreneurship education is defined as the "process of transmitting entrepreneurial knowledge and skills to students to help them exploit a business opportunity" (Tung, 2011).

Entrepreneurship education has an impact on increasing start-up rates (Tung, 2011).Entrepreneurship education leads to the improvement of the level of knowledge about how to launch and manage a new business venture (Schaper, 2007), enables students to gain experience in a real business context, foster favorable attitudes towards entrepreneurial activities (Gorman, et al., 1997), develops perception of self-efficacy of students, raises the level of students' entrepreneurial intentions, and stimulates students to choose an entrepreneurial career (Charney, et al.,2003). Entrepreneurial education in engineering students contributes to develop the attitude and aptitude necessary to foster the venture mindset in future professionals. Universities in developing countries must foster innovation to contribute to economic growth. No longer is the teaching activity enough to create value and to attract funding from industry and financing agencies.

Initiatives from the government have increased entrepreneurship in engineering colleges in the Dominican Republic. According to Won Joon, Byungheon, and Jungtae (2011), it is an initiative directed to the programmatic adjustment of the Dominican Republic's higher education system regarding productive technological innovation. It acknowledges the challenges to adapt the university's engineering academic programs and recognizes the importance and necessity of competitive improvement of the productive sectors. All this within the framework of the Free Trade Agreement with United States and Central America, and other similar processes of commercial integration. The background of this project can be found in two great initiatives: (I) National Plan of Systemic Competitiveness (National Council of Competitiveness, March 2007), and (II) the Strategic Plan of Science, Technology and Innovation 2008-2018 (Ministry of Higher Education, Science and Technology, October 2008).

The group of government initiatives has three main components as part of the National System of Innovation and Technological Development: a) Institutes of Innovation and Technological Development; b) Network of business incubation systems; c) Creation and Strengthening of Technology parks. The second component will support the creation of an entrepreneurship culture, incorporating entrepreneurship activities in engineering curricula.

The Strategic Plan of Science, Technology and Innovation, constitutes the planning tool and political and institutional articulation of the national system of science, technology and

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innovation. Thus, it has become the main tool to lay the foundations for innovation and a knowledge based economy that supports the competitive improvement of the productive sector, elevating the quality of life of the Dominican people and strengthening the commitment with the paradigm of sustainable development. Concretely, this program of the Strategic Plan is oriented to scientific research, innovation and technological development. It provides for the creation of a program for strengthening the incubation and entrepreneurship systems of technology base companies that are incubated in universities (Won Joon et al., 2011).

To enrich the engineering curricula the study program should include these topics:

a) Hands on business experience based on innovating engineering projects,
b) The program must be based on multidisciplinary teamwork projects that improve the entrepreneurial experience while adding versatility and functionality. Students learn from each other and strong partnerships may occur.
c) It has to have a competitive component to encourage in students the entrepreneurial education needed in the real world. This goal may be achieved with competition funding to be awarded to the best proposal that also leads a start-up development.
d) Enterprise participation is made convenient so as to increase the probability of developing new products or improving existing products. This participation is vital for fine tuning the competencies that are included in study programs.
e) Access to funding from the Ministry of Higher Education Science and Technology. This is a specialized fund to incentivize research in basic science and technology.
f) Technology fairs, where students can exhibit their project ideas and get exposure to potential partners and venture capital.

To become an entrepreneur who is able to tackle dynamic, economic, social and potential challenges; one must possess entrepreneurial attributes such as risk-taking, innovation, self-confidence, creativity, problem solving skills, management skills, professional business skills, and readiness for change (Tung, 2011). The reformulation of the engineering curricula is focused on developing in students the characteristics of an entrepreneurial mindset.

From intangible wealth to tangible wealth

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

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G with a straight line (Figure 2). 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, 2003, 2004, 2006) but they yield much lower values of R^2_{adj} and do not explain growth in terms of policy variables that can be modified to create growth.

The 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 resources explains only a negligible 6% of the variation in g. Also, unless well managed, natural resources 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 4% of the variation in G. But, latitude can play no role in policy making. Government spending had no impact on the modelR^2_{adj}. So, latitude and government spending were also dropped from the CDR model.

Entrepreneurship information theory of engineering

Entrepreneurship is the process of starting a business, typically a start-up company offering an innovative product, process or service. Entrepreneurship is different from the routine business activity that has well known outcomes. Consider the conversion of capital to products via a production process (Figure 1). Quanta of new information must be detected if they are to be acted on (Gilder, 2013, Romer, 1990). An environment in which D is and R is low constitutes a high noise environment. A high noise environment blocks exogenous innovative C. On the other hand, a high D, high R 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. Heterogeneous exogenous catalysts D and R are government variables that provide positive social equilibrium effects. D and R are catalysts do not take part in the process (Berzelius, 1835).

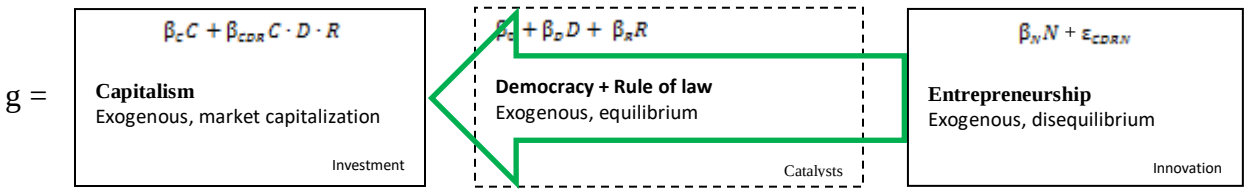

Figure 1. Conversion of exogenous innovation C to g through a DR channel. Process by which exogenous innovative C is converted to products. The variable g is the standardized version of G used to estimate the CDR model (see Appendix).

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Revising the engineering101 course

In order to incorporate the new discovery of the CDR model (see Appendix), it is necessary to revise the extant engineering 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 that of Felipe Llaugel of the College of Engineering, Universidad Dominican a O&M, Dominican Republic. 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.

Table 1. Introduction to Industrial Engineering Course

Traditional Topics	***Proposed Topics***	**Rationale for change/addition/removal**
1.Introduction to engineering -History -Evolution of Engineering -Modern Trends	**1a.Introduction to engineering** -History -Evolution of Engineering -Modern Trends ***1b. Engineering innovation*** *-Entrepreneurship* *-Property* *-Intellectual property rights* *-Property rights* *-Patents filing* *-Administration and*	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 pathways for the optimal deployment of C.

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	operation	
2. Decision making - Decision making process - Alternative generation - Classification - Evaluation	**No Change**	
3. Market Analysis - Demand forecasting - Market segmentation - Statistical methods - Economic environment	**No Change**	
4. The Enterprise - The Organization - Enterprise classification - Operations - Legal aspects	**4a. The Enterprise** - The Organization - Enterprise classification - Operations - Legal aspects ***4b. Entrepreneurship project*** *-Product design*	To start a business some previous background is necessary. The demand analysis will quantify the market size. Funding and financial analysis will reveal the feasibility of the idea. Students learn to identify market opportunities.

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	-Prototype development *-Business plan construction* *-Market analysis* *-Plant design* *-Financial analysis* *-Economic analysis*	
5. Supervision - Supervision techniques - Training - Coaching - Discipline		
6. Quality - History - Evolution - Quality Control - Quality Assurance		

CONCLUDING REMARKS

This paper reminds engineering professors that the true genesis of wealth is human ideas of imagination and creativity. Ideas are the most prized possession of the very students that they teach. Students who lack an entrepreneurial family background are likely to think that wealth comes from existing factories that make products and distribution networks that deliver them to consumers. They may lack a vision of themselves as entrepreneurs (see also Celuch, Bourdeau, Winkel (2017),Tognazzo, Gubitta and Martina (2016)).The CDR global time invariant growth model and introductory course modifications suggested in this paper are designed to bring this

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awareness to the attention of the students. The real tragedy of the poor is the poverty of their aspirations (Smith, 1776). So, even when engineers do not themselves experience an idea, they must be on the constant look out for the ideas of the poorest amongst us that they can bring to fruition through their professional education (see also Ridley, 2017c). For, 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 natural resources, government spending, country size, location, culture, and physical characteristics of the population.

Nomenclature

Endogenous	Generated from within a system.
Entrepreneurship	The process of starting a business, typically a start-up 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 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 andperiodic 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 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.

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APPENDIX: The Source and Mechanism of Wealth

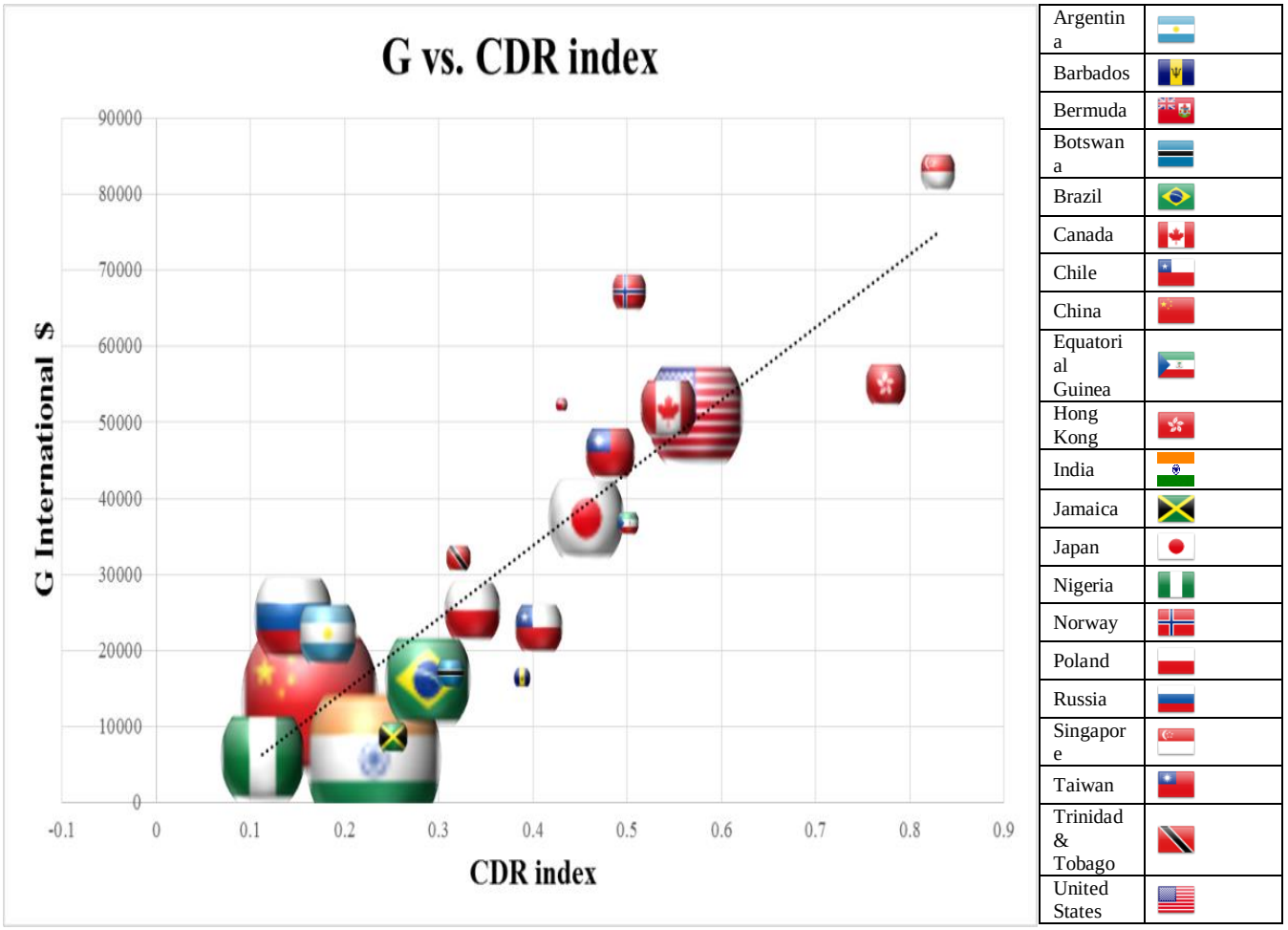

Figure 2. Year 2014 G vs CDR Index for 79 countries (line). Bubble size (21 countries) is the square root of population. This model was re-estimated for years 1995-2016 with similar results. For additional comments on the countries see Ridley (2017a, 2017b).

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:

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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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