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FOUR EARLY ATTEMPTS TO DEVELOP POWER FORMULAS (1741–1955)

1. Introduction and Methodology

The history of power formulas can be roughly divided into different time periods. The first time period refers to all power formulas created before 1960. In 1960 Frank Clifford German published his calculations of national power[1]. The paper has only seven pages and is as such rather rudimentary. German explicitly admits the arbitrary and subjective way in which he pieced together the numbers. He failed to attain any recognition in academia after producing this formula, because he switched to journalism. It seems mere coincidence that this paper was noticed, remembered and subsequently cited by the Correlates of War (COW) network starting in 1963 and led by David Singer. In any case, a more systematic era commenced with Clifford German's power equation in 1960. From this point power equations became much more common. A number of individuals started to quantify power with more attentiveness to the past and current efforts in that direction, so that these people became more or less mutually aware of each other.

I was able to trace only four formulas preceding 1960, but there may well be many more. What is typical for that time period is again that no quantitative network existed to review and collect power formulas. The power formulas created in that period were more or less randomly isolated incidents unconnected to one another. Therefore, finding such formulas is extremely difficult – little more than a matter of luck. It is best to read the works of scholars competent in the political literature published before 1960 and hope that they mention an approach to measure power in one of their footnotes. The problem is not that political literature is lacking, nor that there was a lack of concern for national power and the discovery of meaningful numbers

[1] See C.F. German, *A Tentative Evaluation of World Power*, "Journal of Conflict Resolution" 1960, Vol., 4, No. 1, pp. 138–144, http://jcr.sagepub.com/content/4/1/138.citation (15.04.2011).

to approximate it. Quite the opposite: political literature is abundant, and concern for national power is ubiquitous, but the fulfillment of these two context conditions does not *ipso facto* guarantee the existence of a formula. In other words, there is far too much related material yielding far too little in the way of systematic research. It is to a greater extent for scholars such as diplomatic historians, who are immersed in all the literature of the past for many reasons other than this specific one, to make a meaningful contribution to the general issue of how national power was assessed in the past[2], and hopefully here and there a forgotten power formula may come to light.

The paper is structured as follows: the power formulas are presented in chronological order with some background information (the historical/political situation, information on the author, specific justification of the designer for his power equation), a detailed breakdown of the factors that went into its calculation (the reasons for the selected factors, the design of the formula, the produced results presented in a table, possible updates on factor availability), and the reception of that power formula along with some analysis (how did others evaluate this formula? what makes this formula special and different from the others?).

2. Johann Peter Süßmilch (1741)

Johann Peter Süßmilch (1707–1767) was a German pioneer in the area of demography and population statistics. He studied law, medicine, and theology before becoming a pastor. In 1741 he published the first volume of his magnum opus *The Divine Order in the Transformations of the Human Race as Demonstrated through Birth, Death, and the Multiplication of the Same* [*Die Göttliche Ordnung in den Veränderungen des menschlichen Geschlechts, aus der Geburt, dem Tode und der Fortpflanzung desselben erwiesen*], reprinted in 1765. His ambition was to gain a better understanding of God, so he looked at the world as God's creation. He wanted to prove God's will in nature by looking at the lawfulness in natural phenomena through the means of statistical observations. For that purpose he analyzed demographic phenomena with self-designed statistical methods. His work received recognition: in 1745 he became a member of the Prussian Academy of Sciences, he also approached the king of Prussia with unpublished memorandums.

In the Bible God says to humankind: "Be fruitful and multiply, and fill the earth, and subdue it"[3], which basically sums up the prevalent pre-Malthusian paradigm on demographic policy. Especially from the time of Jean-Baptiste Colbert (1619–1683)

[2] Harm Klueting's post-doc habilitation thesis is an example for such a work on the assessment of power in the 18th century. See H. Klueting, *Die Lehre von der Macht der Staaten: Das außenpolitische Machtproblem in der „politischen Wissenschaft" und in der praktischen Politik im 18. Jahrhundert*, Berlin 1986.

[3] *Genesis 1:28*, *New American Standard Bible*, Lockman Foundation 1995.

to the end of the 18th century there was a consensus that the welfare and power of the country was directly proportional to its population[4]. Hence, if the aim of the state was to increase its power, then population had to be increased, and the state had to provide every possible incentive to make that happen. In some countries the traditional inheritance laws regarding the indivisibility of farmland were changed to facilitate marriage; emigration was made more difficult, while immigration was encouraged; foreigners were hired to get killed as soldiers. Under Colbert it was decreed that if a father had ten living children, he would be exempt from taxes and other duties. Also the first foundling homes were established for the purpose of maximizing population growth[5]. Süßmilch was most clearly seen as an exponent of this view, and his formula falls into this context.

Süßmilch writes in his work *The Divine Order*:

If a country has as many inhabitants as one three times larger, so is its reputation, power and security three times greater, or the splendor of the latter three-times smaller[6]. The assertion can be directly transformed into a mathematical power formula:

power = population x population density

or

power = population^2 / area

The formula uses the standard population density also known as arithmetic density[7].

Süßmilch reasoned that a larger territory implied more neighbors and thus more potential for conflict. Further, that a lower population density made a country harder to control. His central argument is that high population density implies in general higher development. Thus it is easier and faster logistically to implement measures in a small country with a high population than in a large country with a small population. Such measures include defense and security but also "concern for the preservation of good manners, virtue, bravery, military training and discipline."[8] Along a similar line

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[4] Differences in the *per capita* national income of countries were relatively minor in pre-industrial times (see A. Maddison, 2010. *Statistics on World Population, GDP and Per Capita GDP, 1–2008 AD*, 2010 [spreadsheet], http://www.ggdc.net/maddison/Historical_Statistics/horizontal-file_02-2010.xls (18.04.2011) so this view was not unreasonable. The notion of national income was still in its infancy at the time of Süßmilch; in 1665 William Petty and in 1688 Gregory King had supplied some first estimates on such.

[5] J.E. Wappäus, *Allgemeine Bevölkerungsstatistik*, 1 Theil, Leipzig 1859, pp. 41–42, 64–65.

[6] German text: „Wenn ein Reich ebenso viele Einwohner hat als ein dreimal größeres, so ist desselben Ehre, Macht und Sicherheit dreimal größer oder die Herrlichkeit des letzteren dreimal kleiner." See J.P. Süßmilch , *Die göttliche Ordnung in den Veränderungen des menschlichen Geschlechts, aus der Geburt, dem Tode und der Fortpflanzung desselben erwiesen*, 3 Ausgabe, Göttingen 1765 (1988), 1/402.

[7] Some countries have vast tracts of non-habitable land (e.g. Egypt), that could make it more appropriate to use the physiological density, which is total population divided by the area of arable land. For a formula using physiological population density, one can look at the formula of Saul Bernard Cohen, *Geography and Politics in a World Divided*, 1st edition, New York 1963.

[8] German text: „Sorge für die Erhaltung guter Sitten, der Tugend, der Tapferkeit, der Kriegsübung und Disziplin". See J.P. Süßmilch , *Die göttliche Ordnung*…, op. cit., 1/402.

of reasoning to that of Süßmilch emphasizing the issues of mobilization and centralization, the Cohen Index from 1963[9] and the Composite Index of National Capabilities (CINC) by David Singer from 1972[10] contain urbanization as a positive element of state power[11].

Süßmilch never calculated the results of his formula, though he made a great effort to compile the data that would enable such calculations. The following table shows the results he would have obtained if he had done those calculations:

Table 1. The Power of Countries / Areas in 1765

Country / Area	Population	English /mi²	Population /mi²	Power
China	150,000,000	1,105,000	136	20,361,990,950
Asia (remainder)	383,000,000	7,898,487	48	18,571,784,697
India	100,000,000	1,116,000	90	8,960,573,477
Germany	24,000,000	188,684	127	3,052,723,071
Africa (remainder)	146,000,000	8,359,300	17	2,549,974,280
America	150,000,000	9,000,000	17	2,500,000,000
Japan	17,000,000	138,000	123	2,094,202,899
France	17,000,000	138,837	122	2,081,577,677
Netherlands	5,000,000	12,968	386	1,927,822,332
Italy	10,000,000	75,576	132	1,323,171,377
Poland-Lithuania	12,000,000	222,000	54	648,648,649
Great Britain	8,000,000	105,614	76	605,980,268
European Russia	24,000,000	1,031,550	23	558,383,016
Spain	7,500,000	148,218	51	379,508,562

[9] S.B. Cohen, *Geography and Politics* …, op. cit., p. 11.

[10] D.J. Singer, S. Bremer, J. Stuckey, *Capability Distribution, Uncertainty, and Major Power War, 1820–1965*, in: B.M. Russett (ed.), *Peace, War, and Numbers*, Beverly Hills 1972, pp. 25–26.

[11] Saul Cohen and David Singer are both Jewish, and it may have taken a Jewish pro-urban bias to properly realize and acknowledge the importance of ‚urbanization' as a factor. As for the strong tendency of Jews to live in urban habitats, Singer himself wrote in the *American Jewish Year Book 2006*: "The overwhelmingly urban concentration of Jewish populations globally is evinced by the fact that in 2006 more than half (51.9 percent) of world Jewry lives in only five metropolitan areas - Tel Aviv, New York, Jerusalem, Los Angeles, and Haifa." See D.J. Singer, L. Grossman (eds.), *American Jewish Year Book 2006: Volume 106*, American Jewish Committee, New York 2006, p. 598, http://www.policyarchive.org/handle/10207/bitstreams/17112.pdf (20.04.2011).

European Turkey	8,000,000	212,240	38	301,545,420
Hungary	4,000,000	75,525	53	211,850,381
Latvia	2,000,000	25,939	77	154,207,949
Portugal	2,500,000	47,851	52	130,613,780
Egypt	4,000,000	140,700	28	113,717,129
Switzerland	1,000,000	12,884	78	77,615,647
Denmark (including Norway)	2,500,000	163,001	15	38,343,323
Sweden (including Finland)	2,500,000	228,715	11	27,326,585
Total	1,080,000,000	30,447,089	35	66,671,561,470

Source: J.P. Süßmilch, *Die göttliche Ordnung*…, op. cit., 2/171–238; author's own calculations.

Friedrich Ratzel (1844–1904), who is known as the founder of German geopolitics, mentions Süßmilch's work in his book *Politische Geographie* [*Political Geography*] as an example of how population size has been politically overvalued in the Age of Absolutism[12].

3. Ferdinand Friedensburg (1936)

Ferdinand Friedensburg (1886–1972) was a German politician and mineralogist. After spending a year on a mining apprenticeship, he went on to study law, political science and geology. After World War I he went on to become a high level bureaucrat. Politically he was active for the left-wing liberal German Democratic Party (Deutsche Demokratische Partei DDP) but in 1924 he failed twice to get elected to the national parliament. Through his various high level bureaucratic positions he tried to fight the political extremism of the left and right. As a result he was dismissed from his position in February 1933 after the national socialists came to power[13]. Stigmatized by the new government, he dedicated himself to scientific research and returned to his original passion – the international mining industry. His book *Raw Materials as Political*

[12] F. Ratzel, *Politische Geographie,* 3 Ausgabe, München 1923, pp. 303–304.

[13] A newspaper reported: „This message will cause great satisfaction for all national socialists, who had to see in Mr. Friedensburg one of their most bitter enemies". M. Zirlewagen, *Ferdinand Friedensburg*, in: T. Bautz (ed.), *Biographisch-Bibliographisches Kirschenlexikon*, Band XXVI [online], Nordhausen 2006, http://www.bautz.de/bbkl/f/friedensburg_f.shtml (21.04.2011). German text: "Diese Nachricht wird bei allen Nationalsozialisten, die in Herrn Friedensburg einen ihrer erbittertsten Gegner sehen mussten, große Genugtuung auslösen".

and Military Power Factors [*Die mineralischen Bodenschätze als weltpolitische und militärische Machtfaktoren*], published in 1936, contained his power formula[14]. He built up his reputation in this field and was consulted by corporations and the army. In 1938 he was then expelled from the state-instituted Authors' Association (Reichsschrifttumskammer), which disallowed him to write any longer. After World War II he went on to have a successful political career.

Based on the experiences of World War I that transcended those of a conflict limited to the military dimension, many German scholars testified to the emergence of a new type of war that they called total war. The theory of total war postulates that all resources at the disposal of a nation are significant to the war effort. This also puts more focus on the economic dimension in preparation for a sustainable war economy in a drawn out conflict[15]. While Friedensburg regretted the widespread re-armament of countries in 1936, he anticipated that the next war would be such a total war. Friedensburg discussed the decisive importance of raw materials in such a drawn out conflict[16]. For his calculations he assumed that every country could find itself in a strategic situation where it had to rely on itself completely, though he considered such a drastic situation improbable[17].

In times of peace the price value of raw materials is determined according to mining costs relative to economic utility (that is, supply and demand) on a worldwide level; during war such price values play negligible roles as (especially inflexible) needs determine the effort put into gaining raw materials (that is, "any price is paid")[18]. As such he believed it was improper to look simply at the price value of the total

[14] See F. Friedensburg, *Die Mineralischen Bodenschätze als weltpolitische und militärische Machtfaktoren*, Stuttgart 1936.

[15] See G. Fischer, *Wehrwirtschaft: Ihre Grundlagen und Theorien*, Leipzig 1936; Idem, *Der Wehrwirtschaftliche Bedarf*, „Zeitschrift für die gesamte Staatswissenschaft" 1939, Heft 99, pp. 516–542, http://resolver.sub.uni-goettingen.de/purl?GDZPPN001764799 (15.04.2011). In fact, the moves towards the theoretical concept of total war were already well under way before World War I: Erich Ludendorff in 1910 and Helmut von Moltke (junior) in 1905 thought in this direction (see N. Ferguson, *Der falsche Krieg: Der Erste Weltkrieg und das 20. Jahrhundert*, translated by Klaus Kochmann, Stuttgart 1999, pp. 130, 134. In the post-World War II reflection Hans Morgenthau commented that "total war presupposes total mechanization, and war can be total only to the degree to which the mechanization of nations waging it is total". H. Morgenthau, *Politics among Nations: The Struggle for Power and Peace*, 1st edition, New York 1948 (1949), p. 301.

[16] See F. Friedensburg, *Die Mineralischen Bodenschätze*…, op. cit., pp. 168–188. German theorists were surely not alone in their concern for the importance of raw materials during war. For a similar American view, see B. Emeny, *The Strategy of Raw Materials: A Study of America in Peace and War*, New York 1934 (1936); F.H. Simonds, E. Brooks, *The Great Powers in World Politics: International Relations and Economic Nationalism*, New York 1935.

[17] Even though Germany had suffered from the blockade in World War I, it was still able to conduct important trade with a few remaining neutrals (F. Friedensburg, *Die Mineralischen Bodenschätze* …, op. cit., p. 181).

[18] „The doctrine of limiting factors in biology means, for example, that a plant needing nitrogen is not helped by an excess of phosphate" (S.B. Jones, *The Power Inventory and National Strategy*, "World Politics" 1953, Vol. 6, No. 4, p. 432, http://www.jstor.org/stable/2009020 (15 Apr 2011).

national production of raw materials in peace time[19]. As a result, Friedensburg estimated the domestic supply by creating an index (index total = 100) by weighing raw materials as needed for military supplies and operations. The weights were: "coal 40, oil 20, iron 15, copper, lead, manganese, sulfur compounds 4 each, zinc, aluminum, nickel 2 each, tin and the steel alloying metals counted together 1 each, mercury and antimony 0.5 each."[20] By applying these weights, he calculated a coefficient to determine the degree of self-reliance in terms of supply potential, 0 meaning no ability at self-reliance, 100 meaning complete self-reliance.

This in itself was not yet a power formula, but it became one when Friedensburg effectively suggested multiplying his estimated index numbers for supply potential by the population of a given country:

In all cases it is only about the relative supply potential, i.e. the possibility of supplying the troop strength set up by the country concerned, which may be estimated at most with 7% of the population. The seemingly large supply prospects of Czechoslovakia (index number 48) would therefore, when related to the five times greater military strength of the German Empire, achieve only the fifth part[21].

Hence the formula can be stated this way:

military power = supply potential of raw materials x population

Aside from the example of Czechoslovakia relative to Germany, Friedensburg did not calculate the results. The following table shows the results he would have obtained if he had multiplied the numbers of the supply potential index by the population numbers of 1936. He calculated the supply potential index only for those countries listed:

Table 2. Military Power of Countries in 1936

Country	Supply Potential	Population	Military Power
Russia (future)	80	172,800,000	13,824,000,000
United States	90	127,520,000	11,476,800,000
Russia (current)	50	172,800,000	8,640,000,000

[19] See F. Friedensburg, *Die Mineralischen Bodenschätze*…, op. cit., p. 64.

[20] German text: „Kohle 40, Erdöl 20, Eisen 15, Kupfer, Blei, Mangan und Schwefelverbindungen je 4, Zink, Aluminium und Nickel je 2, Zinn und die als Einheit gerechneten Stahllegierungsmetalle außer Nickel je 1, Quecksilber und Antimon je 0,5". See F. Friedensburg, *Die Mineralischen Bodenschätze*…, op. cit., p. 182.

[21] German text: „In allen Fällen handelt es sich nur um die relative Versorgungsmöglichkeit, d. h. um die Möglichkeit der Versorgung der allenfalls von dem betreffenden Lande aufgestellten Truppenstärke, die mit höchstens 7% der Bevölkerungsziffer geschätzt werden mag. Die scheinbar hohen Versorgungsaussichten der Tschechoslowakei (Kennziffer 48) würden also, auf die fünfmal größere Heeresstärke des Deutsche Reiches bezogen, nur den fünften Teil erreichen". See F. Friedensburg, *Die Mineralischen Bodenschätze*…, op. cit., p. 182.

Germany	62	67,190,000	4,165,780,000
Japan	43	69,450,000	2,986,350,000
United Kingdom	55	50,140,000	2,757,700,000
France	48	41,975,000	2,014,800,000
Italy	19	42,500,000	807,500,000
Czechoslovakia	48	15,155,000	727,440,000
Belgium-Luxembourg	32	8,597,000	275,104,000
Total	62	768,127,000	47,675,474,000

Source: F. Friedensburg, *Die Mineralischen* Bodenschätze, op. cit., p. 182; von der Fischer Eger, 1936. *Erdumfassender Bericht über die Bevölkerungsentwicklung, V: 1935–1936*, „Zeitschrift für Geopolitik" 13 (13), 810, 812–813; author's own calculations.

Hans Morgenthau mentioned Friedensburg in his discussion of raw materials in *Politics among Nations*, where he writes that "the absolute importance of the control of raw materials for national power has increased in proportion to the mechanization of warfare."[22] He cites Friedensburg's ratings of the relative importance of the various raw materials and further emphasizes that this relative importance of specific minerals is constantly shifting. He is sure that in 1886 coal and iron would have received a higher weighting. By 1948 uranium had become enormously significant for its use in nuclear weapons[23]. Morgenthau noted that Friedensburg had not even mentioned uranium.

4. John Quincy Stewart (1945/1954)

John Quincy Stewart (1894–1972) was an American astrophysicist. Initially a civilian aeronautical engineer, Stewart proceeded to teach astrophysics at Princeton University from 1921 to 1963. In 1927 he co-wrote *Astronomy: A Revision of Young's Manual of Astronomy*, which became the standard textbook on astronomy for two decades. He also became interested in social physics, which is the application of concepts

[22] H.J. Morgenthau, op. cit., p. 84.

[23] As for the importance of raw materials for the calculation of power, it is interesting to cite Morgenthau at length: „The release of atomic energy from the uranium atom and the use of that energy for warfare has at once modified the actual and potential hierarchy of nations from the point of view of their relative power. Nations which control deposits of uranium, such as Canada, Czechoslovakia, the Soviet Union, and the United States, have risen in the power calculations. Others, which neither possess nor have access to deposits of that mineral, have fallen". H. Morgenthau, op. cit., p. 86; J.G. Stoessinger, *The Might of Nations: World Politics in Our Time*, New York 1990, p. 16.

from the world of physics to social phenomena[24]. In 1947 he coined a concept called *demographic gravitation* to apply the physical concept of gravitation to demographic behavior[25]. It was typical for the spirit of the time to try to export the real 'scientific' method into what was considered the backward humanities and so-called social 'sciences'[26].

In 1945 Stewart wrote *Coasts, Waves and Weather for Navigators*, a book largely concerned with physical geography, yet he managed to include a few subsections on geopolitics in which he added his own ideas.[27] He mentioned how geopolitics recognized the political importance of spatial factors. From that he went on to population density and the distribution of population while asserting that "when sociologists count numbers of people, they are entering the province of physical science, because number is a physical thing."[28] He then reflected on the influence of people, and he made two common sense propositions: (1) the influence increases with the number of people, (2) the influence decreases with distance[29]. Accordingly, the 1945 formula can be expressed in this simplified way:[30]

population potential = people / distance

Population potential is a geographic concept that refers to the average distance of a set of people to a certain point[31]. Stewart prefers population potential to local population density, because the influence of population is not limited to its immediate vicinity[32].

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[24] Auguste Comte (1798–1857) had developed the term „social physics," but when he discovered that Adolphe Quetelet (1796–1874) had usurped the concept, he changed the name to „sociology" as he opposed Quetelet's statistical approach.

[25] J.Q. Stewart, *Demographic Gravitation: Evidence and Applications* ,"Sociometry" 1948, Vol. 11, No. 1–2, http://www.jstor.org/stable/2785468 (20.04.2011).

[26] Idem, *The Development of Social* Physics, "American Journal of Physics" 1950, Vol. 18, No. 5, p. 239, http://ajp.aapt.org/resource/1/ajpias/v18/i5/p239_s1 (20.04.2011). Compare D. Maxeiner, *Dem Zufall eine Chance* „ Die Zeit" 1995, (32) [online], http://www.zeit.de/1995/32/Dem_Zufall_eine_Chance (18.04.2011).

[27] See J. Stewart, *Coasts, Waves and Weather for Navigators*, Boston 1945, pp. 160–167.

[28] Ibidem, p. 162.

[29] Stewart makes the simplistic argument that Germany lost in Russia due to distance. See J. Stewart, *Coasts, Waves*…, op. cit., p. 161. For the counter-argument emphasizing that space is relative, see K. Vowinckel, ... *ein zweiter Napoleon*?, "Zeitschrift für Geopolitik" 1941, Vol. 18, No. 7, 372–375, where Vowinckel compares the speed of movement and transportation in 1812 and 1939.

[30] This is the correct way to put the formula:

population potential $V_1 = \sum_{f=1}^{n} \frac{P_f}{d_{if}} = \frac{P_1}{d_{i1}} + \frac{P_2}{d_{i2}} + \frac{P_3}{d_{i3}} \ldots + \frac{P_n}{d_{in}}$

„where the population potential (V_1) at point i is the summation (Σ) of n populations (j) accessible to the point i divided by their distance (d_{ij}) to that point", http://www.answers.com/topic/population-potential.

[31] Population potential is similar to market potential, which is useful for business to estimate the probable volume of sales at different locations.

[32] J.Q. Stewart, *Natural Law Factors in United States Foreign Policy*, "Social Science" 1954, Vol. 29,

In 1954 he further developed these ideas[33] to the point of writing a paper on the *Natural Law Factors in United States Foreign Policy*, in which he added (3) social mass, (4) kilowatt-hours and (5) information bytes. "The 'social mass' of a district is the tonnage of material in it which has been moved or fabricated for social purposes."[34] It is unclear to what degree the data for social mass were available, but the variable itself was used by Stewart as a weighting factor in order to emphasize that humans differ in technological standing[35]. Two complementary alternatives were discussed, one is kilowatt-hours, the other is information bytes as appropriate for the computer age which had recently commenced. Accordingly, the 1954 formula can be put this way:

influence = social mass / distance

or

political potential = technology x population / distance

It is not entirely clear whether the distance should be squared or not in order to relate to the difference of force and energy in Newton's gravitation law[36].

What makes Stewart's formula stand out is that it is geopolitical in the truest sense, meaning that the power of countries changes with location (the 'geo'). For example, Germany is more powerful vis-à-vis Denmark than vis-à-vis New Zealand. "That is, the impact of one nation's power diminishes when the distance between this nation and impacted nation increases. Therefore, not all nations will be under the same amount of pressure resulting from the national power of others."[37] The challenge perhaps is to combine all these multiple possible local power indexes into a uniform worldwide power index; perhaps a gravity model could be designed where proximity

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No. 3, pp. 162–165.

[33] In the 1954 paper Stewart also gives credit to the American economist Henry Charles Carey (1793–1879) for suggesting that people exert a gravitational influence and that the distance factor matters politically. See J.Q. Stewart, *Natural Law Factors* ..., op. cit., p. 129.

[34] Ibidem, p. 130.

[35] Harold Sprout commented on the Stewart Formula: „In a system such as the international political system of today, in which technological differentials among members of the system range from slight to enormous, the technological weighting factor may well be more significant than the other two variables [population-size and distance] as a rough and ready indicator of relative levels of political potential". H. Sprout, *Geopolitical Hypotheses in Technological Perspective*, "World Politics" 1962, Vol. 15, No. 2, p. 204.

[36] J.Q. Stewart, *Demographic Gravitation*…, op. cit., pp. 32–34; idem, *Natural Law Factors*…, op. cit. p. 130.

[37] I. Xierali, *Foreign Diplomatic Interaction with the United States, 1990–2000: A Gravity Model Approach*, Paper presented at the Association of American Geographers (AAG) Pre-Conference at the University of Colorado, 3–5 April 2005, Boulder, United States, p. 1, http://www.colorado.edu/ibs/aagpreconference/papers/Xierali_paper.pdf (21.04. 2011). Geopolitical pioneer Alexander Supan (1847–1920) designed a 'pressure quotient' along this line of thought in order to calculate how much pressure the immediate external environment is putting on a country: pressure quotient = state population / total population of neighboring states Supan states that one may prefer using the size of the armed forces (military personnel) instead of population. A. Supan, *Leitlinien der allgemeinen politischen Geographie: Naturlehre des Staates*, 2 Ausgabe, Leipzing 1922, p. 75-78; K. Höhn, *2011Power in Alexander Supan's Guidelines to General Political Geography (1918/1920)*, "Przegląd Geopolityczny" 2011, Vol. 3, pp. 10-11.

matters and is accounted for[38]. For example, Canadian power seems diminished due to its close proximity to the US, while Australian power seems augmented due to the relative weakness of its closer neighbors.

5. Philip Quincy Wright (1955)

Philip Quincy Wright (1890–1970) was an American political scientist and pioneer in quantitative war studies. After teaching at Harvard University from 1916 to 1919 and the University of Minnesota from 1919 to 1923, he spent most of his career at the University of Chicago, where he was professor of political science from 1923 to 1931 and professor of international law from 1931 to 1956. In 1926 Charles Edward Merriam initiated an inter-departmental study on the causes of war at the University of Chicago that resulted in 40 dissertations and 10 books on the topic. In 1942 Wright published *The Study of War* that summarized and concluded this research project; the two volumes contain massive amounts of information including statistical data. In 1955 Wright published *The Study of International Relations* as "the only major scholarly attempt to encompass the whole discipline of international relations."[39]

Wright developed a field theory of international relations "to conceive the world as a field of conditions, values, ideals, and attitudes, in continuous flux, but at any point and moment exerting influence upon the actions of individuals, associations, and nations."[40] He makes a distinction between a geographical field, in which actual time-space events take place, and an analytical field defined by coordinates that measure continua influencing choices, decisions, and actions. He further differentiates between two types of dimensions: one type representing the values of the system, and the other representing the capabilities of the system. Vectors describe tendencies in the system. Depending on the movement of vectors, one can recognize trends towards stability or instability. "It is an organic view of international relations emphasizing the interrelations of things and events."[41]

Discussing the specifics of power[42], Wright points out that the power position of countries usually depends on (1) armaments in being, (2) military potential,

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[38] For a concise introduction into basic gravity modeling in geography, see K.E. Haynes, S.A. Fotheringham, *Gravity and Spatial Interaction Models*, Beverly Hills 1984.

[39] R.J. Rummel, *Understanding Conflict and War*, Vol. 1*: The Dynamic Psychological Field*, New York 1975, p. 60. In the book Wright listed four methods to the study of international relations: (1) historical-descriptive, (2) analytic-rational, (3) synthetic-practical and (4) statistical-mathematical. Q. Wright, *The Study of International Relations*, New York 1955, pp. 125–126).

[40] Q. Wright, *The Study of International Relations*, op. cit., p. 491, 540–553. Also see R.J. Rummel, *Understanding Conflict and War…,* op. cit., pp. 60-65.

[41] R.J. Rummel, *Understanding Conflict and War*…, op. cit., p. 62.

[42] Q. Wright, *The Study of International Relations*, op. cit., pp. 138–141.

(3) national morale, and (4) international reputation[43]. He disagrees with the realist idea that states can rely only on their military force and military potential (including economy) to secure their independence; rather, he takes the liberal position that the interest of states in their self-preservation may get a wider appeal through international law and international organizations, hence the importance of international reputation. Nevertheless, he concedes that "all politics is power politics."[44] He lists many different manifestations of power and doubts that any common measure for political and social power comparable to kilowatt-hours in physics can be found. He is especially concerned how persuasive forms of power can be equated with coercive forms of power, though he acknowledges that coercion and persuasion go hand-in-hand.

Wright designed six field diagrams that graph the motion of vectors[45]. For that purpose he defined six value dimensions and six capability dimensions, one capability dimension called strength-weakness defined by military potential (war potential):

military potential = population x secondary energy production

Wright did not provide any justification for making the formula this way. He only explains that he chose secondary energy production[46] rather than unexploited energy resources, because unexploited energy resources "could not be utilized in a major degree during the course of a war."[47] He did not present the calculated results except for location values for the diagrams, but he listed the data that were used for the calculations, so the following table presents the recalculated results for all countries for which he provided data:

Table 3. Military Potential of Countries in 1954

Country	Population 10 million	Secondary Energy Production 10 mil tons bituminous coal	Military Potential
USA	16.0	62.1	993.6
USSR	20.0	14.1	282.0

[43] Wright cites as his source a text compilation *The Foundations of National Power* edited by Harold and Margaret Sprout. After discussing a number of elements of national power, the Sprouts themselves produced a theoretical power formula: "an estimate [of a nation's power potential] can be expressed in the form of a crude equation thus: manpower plus economic resources plus tools and skills plus organization plus morale equals power potential which, given time, can be transmuted into power in being". H. Sprout, M. Sprout (eds.), *Foundations of National Power*, Princeton 1945, p. 30.

[44] Q. Wright, *The Study of International Relations*, op. cit., p. 140.

[45] Ibidem, pp. 547–549, further 595–603.

[46] Wright talks only of „energy production", he does not distinguish between primary and secondary energy (compare section 13.10). Secondary energy is energy in the form of heat, electricity, et cetera, resulting from the transformation of the primary energy sources like oil, coal, gas, et cetera. Hence secondary energy production is more or less equivalent to energy consumption or electricity production.

[47] Q. Wright, *The Study of International Relations*, op. cit., p. 600.

Germany	7.0	20.7	144.9
China	47.0	2.7	126.9
UK	5.0	22.6	113.0
India	36.0	2.5	90.0
France	4.2	5.4	22.7
Brazil	5.4	1.0	5.4
Italy	4.7	1.1	5.2
Egypt	2.0	0.4	0.8
Switzerland	0.5	0.8	0.4
Denmark	0.4	0.5	0.2
Total	149.2	298.9	1,950.1

Source: Quincy Wright, *The Study of International Relations*…, op. cit., pp. 587-588; author's own calculations.

Rudolph J. Rummel used Wright's measure in his Dimensionality of Nations Project (DON), population multiplied by energy production counting as variable number 63 among 236 variables[48].

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Unsurprisingly the four formulas have nothing in common in terms of variables, except for population. If the four formulas have something in common, then it is their parsimony[49] and relative simplicity. These four formulas all basically have two variables, which is very different from most formulas afterwards, starting with the intricate formula of Clifford German in 1960, which has 20 variables going into the calculations. Also the formulas reflect what variables were available at the time of their creation. In 1741 two available variables were rough estimates of territorial size and population. In 1936 information on the production of different raw materials was available, though the evaluation (weighting) of their importance could only be done by an expert like Friedensburg. In 1954 Stewart played with the idea of replacing population as a variable; one suggested replacement was information bytes reflecting the enthusiasm of the early computer age. A year later Wright used data on energy production in his formula. If used nowadays, all these formulas would yield implausible results, but at their time they were the first steps in the right direction. As for providing possible inspiration for future power formulas, Stewart's formula is the most outstanding because of his unique usage of distance as a factor. One basic idea of geopolitics is that the relative location of countries matters strategically.

[48] R.J. Rummel, *The Dimensions of Nations*, Beverly Hills 1972, p. 124.

[49] In statistics „parsimony" refers to a general preference for fewer variables (Occam's razor).