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Quasity, when quantity has a quality all of its own—toward a theory of performance

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Abstract Quality, Quantity, Performance,… An unresolved challenge in performance evaluation in a very general context that goes beyond scientometrics, has been to determine a single indicator that can combine quality and quantity of output or outcome. Toward this end, we start from metaphysical considerations and propose introducing a new name called Quasity to describe those quantity terms which incorporate a degree of quality and best measures the output. The product of quality and quasity then becomes an energy term which serves as a performance indicator. Lessons from kinetics, bibliometrics and sportometrics are used to build up this theme.

Keywords Quality · Quantity · Quasity · Performance · Bibliometrics · *p*-index · Energy-index · $X = lO = l^2I$

Introduction

Quantity has a quality all of its own—Joseph Stalin

An unresolved challenge in performance evaluation in a very general context has been to determine a single indicator that, when given an input of size I, can combine quality (l) and quantity of output or outcome (O). Typically, the situation can be summed up as one in which an activity where input(s) I (a quantity term) lead to an output or outcome O (also a quantity term but now with an element of quality attached to it). Many countries took part in the recently concluded Asian Games at Guangzhou (Prathap 2011). In each case, let I be the size of the population and O be the number of medals won. China, the largest country participating (1.355 billion people), had a medal tally that far exceeded that of everyone else (416 medals), due to its overwhelming size and its superior, but not decidedly the best, quality of performance (0.31 medals per million of population). Note that the proxy for quality is obtained by rationalizing for size, i.e. the performance per capita, given by

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$l = O/I$. In per capita terms, tiny Qatar had the best performance (18.5 medals per million of population). We therefore find cases of high input but low output and therefore low quality, or low input and medium output but of high quality, etc. An intermediate sized participant may have actually performed best by combining low input (48.9 million people), modestly high output (232 medals) with modestly high quality (4.74 medals per million of population), as indeed South Korea did. How does one use a single scalar indicator to compare these performances so that a single ranking can be made which optimally combines quality and quantity? Or will this remain forever a incommensurable problem?

To work towards a theory of performance, one must start from metaphysical premises. It is seen that there is a missing term out of a trinity that mediates between the quantity of input, quality associated with the input and the energy associated with these terms. This missing link, we shall call quasity, inspired by *quasi*-, a prefix, which when used with *–ty* implies that the object has some of the attributes of quality and some of the attributes of quantity. With such a term introduced, a theory of performance can be proposed based on the energy analogy. Insight into this first came from some recent work in bibliometrics (Glanzel 2008; Prathap 2010a).

Research assessment based on bibliometric methods assumes that the number of papers (P) and the number of citations (C) have a source-item relationship. We can draw parallels between P and I, and C and O. The impact $i = C/P$ is the best proxy for quality (our l) we have, given that in most bibliometric research assessment at the level of large aggregations, only the information P and C are available and none of the internal details such as the actual bibliometric (also called citation) sequences of all individual scientists. The recent studies in bibliometrics led to an indicator called the performance index (p-index) which was able to effectively combine size (quantity) and impact (quality) of scientific papers (Prathap 2010a), mocking what the h-index could do (Hirsch 2005). Prathap (2010a) used dimensional analysis to note that h and P have the same dimensions, and that every citation is actually a paper that cites the publication and has the same dimensions as h (or P). Thus, the total received citations C which sums over P has the dimension of area, i.e. h^2 or P^2. A composite indicator $(C^2/P)^{1/3}$ (see Glanzel 2008) is seen immediately to have the dimensions of h. Thus $(C^2/P)^{1/3}$ $[=(C.C/P)^{1/3}]$ is an indicator that senses both size and quality.

The curious structure of the p-index (or mock h-index) shows that it can be interpreted using an energy argument and here, borrowing from electrical analogy, a power/energy basis for bibliometric research assessment emerged. The proxy for the energy of ideas turned out to be $X = p^3 = i^2P$, where p is also a proxy for a performance indicator. We propose in this paper that X is a scalar performance indicator that best serves the purpose of reconciling quality with quantity.

What is interesting is that this can be applied to any general situation where performance needs to be evaluated, given an input I (for quantity) and an output or outcome O (for quasity). The quality, is defined as quasity/quantity ($l = O/I$). The simplest indicator for performance becomes $X = lO = l^2I$.

A parallel from kinetics

We can reinforce our metaphysical notions regarding the use of the words quantity and quality above by learning from a famous episode in the development of the field of kinetics (dynamics), the *vis viva* controversy (Terall 2004). In 1686, as the relationship between force and motion was being formulated, Leibniz introduced the energy like term called *vis viva* ($e = mv^2$) for a mass m moving with a velocity v, and suggested that this was universally conserved. This was in opposition to the prevailing wisdom, which was Descartes' law of conservation for "quantity of motion", namely mv. Note that in the light of the discussion above, m is a scalar quantity term and v is a vector term, and that mv, the momentum term is consequently also a vector term. We can think of this as our "quasity" term. From this, energy can easily be obtained as $v \cdot mv$, the vector dot product between velocity and momentum which results in a scalar quantity. Indeed then, the basic kinetic "quantity" is expressed by mass, kinetic "quality" is expressed by velocity, and the kinetic "quasity" term is momentum. From this, the kinetic energy (which we represent here by the archaic *vis viva* term) is a scalar quantity. Carrying this wisdom back to our discussions above, energy = (quality) · (quantity × quality) = (quality) · (quasity)! For both Leibniz, and Descartes, "conservation was a key metaphysical question, with unavoidable implications for physics" (Terall 2004). Whether, it was for momentum, or for energy, or for both simultaneously, took some time to establish. We are in the same predicament today as we try to establish a metaphysical theory of performance.

An application to sports

We shall now take a closer look at the results from the Asian Games at Guangzhou (Prathap 2011). China (population 1.35 billion) collected 416 medals and was also competing against tiny states (e.g. Macau with 460,000 people, Bahrain with 710,000 people, etc.). On a per capita basis (i.e., in terms of medals per capita) things look different. Forty-five countries took part. Of these, nine returned without a medal. Of the 36 countries that won medals (1577 in all), tiny Qatar "won" the honours (18.5 medals per million of population).

In Quantity-Quality-Quasity terms, we can re-arrange the performance position as shown in Table 1. The indicator *M/P* (medals/per million of population) is the "quality" measure. The quantity (read size) measures are P (million of population) and the quasity measure is now M (number of medals). Attention is now drawn to the last column in Table 1 where term $X = M/P \times M$ appears. This is a product of the quality and the quasity term and perhaps best represents the "performance" of a country. On a quality (medals per million) basis, Qatar "won" at Asiad 2010. On the quasity (medals) basis, China tops. On the energy indicator basis, six countries led by S Korea precede China.

A graphical representation that best captures the process is given in Fig. 1.

An application to research evaluation

A typical manner in which research evaluation is done and presented is exemplified by lists of "Top 20" countries in various scientific disciplines found in Science Watch, a Thomson-Reuters product. The recent Rankings in Molecular Biology and Genetics (http://sciencewatch.com/dr/cou/2010/10sepMOL/) use citations as the sole basis (data extracted from the *Essential Science Indicators*^{SM} database, also from Thomson Reuters, covering the period January 1, 2000–April 30, 2010, surveying only journal articles (original research reports and review articles) indexed by Thomson Reuters).

Table 2 (taken from Prathap 2010b) rearranges this list, using demographic weighting [Populations data for 2010 taken from the Internet Answer Engine, True Knowledge

Table 1 On a quality (medals per million) basis, Qatar "won" at Asiad 2010

Country	Population in millions	Medals	M/P	M/P × M
SOUTH KOREA	48.9	232	4.74	1100.70
KAZAKHSTAN	15.29	79	5.17	408.18
JAPAN	127.4	216	1.70	366.22
QATAR	0.865	16	18.50	295.95
HONG KONG	6.98	40	5.73	229.23
CHINESE TAIPEI	23.29	67	2.88	192.74
CHINA	1355	416	0.31	127.72
BAHRAIN	0.71	9	12.68	114.08
UZBEKISTAN	28.71	56	1.95	109.23
MONGOLIA	2.86	16	5.59	89.51
MACAU	0.46	6	13.04	78.26
SINGAPORE	4.54	17	3.74	63.66
MALAYSIA	28.31	41	1.45	59.38
NORTH KOREA	23.26	36	1.55	55.72
KUWAIT	2.47	11	4.45	48.99
IRAN	74.2	59	0.80	46.91
THAILAND	67.76	52	0.77	39.91
VIETNAM	87.38	33	0.38	12.46
SAUDI ARABIA	27.5	13	0.47	6.15
JORDAN	6.02	6	1.00	5.98
UAE	4.3	5	1.16	5.81
KYRGYSTAN	5.36	5	0.93	4.66
INDIA	1198	64	0.05	3.42
INDONESIA	229.96	26	0.11	2.94
PHILIPPINES	91.98	16	0.17	2.78
LEBANON	3.9	3	0.77	2.31
TAJIKISTAN	7.14	4	0.56	2.24
MYANMAR	55.39	10	0.18	1.81
LAOS	6.54	2	0.31	0.61
PAKISTAN	180.8	8	0.04	0.35
AFGHANISTAN	28.15	3	0.11	0.32
OMAN	3.25	1	0.31	0.31
IRAQ	31.23	3	0.10	0.29
SYRIA	22.33	2	0.09	0.18
BANGLADESH	149.54	3	0.02	0.06
NEPAL	28.87	1	0.03	0.03
TOTAL	3978.645	1577	0.40	625.07

On the quasity (medals) basis, China tops. On the energy indicator basis, six countries led by S Korea precede China (from Prathap 2011)

(http://www.trueknowledge.com)]. In Table 2, the number of articles, P, is the quantity term (i.e. proxy for I) while citations C is the quasity term (i.e. proxy for O). These are taken for the time window January 1, 2000–April 30, 2010. The impact i which is

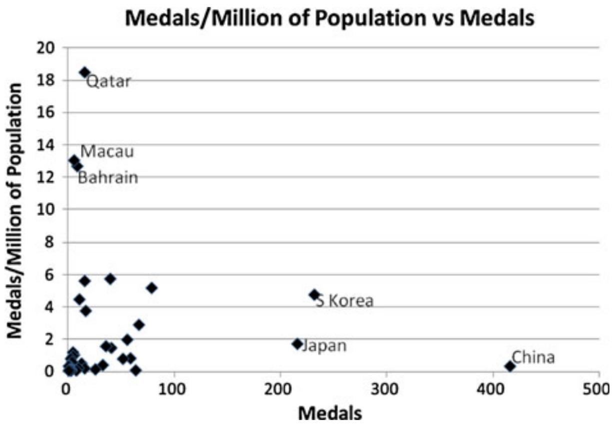

Fig. 1 The graphical representation of performance at the 16th Asian Games on a quality-quasity map (from Prathap 2011)

computed as *C/P* is therefore the quality term (proxy for *l*). In quantity (number of articles *P*) or quasity (number of citations *C*) terms, the USA is leading nation in this discipline. Large countries like Brazil, Russia and India, are missing, and China has just made it into the list, and do not seem to be able to match the impact of even small countries and regions like Scotland, Denmark and Finland! In quality terms alone, by rationalising for population, Scotland appears at the top, followed by Switzerland and Denmark.

All this can be easily represented on a Quantity-Quality-Quasity diagram, what this author calls an iCX map, where the product iC (also i^2P) is the energy like term (called exergy X) and is a scalar measure of the scientific activity during the window concerned that takes into account both quality and quantity. We see from Table 2 and Fig. 2 that USA's research during this period eclipses the rest of the field. In exergy terms, USA is several times as active as England, Germany, France or Japan. A better picture of scientific activity is obtained if the citations and exergies are weighted on a per capita basis, where $C' = C/Million\ of\ population$ and $X' = X/Million\ of\ population$. Now, C' becomes the quasity term while i remains the quality term. The corresponding $iC'X'$ map is shown in Fig. 3. Orders of magnitude differences are seen, when countries and regions like Scotland and Switzerland are compared with the countries at the bottom of the list.

Conclusions

We have shown that a practical theory of performance can be obtained from metaphysical premises, associating quality with vector properties, input quantity with scalar properties and proposing an intermediate term, quasity, also a vector (quantity × quality). This missing term, becomes one of a trinity, and in conjunction with the other two terms, helps generate the energy associated with these terms. A lesson from the history of the development of kinetics from metaphysical positions regarding the conservation of momentum and the conservation of energy allows parallels to be drawn between quantity and mass, quality and velocity and quasity and momentum. The dot product between the quality and quasity terms yields the energy (*vis viva*) term.

Table 2 Research Performance in Molecular Biology and Genetics ranked by the Exergy/Million of Population criterion (from Prathap 2010b)

Rank	Field	Papers (P)	Citations (C)	Citations per paper	Exergy X	Population	C/MillionPop	X/MillionPop	Normalised
1	SCOTLAND	4,531	151,478	33.43	5,064,132.53	5,168,500	29,307.92	979,807	1,247.8
2	SWITZERLAND	6,492	218,290	33.62	7,339,883.56	7,834,000	27,864.44	936,927	1,193.2
3	DENMARK	3,054	97,859	32.04	3,135,685.62	5,519,441	17,729.88	568,117	723.5
4	ISRAEL	3,698	119,821	32.40	3,882,388.33	7,688,667	15,584.11	504,949	643.0
5	ENGLAND	23,572	780,178	33.10	25,822,064.81	51,446,000	15,164.99	501,926	639.2
6	SWEDEN	5,467	150,419	27.51	4,138,627.32	9,259,000	16,245.71	446,984	569.2
7	USA	117,426	3,832,395	32.64	125,076,656.24	305,689,000	12,536.91	409,163	521.1
8	FINLAND	2,673	72,403	27.09	1,961,165.14	5,367,219	13,489.85	365,397	465.3
9	AUSTRIA	2,686	88,512	32.95	2,916,743.91	8,190,000	10,807.33	356,135	453.5
10	NETHERLANDS	7,513	207,811	27.66	5,748,091.54	16,558,674	12,549.98	347,135	442.1
11	CANADA	13,942	360,560	25.86	9,324,595.73	33,100,000	10,893.05	281,710	358.8
12	GERMANY	25,697	723,916	28.17	20,393,601.40	82,400,000	8,785.39	247,495	315.2
13	BELGIUM	3,643	91,162	25.02	2,281,227.08	11,118,493	8,199.13	205,174	261.3
14	AUSTRALIA	7,007	172,960	24.68	4,269,325.19	21,885,016	7,903.12	195,080	248.4
15	FRANCE	17,819	475,314	26.67	12,678,792.22	65,073,482	7,304.27	194,838	248.1
16	JAPAN	24,469	552,938	22.60	12,495,011.31	127,430,000	4,339.15	98,054	124.9
17	ITALY	11,812	247,537	20.96	5,187,484.45	60,157,214	4,114.83	86,232	109.8
18	SPAIN	7,821	158,597	20.28	3,216,085.97	45,840,557	3,459.75	70,158	89.3
19	SOUTH KOREA	4,658	59,133	12.69	750,689.50	48,861,257	1,210.22	15,364	19.6
20	PEOPLES R CHINA	9,968	102,962	10.33	1,063,520.61	1,354,370,754	76.02	785	1.0

Source: Essential Science Indicators from Thomson Reuters

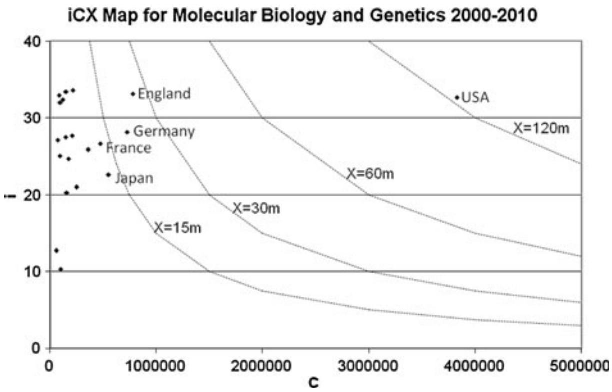

Fig. 2 The iCX Map without taking into account the sizes of the countries (from Prathap 2010b)

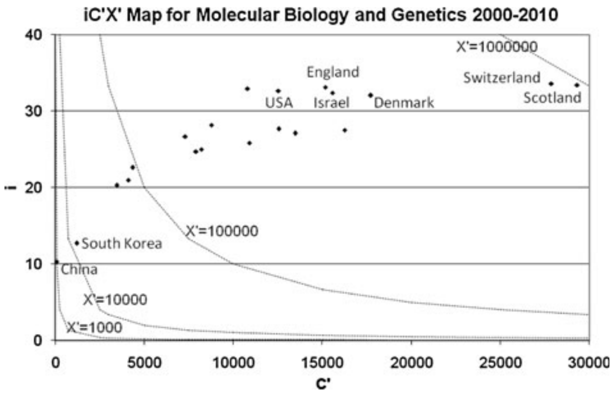

Fig. 3 The iC'X' Map taking into account the sizes of the countries (from Prathap 2010b)

Thus, by introducing the concept of Quasity, it is possible to reconcile Quality of performance and Quantity of input to obtain an energy term that serves as a performance indicator in a very general context. Quasity is therefore a quantity term tinged with a quality flavor that best describes the "quantity" of output or outcome.

Given any general situation where performance needs to be evaluated, for an input *I* (for quantity) and an output or outcome *O* (for quasity), the quality, is defined as quasity/quantity ($l = O/I$). The simplest indicator for performance becomes $X = lO = l^2 I$.

The foregoing has important implications in the area of research evaluation. For the most part, this is done using quality indicators (impact, crown indicators, normalized citation scores, etc.) or quantity indicators (*P*, *C*, etc.). The best effort so far to recommend an indicator that tries to reconcile quality with quantity is the *h*-index, and its many variants. Our metaphysical considerations show that the best, single scalar indicator of performance is an energy like term that requires the recognition of an intermediate term so that the product of this term with the quality term gives the energy term. These can also be very elegantly displayed as maps, with quality on the y-axis and quasity on the x-axis, and constant exergy lines being marked as contours on the map. What is most encouraging is that these concepts, which emerged out of recent work in bibliometrics has a reach that goes beyond to very general contexts where performance evaluation is needed.

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