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A quantitative relationship between per capita GDP and scientometric criteria

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There exists a quantitative relationship, which can be expressed as G=kF(lgP)N, where G is per capita GDP, F gross expenditure on R&D as % of GDP, P patent applications, N Internet users per 10,000 inhabitants, and k a constant ranging from 0.4 to 1.2 in most countries. The mechanism of the relationship is explained in the paper.

Introduction

It is well known that S&T (scientific and technical) and R&D (research and development) levels relate to the economic level in the information age. But we have not yet developed quantitative evaluation measures to assess the correlation between economic development levels and S&T or R&D. For finding the quantitative relationships between economic indicators and certain scientometric criteria, let us consider that S&T contribute their effects to every economy and that R&D promotes economic development in every country. There should be relationships between economic indicators such as GDP and some scientometric criteria such as gross expenditure on R&D as % of GDP. So, it is very important whether a quantitative relationship exists between per capita GDP and scientometric criteria.

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In informetrics (EGGHE & ROUSSEAU, 1990), some bibliometric laws have been integrated. But there are not enough empirical laws among scientometric criteria and economic indicators. Thus, scientometrics seems only a name without rich contents. For constructing the systematical theory of scientometrics, I attempt to find more quantitative patterns between economic indicators and scientometric criteria, referring to past informetric empirical laws and current theoretical research (BURRELL, 2005; EGGHE, 2002, 2005; ROUSSEAU, 2005). In this paper, a quantitative relationship between per capita GDP and scientometric criteria is set up, based on IMF (International Monetary Fund), WIPO (World Intellectual Property Organization) and UNESCO (United Nations Education, Science and Culture Organization) statistical data.

Methodology

Subject

IMF, WIPO and UNESCO have collected a lot of data from all countries around the world. Their statistical data are the foundation of this study. While checking systematically all data of IMF, WIPO and UNESCO statistics from the viewpoint of informetrics and scientometrics, I find that there exists a quantitative relationship between per capita GDP and some scientometric criteria such as gross expenditure on R&D as % of GDP, patent applications, and Internet users per 10,000 inhabitants.

During the research, I chose per capita GDP as an economic indicator, and gross expenditure on R&D as % of GDP, patent applications, Internet users per 10,000 inhabitants and others as scientometric criteria, then tried to find a quantitative pattern between the economic indicator and these scientometric criteria. At last, a quantitative relationship is revealed between per capita GDP and gross expenditure on R&D as % of GDP with patent applications and Internet users per 10,000 inhabitants. Rather than being the result of systematic research, this is much more an accidental discovery.

Methods

The basic method is data analysis with test calculation. Through calculation and comparison, quantitative relationships can be observed and established. Software MS Excel is simply applied.

Procedures

(1) Collection of data. First, I collected statistics from IMF, WIPO and UNESCO web sites.

(2) Comparison of data. Then, I compared all data from various countries, using the same economic indicators and scientometric criteria.

(3) Analysis of data. Last, I tried to find the quantitative relationships among the data.

Data

Typical statistical data which are collected for the study are shown in Table 1.

Table 1. Typical statistical data (2001)

Country=C	PCGDP=G (Per capita GDP) [1)]	GERD=F (Gross expenditure on R&D as % of GDP) [2)]	PA=P (Patent applications)[3)]	PG=Q (Grants of patents) [4)]	IUPI=N (Internet users per 10,000 inhabitants) [5)]
Canada	22730.2	2.11	98489	12019	4514
USA	35366.6	2.74	375657	166038	4995
Mexico	6030.9	0.39	82470	5476	362
Brazil	2984.1	1.04(2000)	94007	3385	464
Australia	18458.7	1.55(2000)	94893	13983	3723
Austria	23217.6	2.07	233181	14328	3901
Denmark	30148	2.4	232921	10618	4313
Finland	23718.9	3.4	230441	5362	4317
France	21535	2.23	175122	42963	2633
Germany	22529.9	2.65	292398	48207	3756
Greece	10679.4	0.65	155346	7870	1318
Italy	18910.3	1.11	156858	25130	2713
Netherlands	23957.4	1.89	158932	20624	4959
Norway	37232.7	1.6	84373	2448	4679
Poland	4561.3	0.65	81074	2022	985
Russia	2134.7	1.16	107678	16292	297
Spain	14979.1	0.96	234543	19709	1851
Sweden	23546.7	4.27	231483	14873	5208
Switzerland	33951.4	2.63(2000)	233652	15639	3102
UK	23735.7	1.86	264706	39649	3325
China	910.8	1.07	149294	16296	262
Japan	32765.8	3.06	496621	121742	3840
Turkey	2283.5	0.72	229339	2137	591
Egypt	1490	0.19(2000)	1387	430	87

Data sources:
1) http://www.imf.org/external/pubs/ft/weo/2002/02/data/index.htm
2) http://www.uis.unesco.org/ev_en.php?ID=2867_201&ID2=DO_TOPIC
3) & 4) http://www.wipo.int/ipstats/en/statistics/patents/index.html
5) http://www.uis.unesco.org/ev.php?URL_ID=5495&URL_DO=DO_TOPIC&URL_SECTION=201

As there are no complete data for the statistical items in some countries, I choose following representatives countries for the study, which are Canada and USA as representatives of North America, Mexico and Brazil as representatives of Latin

America, Australia as a representative of Oceania, Austria, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Russia, Spain, Sweden, Switzerland and UK as representatives of Europe, China, Japan and Turkey as representatives of Asia, and Egypt as a representative of Africa.

The data from IMF, WIPO and UNESCO seem unique. Accidentally, when I integrate the data with simple calculations, a quantitative relationship is revealed and shown naturally.

Results

With the data in Table 1, I made some calculations. The results are shown in Table 2.

Table 2. Quantitative relationships between per capita GDP and various scientometric criteria

Country	Per capita GDP(G)	F(P/Q)N	F(lgP)N	0.5F(lgP)N	2F(lgP/lgQ)N	k
Canada	22730.2	78048.29	47559.72	23779.86	23314.34	0.47793
USA	35366.6	30964.93	76298.27	38149.13	29231.89	0.463531
Mexico	6030.9	2126.208	694.0827	347.0413	371.3198	8.689022
Brazil	2984.1	13401.48	2399.848	1199.924	1359.857	1.243454
Australia	18458.7	39161.43	28721.88	14360.94	13856.56	0.64267
Austria	23217.6	131417.7	43344.5	21672.25	20857.83	0.535653
Denmark	30148	227068.4	55557.05	27778.53	27598.84	0.542649
Finland	23718.9	630803.2	78710.58	39355.29	42211.68	0.301343
France	21535	23933.26	30786.75	15393.37	13289.93	0.699489
Germany	22529.9	60372.03	54405.03	27202.51	23234.57	0.414114
Greece	10679.4	16910.41	4447.387	2223.693	2283.068	2.401275
Italy	18910.3	18796.93	15645.9	7822.952	7111.464	1.208643
Netherlands	23957.4	72226.13	48748.41	24374.2	22598.14	0.49145
Norway	37232.7	258027	36879.53	18439.76	21765.47	1.009576
Poland	4561.3	25671.43	3142.911	1571.456	1901.464	1.451298
Russia	2134.7	2277.021	1733.668	866.8342	823.2094	1.23132
Spain	14979.1	21146.36	9542.671	4771.335	4443.965	1.569697
Sweden	23546.7	346114.2	119297	59648.52	57183.91	0.197379
Switzerland	33951.4	121887.2	43798.19	21899.09	20885.08	0.775178
UK	23735.7	41289.17	33537.08	16768.54	14586.95	0.707745
China	910.8	2568.304	1450.491	725.2455	688.7289	0.627925
Japan	32765.8	47933.3	66930.57	33465.29	26322.43	0.489549
Turkey	2283.5	45666.04	2280.991	1140.495	1370.045	1.0011
Egypt	1490	53.31886	51.93852	25.96926	39.44496	28.68776

The above data show directly that there exists a quantitative relationship between per capita GDP and gross expenditure on R&D as % of GDP with patent applications and Internet users per 10,000 inhabitant in most countries, which can be expressed as G=kF(lgP)N, where G is Per Capita GDP, F is Gross Expenditure on R&D as % of GDP (GERD%), P is Patent applications, N is Internet users per 10,000 inhabitants, and k is a constant among 0.5 to 1. This result is shown in Figure 1.

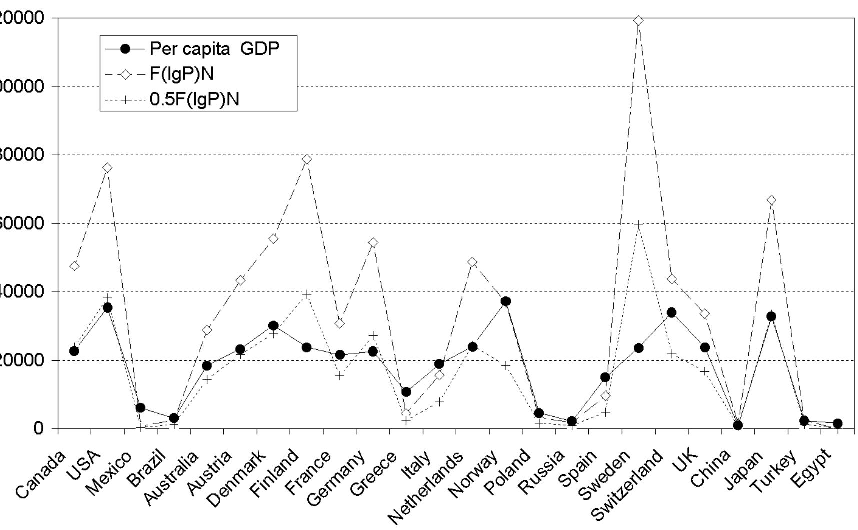

Figure 1. Per capita GDP among 0.5F(lgP)N and F(lgP)N

Analysis and discussion

On the basis of the above data and calculations, it is shown that per capita GDP lies between 0.5F(lgP)N and F(lgP)N. As the GERD% expresses a level for investing in R&D, P is a direct measurement of R&D, and IUPI (Internet users per 10,000 inhabitants) indicates the informational level of the economy. Thus, we can conclude that the economic level, as expressed by per capita GDP, is proportional to GERD%, lg(P), and IUPI.

In modern societies, GERD% is obviously an important factor for R&D. Patent applications are an important factor for both S&T and R&D, since patent information is one of the most crucial elements for S&T and R&D. In the information age, the Internet is a necessary tool for economic development, so that IUPI (Internet users per 10,000 inhabitants) is also an important indicator for the economy and R&D.

The quantitative relationship shows that economic level is proportional to investment level in R&D, information level of society, and the logarithm of patent activities.

For the meanings of F(GERD%), P and N(IUPI), in other words, the factor F is similar to an accelerator for R&D as a percent of investment to R&D. The factor P is an important index for S&T and R&D. And the factor N is a technical indicator, or information indicator, of a society.

The significance of the constant k can also be clarified. For most cases, we see the constant k falls in 0.4 to 1.2 in most countries. Normally, k~0.5 seems better, and 0.4 to 1.6 seems acceptable.

If k>1, it shows that GERD% is weaker and fewer than in normal cases. When k>1.6, there are few patents, so that innovative activities seem very weak in the country.

If k<0.4, it shows that there are many more patent applications than grants of patents, so that the creative quality seems bad in the country.

Generally, constant k is a measure for innovative level in a country. Thus, we can call it the innovative coefficient.

From formula or equation G=kF(lgP)N, we can see that the constant k and the GERD% F will vary reversely, if P and N maintain same. So, more F is, less k is. For example, Mexico, its F=0.39 and k=8.689. Oppositely, less F is, more k is. For example, Sweden, its F=4.27 and k=0.197. Generally, F=2 to 3 seems normal.

At present, only 2001(2000) data are collected and checked. As there are no more comparable time series of data are found on IMF, WIPO and UNESCO websites, more years of data may further seek in future.

Conclusion

Let G be per capita GDP, F be GERD% (gross expenditure on R&D as % of GDP), P be patent applications, N be IUPI (Internet users per 10,000 inhabitants), and k be a constant. The above discovery means there exists an approximate relationship in most countries, which can be expressed as G=kF(lgP)N. And the mechanism of this relationship is discussed in the paper, which shows that GERD% means the investment for R&D, patent applications concern the scientific and technical research level, and IUPI correspond to the level of the information economy. This is a result from 2001 data only. More years of data are needed to confirm the results. I will look for more data to check the above results, if the IMF, WIPO and UNESCO statistics becomes richer.

The advantage of scientormetric methodology as a means of research is that it provides a global view of science and economy and applicable concepts or viewpoints for an informetric study. And the methodology will be effective for analysis of other economic indicators and scientometric criteria.

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