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GEARING NATIONAL S & T CAPABILITY FOR GLOBAL COMPETITIVENESS IN THE 21ST CENTURY: THEORETICAL AND EMPIRICAL CONSIDERATIONS

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ABSTRACT

Although many explanations have been offered about why some nations, but not others, are able to industrialize and attain rapid and sustained economic growth, the role of the development of technological capability appears to be the most compelling. This paper initially presents some historical and theoretical arguments about the vital role of the adoption of new technologies in the industrialization and economic success of the rich nations of the world. It then examines the technological capability appears to be the most compelling. This paper initially presents some historical and theoretical arguments about the vital role of the adoption of new technologies in the industrialization and economic success of the rich nations of the world. It then examines the empirical relationship between (1) economic success, measured by per capita GNP of nations, and (2) technological capability, measured by: (a) size of R&D manpower, and (b) level of expenditure on R&D activities. Results of the analysis of both worldwide (70 nations, World Bank and UNESCO) and time series (Japan, South Korea and Taiwan) data support the contention that indeed economic success is a function of technological capability. On the basis of consistent historical, theoretical and empirical evidence, it is proposed that the Philippines, or any country for that matter, may only attain global competitiveness in the 21st century for the matter, may only attain global competitiveness in the 21st century by adequately improving its national technological capability. This can be done by increasing its number and quality of R&D personnel and spending a bigger proportion of GNP and R&D activities.

Statement of Purpose

Although many explanations have been offered about why some nations, but not others, are able to industrialize and attain sustained economic growth, the role of science and technology (S & T) seems to be the most compelling. Evidence from various sources point to the adoption by rich and industrialized nations of modern technology in the production of goods and services as they improve their scientific and technological capability and enhance their research and development (R & D) activities. This paper therefore: (a) presents evidence that science and technology capability (STC) is the major engine of economic growth among rich and industrialized nations; (b) offers to explain the apparent inability of Philippine education to contribute to the nation's economic growth; and (c) recommends a strategy to make the Philippines join the ranks of the rich and industrialized nations by strengthening its science and technology capability (STC) and enhancing its research and development effort (RDE).

Although most of the recommendations made in this study are specific to the Philippines, they may also apply to other countries whose levels of science and technology capability and economic success are similar to that of the Philippines. Among good models of economic success through strengthened national science and technology capability are the Asian Pacific nations of Japan, South Korea, Taiwan, Singapore and Hong Kong.

The Role of Technology in Economic Growth

Both historical and theoretical evidence exist to support the vital role of the adoption of modem technologies in the industrialization and economic success of the rich nations of the world:

Historical Evidence. The success of the industrial revolution in transforming the economies of European countries beginning with England in the middle of the eighteenth century established the role of technology in industrialization and economic success. The rapid industrialization of the USA, which eventually became the world's largest economy, and later on that of Japan, following its defeat in World War II, bolstered further the crucial role of technology in economic growth. The more recent experience of Asia's four "newly industrializing economies" (NIE's), namely, Singapore, Taiwan, South Korea and Hong Kong, is truly phenomenal in that they achieved in some thirty years what it took European countries more than 200 years, the USA over 100 years and Japan over 60 years to accomplish. Common among the strategies of these four Asian "NIE's" is the adoption of modern technology in the production of big volumes of high quality products aimed primarily at the export market.

Theoretical Evidence. The Nobel laureate, Robert M. Solow (1957), theorized that more than the billions in dollars of capital investment, it was technological progress or the application of modern technology, which accounted for over 80 per cent of the growth in output per labor hour in the USA from 1909 to 1949. Denison (1974, 1980), likewise, theorized that over 76 per cent in the growth in output per labor hour also in the USA from 1929 to 1969 was also the result of technological progress or the adoption of new technologies. Finally, Dumbusch and Fisher (1985) attributed Japan's ability to almost triple its output per labor hour from 1960 to 1973 to the adoption of new technologies.

Empirical Evidence. In a study of 70 nations of the world, this investigator (Umpa, 1997) finds that indeed science and technology capability (STC), as embodied in the level of research and development effort (RDE), is a very effective predictor of economic success (ES), as measured by per capita gross national product (PCGNP) in 1994 US dollars (Table 1, Figures 1 & 2). Furthermore, analysis of three sets of time-series data from Japan, South Korea and Taiwan bolsters the worldwide finding about the role of science and technology capability and research and development effort in the economic success of the three nations (Tables 2,3 & 4; Figures 3,4 & 5).

Theoretical Framework

A Model of Economic Success. Classical economic theory emphasizes the role of the traditional factors of production (e.g. land, labor and capital) in the expansion of the economy as a nation attains economic growth and development. However, the role of technological progress has been found to account for a big portion of economic growth (Solow, 1957; Denison, 1974 & 1980; Dumbusch & Fisher, 1985). The adoption of modern technology is therefore crucial to the growth and development of a nation's economy since it provides increasingly newer and more efficient methods of production of goods and services.

In order therefore for a country to develop economically and remain competitive, it must adopt modern technology. But the adoption of modern technology cannot be done simply through the purchase of imported machinery because imported machinery is usually expensive, exporting countries do not sell their advance machinery to prevent competition and that imported machinery often requires parts, services, repairs, modifications and technicians not readily available in importing countries.

The successful adoption of modern technology requires that a country ultimately develops its own technology capability by monitoring worldwide technological discoveries and application, studying and innovating them and eventually inventing creating and designing its own new products and services. Such technological capability requires that a large sector of the population becomes familiar with not only modern technology itself but also with the whole gamut of the fundamental sciences that feed technology with increasing understanding of underlying relationships among various natural phenomena.

But scientific and technological capability (STC) itself does not necessarily translate into economic growth and development unless it is mobilized through the conduct of research and development (R & D) activities, whereby a nation's scientists and engineers are tasked to invent, create, innovate and design new high quality goods and services.

|Table 1. PCGNP, SEMP, and GERD/GNP of 91 Countries of the World

No.	Country	1984 PCGNP (US$)	SE/MP	GERD/GNP
1	Switzerland	37930	2409	1.8
2	Japan	34630	5183	3.0
3	Denmark	27970	2343	1.8
4	Norway	26390	3159	1.9
5	United States	25880	3874	2.9
6	Germany	25580	2713	2.8
7	Iceland	24630	3057	1.1
8	Austria	24630	1146	1.4
9	Sweden	23530	3061	2.9
10	France	23420	2267	2.4
11	Belgium	22870	1856	1.7
12	Singapore	22500	2305	1.27
13	Netherland	22010	2656	1.9
14	Canada	19510	2347	1.6
15	Kuwait	19420	924	0.9
16	Italy	19300	1310	1.3
17	Finland	18850	2283	2.1
18	United Kingdom	18350	2334	2.1
19	Australia	18000	2115	1.4
20	Israel	14530	4836	2.1
21	Brunei Darusalam	14240	91	0.1
22	Ireland	13530	1737	0.9
23	Spain	13440	1060	0.9
24	New Zealand	13350	1555	0.9
25	Qatar	12820	746	0.0
26	Cyprus	10260	205	0.2
27	Portugal	9320	599	0.6
28	Korea, Republic of	8260	1343	2.1
29	Argentina	8110	352	0.3
30	Greece	7700	54	0.3
31	Slovenia	7040	2993	1.5
32	Seychelles	6680	281	1.3
33	Urugay	4660	686	–
34	Mexico	4130	226	0.2
35	Gabon	3880	192	0.0
36	Hungary	3840	1200	1.1
37	Trinidad & Tobago	3740	240	0.8

|Table 1 (continued)

No.	Country	1984 PCGNP (US$)	SE/MP	GERD/GNP
38	Chile	3520	364	0.7
39	Malaysia	3460	327	0.1
40	Czekoslovakia	3200	3247	1.8
4J	Mauritius	3150	180	0.4
42	South Africa	3040	319	1.0
43	Brazil	2970	390	0.4
44	Venezuela	2760	279	0.5
45	Russian Federation	2650	5930	1.8
46	Croatia	2560	1977	–
47	Turkey	2500	225	0.8
48	Thailand	2410	173	0.2
49	Poland	2410	854	0.9
50	Costa Rica	2400	534	0.3
51	Latcia	2320	3387	0.3
52	Fiji	2250	50	0.3
53	Belarus	2160	2300	0.9
54	Peru	2110	274	0.2
55	Ukraine	1910	6736	–
56	Tunisia	1769	388	0.3
57	Colombia	1670	39	0.1
58	Paraguay	1580	248	0.03
59	Jamaica	1540	8	0.0
60	Jordan	1440	119	0.3
61	El Salvador	1360	27	0.0
62	Lithuania	1350	1278	–
63	Ecuador	1280	169	0.1
64	Romania	1270	1220	0.7
65	Bulgaria	1250	4240	1.7
66	Guatemala	1200	99	0.2
67	Uzbekistan	960	90	0.1
68	Philippines	950	90	0.1
69	Indonesia	880	181	0.2
70	Macedonia	820	1258	–
71	Bolivia	770	250	1.7
72	Egypt	720	436	1.0
73	Sri Lanka	640	173	0.2
74	Congo	620	458	0.0

Table 1 (continued)

No.	Country	1984 PCGNP (US$)	SE/MP	GERD/GNP
75	Senegal	600	342	–
76	Honduras	600	138	–
77	China	530	1128	0.5
78	Guyana	530	115	0.2
79	Guinea	520	264	–
80	Pakistan	430	58	0.9
81	Central Afr. Rep.	370	177	0.7
82	Benin	370	177	0.7
83	Nicaragua	340	207	–
84	India	320	145	0.8
85	Nigeria	280	14	0.1
86	Guinea-Bissau	240	263	–
87	Vietnam	200	334	0.4
88	Nepal	200	22	0.5
89	Madagascar	200	22	0.5
90	Burundi	160	32	0.3
91	Rwanda	80	12	0.5

Sources: UNESCO. *Statistical Yearbook* (1995)
UNESCO. *World Science Report* (1996)
World Bank. *World Development Report* (1996)

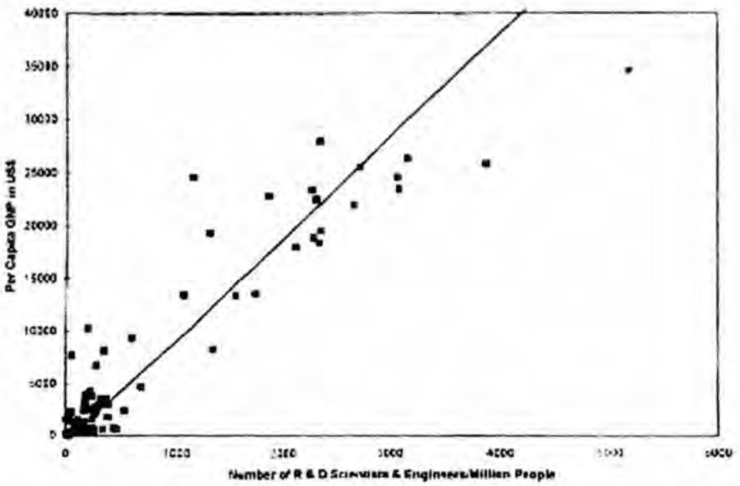

Figure 1. Scattergram of PCGNP and SE/MP among 70 Countries of the World

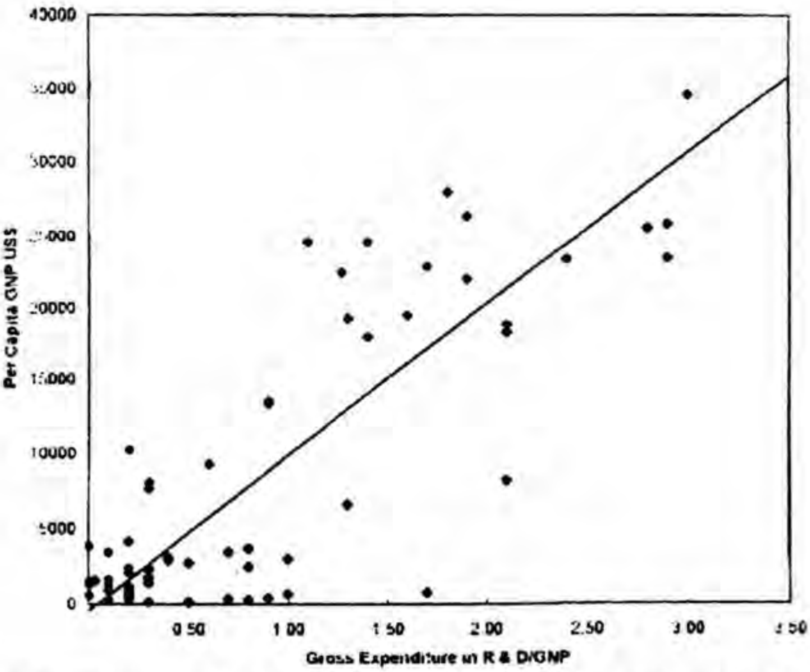

Figure 2. Scattergram of PCGNP and GERD/GNP among 63 Countries of the World

Table 2. Time-Series Data from Japan (1953-1994)

No.	Year	PCGNP	GERD/GNP	SE/MP
1	1953	61157	0.45	437
2	1954	86724	0.52	571
3	1955	96651	0.53	674
4	1956	107852	0.53	731
5	1957	121874	0.54	781
6	1958	125531	0.65	899
7	1959	139529	0.73	946
8	1960	165778	1.10	1265
9	1961	202832	1.10	1345
10	1962	222767	1.30	1507
11	1963	254524	1.30	1720
12	1964	297561	1.27	1896
13	1965	325165	1.37	1984

Table 2 (continued)

No.	Year	PCGNP	GERD/GNP	SE/MP
14	1966	371779	1.38	2167
15	1967	434820	1.32	2299
16	1968	509217	1.36	2546
17	1969	581919	1.47	2527
18	1970	681720	1.51	2762
19	1971	753966	1.71	2957
20	1973	842560	1.69	2956
21	1973	1018249	1.61	3293
22	1974	1197088	1.67	3367
23	1975	1301179	1.86	3540
24	1976	1453886	1.81	3577
25	1977	1625175	1.79	3105
26	1978	1775111	1.79	3052
27	1979	1909815	1.82	3126
28	1980	2051068	1.89	3307
29	1981	2178631	2.04	3438
30	1982	2272281	2.22	3538
31	1983	2348242	2.33	3651
32	1984	2483482	2.40	3880
33	1985	2646997	2.46	3966
34	1986	2750362	2.66	4254
35	1987	2850335	2.64	4286
36	1988	3026145	2.65	4487
37	1989	3215885	2.69	4650
38	1990	3434488	2.78	4874
39	1991	3626332	2.90	5029
40	1992	3721535	2.97	5153
41	1993	3734947	2.98	5343
42	1994	3831640	2.86	5505

Sources: *Historical Statistics of Japan, 1987*
Japan Statistical Yearbooks, 1979-1996

Table 3. Tune-Series Data from South Korea (1972-1994)

No.	Year	SE/MP	PCGNP (US$)	GERD/GDP
1	1972	167	304	0.29
2	1973	177	375	0.29
3	1974	219	501	0.31
4	1975	292	573	0.43
5	1976	325	765	0.46
6	1977	350	965	0.63
7	1978	399	1,279	0.65
8	1979	418	1,624	0.59
9	1980	483	1,605	0.57
10	1981	535	1,735	0.64
11	1982	723	1,800	0.88
12	1983	804	1,884	1.01
13	1984	918	1,999	1.19
14	1985	1,016	2,277	1.48
15	1986	1,141	2,564	1.68
16	1987	1,268	3,147	1.77
17	1988	1,346	4,124	1.87
16	1989	1,561	4,962	1.9
19	1990	1,647	5,883	1.88
20	1991	1,765	6,757	1.94
21	1992	2,035	7,007	2.09
22	1993	2,244	7,513	2.32
23	1994	2,586	8,508	2.61

Sources: *Korea Statistical Yearbooks* (1962-1996)

Note: Due to the use of different base years, some data vary from one edition to another.

Table 4. Time-Series Data from Taiwan {1979-1992)

No	Year	SE/MP	PCGNP (US$)	GERD/GDP
1	1979	488	1,758	0.29
2	1980	767	2,155	0.29
3	1981	863	2,443	0.31
4	1982	999	2,419	0.43
5	1983	993	2,573	0.46
6	1984	1,176	2,890	0.63
7	1985	1,281	2,992	0.66
8	1986	1,430	3,646	0.59

Table 4. (continued)

No.	Year	SE/MP	PCGNP (US$)	GERD/GDP
9	1987	1,676	4,825	0.57
10	1988	1,780	5,798	0.64
11	1989	1,977	6,889	0.88
12	1990	2,269	7,284	1.01
13	1991	2,252	8,050	1.19
14	1992	2,336	10,453	1.48

Sources: *China Statistical Yearbooks* (1970-1995)

Note: Due to the use of different base years, some data vary from one edition to another.

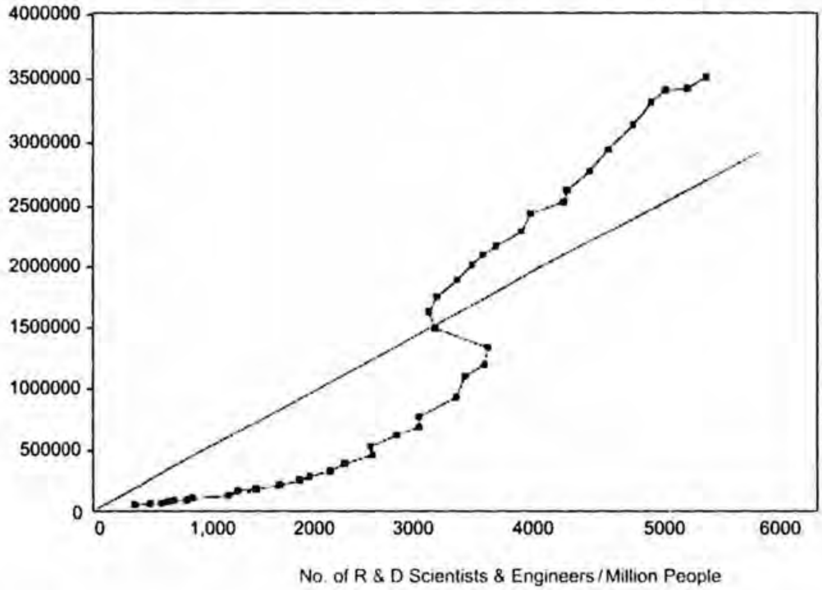

Figure 3. Plot of Time-Series Data from Japan (1953-1994)

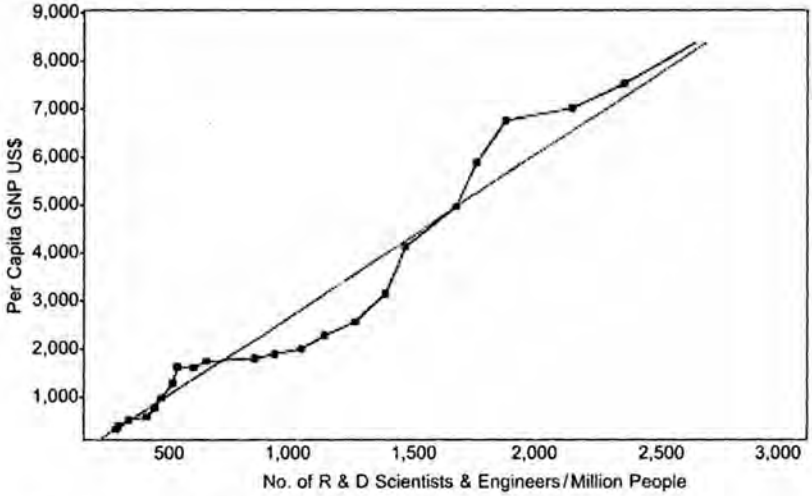

Figure 4. Plot of Time-Series Data from South Korea

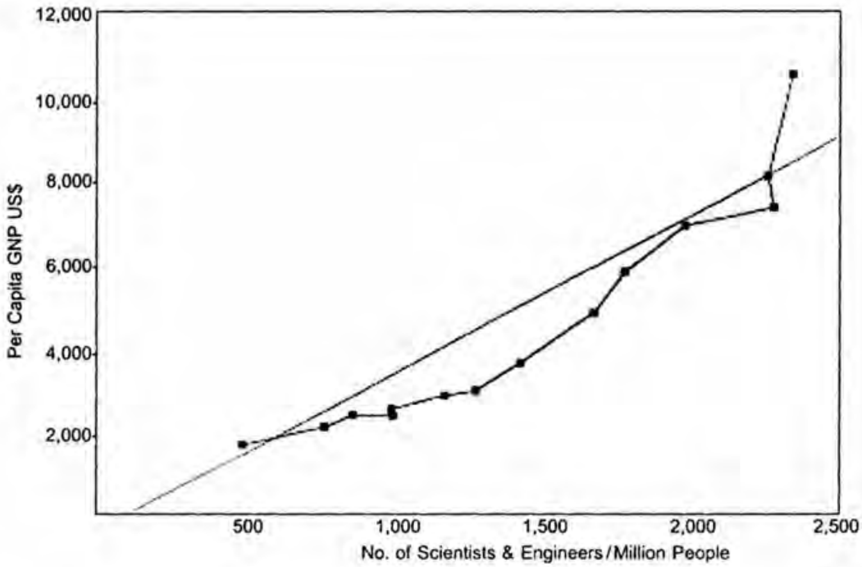

Figure 5. Plot of Time-Series Data from Taiwan

Considering that the adoption of modern technology can account for a big portion of the increase in economic output and considering further that the scarcity of the factors of production has not prevented economies like Singapore and Hong Kong from growing economically, a model is hereby proposed which emphasizes the role of science and technology capability (STC), as embodied in the level of research and development effort (RDE), in the creation of economic success.

The model is as follows: **ES = f(STC=RDE),** where "**ES**" means "economic success", **"STC"** means "science and technology capability", **"RDE"** means "research and development effort', and **"f"** means "function of'.

Variables and Measures

Economic success (ES) is measured by per capita gross national product (PCGNP) in US dollars from 1994 World Rank data (World Development Report, 1996). Research and development effort (RDE) is measured by (a) the number of scientists and engineers per million population (SEMP) engaged in research and development (R&D) activities and (b) the gross expenditure on research and development as a percentage of gross national product (GERD/GNP). These two measures of RDE, both taken from UNESCO's *Statistical Yearbook (1995)* and *World Science Report (1996)* have a range from 1982 to 1990 and the average they are taken is 1989. There is therefore an average difference of five (5) years from the time the measures of research and development effort (RDE) are taken and that of per capita gross national incomes (PCGNP), which is consistent with the notion that it takes some time for science and technology capability (STC) and research and development effort (RDE) to translate into increasing national incomes.

Time-series data from Japan, South Korea and Taiwan are taken respectively from the *Historical Statistics of Japan* (1987), the *Japan Statistical Yearbooks (1979 to 1996)*, the *Korea Statistical Yearbooks (1962 to 1996)* and the *China Statistical Yearbooks (1970 to 1995).*

Data Analysis

R & D Scientist and Engineers and Per Capita Income. In the performance of regression analyses, two models are initially used. First, a constant or intercept is required to represent the contributions of other factors to the prediction of the dependent variable, per capita income of nations. However, in all the analyses performed on the worldwide data, the model with a constant or intercept invariably explains a smaller portion of the variance in the dependent variable compared with the second model without an intercept. Thus the reports in this study are based on the model without a constant or intercept.

The first regression analysis of the data involving all 91 nations (Table 1), produced the following equation: **PCGNP = 4.56 SEMP (N=91, R^2 = .49, p = .0001)**. The equation suggests that every one (1) unit increase in the number of scientists and engineers per million population (SEMP) doing research and development work produces an increase of $4.56 in per capita gross national product (PCGNP) among the nations. However, only 49 percent of the variance in PCGNP is accounted for by SEMP, which suggests that the latter is able to account for less than half of the total variance in the dependent variable which suggests a rather weak relationship. The findings however is significant considering the probability that the configuration in the data would occur if in reality the two variables are unrelated is less than one in ten thousand.

Upon further examination of Table 1, it becomes clear that 21 of the nations must be excluded from analysis for various reasons. Sixteen (16) present or former Communist countries are expected to use their scientists and engineers to produce weapons and not incomes during the Cold War (Slovenia, Hungary, Czechoslovakia, Russia, Croatia, Poland, Latvia, Belarus, Ukraine, Lithuania, Romania, Bulgaria, Uzbekistan, Macedonia, China and Vietnam). Three (3) oil-producing countries do not need scientists and engineers to pump oil to produce huge incomes. Switzerland is a small country with a very mature economy, which focuses on high-value products and has rich financial centers that allow it to obtain a higher income compared with other nations. Finally, Israel is a small country faced with hostile Arab neighbors and although it has many scientists, it cannot receive their full economic benefits due to unstable investments by foreign business concerns due to the war situation

With only seventy (70) nations, after removing the 21 nations where the relationship between STC/RDE and ES is believed to be distorted, the regression equation is: **PCGNP = 8.44 X SEMP (N = 70, R^2 = .91, p. = .0001).** The equation suggests that every SEMP contributes $8.44 to a country's PCGNP. The amount of variance, 91 percent, in the dependent variable explained by the independent variable is extremely high. Furthermore, the result is very significant because the probability that the same configuration in the data can occur if in reality the variables are unrelated is one in ten thousand. The strong relationship of the variables may be visually observed in Figure 1.

R &D Expenditure and Per Capita Income. Considering that in the previous analysis, 21 nations are excluded because it is presumed that the relationship between scientists and engineers, on the one hand, and per capita income, on the other hand, is distorted, the same nations are also excluded in the present analysis. With only sixty-three (63) nations, the regression equation is: **PCGNP= 9,866.82 X GERD/GNP (N = 63, R^2 = .82, p = .0001).** The equation suggests that every one percent of GNP spent on R & D produces for a country $9,866.82 in PCGNP, with the independent variable predicting 82 percent of the variance in the dependent variable. The finding is significant a the .0001 level.

Time Series Data. Time-series data from Japan (Table 2, Figure 3) cover the period 1953 to 1994 or 42 years. PCGNP is measured in Yen and not US dollars. An examination of Table 2 shows that SEMP rose from 437 to 5,505, GERD/GNP from 0.45 percent to 2.86 percent, and PCGNP from Y81.157 to Y3,831,640 for the period. Under regression analysis, SEMP and GERD/GNP account for 90

Table 5. Tertiary Education across Selected Pacific Rim Countries

Country	No. Students at Tertiary Level	No. of Tertiary Students as % of Population	No. of Post-Baccalaureate Students	Post-Baccalaureate as % of Teriary Students	No. of Post-Baccalaureate Science & Eng'g Students	Post-Baccalaureate Science & Eng'g as % of Post-Baccalaureate Students
China (1991)	2,124,121	0.17	80,459	3.79	59,748	74.26
Japan (1989)	2,683,035	2.13	85,263	3.18	54,167	63.53
South Korea (1991)	1,723,886	3.83	92,599	5.37	28,479	30.76
Australia (1991)	534,538	2.92	92,903	17.38	26,876	28.93
Singapore (1983)	35,192	1.113`1,869	5.31	532	28.46	
Malaysia (1990)	121,412	0.58	4,981	4.1	1,251	25.12
Thailand (1989)	765,395	1.24	21,044	2.75	4,928	23.42
New Zealand (1991)	136,332	3.78	13,792	10.12	2,863	20.76
Philip-pines (1991)	1,656,815	2.39	63,794	3.85	5,520	8.65

percent and 88 percent, respectively, of the variance in PCGNP, both results being significant at the .0001 level. When a time lag of five years is used on the data from Japan so that measures of SEMP preceded by five years those of PCGNP, the percentage of variance in the dependent variable explained rose to 93 percent. However the relatively high percentage of variance in the dependent variable explained by the independent variable, even when no time difference is adopted, suggests that there is a strong dynamic interaction occurring between the variables amounting to autocorrelation. Thus, while more scientists help produce more incomes, bigger incomes also help train and employ more scientists who shall produce more incomes.

The presence of autocorrelation is confirmed when a predictive mathematical model was created that allowed the fullest extent of autocorrelation. The full Yule-Walker estimate of variance explained, including autocorrelation, is near perfect at over 99 percent. However, under the same estimates, at least 61 percent of the variance explained is not due to autocorrelation.

Time series data from South Korea cover the period 1972 to 1994 (Table 3, Figures 4) or '23 years. An examination of the data show that PCGNP rose from \$304 to \$8,508, SEMP from 167 to 2,586 and GERD/GNP from 0.29 percent to 2.61 percent for the period. SEMP accounts for 97 percent, while GERD/GNP accounts for 92 percent, respectively, of the variance in PCGNP, both results are significant at .0001 level. Under the Yule-Walker estimates of autocorrelations, over 99 percent of the variance in PCGNP is accounted for by SEMP, of which at least 93 percent is not due to autocorrelation.

Time series data from Taiwan cover the period 1979 to 1992 or 14 years. Table 5 shows that PCGNP increased from \$1,758 to \$10,453, SEMP from 488 to 2,336 and GERD/GNP from 0.71 percent to 1.79 percent for the period. SEMP explains 96 percent, while GERD/GNP explains 94 percent, respectively, in the variance of PCGNP, both result are significant at .0001 level. Under the Yule-Walker estimates which includes autocorrelation, up to 97 percent in the variance of PCGNP is accounted for by SEMP, but at least 93 percent of the same variance is not due to autocorrelation

Under statistical inference three conditions must be satisfied before one can establish causality between two variables, (a) that the two variables are strongly related, (b) that the independent variable precedes the dependent variable, and (c) that the joint association of the two variables are not due to other causes.

First, the association between the measures of economic success (PCGNP) and science and technology capability (STC), as embodied in research and development effort (SEMP and GERD/GNP) is indeed very strong because more than 90 percent of the variance in the former is accounted for by the latter, and that the probability of the occurrence of the findings, if in reality the variables are unrelated, is less that one chance in ten thousand. Second, the measures of RDE for the worldwide data are taken an average of five years preceding the measure of PCGNP. Finally, the results of the time-series analysis of data from Japan, South Korea and Taiwan removes any doubt that the observed relationship between the variables is due to other causes.

The results of the analyses of both the worldwide data on 70 nations and the time-series data on Japan, South Korea and Taiwan provide a strong evidence that indeed economic success (ES), as measured by PCGNP, is almost accurately predicted by science and technology capability (STC), as embodied in research and development effort (RDE), which is measured by the number of R&D scientists and engineers per million population (SEMP) and by the gross expenditure on R&D as percentage of GNP (GERD/GNP).

These findings are consistent with the historical evidence of the industrialization process that occurred in Europe on the occasion of the Industrial Revolution, that of the USA, Japan and the four Asian "NIEs" of Singapore, South Korea, Taiwan and Hong Kong. The findings are further consistent with the theoretical conclusions of Solow (1957), Denison (1974) and Durnbusch and Fisher (1980) that attribute much of the growth in the American and Japanese economies for some specific periods to technological progress or the adoption of new technologies.

On the basis of the strong relationship between economic success (ES) and science and technology capability (STC), as manifested by research and development effort (RDE), it is suggested that a country, like the Philippines, must strengthen its STC and enhance its RDE in the 21st century. The beta coefficients of the equation provide estimates of the needed SEMP and GERD/GNP for a country to earn a given level of PCGNP.

Why Did Philippine Education Not Contribute to Economic Growth?

Some studies in the 1970's suggest that while expanding education, as indicated by increasing enrolment and graduation in all levels of education, was positively correlated with economic growth among other nations of the world, this was not true to the Philippines. Until recently, this paradox could not be adequately explained.

A comparison or enrolment data among key Pacific Rim nations show that while the Philippines does not lag behind in the proportion of its population enrolled in both tertiary and graduate education, the country had the lowest concentration of its graduate students enrolled in science and engineering (Table 5), which explains its small size of SEMP (Table 1). It is obvious that the Philippines with SEMP of 90 in 1984 (which increased to 155 in 1997) cannot match that of its neighbors in Asia like Japan, South Korea, Singapore and Taiwan.

The results of the Third International Mathematics and Science Study (TIMSS) showed a poor performance of Filipino elementary and secondary students who landed 37th and 38th among 39 nations in mathematics and science, respectively, which cast doubt on the quality of basic education.

While most other countries have twelve to thirteen years of basic education, the Philippines has only ten years, which further casts doubt on the adequacy of its basic education.

Official data from Philippine government education agencies, including the Department Education, Culture and Sports (DECS) and the Commission on Higher Education (CHED) reveal that many primary, elementary, secondary and tertiary teachers are not qualified to teach the subjects assigned to them because they are either not majors in the said disciplines or they lack the necessary graduate degrees for their level.

Tertiary and advance education in the Philippines are not geared toward research undertaking. Instead, they emphasize the accumulation of credit hours or units mostly through classroom instruction. Institutions of higher learning also rarely base their academic programs and researches on the needs of business and industry.

Making the Philippines Join the Ranks of the Richest Nations of the World.

Under the regression equation, **PCGNP = 0 + 8.44 x SEMP,** a country's leaders can determine how rich they want their country to be. By dividing the desired PCGNP by the beta coefficient (8.44), one can determine the number of SEMP needed to conduct R & D work to obtain the desired PCGNP. Thus a PCGNP of $10,000 requires the employment of at least 1,185 SEMP.

Furthermore, under the regression equation, **PCGNP = 0 + 9,866.82 x GERD/ GNP,** a PCGNP of $ 10,000.00 requires that the country spends at least 1.02% of its GNP in R & D activities.

Strengthening R&D in S&T Among Institutions of Higher Learning

In order for the Philippines to strengthen its S & T capability and enhance its R & D activities, it should lengthen its basic education to thirteen years to make it comparable and competitive with those of other countries, while emphasizing science, mathematics and language. Such concepts as the "scientific method" and learning by self-discovery" should be introduced early to pupils and students.

At least 75 percent of all secondary schools in the country should be converted to science and technology high school in order to provide adequate input to science engineering programs at the tertiary level. Simple applications of the "scientific method of research" should be introduced to students at the secondary level.

At least 75 percent of all enrollees in tertiary and advance education should eventually be in science, engineering and technology fields. The grant of degrees, particularly at the graduate level. Should be more knowledge-and research-based, rather than being very dependent on the number of lecture hours or units obtained.

In all levels of education, particular attention should be given to quality with a view to making the country land in the top places of future international science and mathematics studies and making its researchers, scientists and engineers world-class.

All institutions of higher learning should encourage the conduct of high quality researches among its faculty members, preferably in coordination with business and industry people, while addressing the latter's real needs or problems. These institutions should adopt research agenda which are geared toward the production of good and services that the nation can sell in the export markets.

CONCLUSIONS

Three types of evidence, namely, historical, theoretical and empirical, exist to support the contention that the adoption of modern technology is indeed the precursor of industrialization and economic success among the rich nations of the world. There is also evidence that the successful adoption of modern technology can be made through the strengthening a nation's science and technology capability as demonstrated by the regression analyses of data from 70 nations and the three sets of time-series data from Japan, South Korea and Taiwan.

A comparison of the Philippines and other countries reveals that the former lags behind in S & T capability as indicated by its low SEMP and GERD/GNP. This situation helps explain the findings of some studies that while expanding educational opportunities in other nations contribute to their economic success, this same did not happen to the Philippines.

Given the strong degree of relationship found in the regression analyses of the worldwide data, and the high level of its statistical significance the beta coefficients provide a formula for a country to achieve industrialization and economic success. By dividing the desired PCGNP by the appropriate beta coefficient, one arrives at the needed SEMP or GERD/GNP to achieve the target PCGNP. Thus it may be possible for the Philippines (or any country in Asia and the Pacific) to achieve a PCGNP of $ 10,000.00, $20,000.00 at 1994 prices in 15 to 30 years from now.

In order to achieve that goal, the Philippines should strengthen its science and technology capability in the 21^{st} century. In doing so, the country should also rectify some inadequacies in its educational system. First, the length of basic education should be increased to 12-13 years to make it at par with those of other countries. Second, tertiary and advanced education should be re-focused so that three-fourths of all enrollees and graduates in both educational levels shall be in S & T fields. Third, three-fourths of all secondary schools should be converted to S & T high schools. Fourth, there should be an improvement in the quality of education at all levels of the educational ladder. Fifth, there should be a program to encourage and stimulate the conduct of fundamental research and R & D in all institutions of higher learning. Sixth, adequate compensation and incentive packages should be adopted to attract the best and the brightest persons in the conduct of R & D in S & T fields. Finally, private firms should be persuaded to invest in and conduct world-class R & D work in collaboration with universities and research and development (R &. D) institutes.

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