行政院國家科學委員會專題研究計畫成果報告
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國家競爭力指標之重構及教育對競爭力之可能貢獻之探討
Reconstruction of the national competition indices and the possible contribution of education to national competition capability

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國家競爭力指標之重構及教育對競爭力之可能貢獻之探討

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摘要

本研究之目的在探討教育是否對提升國家競爭力有貢獻。所使用之原始資料為美國國科會及瑞士管理與發展研究所之資料庫，以相關、迴歸、及線性結構模式分析為分析工具。重大發現有：(a)「知識本位之服務業之每位國民產值」與「每位國民國內生產毛額」之相關大於「每位國民高科技產值」與「每位國民國內生產毛額」之相關，顯出知識本位之服務業對國內生產毛額貢獻之重要性。(b)科技落差理論(technology gap theory)在本研究只獲得部分的支持。高科技與每名國民國內生產毛額之連動性有越來越弱的趨勢，且日本自1980年無論在「每國民高科技產值」或在「以知識本位之服務業之每國民產值」皆超越美國，但其每國民國內生產毛額卻自1980仍然低於美國。(c)在與教育有關的變項中，「每1000人中研發人員數」是與「每國民國內生產毛額」相關最高的變項，高於「24歲年齡組人口中有理工學位者」、「中等教育在學率」、及「中等教育之生師比」等三個變項各與每國民國內生產毛額之相關。如以教育為潛在自變項，以競爭力為潛在依變項，以每1000人中研發人員數為可測量的自變項，用來代表不可測量的教育。以「國民預期壽命」、「每國民國內生產毛額」、及「民間每國民消費支出」為可觀察依變項，用來代表競爭力，以線性結構模式加以分析(這是依經濟合作與發展組織(OECD)及世界經濟論壇對競爭力所下的定義，本文作者將之作操作型定義，意即競爭力愈強的國家，每國民國內生產毛額會愈高，購買力愈強，壽命愈長)。結果顯出教育所培養的「每千人中研發人員數」可解釋競爭力變異量60%。(d)本研究的結果對台灣教育政策的啟示是以瑞士為模範。瑞士亦為天然資源稀少的小國家，但其競爭力卻排在世界第5名，且從1996年之第9名逐年進步。而在2000年之「每千人研發人員數」在世界排名第2。台灣如能在研發人員數上趕上瑞士的水準，國際競爭力可望往上提升。

ABSTRACT

This study investigates whether education-related variables make a contribution to international competitiveness. Analyzing longitudinal and cross-sectional data from the data-bases of the National Science Board and the International Institute for Management and Development, the present study shows that: (a) knowledge-based service industry production per capita has a stronger correlation than high-tech industries production per capita with the GDP per capita, (b) the technology gap theory is only partially supported, as Japan has replaced the USA as the country with the highest high-tech production per capita and knowledge-based service industry production per capita since 1980, but has still been behind the USA in terms of GDP per capita ever since, (c) "R&D personnel per 1000 people," which represents the latent variable "education," standing alone, can explain 60% of variance in competitiveness.

Reconstruction of the national competition indices and the possible contribution of education to national competition capability

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Competitiveness is an important element in Social-Darwinian theory in claiming that the dynamics of social evolution lie in the principle of "equal opportunity and fair competition."   Competition is different from struggle. Struggle is a zero-sum game, with the motto: "The death of your enemy is your bread," while competition is a win-win strategy. During the process of competition, all the competitors focus their attention on the improvement of their own competitive capabilities. In a society full of competition, its total capabilities will be accelerated automatically, and this is just the process of the endless evolution of the society.

The Organization for Economic Cooperation and Development (OECD) (1992, cited by Llewellyn, 1996) defines a nation's competitiveness as: "the degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term" (p.237), and the World Economic Forum defines competitiveness as 'the ability of a nation's economy to make rapid and sustained gains in living standards' (Llewellyn, 1996, p.89). The two definitions are compatible in that expanding real incomes is a necessary condition for making sustained gains in living standards. An expansion of real incomes depends on an increase in production and exportation of goods and services.   There would be a strong relationship between a nation's productivity and its competitiveness. It is evident that some countries grow at a faster rate than others. It can be hypothesized that the stronger competitiveness a country possesses, the faster its economic growth will be.

In addressing the question: why growth rates differ over time and across countries, there are two somewhat controversial theories: The technology-gap theory which regards the technological differences as the prime cause for differences in GDP per capita across countries, and the neoclassical growth theory which asserts that technology is not the source of cross-country differences in GDP per capita, because technology is supposed to be a public good (Fagerberg, 1994).

Dosi, Pavitt, and Soete (1990) stand among the technology-gap theorists. According to the reasoning of the technology-gap theory, if the countries falling behind want to reach the level of economic growth of countries with a higher GDP per capita, a promising approach is to commit them to technological catch-up.

Llewellyn (1996) remarked that a healthy way to strengthen a country's competitiveness is to "reduce its prices or costs per unit of output relative to those of its trading partners" or to create new products or improve the quality of its products to meet the demands of other countries. However, in testing the 'Kaldor Paradox', Fagerberg

(1988; 1996) confirmed that the relation between growth in relative unit labor costs and growth in market shares seems to go hand in hand. This relation implies that higher remuneration paid to employees possessing higher qualifications would, instead of 'decrease', increase competitiveness, and in turn, increase in market shares would feed back to wages. Fagerberg (1996) found out that (a) the impact of investment in Research and Development (R&D) on exports may exceed the impact of investment of similar size in physical capital, (b) although R&D investment may have most pronounced effect on the high-tech industry, it plays also an important role in many other industries.

Investment in R&D expenditures and personnel (scientists and engineers produced by the higher education institutions) are important factors for technological innovation, which can be shown by granted patents. Technological catch-up relies heavily on technological activities. If the technologically advanced countries make further investments in R&D, then the technology gap and economic growth between them and countries following behind them would be persistent, or even enlarged. Patents are outputs of innovation while the expenditure and personnel of R&D are inputs to it. In Fagerberg's (1994) review of empirical literature, he found that variables in technological innovation, such as R&D investment, patents, scientists and engineers etc. could have an impact on levels and growth of productivity. Also Dosi (1988) discerned that some variables might exert an influence upon technological innovation:

1. Market size and market growth may facilitate the propensity to innovation.

2. Within industries, there is a certain relation between firm size and innovative activities (R&D expenditure, R&D employment, and number of patents or number of innovations): the larger the size of a firm is, the more intensive its technological activities may be.

3. There is interdependence between science and technology. Although the ethos of technology is different from science, (i.e. privately generated technology would likely be appropriated in the form of patents or turned into products, while the role of science is to disclose its research results), scientific breakthroughs will lead to the emergence of technological innovations and the scientific instruments developed by technology will exert an impact on scientific progress.

4. The higher the level of innovativeness a country has achieved, the higher the probability that it will maintain or increase its level of competitiveness, and vice versa.

These principles will also be valid for individual firms.

The presence of universities with major programs in science and engineering, venture capital, technological and scientific employees in the local population, and a good quality of life are alleged as necessary preconditions of high technology development in particular places, such as the production center of semiconductors and computers in Silicon Valley and that of communications equipment, computers and biomedical instruments in Range County (Scott & Storper, 1987).

The majority of the workforce in advanced countries has shifted from industrial sector to the service sector.   Windrum and Tomlinson's (1999) study shows that in UK, Netherlands, Germany, and Japan, the knowledge intensive services, as the variable of

material input controlled, have a significant ($p <. 01$) nonlinear contribution to national productivity. But there is still a positive feedback between technological innovations and innovations in knowledge-intensive services: new technologies produce new service industries that in turn play a significant role in developing these technologies through laboratory, design and engineering activities, e.g. specialized expert-knowledge, research and development ability, and problem-solving know-how. Therefore knowledge-intensive services are also important to international competitiveness. Windrum and Tomlinson (1999) define knowledge-intensive services as services that rely on professional knowledge or expertise relating to specific technical or functional domains. They are provided in the form of information and knowledge, by means of reports, training, consultancy, etc. or in form of intermediate inputs in the products or production processes of other businesses (e.g. communication and computer services).

How can technology be operationally defined? Can it be defined with high-tech production or with knowledge-based service industry production? Both data are available in the database of the National Science Board (2000). By calculation, the high-tech production contains 10 major technology areas classified by the U.S. Bureau of the Census: (a) biotechnology, (b) life science technologies, (c) opto-electronics, (d) computers and telecommunications, (e) electronics, (f) computer-integrated manufacturing, (g) material design, (h) aerospace, (i) weapons, and (j) nuclear technology, while the five knowledge-based service industry production contains five areas: (a) communication services (including telecommunications and broadcast services), (b) financial institutions, (c) business services (including computer), (d) education services (including commercial education and library services) and (e) health services.

Other variables which might contribute to international competitiveness are mentioned by Boltho (1996), such as improvements in infrastructure, raising the level of education and training of workforce, opening markets to foreign competition to invoke an imagined external threat, deregulating some aspects of economics, and sales and advertising campaigns.

The International Institute for Management and Development (IMD) (2000) used 290 variables in comparing the competitiveness of 47 countries. Among those variables, some can be classified as end product (outcome) elements of competitiveness, such as Gross Domestic Product (GDP) per capita and exports of goods, which might indicate the "real incomes" of a country's people; life expectancy at birth, which represents the level of the standard of living; and patents granted to residents, and some as process (driving force) elements of competitiveness, which lead to a strengthening of competitive capability, such as connections to internet; total expenditure on R&D per capita; and total R&D personnel in business enterprises. Among the 290 competitive variables in the IMD study, 139 were official statistics. All the variables were categorized into eight factors: domestic economy, internationalization, government, finance, infrastructure, management, science & technology, and people.

The purposes of the present study are to investigate: (a) is the technology gap theory universally valid? (b) whether education related variables have contribution to competitiveness, and if it so, by how much? (c) how is the causal relationship between process and product elements of international competitiveness. What proportion of variance in product elements can be accounted for by process elements of competitiveness?

The hypotheses to be tested are:
1. If the technology gap theory is true, then the trend curve of GDP per capita of a country falling behind would catch up that of an advanced country, as the curve of high-tech production per capita or the total 5 knowledge-based service industry production per capita of that country reached the level of that advanced country.
2. According to the definition of competitiveness made by the OECD and the World Economic Forum, stronger competitiveness means higher incomes (to use GDP per capita as a proxy) and higher living standard (to use life expectancy at birth and private consumption expenditure per capita as proxies). Higher private consumption expenditure per capita stands for stronger purchasing power. These three variables are end product elements of competitiveness. If education makes a contribution to national competitiveness, then education-related variables would have a significant association with competitiveness-related variables.

Method

To test the first hypothesis, longitudinal data from the database of the National Science Board (2000) were used. As each country has a different size of population, it is justified to transform the total production of each country into production per capita of each country in order that each country may have a similar comparative base. However, there are no population data in the database of the National Science Board (2000). Data were thus calculated using the following formulae:

High-tech industries production per capita =
   High-tech industries production / (GDP / GDP per capita)   (1)

All five knowledge-based service industry production per capita =
   All five knowledge-based service industry production / (GDP / GDP per capita)   (2)

The population of each country can be calculated by dividing GDP through GDP per capita. Data for the GDP of each country are obtained from Table 7-1 of the National Science Board (2000), and data for GDP per capita are from Table 7-2. Data on high-tech industries production are from Table 7-4, and data of the all five knowledge-based service industry production are from Table 7-5.

To test the second hypothesis, only the cross-sectional hard data (official statistics) from the database of the International Institute for Management and Development (2000) were used. Although the survey data in the database were gathered from questionnaire responses from high-ranking executives in each country and generated valuable information not available in official statistics, but the method violates the objectivity necessary in measurement instruments. It seems as though there was a measurement of the same variables with different instruments (different executives in different countries), each executive possibly having different strictness in subjective judgment. Therefore the survey data were not used in this study.

The International Institute for Management and Development (2000) does include

indicator of educational infrastructure relevant for producing engineers and scientists. The indicator "higher education enrollment of 1996" (net enrollment in tertiary education for persons 17-34 years old) has however 15 missing values. A variable "ratio of total science and engineering degrees to the 24-year-old population: 1997 or most recent year" was adopted by the present author from the Appendix Table 5-18 of the database of the National Science Board (2000), which has only four missing values.

To test the hypotheses, Pearson's correlation, regression, as well as structural equation model (Jöreskog & Sörbom, 1993) were employed.

Results

Testing the Phenomena of the Technology Gap

Figure 1 shows GDP per capita of eight countries, which are the only countries with complete data for GDP, GDP per capita, high-tech industries production, and all five knowledge-based service industries. It can be seen in Figure 1 that the USA has the highest GDP per capita while South Korea has the lowest.
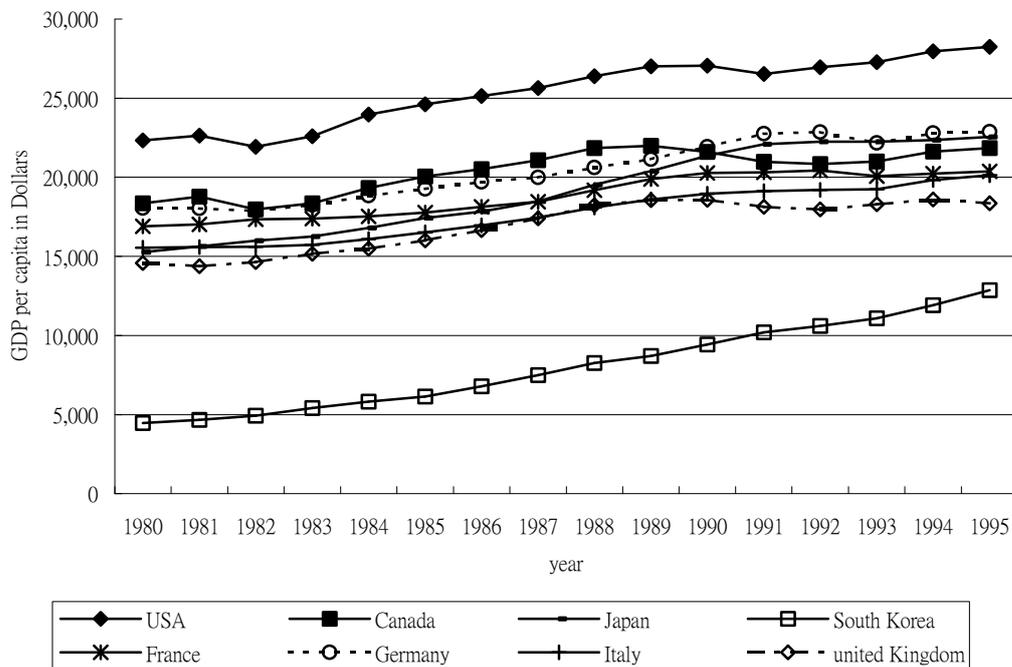
Figure 1. Real GDP per capita for 8 selected countries. Data obtained from *Science and Engineering Indicators, 2000,* (Appendix Table 7-2), National Science Board. Virginia, Author (http,//www.nsf-gov/sbe/srs/seind00/append/7c/at07-02.xls)

In the Figure 2 and Figure 3, however, Japan has superseded the USA as the country with the highest high-tech production per capita and highest knowledge-based service industry production per capita since 1980, but its GDP per capita has still stayed behind the USA.

Figure 2. High-tech production per capita for 8 selected countries. Data obtained from *Science and Engineering Indicators, 2000,* (Appendix Table 7-1, 7-2 and 7-4), by National Science Board. Virginia, Author.
(http,//www.nsf-gov/sbe/srs/seind00/append/7c/at07-01.xls)
(http,//www.nsf-gov/sbe/srs/seind00/append/7c/at07-02.xls)
(http,//www.nsf-gov/sbe/srs/seind00/append/7c/at07-04.xls)

Figure3. Total 5 Knowledge-based service industry
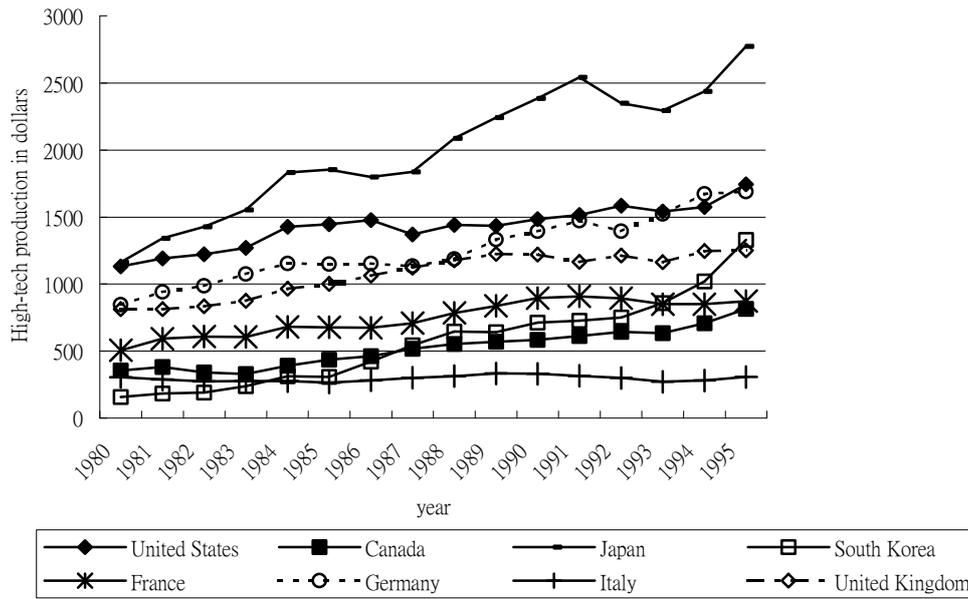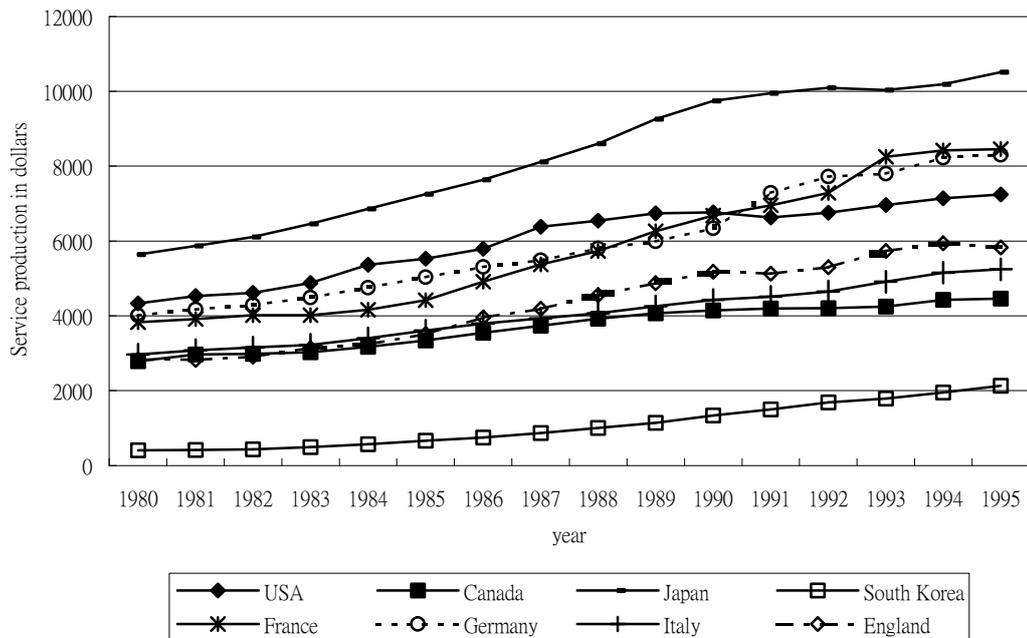
production per capita for 8 selected countries. Data obtained from *Science and Engineering Indicators, 2000,* (Appendix Table 7-1, 7-2 and 7-5,), by National Science Board. Virginia, Author (http,//www.nsf-gov/sbe/srs/seind00/append/c7/at07-01.xls) (http,//www.nsf-gov/sbe/srs/seind00/append/c7/at07-02.xls) (http,//www.nsf-gov/sbe/srs/seind00/append/c7/at07-05.xls)

It is not easy to reach a clear understanding as one views figures which have eight curves in each. Table 1 would help us to have a better insight. If the technology gap theory is true, then the correlation between GDP and technology production variables would be significant.

Table 1 is the Pearson correlations between these three variables of the eight selected countries.

Table 1.

Pearson Correlations Between GDP Per Capita, High-Tech Production Per Capita, and All Five Knowledge-based Service Production Per Capita of the Eight Selected Countries (N=8)

Year	GDP with high-tech	GDP with knowledge-based services	High-tech with knowledge-based services
1980	.57	.73*	.82*
1981	.54	.74*	.84**
1982	.54	.76*	.84**
1983	.51	.73*	.85**
1984	.47	.73*	.71*
1985	.49	.71*	.85**
1986	.46	.70	.82*
1987	.38	.71*	.79*
1988	.35	.70	.79*
1989	.36	.69	.81*
1990	.39	.70	.81*
1991	.45	.74*	.81*
1992	.48	.72*	.78*
1993	.44	.68	.70
1994	.37	.65	.65
1995	.30	.62	.60

*$p<.05$,   **$p<.01$

From Table 1, it can be seen that association between GDP per capita and technology has become weaker and weaker in recent years, and all five knowledge-based service industry production per capita has a stronger correlation with the GDP per capita

than high-tech production per capita. After 1993, the correlation between technology variables (the high-tech as well as the service industries) and GDP per capita has not been significant any more. Therefore the technology-gap theory is only partially supported.

Investigating the Potential Contribution of Education to the International Competitiveness

Among the 139 variables of hard data from the International Institute for Management and Development (2000), 111 have significant correlations with GDP per capita (See Appendix A), but only 37 have significant correlations with GDP growth per capita (See Appendix B). The correlation between GDP per capita and GDP growth per capita is not significant (r (45) = .26).

In Table 2, the variable "R&D personnel per 1000 people" accounts for 61.66% of the total variance in the dependent variable. As the other educational variables were added to the regression equation, no increments to the R^2 were observed. The matrix of correlations in Table 3 makes clear that all the four education-related variables analyzed in Table 2 have significant correlation with GDP per capita, and they are interdependent with the exception of correlation between the "ratio of science and engineering degrees to the 24-year-old population in 1997" and the "pupil-teacher ratio in secondary education." Consequently, the variable "R&D personnel per 1000 people" can be used as a representative variable for education-related variables contributing to GDP per capita.

Table 2.
Coefficients From the Regression of GDP Per Capita on Education-related Variables

	Model 1	Model 2	Model 3	Model 4	Model5
R&D personnel	.79**		.67**	.54**	.46*
S & E degrees		.62**	.15	.18	.22
Enrollment				.13	.07
Pupil-teacher ratio					-.18
F values	$F(1,40)=$ 66.93**	$F(1,41)=$ 25.45**	$F(2,37)=$ 28.23**	$F(3,33)=$ 16.18**	$F(4,31)=$ 12.21**
Adjusted R^2	.6166	.3679	.5827	.5585	.5616

Notes, R&D personnel = Total R&D personnel nationwide / 1000 people;
S&E degrees = Ratio of science and engineering degrees to the 24-year-old population in 1997; Enrollment = Secondary school enrollment / Relevant age group;
Pupil-teacher ratio = Pupil-teacher ratio in secondary education
p<.05   ** p<.01

Table 3
Correlations Between Education-related Variables

	1. GDP per capita (N=47)	2. Total R&D personnel nationwide /1000people (N=42)	3. Ratio of science & engineer degrees to the 24-year-old population in 1997 (N=43)	4. Secondary school enrollment/ relevant age group (N=43)	5. Pupil-teacher ratio in secondary education (N=45)
1	--	.79**	.68**	.63**	-.45**
2		--	.70**	.73**	-.47**
3			--	.59**	-.17
4				--	-.37*

 * $p < .05$ ** $p < .01$

Testing the Competitiveness Theory

We treat GDP per capita (or GDP growth per capita) as the dependent variable and choose one variable, which had the highest correlation coefficient with the dependent variable, from each factor (there being eight factors as described previously) of competitiveness used by the IMD as the regressors in the multiple regression equation, it turns out that in Model 1 of Table 4, the adjusted R^2 = .9318, i.e. seven variables can explain 93.18% of variance in the GDP per capita. The negative signs of the first two variables were due the multicollinearity, because all exogenous variables had positive significant correlation with each other and with the endogenous variable. After omitting these two variables, the R^2 remained almost the same (0.9316). The R^2 in Model 3 with the GDP growth per capita as the dependent variable was only 0.5001. In Table 4, it was concluded that it was more difficult to predict the GDP growth per capita than to predict the GDP per capita from other Indicators of international competitiveness adopted by IMD, because the GDP growth per capita had lower and less correlations with the independent variables. Thus, the GDP per capita, instead of GDP growth per capita, was chosen as a representative variable for the product element of the international competitiveness.

Table 4.

Comparison of Predictability of GDP Per Capita and GDP Growth Per Capita as an Endogenous Variable.

	Dependent variable = GDP per capita		Dependent variable = GDP growth per capita	
	Model 1	Model 2		Model 3
Direct investment stocks abroad	-.08		Growth in exports of goods	.22
Collected personal income tax / GDP	-.02		Central government budget surplus (or deficit) / GDP	.11
Country credit rating	.2*	.17*	Short-term interest rate	-.12
Computer power per capita	.23	.23*	Telephone lines / 1000 people	-.34
Advertising expenditure per capita	.3**	.26**	Unit labor costs growth in the manufacturing sector	.05
Total expenditure on R&D per capita	.29**	.28**	Total expenditure on R&D / GDP	-.07
Human development index	.11	.13	Secondary school enrollment / relevant age group	.84**
	Model 1	Model 2		Model 2
F values	$F_{(7,36)} = 84.88**$	$F_{(5,38)} = 118.09**$		$F_{(7,32)} = 6.57**$
Adjusted R^2	.9318	.9316		.5001

*$p<.05$ **$p<.01$

Table 5

Different Structural Equation Models Demonstrating Effects of Determinants of Competitiveness

Model 1	Model 2	Model 3	Model 4	Model 5
X1=RDPERSON	X1=RDPERSON	X1=RDPERSON	X1=RDPERSON	X1=RDPERSON
Y2=LIFE	X2=RDEXPEND	X2=RDEXPEND	X2=RDEXPEND	X2=RDEXPEND
Y3=GDP	Y3=LIFE	X3=COMPUTER	X3=COMPUTER	X3=COMPUTER
Y4=CONSUMPT	Y4=GDP	X4=HANDY	X4=HANDY	X4=HANDY
ξ1=Educat	Y5=CONSUMPT	Y5=LIFE	X5=ADVERTIS	X5=ADVERTIS

η2=Compet	ξ1=Techinno	Y6=GDP	Y6=LIFE	Y6=PATENT
δ1= -0.01	η2=Compet	Y7=CONSUMPT	Y7=GDP	Y7=LIFE
ε2=0.36	δ1=.27	ξ1=Techinno	Y8=CONSUMPT	Y8=GDP
ε3=0.00	δ2=0.08	ξ2=Techinfr	ξ1=Techinno	Y9=CONSUMPT
ε4=0.05	δε23= −0.06	η3=Compet	ξ2=Techinfr	ξ1=Techinno
λ22=0.80*	ε3=0.36	δ1=0.23	ξ3=Market	ξ2=Techinfr
λ32=1.00*	ε4= 0.00	δ2=0.13	η4=Compet	ξ3=Market
λ42=0.97*	ε5=0.06	δ3=0.08	δ1=.23	η4=Patents
ζ2=0.40	λ11=0.85*	δ4=0.31	δ2=.13	η5=Compet
γ21=0.77*	λ21=0.96*	δ34=−0.03	δ3=.11	δ1=.22
	λ32=0.80*	ε5=0.32	δ4=.34	δ2=.10
	λ42=1.00	ε6=0.02	δ5=0.11	δ3=.13
	λ52=0.97*	ε7=0.08	ε6=0.33	δ4=.36
	ζ2=0.17	λ11=0.88*	ε7=0.03	δ5=0.15
	γ21=0.91*	λ21=0.93*	ε8=0.07	δ34=0.02
		λ32=0.96*	λ11=0.88*	ε6=0.06
		λ42=0.83*	λ21=0.93*	ε7=0.33
		λ53=0.82*	λ32=0.94*	ε8=0.02
		λ63=0.99*	λ42=0.81*	ε9=0.08
		λ73=0.96*	λ53=1.00	λ11=0.88*
		ζ3=0.07	λ64=0.82*	λ21=0.95*
		φ12=0.89*	λ74=0.99*	λ32=0.93*
		γ31=0.21	λ84=0.97*	λ42=0.80*
		γ32=0.78*	ζ4=0.03	λ53=1.00
			φ12=0.91*	λ64=1.00
			φ13=0.83*	λ75=0.82*
			φ23=0.91*	λ85=0.99*
			γ41=0.04	λ95=0.96*
			γ42=0.64	ζ4=0.26
			γ43=0.33	ζ5=0.02
				φ12=0.91*
				φ13=0.81*
				φ23=0.92*
				β54=0.01
				γ41=0.82*
				γ52=0.55
				γ53=0.47*
χ(1,N=42)=0.002, p= 0.96	χ(3,N=42)=3.69, p= 0.30	χ(10,N=42)= 3.61, p= 0.96	χ(14,N=42)= 4.66, p= 0.99	χ(19,N=42)= 14.2, p= 0.77
GFI=1.00	GFI=1.00	GFI=1.00	GFI=1.00	GFI=1.00
RMR= .00	RMR= .0085	RMR= .031	RMR= .028	RMR= .026
R^2= .60	R^2= .830	R^2= .93	R^2= .97	R^2= .98

Note.

RDPERSON= Total R&D personnel nationwide / 1000people

RDEXPEND= Total expenditure on R&D per capita

COMPUTER= Number of computers / 1000 people

HANDY= Cellular mobile telephone subscribers / 1000 people
ADVERTIS= Advertising expenditure per capita
PATENT= Number of patents in force / 100000 inhabitants
LIFE= Life expectancy at birth.   GDP= GDP per capita
CONSUMPT= Private consumption expenditure per capita
Techinno= Technology innovation activities   Techinfr=Technological infrastructure
Market=Market activity   Patents=Granted Patents   Compet=Competitiveness
* At least significant at .05 level
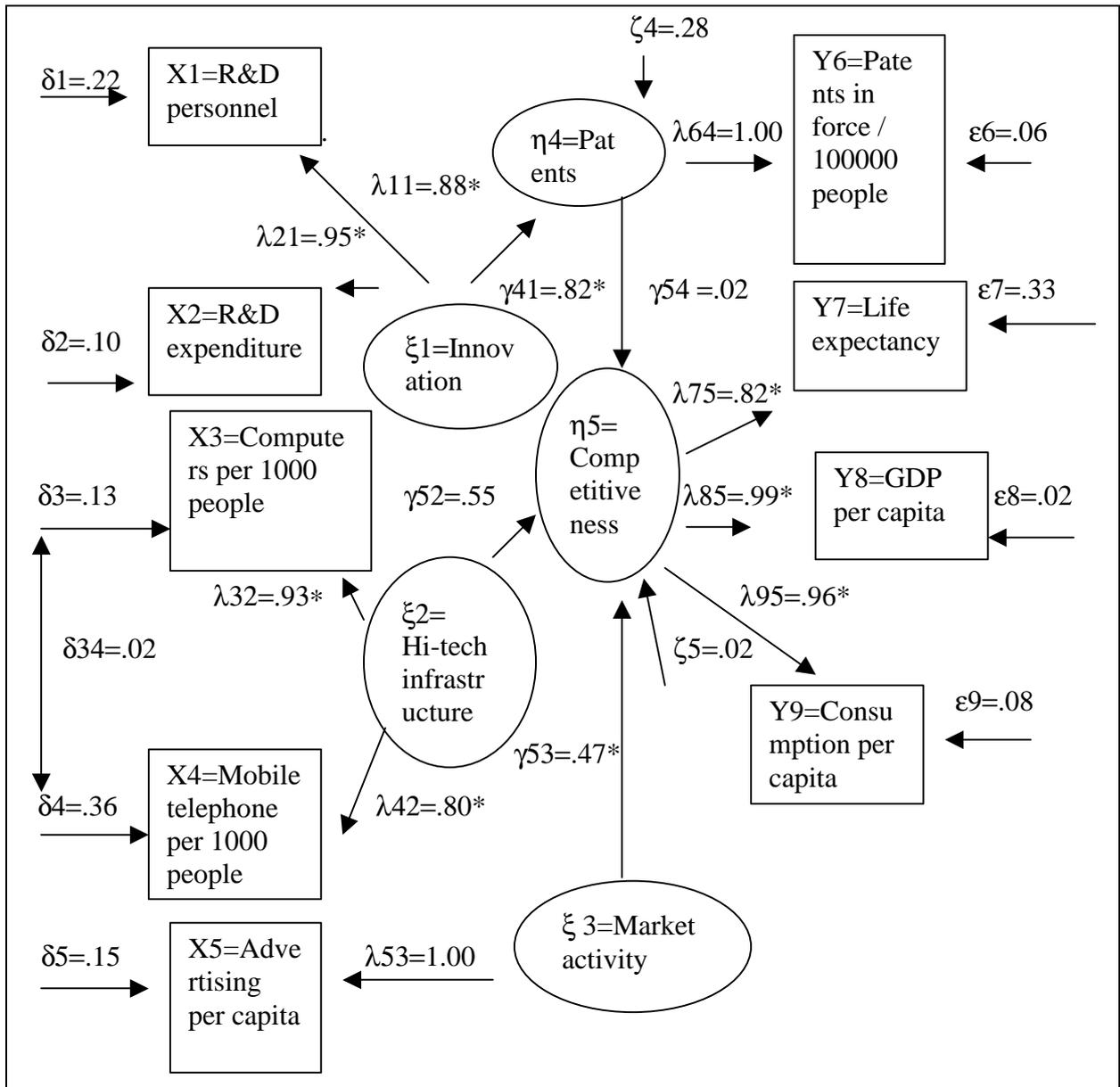
Figure4. Effect of patents, high-tech infrastructure and market activity on the competitiveness with patents in force per 100000 habitants as intervening variable.
* At least significant at .05 level

Table 5 demonstrates different models of LISREL. Because of multicollinearity, it is necessary to introduce variables step by step to show the effect of education on the competitiveness.

The parameter specifications used by Jöreskog & Sörbom (1993) were applied, but with miner amendment in the present study. Instead of $\lambda_{II}^{(X)}$ and $\lambda_{II}^{(Y)}$, λ_{ij} was employed to stand for the standardized effect of a latent variable on an observed variable.

Therefore, the serial number of the first latent endogenous variable follows that of the last latent exogenous variable, and the serial number of the first observed endogenous variable comes after that of the last observed exogenous variable.

The international competitiveness is a latent variable (an abstract construct) and must be indicated by measurable and observable variables. It was indicated by three observed variables: life expectancy at birth, GDP per capita, and private consumption expenditure per capita.

In the Model 1 of Table 5, "R&D personnel per 1000 people" was selected as an indicator for human capital produced by education. $\gamma_{21}=0.77*$ in Model 1 means that the education makes a significant contribution to competitiveness. Adjusted $R^2= .60$ designates that education alone can explain 60% of the variance in competitiveness. This result supports the second hypothesis that the education-related variable "R&D personnel per 1000 people" does have a significant association with the competitiveness-related variables.

In Model 2, "total expenditure on R&D per capita" was combined with "R&D personnel per 1000 people" to form indicators for the latent variable "technological innovative activities". The latent variable "innovative activities" explained 83% of variance in competitiveness, $\gamma_{21}=0.91*$ denoting that "innovative activities" is a significant determinant of competitiveness. The error term $\delta \varepsilon_{23}=-0.06$ was generated by a statement: "set the errors between RDEXPEND and LIFE correlate" in the LISREL 8 program, because the Maximum Modification Index located at this term. After modification, the fitness of the model improved.

In Model 3 and Model 4, the latent variables "technological infrastructure" and "market activity" were introduced stepwise. They both brought about increment of R^2.

"Granted patents" was inserted to Model 5 as an intervening variable between innovative activity and competitiveness. The diagram of Model 5 is presented in Figure 4. The non-significance of γ_{31} (the effect of innovative activities on competitiveness) in Model 3 was due to multicollinearity, because it was originally significant in Model 1. Its effect was partialed out. γ_{41}、γ_{42}、γ_{43} in model 4 and γ_{52} in Model 5 are much the same.

4.The case of Taiwan

The situation of Taiwan is analogous to that of Switzerland. They are small countries with scarce resources and limited domestic market. Their competitiveness hangs on human capital, especially on the innovation of R&D personnel. To cultivate more and more creative R&D personnel is what the education can contribute to competitiveness. In this case, Switzerland is a model country for Taiwan. From Table 6, it can be seen that R&D personnel per 1000 people in Switzerland is about 1.5 times as many as in Taiwan. To catch-up the level of Switzerland in this respect would be a reasonable goal for the educational policy of Taiwan, if Taiwan wants to improve its international competitiveness.

Table 6
Different structural equation models demonstrating effect of determinants of competitiveness

Code number of IMD	Variable	Value of Taiwan	Rank of Taiwan	Value of Switzerland	Rank of Switzerland	Value of best country
1.02	*GDP per capita*	$13,111	25	$36,071	2	$44424(Luxembourg)
1.14	Private consumption expenditure per capita	$7,973	26	$18,260	5	$21953(USA)
5.12	Number of computers/1000 people	260.1	23	408.3	10	538.9(USA)
5.18	Cellular mobile telephone subscribers/ 1000 people	493.60	10	441.65	13	679.10(Finland)
6.18	Advertising expenditure per capita	151.1	19	346.53	13	419.41(USA)
7.02	Total expenditure on R&D per capita	$242.80	20	1142.3	1	1143.2(Switzerland)
7.07	Total R&D personnel /1000people	4.662/1000 people	14	7.11	2	7.401(Sweden)
7.26	Number of patents in force/100000 in habitants	686.8/100000 people	7	1342.2	1	1342.2(Switzerland)
8.05	Life expectancy at birth	73.7	31	79.1	5	80.3(JAPAN)

Discussion

Analyzing longitudinal and cross-sectional data from the data base of American National Science Board (2000) and the International Institute for Management and Development (2000), the present study found that: (a) "knowledge-based service industry production per capita" has a stronger correlation with the GDP per capita than high-tech production per capita does, (b) the technology gap theory assuming that if the countries falling behind want to reach the level of economic growth of countries with a higher GDP per capita, a promising way is to commit themselves to technological catch-up (Dosi, et al, 1990; Fagerberg, 1994) was only partially supported, as Japan has taken the place of the USA as the country with the highest high-tech production per capita and highest knowledge-base service industry production per capita since 1980, but the GDP per capita has still stayed behind the USA ever since, (c) Among education-related variables, which may contribute to competitiveness, "R&D personnel per 1000 people" is most suitable choice as indicator for the latent variable "education," because it has stronger correlation with GDP per capita than other variables , such as "ratio of science and engineer degrees to the 24-year-old population," "ratio of secondary school enrollment to the relevant age group," or "pupil-teacher ratio in secondary education," (d) "R&D personnel per 1000 people" standing alone, can explain 60% of variance in competitiveness, which was represented by three observed variables: "life expectancy at birth," "GDP per capita," and "private consumption expenditure per capita."

The significant correlation between the "ratio of secondary school enrollment to the relevant age group" and GDP per capita found in the present study confirms the result of Mankiw, Romer, & Weil's (1992) study which demonstrated that adding human capital, with the "ratio of secondary school enrollment to the relevant age group" as a proxy, to the exogenous variables (saving and population growth) of regression equation led to a significant increment of .2 in R^2.

The result of the present study seems to discount the assertion that a technology gap is the only cause for the differences in GDP per capita across counties, but technological innovation remains to a substantial factor in influencing international competitiveness. Perhaps GDP per capita could also be influenced by other variables, such as labor costs and forms of industrial organization, as proposed by Dosi, et al. (1990, p.160).

The results displayed in Figure 1 to Figure 3 are constructed with sample data from only eight developed and newly industrializing countries, so that they can not be generalized to the developing countries. Further researches in this respect are needed.

A direct way to expand the number of R&D personnel is to increase the scale of doctoral programs in Science and Engineering. The National Science Board (2000, Chapter 4) describes the worldwide effort to expand doctoral programs in science and engineering. The major Asian countries, China, India, Japan, South Korea, and Taiwan, awarded science and engineering degrees in an average annual increment of 12% from 1993 to 1997. In Germany, the number of science and engineering degrees increased 4.3% annually between 1975 and 1997, but non-science and engineering doctoral degrees increased only 2.8% during this period. The number of science and engineering doctoral degrees awarded in France from 1989 to 1997 increased about 83%.

All the endeavors of strengthening and expanding doctoral education in science and engineering are to develop the capacity for high quality research leading to technological

innovation and to build up the knowledge-based economy, and in the end to gain strength in competitiveness.

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APPENDIX A

Variables, which have significant correlation coefficient with GDP per capita

Code of IMD	Variables	r
1.01	GDP	.33*
1.04	GDP per capita estimates	.97**
1.07	Gross national income	.33*
1.10	Total gross domestic investment	.32*
1.13	Gross domestic savings real growth	.37*
1.14	Private consumption expenditure per capita	.97**
1.16	Government final consumption expenditure	.37**
1.19	Non-agriculture economic sector/ GDP	.62**
1.23	Retail sales	.95**
1.24	Real growth in retail sales	.51**
1.25	Annual rate of consumer price inflation	.37*
1.26	Cost-of-living comparisons	.59**
2.04	Balance of commercial services/GDP	.30*
2.07	Exports of goods	.39**
2.08	Exports of goods/GDP	.39**
2.10	Exports of commercial services	.41**
2.11	Experts of commercial services/GDP	.39**
2.17	Imports of goods and commercial services	.38**
2.19	Growth in imports of goods and commercial services	.33*
2.25	Portfolio investment assets	.47**
2.26	Portfolio investment liabilities	.40**
2.27	Direct investment flows abroad	.42**
2.28	Direct investment stocks abroad	.52**
2.31	Direct investment stocks inward	.32*
3.01	Central government domestic debt	.41**
3.06	Central government budget surplus/deficit GDP	.57**
3.10	General government expenditure/GDP	.51**
3.12	Collected total tax revenues/GDP	.55**
3.13	Effective personal income tax rate/GDP per capita	.43**
3.14	Collected personal income tax/ GDP	.62**
3.16	Collected employee's social security contribution/GDP	.36*
3.23	Collected capital and property taxes/ GDP	.61**

4.03	Country credit rating	.85**
4.09	Factoring (% of merchandise exports)	.38**
4.12	Stock market capitalization	.32*
4.13	Value traded on stock markets per capita	.49**
4.18	Number of banks among world's top 500 (ranked by assets)	.38**
4.19	Banking sector assets	.45**
4.26	Number of credit cards issued	.59**
4.27	Credit card transactions	.65**
5.03	Roads(density of network)	.43**
5.04	Railroad (density of network)	.40**
5.10	Investment in telecommunications(95-97)	-.43**
5.11	Computers in use(% of worldwide computer in use)	.34*
5.12	Number of computers/1000 people	.88**
5.13	Computer power	.34*
5.14	Computer power per capita	.92**
5.15	Connections to internet/1000 people	.67**
5.18	Cellular mobile telephone subscribers/ 1000 people	.77**
5.19	Office rent	.31*
5.21	Telephone lines/ 1000 people	.90**
5.23	Total health expenditure/GDP	.67**
5.24	Public expenditure on health/GDP	.38*
5.25	Number of doctors per 10000 inhabitants	.40**
5.28	Commercial energy consumed/GDP	-.53**
5.33	% of population served by waste water treatment plants	.58**
5.34	GDP/per metric tons of CO_2 emission =co2 control	-.60**
6.01	Estimated GDP per employee	.87**
6.02	GDP per employee	.97**
6.04	GDP (PPB) estimates per employee per hour	.88**
6.05	GDP per employee per hour	.97**
6.06	Estimated GDP per employee in agriculture	.57**
6.07	GDP per employee in agriculture	.71**
6.08	Estimates GDP per employee in industry	.72**
6.09	GDP per employee in industry	.90**
6.10	Estimates GDP per employee in service	.80**
6.11	GDP per employee in services	.95**
6.12	Compensation levels(wage + supplementary benefits)	.89**

6.13	Unit (labor costs growth in the manufacturing sector)	-.30*
6.14	Remuneration of primary school teacher	.81**
6.15	Remuneration of engineer	.68**
6.16	Number of companies in fortune 500 companies (ranked by sales)	.38**
6.18	Advertising expenditure per capita	.90**
7.01	Total expenditure on R&D	.41**
7.02	Total expenditure on R&D per capita	.88**
7.03	Total expenditure on R&D /GDP	.74**
7.04	Business expenditure on R&D	.40**
7.05	Business expenditure on R&D per capita	.82**
7.07	Total R&D personnel nationwide /1000people	.79**
7.09	R&D personnel in business per capita	.76**
7.17	Nobel prizes since 1950	.29*
7.18	Nobel prizes per capita	.56**
7.22	Patents granted to residents	.32*
7.24	Securing patents abroad	.45**
7.26	Number of patents in force/100000 inhabitants	.74**
8.01	Estimates of population	-.29*
8.02	% of population under 15 years	-.67**
8.03	% of population over 65 years	.70**
8.04	Dependency ratio population under 15 and over 64 years / active population (15-64years)	-.38**
8.05	Life expectancy at birth	.78**
8.07	Labor force / population	.42**
8.09	Active population (15-64years)total population	.37*
8.14	% of employment by non-agriculture sector	.67**
8.16	Employment/population	.51**
8.19	Number of working hours per year	-.59**
8.20	Unemployment/work force	-.33*
8.21	Unemployment of population under 24years/ total unemployment	-.45**
8.23	Secondary school enrollment/ relevant age group	.63**
8.27	Pupil-teacher ratio in primary education	-.50**
8.28	Pupil-teacher ratio in secondary education	-.45**
8.29	Total and current public expenditure on education/ GNP	.34*
8.30	Non-illiteracy adult (over 15 years) literacy / population	.52**
8.31	Newspaper circulation	.69**

8.33	Urban population/ total population	.32*
8.34	Income distribution lowest 20%	.38**
8.35	Income distribution highest 20%	-.58**
8.38	Human development index	.82**
	Ratio of science & engineer degrees to the 24-year-old population in 1997	.62**

*$p<.05$ **$p<.01$

APPENDIX B

Variables, which have significant correlation coefficient with real GDP growth per capita

Code of IMD	Variables	r
1.04	GDP per capita estimates	.30*
1.05	Real GDP growth	.96**
1.12	Growth domestic savings/GDP	.34*
1.13	Gross domestic savings real growth	.46**
1.15	Growth in private final consumption expenditure	.31*
2.09	Growth in exports of goods	.42**
2.18	Imports of goods and commercial services/GDP	.30*
2.23	Exchange rate stability	-.42**
2.43	(Exports + Imports)/GDP*2	.31*
3.06	Central government budget surplus (or deficit)/GDP	.44**
3.09	Government employment/ total employment	.32*
3.12	Total tax revenues/ GDP	.29*
3.23	Collected capital and property taxes/ GDP	.39**
4.01	Short-term interest rate	-.47**
4.03	Country credit rating	.39**
5.12	Number of computers/1000 people	.32*
5.14	Computer power per capita	.31*
5.21	Telephone lines/ 1000 people	.33*
6.01	Estimated GDP per employee	.31*
6.03	GDP growth per person employed	.79**
6.04	GDP (PPB) estimates per employee per hour	.29*
6.10	Estimates GDP per employee in service	.34*
6.13	Unit labor costs growth in the manufacturing sector	-.49**
7.03	Total expenditure on R&D /GDP	.33*

8.02	% of population under 15 years	-.44**
8.04	Dependency ratio population under 15 and over 64 years / active population (15-64years)	-.48**
8.07	Labor force / population	.40**
8.11	Female labor force/ total labor force	.45**
8.16	Employment/population	.43**
8.19	Number of working hours per year	-.31*
8.20	Unemployment/work force	-.31*
8.23	Secondary school enrollment/ relevant age group	.64**
8.26math	TIMSS average achievement of 8th grade	.38*
8.26scie	TIMSS average achievement of 8th grade	.44*
8.35	Income distribution highest 20%	-.54**

*$p<.05$ **$p<.01$