Modelling Technological Progress and Economic Growth at Wider Scales

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EXTENDED ABSTRACT

Technological progress is the key to economic growth hence the efforts to learn more on the link between the two have triggered research into modelling them independently and linked using composite indicators. Such composite indicators used could be classified into three major categories; firstly, those used for measuring an aspect individually using its own component factors and the second is studying two related aspects linked using components from that of both and finally, the kind of indicators generated to model the progress of an aspect with influence from one or more different aspects, such as the inclusion of technological progress and socio-economic status of a nation to study its citizens' health condition and care delivered. Examples of these are outlined. A few composite indicators used to measure national and regional scale performance in achieving the United Nations (UN) Millennium Development Goal (MDG) targets are discussed in detail. Finally, the paper elaborates upon a multidimensional data clustering approach with an unsupervised neural network, to analysing multiple indicators chosen by the United Nations and the World Bank to measure technological progress achieved in different countries on a world scale. This national performance appraisal study uses gross domestic product (GDP) % growth for the economic sector, and researchers in research and development (R&D-per million people (pmp) or RR&D pmp), technicians in R&D-pmp, scientific and technical journal articles-pmp, expenditure for R&D-% of national GDP, high technology exports-millions, royalty and license fees receipts and payments in millions, patent applications filed and trademark applications filed by residents and non residents in 2002 as technological progress indicators. These are the indicators used by the World Bank to measure progress achieved in the areas that are considered to be essential in alleviating poverty and meeting the UN's MDG 1 targets. The country groupings generated by the approach employed are then analysed using the cluster profiles (figure 1a-c).

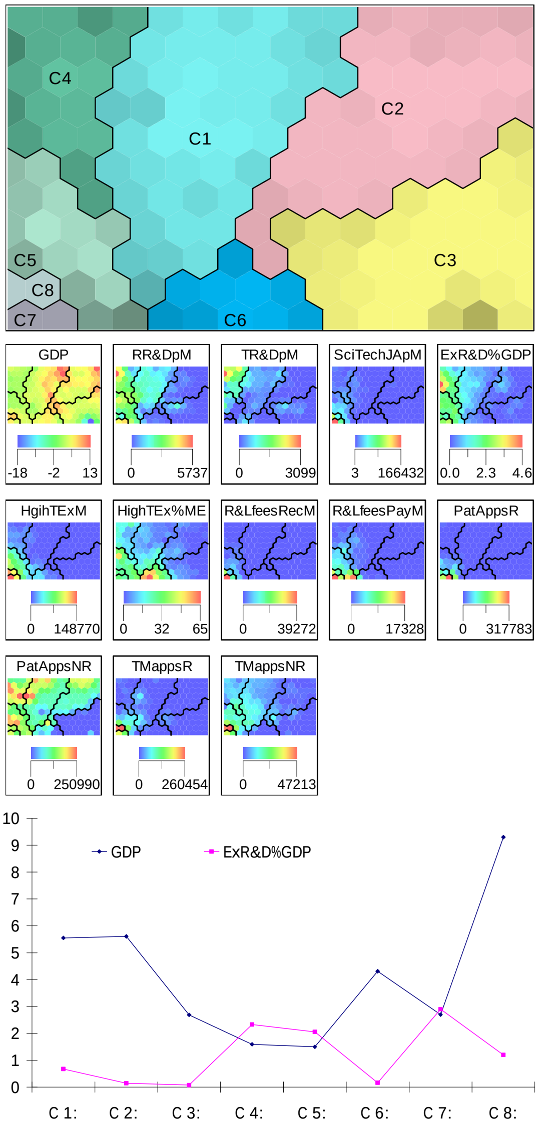

Figure 1: a: Country clusters (C1-C8) generated using b: component indicators for economic growth (GDP % growth 2002-03) and technological progress (listed in the text left) from the United Nations and the World Bank reports. c: graph showing cluster profiles, in C8, China alone with the world's highest GDP growth 9.3% (2002-03) and 1 % of expenditure for R&D of total % of national GDP between 1996-2002 .

1. INTRODUCTION

Technological progress is the key to economic growth (Debackere, Verbeek et al.; Sood and Tellis 2005; The World Bank Group 2005b) and the efforts to understand how the two could be quantitatively measured have led to widespread investigation into modelling the two independently and linked using composite indicators (Grupp 2006b). The use of composite indicators in general provides a mechanism to model complex aspects, such as the progress in technological innovation and the empirical models used for this purpose could be classified into three major categories; firstly, those that are used to measure an aspect using its own component factors, for example, Grupp (2006b) discusses this approach where the performance of national innovation systems was evaluated using a composite indicator/ number generated by combining (or aggregating) several indicators of science, technology and innovation. The second is, to analyse two aspects linked, such as the progress of technology and economic growth together (Sood and Tellis 2005), and the third category consists of those generated by using the influence of one or more aspects in the progress of a different one, such as the progress made in the health care sector being studied using a composite indicator developed from technological and economic growth factors (Maitlamo for National Policy ICT Development 2004).

Two international reports discussed herein give classic examples of performance measuring practice using individual and composite indicators at large scales i.e., country/ regional on a world stage. The two reports are significant in that they discuss the indicators used by the United Nations (UN) and the World Bank (WB) to measure progress in science and technology for policy/ decision making purposes. The progress in these areas is seen as a major contributing factor in meeting the UN Millennium Development Goal (MDG) 1 targets. The indicators used provide a concise and precise manner despite the complexity involved in the way various systems and their component factors interact in reality.

The UN report elaborates upon the link between GDP growth and poverty alleviation in the East Asia and the Sahara regions. This model developed by the UN is still being used to measure the progress made in achieving the targets of MDG 1, to halve the proportion of people living in poverty during the 1990-2015 time period. From this UN measure, a significant link between gross domestic product (GDP) growth rates and socio-economic status at country and regional levels has been confirmed. The report describes the reductions in poverty so far observed as dramatic in Eastern Asia in terms of the proportion of people living in extreme poverty, while sub-Saharan Africa becomes poorer. The interesting aspect in this is that the WB estimated figures of poverty rates released in 2004 from 1981 to 2001 show that global trends in poverty reduction have been dominated by the rapid economic growth seen in China and Eastern Asia. Details from this report as well as from the WB's data source are elaborated upon. Finally, eight clusters formed using Kohonen's self-organising map (SOM), an unsupervised artificial neural network based clustering technique, are studied to see the country groupings, their characteristics and trends in technological progress and economic growth.

2. MODELLING TECHNOLOGICAL PROGRESS AND ECONOMIC GROWTH: A REVIEW

The fact that further knowledge on technological progress and its influence on a nation's economic growth could provide vital information for stimulating the later has triggered research into modelling the two independently and linked using composite indicators (Sood and Tellis 2005). Empirical studies as well as recent reports demonstrate the continued use of composite indicators for studying technological progress and economic growth at national and further wider scales (Science and Technology Indicator Project Team 1995; Bakhshi and Larsen 2005; Kwack and Sun 2005; Qayum 2005). All these papers elaborate upon the use of a composite indicator/ number to study a nation's progress in the relevant aspect/s either linked or independently stating it as a common practice. For example Grupp (2006b) looked at the use composite technological innovation indicators calculated from science, technology and innovation to measure a nation's progress made in technological innovation. It is also possible to study the progress of an aspect using one or more factors from other areas as discussed in (Maitlamo for National Policy ICT Development 2004)) where Botswana's progress in that county's hearth care sector was analysed using a composite indicator calculated from computer literacy and socio-economic growth indicators in addition to that of real health care. This is all done despite the controversies debated on the composite indicator development practice that can be taken advantage of by analysts to suite their own theories by manipulating the real figures. The main point of all such controversies discussed over the years has been centred on the ways in which weights are given to obtain the aggregated or averaged composite value (Grupp 2006a).

Given that background on composite indicator use to measure progress and the controversies surrounding the way the indicator weightings could be manipulated, the paper presents the initial results of an approach where chosen factors could be analysed to see the major influencing factors if any such exist without setting any priority weightings.

3. COMPONENT INDICATORS FOR TECHNOLOGICAL PROGRESS AND ECONOMIC GROWTH

Firstly, two recent international reports are elaborated upon as the indicators used herein come from these reports.

3.1. The UN and MDG

The Millennium Development Goals or MDG for short, set by the UN, agreed by virtually all counties in the year 2000 led to the launch of a concerted attack on poverty and the problems of illiteracy, hunger, discrimination against women, unsafe drinking water and a degraded environment. The world leaders participated in this historically significant UN forum agreed to act on a set of eight goals (see Millennium Development Goals: 2005 Progress Chart in United Nations, 2005 for further details on the goals and progress achieved so far). Among the eight goals, the first seven relate to developing countries, the most highly victimized by poverty and these countries have been taking a lead role in the campaign, especially in the areas of direct improvements in human well-being. The eighth goal involves support from developed countries in the campaign by the developing nations to win the fight to ultimately eradicate poverty from the face of the earth. All the MDG goals have set progress targets and benchmarks for a 25 year period from 1990-2015. For example, MDG 1 to eradicate extreme poverty and hunger consists of a set targets worked out using the composite indicators as listed below under each target:

" Target 1: Reduce by half the proportion of people living on less than a dollar a day

1. Proportion of Population Below $1 (PPP) per Day (World Bank)

2. Poverty Gap Ratio, $1 per day (World Bank)

3. Share of Poorest Quintile in National Income or Consumption (World Bank)

Target 2: Reduce by half the proportion of people who suffer from hunger

4. Prevalence of Underweight Children Under Five Years of Age (UNICEF)

5. Proportion of the Population below Minimum Level of Dietary Energy Consumption (FAO)"

(United Nations Development Programme 2007:1)

Furthermore, a set of indicators employed by the World Bank to measure the performance of the world's developing countries in alleviating poverty show real progress made by several counties. The figures released in 2005 (The World Bank Group 2005b, see table 2 for figures) is given herein as it appeared in the report:
"GDP per capita more than tripled and the proportion of people in extreme poverty fell from 56 per cent to 17 per cent over two decades. Southern Asia also experienced a long-term drop in poverty rates in the last 20 years, with the number of people in extreme poverty dropping by almost 50 million. But in sub-Saharan Africa, where GDP per capita fell by 14 per cent, the poverty rate raised from 41 per cent in 1981 to 46 per cent in 2001, and the number of people living in extreme poverty increased by more than 140 million" (The World Bank Group 2005b Table 5.12 Science and technology:6)

3.2. Science and technology indicators

From the literature and international reports discussed so far it is clear that science and technology play a major role in determining a country's socio-economic status. The influence of technological progress on a county's economic growth is set to continue in the future as well. "The best opportunities to improve living standards, including new ways of reducing poverty, will come from science and technology. Science, advancing rapidly in virtually all fields—particularly in biotechnology—is playing a growing economic role: countries able to access, generate, and apply relevant scientific knowledge will have a competitive edge over those that cannot. And there is greater appreciation of the need for high- quality scientific input into public policy issues such as regional and global environmental concerns. Technological innovation, often fueled by government-led research and development (R&D), has been the driving force for industrial growth around the world" (The World Bank Group 2007:1).

In view of the above fact, component indicators listed in The World Bank Group (2005a&b) are analysed along with economic growth represented by 2002-03 national GDP % growth using Kohonen's self-organising map based clustering.

The reasons for the country groupings observed could be established by studying the SOM cluster profiles. SOM cluster profile analysis could as well enhance the possibilities of learning the future trends characteristic to the county groupings. The research herein is conducted in a similar manner to how Deboeck (2002) explored country risk indicators and stock market characteristics using weekly returns of 30 emerging markets, based on market price indices (market capitalisation, market dividend yield and P/E and P/B rations for 1996). The stock market analysis results were found to be more logical than the Wall Street Journal's (WSJ) five groupings of the 52 countries studied

3.3. Science and technology data and SOM analysis

Further to the fact that science and technology could be the determining factors of a nation's future economic growth the following data from The World Bank Group (2005a&b) reports are analysed:

1. national GDP % growth (for 2002-03) / GDP
2. researchers in research and development-R&D-per million people (or pmp) 1996-2002 / RR&D pmp
3. technicians in R&D- pmp 1996-2002 / TR&D pmp
4. scientific and technical journal articles-pmp 2001 / SceiTechJApp pmp
5. expenditure for R&D-% of national GDP 1996-2002 / Ex R&D%GDP
6. high technology exports in $ millions 2003 / HighTExM
7. % of manufactured exports 2003 / HighTEx%ME
8. royalty and license fees receipts $ millions 2003 / R&LfeesRecM
9. payments in $ millions 2003 / R&LfeesPayM
10. patent applications filed by residents 2002 / PatAppsR
11. patent applications filed by non- residents 2002 / PatAppsNR
12. trademark applications filed by residents in 2002 / TM apps R
13. trademark applications filed by non residents in 2002 / TMappsNR

The eight major clusters of a SOM created with the above 13 components (figures 2 a & b) of 152 countries, and their profiles (figures 3 a & b) are discussed in detail in the next section.

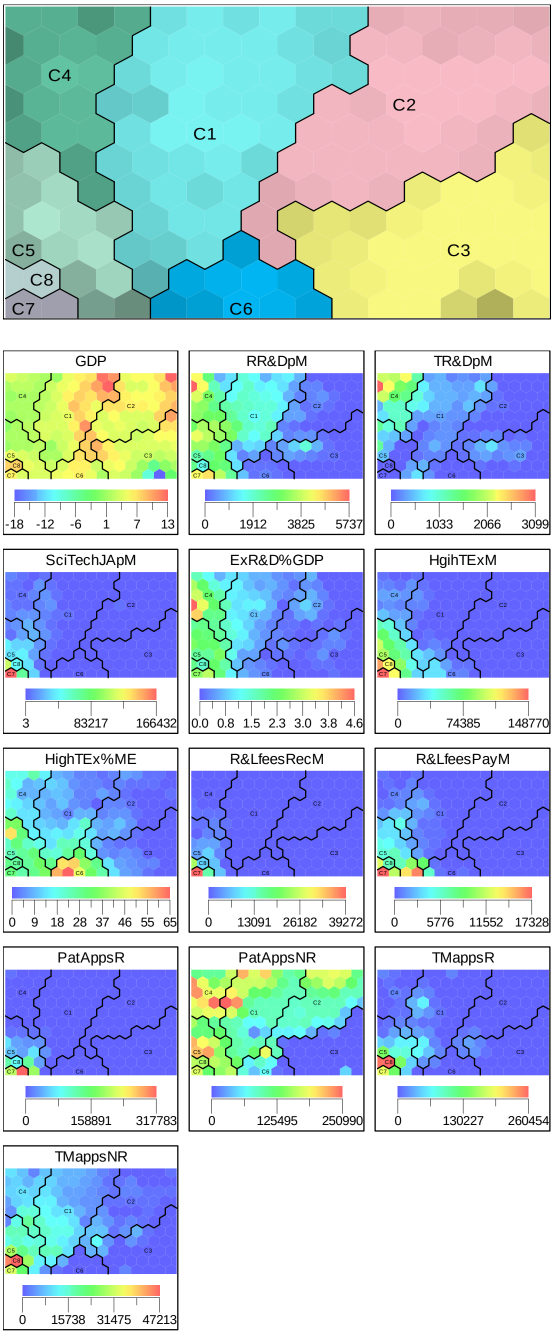

Figure 2: a: SOM created with 200 nodes using county GDP % growth (for year 2003) and 12 components chosen as science and technology indicators by a World Bank study. b: the SOM components.

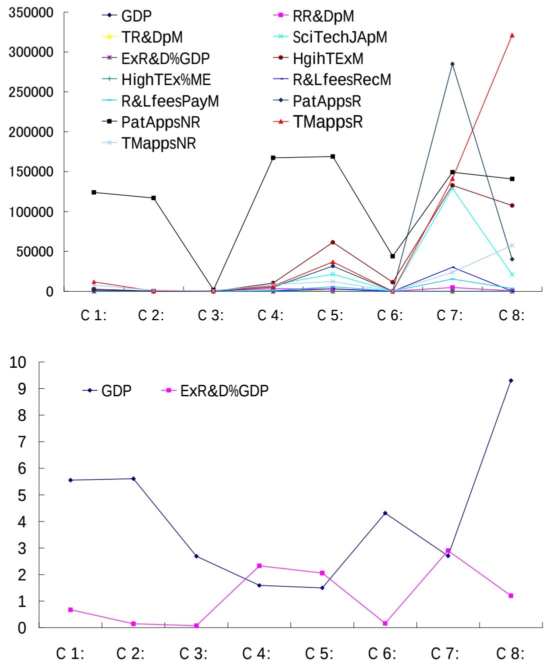

Figure 3: a: graph showing SOM cluster profiles b: GDP % growth (2002-03) and % expenditure GDP spent on research during 1996-2992

Even though it is possible to assign priority values/ preferential weights to factors expected of having more influence in the final composite indicator no such priority has been assigned in this initial analysis. In doing so the SOM clustering is made to reflect the major influencing factors analysed.

4. RESUTLS AND DISCUSSION

The initial results of the 8 cluster SOM created with the World Bank's indicators considered to be the determining factors of economic growth are discussed here onwards.

Based on the SOM clustering it is clear that no single factor or selected factors could be isolated as major contributing component. However, the SOM grouping of the countries indicate some significant correlation and trends within the data being analysed.

4.1. SOM clusters

The following are the 8 SOM clusters with the countries grouped in them:

C 1: Portugal, Greece, Slovak Republic, Turkey, Latvia, Romania, Armenia, Azerbaijan, Czech Republic, Estonia, Bulgaria, Lithuania, Trinidad and Tobago, Kazakhstan, Spain, Croatia, Ukraine, Belarus, Serbia and Montenegro, Poland, New Zealand, Georgia, Australia, Hong Kong (China), Brazil, Hungary and Mexico.

C 2: Uganda, Sudan, Ghana, Malawi Zimbabwe, Gambia, The Mozambique, Tanzania, Turkmen-, Macedonia, FYR, Kenya Lesotho, Zambia, Madagascar, Tajikistan, Mongolia, Albania, Algeria, Vietnam, India, Moldova, Kyrgyz Republic, Sri Lanka, Korea, Dem. Rep., Uzbekistan, Oman, Tunisia, South Africa, Bosnia and Herzegovina, Colombia, Ecuador, Indonesia Morocco, Swaziland and United Arab Emirates.

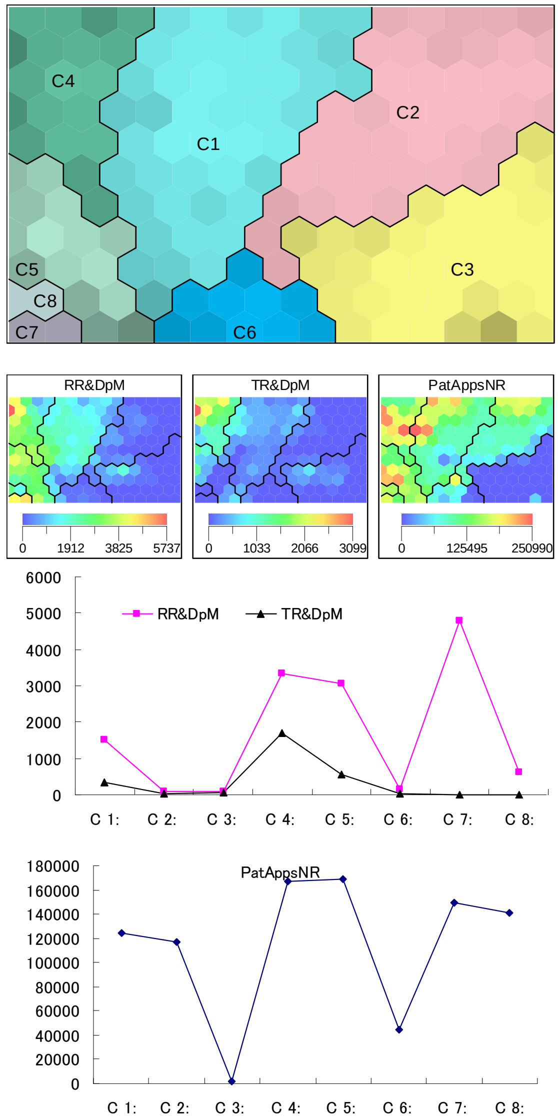

Figure 4: a: SOM of national GDP % growth (for year 2002-03) and 12 components chosen by the World Bank as science and technology component indicators. b: components of researchers in R&D-per million people (pmp), technicians in R&D-pmp during 1996-2002 and patent applications filed by non-residents in 2002, c: graph showing cluster profile of the first two components of b and d: graph showing the last component of b. Note that the correlation between the three components (shown in b) could be observed in graphs c and d.

Table 1: SOM cluster profiles.

No	Country	C 1:	C 2:	C 3:	C 4:
1	GDP	5.55	5.61	2.69	1.59
2	RR&DpM	1501.52	103.14	99.90	3347.38
3	TR&DpM	348.59	24.97	56.10	1716.23
4	SciTechJApM	2736.15	475.86	175.17	8516.62
5	ExR&D%GDP	0.67	0.15	0.08	2.33
6	HgihTExM	2665.56	267.11	27.61	10450.92
7	HighTEx%ME	8.81	2.91	1.76	16.54
8	R&LfeesRecM	74.37	5.20	7.10	597.31
9	R&LfeesPayM	347.33	25.60	21.02	954.15
10	PatAppsR	1270.33	51.49	17.98	5147.08
11	PatAppsNR	124048.81	117015.11	1778.27	167303.85
12	TMappsR	11707.67	456.51	1066.29	6561.62
13	TMappsNR	7660.85	1401.57	728.44	8717.92

No	Country	C 5:	C 6:	C 7:	C 8:
1	GDP	1.50	4.31	2.70	9.30
2	RR&DpM	3074.14	139.50	4805.50	633.00
3	TR&DpM	560.86	21.63	0.00	0.00
4	SciTechJApM	21501.00	189.63	129145.00	20978.00
5	ExR&D%GDP	2.06	0.16	2.90	1.20
6	HgihTExM	61346.00	11367.00	132833.00	107543.00
7	HighTEx%ME	31.00	40.50	27.50	27.00
8	R&LfeesRecM	3151.57	3.63	30249.00	107.00
9	R&LfeesPayM	5854.29	298.38	15526.00	3548.00
10	PatAppsR	31773.29	139.63	284917.00	40346.00
11	PatAppsNR	168942.86	44104.50	149404.50	140910.00
12	TMappsR	36825.14	2.50	141169.00	321034.00
13	TMappsNR	12208.14	114.88	23885.50	57597.00

Table 2: Regional figures for the indicators analysed

	country	Low income	Middle income	Lower middle income	Upper middle income	Low & middle income	East Asia & Pacific
1	GDP	6.9	4.9	5.7	3.3	5.2	8.1
2	RR&DpM	0	806	820	705	0	627
3	TR&DpM	0	0	0	275	0	0
4	SciTechJApM	13147	84507	61791	22716	97654	22722
5	ExR&D%GDP	0	0.7	0.9	0.5	0.7	1.1
6	HgihTExM	0	198304	103213	88846	0	0
7	HighTEx%ME	4	21	20	22	20	33
8	R&LfeesRec	44	1570	902	668	1614	136
9	R&LfeesPayM	111	12353	8404	3948	12464	5877
10	PatAppsR	1469	81554	76113	5441	83023	40469
11	PatAppsNR	3003874	4790264	2876674	1913590	7794138	581580
12	TMappsR	8489	589487	480507	108980	597976	321648
13	TMappsNR	26165	258839	155982	102857	285004	66765

		Europe & Central Asia	Latin America & Carib.	Middle East & N. Africa	South Asia	Sub-Saharan Africa	High income	Europe EMU
1	GDP	5.8	1.6	5.7	7.5	3.9	2.2	0.5
2	RR&DpM	1952	0	0	120	0	3575	2511
3	TR&DpM	1190	0	0	102	0	0	1266
4	SciTechJApM	39077	16045	4699	11611	3500	550846	148169
5	ExR&D%GDP	0.9	0.6	0	0.7	0	2.5	2.2
6	HgihTExM	26221	36799	993	0	0	834168	306581
7	HighTEx%ME	12	14	2	4	0	18	14
8	R&LfeesRec	700	518	164	14	81	90502	12188
9	R&LfeesPayM	2956	3050	210	40	330	87482	33325
10	PatAppsR	34159	7255	730	220	190	853607	129155
11	PatAppsNR	3071921	1166254	327948	181463	2464972	5087927	2448271
12	TMappsR	106252	163101	1313	5342	320	718588	222821
13	TMappsNR	137176	62928	8433	2242	7460	319893	92713

From The World Bank Group (2005a & b).

C 3: Chad, Kuwait, Nigeria, Burkina, Faso, Saudi Arabia, Peru, Uruguay, Nepal, Pakistan, Dem. Rep. Congo, Bangladesh, Benin, Botswana Cambodia, Cameroon, Lao PDR, Mauritania Niger, Argentina, Jordan, Panama, Egypt, Arab Rep., Yemen, Rep., Angola, Namibia, Iran, Islamic Rep., Chile, Honduras, Libya, Syrian Arab Republic, Congo, Rep., Eritrea, Gabon Jamaica, Lebanon, Togo, Mali, Senegal, Bolivia Mauritius, Nicaragua, Paraguay, C'te d'Ivoire, Dominican Republic, West Bank and Gaza, Afghanistan, Guinea , Guinea- Bissau, Haiti, Iraq Myanmar Puerto Rico Somalia, Guatemala, El Salvador, Venezuela RB, Central African Republic, Liberia and Ethiopia.

C 4: Norway, Russian Federation, Cuba, Denmark, Finland, Slovenia, Italy, Switzerland, Belgium, Israel, Sweden, Austria and Canada.

C 5: Netherlands, Singapore, Germany, France, United Kingdom, Korea, Rep., and Ireland.

C 6: Sierra Leone, Malaysia, Philippines, Costa Rica, Papua New Guinea, Thailand, Burundi and Rwanda

C 7: United States and Japan.

C 8: China.

The following are the observations made from the SOM cluster profiles:

1. of the 13 component indicators analysed there is a correlation between three of them, they are; researchers in research and development (R&D-per million people (pmp) 1996-2002 / RR&Ddpm), technicians in R&D- pmp 1996-2002 and patent applications filed by residents 2002 (see figures 4 a, b, c and d).

2 cluster 7 countries, US and Japan show the highest % of GDP expenditure (2.90 %), spent on research during this period 1996-2002 (see table 1)

3 China alone in cluster 8 shows 9.3 %, world's highest GDP growth rate (2003) and 1.2 % expenditure, spent on research from its total GDP % growth for 1996-2002.

4 cluster 1 consists of not so wealthier European countries along with Australia and New Zealand and show 5.55 GDP % growth (2002-03) with 0.67 of total % GDP growth for science and research expenditure during 1996-2002.

5 cluster 4 and 5 countries show a little less but similar values to that of the US and Japan figures for GPD growth and expenditure on science and research

6 cluster 3 consists of developing and African countries with the world's lowest on GDP growth and science and technology expenditure.

7 finally, trademark applications by residents in 2002 is seen to be normally higher than that of non-residents. However, as far as patent application figures in 2002 are concerned non-residents in all the clusters is higher than that of the residents except for cluster 7, in the US and Japan. China in cluster 8 has the opposite of cluster 7 with regards to patent and trademark applications made by resident and that of non-residents.

5. CONCLUSION

In summary, it could be stated that despite the controversies surrounding the way composite indicators could be manipulated by analysts to prove their own theories the approach is widely used to measure technological progress and its influence on economic growth and human well-being at national and wider scales. The initial results of this research on the use of SOM based clustering to analyse contributing component indicators and their influence show potential for modelling such complex issues using this approach without a need for any weights. Future work is being considered to apply the same approach to time series data to see the trend over the years in measuring the MDG (goals) quantitatively.

6. REFERENCES

Bakhshi, H. and J. Larsen (2005). "ICT-specific technological progress in the United Kingdom." Journal of Macroeconomics 27 (2005) 648–669 **27(2005)**: 648–669.

Debackere, K., A. Verbeek, et al. "Measuring progress and evolution in science and technology – II: The multiple uses of techno metric indicators." **4**(3).

Deboeck, G. (2002). "Data Mining with Self-Organizing Maps: Part II: A Practical Application." 2002 13 pp

http://citeseer.ist.psu.edu/cache/papers/cs/20346/http:zSzzSzwww.dokus.comzSzpdf-filesontheWebzSzpcai3.pdf/data-mining-with-self.pdf last accessed; 2 October 2007

Grupp, H. (2006a). Composite innovation indicators reconsidered. The Future of Science, technology and Innovation Policy: Linking Research and Practice (SPRU) 40th Anniversary Conference - The Future of Science, Technology and Innovation Policy, University of Sussex, Freeman Centre, Brighton, East Sussex, United Kingdom, BN1 9QE

http://www.sussex.ac.uk/Units/spru/events/ocs/viewabstract.php?id=245 last accessed 2 October 2007

Grupp, H. (2006b). How robust are composite innovation indicators for evaluating the performance of national innovation systems? SPRU 40th Anniversary Conference - The Future of Science, Technology and Innovation Policy, University of Sussex, Freeman Centre, Brighton, East Sussex, United Kingdom, BN1 9QE.

Kwack, S. Y. and L. Y. Sun (2005). "Economies of scale, technological progress, and the sources of economic growth: case of Korea, 1969-2000." Society for Policy Modeling .(27): 265-283.

Maitlamo for National Policy ICT Development (executive draft) (2004). 2.2 Healthcare Indicators.

Qayum, A. (2005). "Endogenicity of economic growth models." Technological Forecasting & Social Change **72 (2005)**: 75-84.

Science and Technology Indicator Project Team (1995). Science and Technology Indicators: A systematic Analysis of Science and Technology Activities in Japan. N. I. O. S. A. T. P. (NISTEP), Sci. and Tech. Agency.

Sood, A. and G. J. Tellis (2005). "Technological Evolution and Radical Innovation." Journal of Marketing **69**(July 2005): 152–168.

The World Bank Group (2005a). 1.1 Size of the economy, The World Bank 22-25. http://devdata.worldbank.org/wdi2005/Section1.htm last accessed 2 October 2007

The World Bank Group (2005b) 2005: World Development Indicators. Table 5.12 | Science and technology.

http://devdata.worldbank.org/wdi2005/Table5_12.htm last accessed 2 October 2007

United Nations (2005). Millennium Development Goals: Progress Chart, the UN Department of Economic and Social Affairs and the UN Department of Public Information. **DPI/2363/Rev.:** 3pp.

United Nations Development Programme. (2007). "MDG Targets and Indicators." UNDP, Millennium Development Goals Retrieved 28 September 2007

www.undp.org/mdg/goallist.shtml.