APPENDIX N

TWO IT-INFRASTRUCTURE INDEXES: RESULTS OF EXERCISES IN ESTIMATION

This appendix includes findings and results for two types of exploratory factor analysis carried out using estimated values for all the missing values of the variables related to core national and computing capacity and national info tech infrastructure (IT-infrastructure).

First, a factor analysis was carried out using values for personal computers, internet users and internet hosts divided *per* 100,000 habitants. The second type of factor analysis was carried out with the *total* number of personal computers, internet hosts and internet users. The absolute values for the total number of personal computers, internet hosts and internet users were important to include in the analysis, because personal computers, internet hosts and internet users are resources that are often shared among many individuals, specially in the developing world. So, even if the absolute values of the indicators may not be growing as expected, the resources may be shared by an increasing number of users. For example, the same number of internet hosts can offer its services to an increased number of users if the hardware is upgraded. Or the same internet user accounts may be used by an increasing number of individuals. On the other hand, increases in absolute numbers do not necessarily mean increases in population coverage. An individual may increase PC ownership, or increase the number of internet accounts, which would increase the indicator of IT-infrastructure as a proportion of the population, but not the real coverage of IT-infrastructure. This index is also important because unusually high IT-infrastructure indicators may be present for small countries[1], which have to be analyzed carefully when comparing to larger ones.

The indicators for teledensity and electricity consumption per capita remained the same for both types of analysis. For both cases, Principal Components Analysis (PCA) was used. This implied an additional advantage, because PCA carries out standardization of all variables solving the scale problem between ratios, percentages and units per 100 habitants, or 100,000 habitants. Findings arereported for each procedure.

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[1] See Appendix J for a discussion on high indexes for small countries.

IT-infrastructure Individualized Indexes (indicators divided by populations)

The IT-infrastructure indicators are highly correlated among them. The Kaiser-Meyer-Olkim measure of sampling adequacy for 1990 was 0.789, whereas in 1997 it was 0.813. These values suggest that a factor analysis adequately solves the high correlations between pairs of indicators for IT-infrastructure. Principal Components Analysis was carried out using the correlation matrix values for indicators for electrical consumption per capita, main telephone mainlines per 100 hab. (teledensity), percentage of automatic and digital lines, number of personal computers, internet hosts and internet users per 100,000 habitants. Two components with Eigenvalues greater than 1.0 were produced to explain 72.16% of the variance for 1990, and 77.70% for 1997. Each component was used to create a single aggregate IT-infrastructure individualized index: the IT-infrastructure availability Index and the Quality of Phone Line Index. The IT-infrastructure availability index explains 54.90% of the variance, whereas the Quality of Phone Lines Index explains 17.26% of the variance. Varimax rotation with Kaiser normalization was used to produce factor loadings. The rotation converged in three iterations.

	Component 1 IT-infrastructure availability	Component 2 Quality of Phone Line
Number of personal computers per 100,000 habitants	0.918	0.067
Teledensity (main phone lines per 100 habitants)	0.864	0.196
Electricity consumption in kw. per capita	0.862	0.088
Number of Internet users per 100,000 habitants	0.857	-0.013
Number of internet hosts per 100,000 habitants	0.823	-0.038
Percentage of automatic phone lines	0.097	0.795
Percentage of digital phone lines	0.208	0.754

Table N.1. Rotated Varimax principal components analysis (PCA) factor loadings of IT-infrastructure Individualized Index for 1990

	Component 1 IT-infrastructure availability	Component 2 Quality of Phone Line
Number of Internet users per 100,000 habitants	0.947	0.109
Electricity consumption in kw. per capita	0.916	0.063
Number of personal computers per 100,000 habitants	0.897	0.201
Number of internet hosts per 100,000 habitants	0.886	0.046
Teledensity (per 100 habitants)	0.874	0.168
Percentage of automatic phone lines	0.092	0.791
Percentage of digital phone lines	0.106	0.786

Table N.2. Rotated Varimax principal components analysis (PCA) factor loadings of IT-infrastructure Individualized Index for 1997

We can distinguish two distinct components from the factor analysis for the construction of the IT-infrastructure Individualized Index. One is the availability of IT-resources such as electricity, phone lines, personal computers and internet, and the other component is the quality of the phone lines. Even if the quality of phone lines is low, the rest of the indicators are *more* important for the construction of the IT-infrastructure availability index. It is interesting to point out that in 1990, the number of personal computers, teledensity and electricity were the most important factors in the index. In contrast, for 1997 the proportion of internet users became the most important factor, even more important than teledensity. In fact, in 1997 teledensity became less important than internet hosts, internet users, number of personal computers and electricity consumption. This may be due to the increases in IT-infrastructure required for the internet but unrelated to teledensity, such as increases in bandwidth capacity, fiber optic backbone upgrades, and wireless last-mile connections. These technological solutions installed in many countries between 1990 and 1997 increased IT-infrastructure, but are completely unrelated to teledensity indicators. However, the use of technological solutions did allow increases in the number of internet hosts and users. As stated before, teledensity is an important indicator for 1990, but less so for IT-infrastructure availability in 1997.

The indexes constructed by the principal component analysis (PCA) for 1997 and 1990 are not directly comparable, because the component scores for each variable are weighed differently. For example, in 1990 teledensity is the most important indicator, whereas the number of Internet users is the most important indicator in 1997. Comparing the indexes would be to compare two different constructs. For example, raw component values in 1997 are smaller than in 1990 for countries such as Australia, Switzerland, United States,

Sweden, Canada, France and The Netherlands. If we were to calculate change in terms of percentual increases or decreases for indexes in 1990 and 1997, we would erroneously conclude that these countries have *decreased* in their IT-infrastructure, which is not true if we analyze each IT-infrastructure indicator separately. What has really decreased is the standardized value of the indicators in 1997 for some OECD countries *compared* to values for developing countries. This means that the advantage that OECD countries had created for themselves in 1990 was closed by other countries that had caught up by 1997. In other words, other countries indicators increased faster, therefore the advantage became smaller, hence the value for the index became smaller too.

However, the fact that the IT-infrastructure index for 1997 explains more variance (60.96%), than in 1990 (54.90%) indicates that the IT-infrastructure country variation is better explained in 1997 than in 1990. This means that in 1997, an index constructed by the principal component of IT-infrastructure indicators in which number of internet users per 100,000 individuals was the most important indicator is better for explaining the differences among countries, than a similar index in 1990 in which teledensity was the most important indicator.

IT-infrastructure Shared Index – ISI (assuming individuals share IT resources)

Again, the IT-infrastructure indicators using absolute values are highly correlated among them. The Kaiser-Meyer-Olkim measure of sampling adequacy for 1990 was 0.63, whereas in 1997 it was 0.70. Principal components factor analysis with absolute values for indicators for PCs, internet hosts and internet users produced three components with Eigenvalues greater than 1.0. Varimax rotation with Kaiser normalization was used to produce factor loadings. The rotation converged in three iterations. These components explain 83.388% of the variance for 1990, and 86.01% for 1997. Each component was used to create a single aggregate IT-infrastructure Shared index: the IT-infrastructure Internet Index, The IT-infrastructure Wired Index and the Quality of Phone Line Index. In 1990, the IT-infrastructure Internet index explained 45.87% of the variance among countries, the Wired Index explained 21.35% of the variance among countries, and the Quality of Phone Line explained 16.16% of the variance among countries. In 1997 the IT-infrastructure Internet index explained 47.42% of the variance among countries, the Wired Index explained 23.34% of the variance among countries, and the Quality of Phone Line explained 15.31% of the variance among countries. Again the indexes for 1997 are better at explaining variances among countries than indexes in 1990. The Internet Index and the Wired Index increased their share of explained variance, whereas the quality of the phone line decreased its shared.

	Component 1 The Internet Index	Component 2 The Wired Index	Component 3 Quality of Phone Line Index
Number of personal computers	0.978	0.127	0.013
Number of internet hosts	0.973	0.006	0.011
Number of Internet users	0.745	0.496	0.001
Teledensity (main phone lines per 100 habitants)	0.195	0.911	0.105
Electricity consumption in kw. per capita	0.175	0.915	-0.001
Percentage of automatic phone lines	-0.003	0.380	0.671
Percentage of digital phone lines	-0.004	-0.153	0.865

Table N.3. Rotated Varimax principal components analysis (PCA) factor loadings of IT-infrastructure Shared Index for 1990

	Component 1	Component 2	Component 3
Number of internet hosts	0.982	0.009	0.013
Number of personal computers	0.980	0.162	0.011
Number of Internet users	0.980	0.169	0.001
Electricity consumption in kw. per capita	0.147	0.932	-0.001
Teledensity (main phone lines per 1000 habitants)	0.168	0.918	0.105
Percentage of digital phone lines	0.040	-0.006	0.865
Percentage of automatic phone lines	-0.001	0.080	0.671

Table n.4. Rotated Varimax principal components analysis (PCA) factor loadings of IT-infrastructure Shared Index for 1997

From these exercises we have constructed 10 Indexes, 5 for 1990 and 5 for 1997, that measure different aspects of a country's IT-infrastructure.

There are two ways to overcome the difficulty in comparing their values. One way is to rank countries according to each IT-infrastructure index, and analyze which countries rank well in both circumstances (1990 and 1997). Another way is to classify countries in categories for 1990 and 1997, and analyze which countries remain in the same category despite changes in the construction of the indicator.

Countries were ranked in 1990 and 1997 according to their IT-infrastructure Individual Index in the following categories:

Categories	IT-infrastructure Individual Index	Number of Countries in 1990	Number of Countries in 1997
Well prepared	> 0.70	22	25
Creating an IT infrastructure	0.10 to 0.60	15	18
Starting to create an IT infrastructure	0.10 to -0.10	16	6
Badly prepared	-0.24 to -0.10	16	21
With IT-infrastructure obstacles	-1.00 to -0.25	69	90

Table N.5. Categories for countries based on the IT-infrastructure Individual Index

Changes in IT-infrastructure Individual Index

All countries that had well prepared IT infrastructure in 1990, were well prepared in 1997. Norway remained as leader of the group in 1990 and 1997. Countries that in 1990 were creating their IT-infrastructure and increased to a well prepared IT-infrastructure were: St. Kitts, Slovenia, and Kuwait. Of special mention are: Mauritius, Congo (DROC), Jamaica, Botswana and Niger which increased their ranking in spite of starting with IT-infrastructure obstacles in 1990. Countries that ranked as having IT-infrastructure obstacles in 1990, which increased their IT infrastructure index as well as their ranking position in 1997 were: Iran, Colombia, Sao Tome and Cape Verde.

	Country	Number of ranks increased in 1997 IT-infrastructure Individual Index
Countries having IT-infrastructure obstacles in 1990		
Highest increases in the ranks		
	Mauritius	63
	Congo, DROC	49
	Jamaica	58
	Botswana	36
	Niger	35
Highest declines in the ranks		
	Cambodia	-23

	Haiti	-22
	Yemen	-18
	Senegal	-13
	Burkina Faso	-7
Countries with badly prepared IT-infrastructure in 1990		
Highest increases in the ranks		
	Myanmar	65
	Belize	61
	Saint Lucia	60
	Saint Vincent and the	54
	Ethiopia	50
Highest declines in the ranks		
	Togo	-63
	Viet Nam	-59
	Guinea	-58
	Chad	-56
	Sudan	-52
Countries creating an IT-infrastructure or with well prepared IT-infrastructure in 1990		
Highest increases in the ranks		
	Luxembourg	10
	Slovenia	10
	Estonia	10
	United Arab Emirates	7
	Iceland	6
Highest declines in the ranks		
	Russian Federation	-11
	Italy	-9
	France	-9
	Greece	-8
	Australia	-8

Table N.6. Country's changes in ranking according to the IT-infrastructure individual Index

Even though well prepared in 1990, Iceland, Finland, New Zealand, Luxembourg and Singapore increased their IT-infrastructure index in 1997, ranking higher in 1997 than in 1990. Percentual changes from 1990 to 1997 in well prepared countries ranged from great percentual increases in countries such as Iceland (121.68%), Singapore (63.23%) and Hong Kong (31.03%), as well as decreases for countries such as Australia (-95.69%), France (-24.18%), and United States (-20.64%). Iceland increased its index, its ranking, and was among the countries with greatest percentual changes.

	Country	Rate of progress 1997-90 (%) IT-infrastructure

		Individual Index
Countries having IT-infrastructure obstacles in 1990		
Fastest progress		
	Mauritius	24.93
	Congo, DROC	21.69
	Jamaica	15.76
	Niger	3.57
	Botswana	0.97
Greatest declines		
	Cambodia	-18.59
	Haiti	-18.02
	Yemen	-16.98
	Senegal	-16.17
	Benin	-16.17

Table N.7. Countries having IT-infrastructure obstacles in 1990
with the fastest progress and greatest declines in IT-infrastructure by 1997

In spite of having great progress from 1990 to 1997, countries that started with IT-infrastructure obstacles were still badly prepared in 1997.

	Country	Rate of progress 1997-90 (%) IT-infrastructure Individual Index
Countries with badly prepared IT-infrastructure in 1990		
Fastest progress		
	Hungary	29.91
	Mauritius	20.35
	Poland	18.05
	Costa Rica	14.34
	Argentina	6.76
	Bulgaria	5.50
Greatest declines		
	Armenia	-23.61
	Azerbaijan	-22.83
	Tajikistan	-21.85
	Uzbekistan	-21.12
	Rwanda	-20.03
	Central African Republic	-19.77
Countries creating an IT-infrastructure or with well prepared IT-infrastructure in 1990		
Highest increases in the ranks		
	Iceland	1.91
	Slovenia	10
	Estonia	10

	United Arab Emirates	7
	Iceland	6
Highest decreases in the ranks		
	Russian Federation	-11
	Italy	-9
	France	-9
	Greece	-8
	Australia	-8

Table N.8. Countries having a badly prepared IT-infrastructure in 1990 with the fastest progress and greatest declines in IT-infrastructure by 1997

There are some perplexing findings. The percentual changes for the United States' IT-infrastructure Individualized Index were negative. So was the percentual change for Australia's IT-infrastructure index showing a negative change of -56.68%, falling from 4th rank in 1990, to 11th rank in 1997.

Changes in IT-infrastructure Shared Index (assuming individuals share computers, internet hosts and internet user accounts)

Analysis of the changes in the IT-infrastructure shared index, as well as analysis of changes in ranks were carried out. Percentual increases were calculated relative to the original position, as well as to a country's rank. Countries were ranked according to their IT-infrastructure shared index in the following categories:

	IT-infrastructure Shared Index	1990 Number of Countries	1997 Number of Countries
Absolute leader (US)	> 1.41	1	1
Well prepared	0.50 to 1.40	10	10
Creating an IT infrastructure	0.10 to 0.49	29	26
Starting from scratch	0 to 0.09	23	23
Starting with an IT disadvantage	-0.09 to -0.01	29	27
Badly prepared	-0.24 to -0.10	54	57
With IT-infrastructure obstacles	-0.76 to -0.25	28	30

Table N.9. Country ranking according to IT-infrastructure shared index

The US is a category by itself. With an index almost four-fold the size of following country, absolute leader in 1990, one would except moderate increases in IT-infrastructure. This however did not occur. Assuming that individuals shared computers, internet hosts and internet user accounts, by 1997 the US had increased its IT-infrastructure in more than 26.7%. Higher increases than this value were only among: Luxembourg (27.83%), Colombia (40.80%), Albania (36.87%), China (47.20%), Viet Nam (68.37%), and Japan (72.61%).

Iceland created an IT-infrastructure advantage in 1990 that left it well prepared in 1997. Two countries overcame IT-infrastructure obstacles present in 1990 and moved up the ranks to start from scratch in 1997: China and Colombia. Three countries also overcame IT-infrastructure obstacles, but were still at disadvantage in 1997: Viet Nam, Poland and Iran. Even though Togo, Chad, Peru, Sudan, and Nigeria moved up the ranks overcoming IT-infrastructure obstacles present in 1990, they were still badly prepared in 1997. Nine countries were not able to sustain their IT-infrastructure and fell through the ranks: Congo, Burundi, Central African Republic, Rwanda, Mali, Cameroon, Nepal, Solomon Islands and Djibouti.

	Country	Rate of progress 1997-90 (%) ISI
Starting from having IT-infrastructure obstacles		
Fastest progress		
	Viet Nam	68.37
	China	47.20
	Albania	36.87
	Colombia	28.25
	Nigeria	25.14
Slowest progress		
	Cote d'Ivoire	1.0
	Mozambique	1.1
	Burkina Faso	2.1
	Niger	2.1
	Ethiopia	2.4
Declines in IT infrastructure		
	Georgia	-5.4
	Kyrgyztan	-3.0
	Myanmar	-1.0

Table N.10. Changes in ranking in the IT-infrastructure Shared Index

Decreases in IT-infrastructure Individualized Index

There are some surprising findings. Australia's IT-infrastructure index shows a negative change of -56.68% falling from 4th rank in 1990, to 11th rank in 1997. This surprising finding for Australia confirm the findings for the IT-infrastructure individualized Index.

Findings for both indexes

For both types of factor analysis, the quality (measured in terms of its digital and automatic nature) of the phone line was distinguished as a distinct component ranking lower in priority than others. This finding suggests, that even though important (ranging from 15% to 17%) the quality of the phone line, measured in terms of its digital and automatic nature, is secondary to all other factors.

Overall increases and decreases in the IT-infrastructure Index (Individualized and Shared) and increases in the Human Development Index (HDI)

Countries worth discussing that consistently show increases in the IT-infrastructure Index (calculated both ways: per individuals or assuming shared resources) and increases in Human Development are the following:

China
Spectacular overall increases in all indicators. The Human Development Index increased by 20.6%, the IT-infrastructure individualized Index increased by 32.08%, and the IT-infrastructure shared Index increased by 47.20%. These values are even more significant if we take into account its population. Findings suggest that from 1990 to 1997, China changed dramatically making progress in IT-infrastructure (considering shared IT resources and individual IT use), as well as progress in human development in income, education and health.

Viet Nam
Even though it was not one of the fastest to progress in Human Development (9.51%[2]), it did increase more than 68% in the overall IT-infrastructure indicators calculated either way.

Iceland and Luxembourg
These small countries, with populations between 300,000 and 400,000 were well prepared for the information revolution in 1990, and increased their IT-infrastructure levels for 1997, as well as making progress in human development.

[2] See Appendix H for full listing of estimated rates of progress in human development.