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Abstract

The recent publication of the *Global Competitiveness Report 2005-2006* by the World Economic Forum (WEF) has focused attention once more upon the relative abilities of many countries to compete in world markets. This paper provides an analysis and evaluation of the approach taken by the WEF in constructing its measure of international growth competitiveness, the Growth Competitiveness Index (GCI) which is used to rank countries. In particular, the paper identifies three areas where the GCI is vulnerable to criticism. First, the treatment of outliers for hard data items. In several cases, we have identified alternative methods for dealing with outliers that are justifiable or even superior. Second, the crucial role of the variable utility patents in the calculation of the GCI is questioned and serious doubts concerning the use of this variable are raised. Third, the paper suggests an alternative approach, based upon Structural Equation Modeling, should be used for the determination of weights in the index calculation process, rather than the arbitrary method adopted by the WEF.

Keywords: World Economic Forum; Growth Competitiveness Index; Structural Equation Modeling; International Growth Competitiveness.
JEL Classification: F10; F15.

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1 Introduction

The recent publication of the *Global Competitiveness Report 2005-2006* (GCR) by the World Economic Forum (WEF) has focused attention upon the ability of many countries to compete in world markets. The GCR is quoted as an authoritative source on global and regional competitiveness and provides rankings of countries according to various competitiveness indexes created by the WEF.

The aim of this paper is to look more closely at the question of international growth competitiveness. In particular, the paper aims to examine the analysis of growth competitiveness undertaken by the WEF. The WEF assesses country competitiveness in terms of a series of indexes it creates. These indexes cover such areas as a country's macroeconomic environment, its technological readiness and its public institutions. The WEF then uses these indexes to rank countries. This paper addresses several questions including: Are the methodologies used by WEF to determine country rankings reasonable? What are the policy implications that flow from the use of these indexes? This paper uses the original WEF data to re-evaluate the calculation of the WEF's competitiveness indexes. That is, the paper assesses carefully the methods used by the WEF to construct the various indexes and raises questions regarding whether alternative and superior methods may have been used. The paper is structured as follows. Section 2 addresses some important definitional issues, including the definition and measurement of the Growth Competitiveness Index (GCI), the cornerstone measure of country competitiveness developed by the WEF. Section 3 takes a closer look at how well various countries do when measured by the GCI and provides a detailed assessment of the measurement of the GCI and its component indexes. Section 4 raises questions concerning the robustness of the GCI, particularly with respect to the treatment of outliers and the arbitrariness of weight selection in calculating indexes. Section 5 provides an alternative, less arbitrary method for measuring the GCI based on structural equation modeling. Section 6 provides a reliability analysis of the latent variables created by the WEF. Section 7 provides concluding comments.

2 Definitions

The WEF produces a GCI for 117 countries in total. The list of the 117 countries is contained in Appendix Table (A1). According to the WEF, its sample of 117 countries account for 97% of world output. The GCI is the embodiment of the WEF's view of what it means to be competitive. The WEF's interpretation of competitiveness may be summarized as follows (Lopez-Claros et al., 2005 p. 3): "We think of competitiveness as that collection of factors, policies, and institutions which determine the level of productivity of a country and that, therefore, determine the level of prosperity that can be attained by an economy." Therefore, according to the WEF view a more competitive economy should be able to achieve greater economic growth in the medium to longer term. Hence the GCI is designed to capture the underlying drivers of productivity that ensure sufficient and rising prosperity for a country's citizens. According to the WEF (Lopez-Claros et al., 2005 p. xiv):

> The GCI brings together a number of complementary concepts aimed at providing a quantified framework for measuring competitiveness. In formulating the range of factors that go into explaining the evolution of growth in a country, it identifies "three pillars": *the quality of the macroeconomic environment, the state of the country's public institutions*, and, given the importance of technology and innovation, *the level of its technological readiness.*

The GCI is constructed using a combination of hard data obtained from a range of independent sources and survey data drawn from the WEF's annual Executive Opinion Survey. Examples of hard data include inflation rates and university enrollment figures. In contrast the Executive Opinion Survey is able to help capture concepts for which hard data are usually unavailable, but are typically important drivers of the economic growth process. Examples of information derived from the Executive Opinion Survey cover such things as judicial independence and the extent of inefficient government activities. Details of all the data used to construct the GCI and its various constituent indexes and sub-indexes are contained in Appendix Table (A2).

The GCI is broken down into three constituent indexes each representing one of the 'three pillars': the Macroeconomic Environment Index (MEI); the Public Institutions Index (PII); and the Technology Index (TI). The details of exactly how each of these three indexes is constructed are contained in Figures (1) and (2). The WEF invoke several important assumptions in constructing these indexes. First, they separate the countries into two categories: core innovators and non-core innovators. Core innovators are the more technologically advanced countries. According to WEF, technological innovation is more important to the economic growth of countries at or close to the technological frontier. Therefore they classify countries as core innovators if technological innovation is more critical for growth. To separate core innovators from non-core innovators they count the number of U.S. utility patents (patents for innovation) each country has per capita, for the most recent year. Countries with more than 15 patents per million people are classified as core innovators, while all others are classified as non-core. Therefore, to reflect this difference between the core and non-core economies, the WEF uses a different formula to construct the GCI for each group as follows:

$$\text{Core-innovators GCI} = \frac{1}{2}TI + \frac{1}{4}PII + \frac{1}{4}MEI \tag{1}$$

$$\text{Non-core innovators GCI} = \frac{1}{3}TI + \frac{1}{3}PII + \frac{1}{3}MEI \tag{2}$$

A second important assumption involves the construction of the TI. Whereas innovation is more important in core economies, the ability to absorb and adopt foreign technologies will be more important to non-core economies. This means that the WEF constructs the TI differently for each of the core and non-core economies. For core economies the TI is comprised of only the Innovation sub-index (ISI) and the Information and Communications Technology (ICT) sub-index (ICTSI). For non-core economies, a third sub-index is included, the Technology transfer sub-index (TTSI).[1] The WEF therefore uses a different formula for each group as follows:

$$\text{Core-innovators TI} = \frac{1}{2}ISI + \frac{1}{2}ICTSI \tag{3}$$

$$\text{Non-core innovators TI} = \frac{1}{8}ISI + \frac{3}{8}TTSI + \frac{1}{2}ICTSI \tag{4}$$

[1] Compare Figures (1) and (2).

A third important assumption involves the weighting of hard data as compared to survey data in the creation of the various sub-indexes. Hard data are always weighted more than survey data, except in one case in the calculation of the MEI. For instance in the calculation of the ISI the hard data items are weighted at 3/4 compared to the survey data, which are weighted at 1/4. In the case of the ICTSI, hard data are weighted at 2/3, compared to survey data at 1/3. In the calculation of the Macroeconomic stability sub-index, hard data are weighted 5/7 compared to the survey data weight of 2/7. In each case the choice of the weights is arbitrary. We return to the question of the allocation of weights in Section 5.

Figure (1) provides details of exactly how the GCI is constructed for core-innovators and identifies the hard data and survey data variables used to construct the various sub-indexes. A full description of the variables is contained in Appendix Table (A2). Figure (1) also identifies the weights assigned to the categories of variables, the sub-indexes and the indexes. Figure (2) provides similar details for non-core innovators. The figures make it clear that it is the treatment of technology that is the key difference between how the GCI is calculated for core and non-core innovators.

3 How Well do Various Countries Perform on the GCI?

Table (1) contains the GCI scores and ranks for 40 of the 117 countries, as well as for the TI, PII and MEI. It should be emphasized that the table includes both GCI scores and ranks. A higher score means better performance in the various constituent components of the GCI. However, a high score does not guarantee a low rank number. If all countries score highly then good performance may not translate necessarily into a low rank number. The table identifies the top 20 countries, the median 10, and bottom 10.

Finland is the number one ranked country with a GCI score of 5.94 compared to a theoretical maximum of 7. The top 20 countries are regionally diverse and include the Nordic countries (Finland, Sweden, Denmark, Norway, Iceland), North America, Europe (Switzerland, Netherlands, UK, Germany, Austria), Asia (Japan, Taiwan, Republic of Korea, Singapore), Pacific countries

(Australia, New Zealand), and Arab countries (UAE, Qatar). Although the USA is the first ranked country on TI (and TI is weighted at 50%), its relatively less impressive performance on PII (18th place) and MEI (23rd place), drags it down to 2nd place behind Finland which performs exceptionally well in all categories. As a regional group, the nordic countries are superior to any other region of the world.

The importance of technology to the GCI scores and ranks is emphasized by the performance of Taiwan whose 5th rank position is due primarily to its 3rd ranking on TI compared to 26th on PII and 17th on MEI. Similarly, Republic of Korea's 17th place on GCI is due to its 7th place rank on TI compared to its lesser performance on PII (42nd) and MEI (25th). There is also considerable regional diversity amongst countries from the middle of the rankings with representation from Central and South America, Central and Eastern Europe, Africa and the Caribbean.

The bottom 10 countries are more regionally concentrated coming mainly from Africa (Zimbabwe, Cameroon, Benin, Chad), Asia (East Timor, Bangladesh, Cambodia), and South America (Paraguay, Guyana). The low scores and poor rankings for these countries are across the board with poor performance in one area correlated with poor performance in the other two. Importantly, Table (1) indicates there is great scope for each of these countries to improve their international growth competitiveness by tackling any or all of the three pillars of growth.

Further insight into the process of growth competitiveness can be obtained by breaking down each index into its constituent sub-indexes. Table (2) provides a breakdown of the composition of the MEI into its sub-indexes: Macroeconomic stability sub-index (MSSI); Government Waste (GW); and Country Credit Rating (CCR). In constructing the MEI, the MSSI is weighted at 50% compared to GW and CCR which are each weighted at 25%. According to Table (2), Singapore has the best MEI score due to its excellent GW score and good performance on MSSI. Norway is only slightly behind Singapore with a better MSSI and CCR performance, but less impressive GW score. Interestingly the Middle East countries, UAE and Qatar are ranked 5th and 6th respectively on MEI due to their excellent MSSI and GW scores. Given that their regional location affects country risk assessments thereby adversely affecting CCR scores, their macroeconomic environments are excellent. Malaysia makes the top 20 on MEI due to its very impressive GW perfomance (2nd) and good MSSI performance.

For those countries around the middle of the ranking list, there is considerable regional and performance diversity. Russia performs poorly on GW but considerably better on CCR and MSSI. By contrast, Azerbaijan does well on MSSI (18th rank) but less well on GW and relatively poorly on CCR. Given its good MSSI, by devoting attention to CCR, it could substantially increase its GCI. Hungary performs reasonably well on CCR, worse on GW, but worse still on MSSI (95th rank). Improvements in MSSI would see substantial improvement in its GCI.

Of the bottom performing countries, there is consistent poor performance across all three areas. Again we see this group comprises African and Central American countries with also some countries that formerly fell under the influence of the old Soviet Union. In all cases, improvements in MEI and GCI could result in improvements in any of these three areas. Unfortunately, Zimbabwe is clearly the worst performing country in terms of its macroeconomic environment.

Table (3) provides scores and rankings for TI and its sub-indexes. For core innovators, there are only two sub-indexes: ISI and ICTSI. For non-core innovators, a third sub-index covering technology transfer (TTSI) is included. Of the top 20 countries, only two, Estonia and Portugal, are non-core innovators. There is considerable diversity amongst the top 20. Whereas the top four countries, USA, Finland, Taiwan, and Sweden score exceptionally well on both ISI and ICTSI, Switzerland, Republic of Korea, and Japan perform relatively better on ISI compared to ICTSI, while Iceland, Singapore, and the Netherlands perform relatively better on ICTSI compared to ISI. Interestingly, Germany is ranked only 20th on ICTSI bringing down its TI score.

In the middle group, we see considerable diversity. Whereas India scores highly on technology transfer (6th rank), it performs relatively poorly on ICTSI (67th rank) and ISI (76th rank). By contrast, Argentina does relatively well on ISI (34th rank).

The bottom 10 countries perform consistently poorly across all three areas of technology readiness, except for the Kyrgyz Republic with a 63rd rank on ISI. All countries do poorly on ICTSI and TTSI. The lessons coming through are that an improvement in either or both the information and communications technology infrastructure or their readiness to accept technologies from elsewhere will improve their TI and GCI.

Table (4) provides scores and ranks for PII and its constituent sub-indexes of Contracts and law sub-index (CLSI) and Corruption sub-index (CSI). There is extremely high correlation between both sub-indexes for the top seven countries with the top two countries Denmark and New Zealand scoring very highly on both. Japan is the only country to do very well on one sub-index (CSI) and not so well on the other (CLSI) indicating the relative opaqueness of the legal system in Japan compared to other top ranked countries.

The middle ranked countries represent a diverse group of countries from Africa, Central and South America, and Eastern Europe. Whereas Mauritius is ranked similarly for CLSI (53rd) and CSI (59th), Peru is ranked 99th on CLSI and 39th on CSI compared to Tanzania which is 44th on CLSI and 85th on CSI. For the bottom 10 countries, we see a high correlation between CLSI and CSI for all 10 countries with Bangladesh ranked as the most corrupt country in this sample of 117 countries.

In summary, the evidence from the tables presents a picture of considerable regional diversity. Nevertheless, by region, countries from the Nordic area, North America, and Western Europe tend to outperform most countries in Eastern and Central Europe, Central and South America and most of Asia, with exceptions such as Japan, Singapore, Republic of Korea, Taiwan, Australia, and New Zealand. However, given that the GCI scores are used not only as indicators of performance but also to rank countries, a closer look at the methods used to calculate scores is required. The creation of rank orders and league tables of countries is a potentially damaging exercise, so extreme care should be exercised when creating rank orders.

4 How Robust is the GCI?

It is clear that the WEF is attempting to provide advice to governments, business leaders and others about the relative economic growth environment of as many countries as they can. Their aim is to identify those countries with the right macroeconomic environment, technology readiness and economic-institutions in place that enhance economic growth, while also identifying those countries that fall short of best practice. To that end the calculation of the GCI and its component indexes and sub-indexes has merit. However, since these index scores are used to rank countries and create league tables then a closer look at the technical aspects of exactly how the various indexes are constructed must be undertaken.

There are four areas that must be considered more closely before we can decide exactly how robust is the GCI and its related indexes and sub-indexes. The four areas are: (i) the treatment of outliers in hard data variables; (ii) the role of the single variable 'utility patents' in separating countries into core and non-core innovators; (iii) the treatment of survey data compared to hard data; and (iv) the arbitrariness of weight allocation used to construct the GCI and its various indexes and sub-indexes. In section 5 of the paper, we examine these latter two points.

4.1 Treatment of Outliers

In the case where indexes and sub-indexes are constructed from survey data only, there is no potential outlier problem since all variables are constrained to the 1-7 range by the nature of the Executive Opinion Survey design. However, in the case of some hard data variables, it is possible for some values to be well outside the standard normal range. In such cases a careful assessment must be made concerning whether these outliers distort the calculation of the individual country scores. For the ease of calculation of indexes, the WEF convert all hard data items to the 1-7 scale using the following formula after controlling for outliers:

$$6 \times [\frac{(\text{country value} - \text{sample minimum})}{(\text{sample maximum} - \text{sample minimum})}] + 1 \tag{5}$$

The treatment of outliers is important since it will affect the actual scores calculated using equation (5). For example, the decision to drop countries from the top or bottom end of the distribution will effectively increase the scores of all other countries when hard data are converted to a 1-7 scale score using equation (5). Given that these scaled scores are then used to calculate the indexes and that hard data are weighted more heavily than survey data, the decision to include or exclude an outlier can have an important impact.

But just how do the WEF control for outliers? Unfortunately, the WEF do not reveal exactly how they deal with outliers for each of the 14 hard data variables used in the construction of the indexes. However, through a pains-taking process of backward engineering we have been able to determine exactly how they dealt with outliers in each of the 14 cases.

Table (5) provides a summary of exactly how we believe the WEF dealt with outliers. In constructing the indexes, the WEF appears not to have been consistent in the way they treat outlier issues related to various hard data items. For any researcher, the treatment of outliers is not a straight-forward matter and there is no single universally agreed method to adopt. Rather, it is more a case of common sense and reasonable practice. For instance, it is well known that dropping outliers sequentially may exacerbate the detection of outliers as the resulting new mean value may result in new outliers more than three standard deviations from the new mean value. A popular method, beyond simply eye-balling the data, is to apply Grubbs' test. However, the definitive use of Grubbs' test requires that the data be normally distributed, which is certainly not the case for several of the hard data variables used by the WEF. Figure (3) summarizes the distributions of the eight hard data items that the WEF adjusted for outliers. In each case, the distribution is skewed, in some cases, heavily. A summary of exactly how the WEF adjusted the hard data for outliers is provided in Table (5). Of the 14 hard data items in only six cases did we not detect outliers using Grubbs' test and also find that there was no adjustment by the WEF, namely: telephone lines, tertiary enrollments, personal computers, Internet users, cellular phones, and country credit rating. Although we did not detect an outlier in the case of the real effective exchange rate variable, we observed that the WEF dropped Zimbabwe.[2] Table (5) compares what the WEF did to adjust for outliers to what we detected and what we believe should have been done. In several cases, the WEF made unusual adjustments, such as in the case of government surplus/deficit and utility patents.

As Table (5) makes clear, there are four cases where an alternative approach to that adopted by the WEF could have been used. In the cases of government surplus/deficit, inflation, utility

[2]The dropping of Zimbabwe in this instance may be defended for other economic performance related reasons.

patents, and Internet users, a different outlier treatment could have been used. If this alternative approach had been used in each of these cases, then the resulting index scores would have been different which would have been passed through to change the GCI scores. The outlier treatment of Government Surplus/Deficit, in particular, by the WEF does appear to be rather contrived. Importantly, the WEF should explain and justify their outlier treatment in detail, rather than leaving it to researchers to backward engineer.

4.2 The influence of the variable 'Utility Patents'

The variable utility patents plays a critical role in determining whether a country is a core-innovator or non-core innovator. But just how reasonable is it to classify countries arbitrarily into either the core or non-core innovator category on the basis of U.S. utility patents? Unfortunately, U.S. utility patents do not proxy the degree of innovation of a particular country but merely measure the extent to which a country uses U.S.-registered technologies. The variable also fails to distinguish between patents for income generating goods and consumables (e.g. patent for assembly line equipment versus patent for medication).

Moreover, the WEF's seemingly arbitrary categorization of economies as either core or non-core innovators has failed to incorporate the significant skew of scores within the distributions (for example the USA scores 283.7 at the top of the boundary of the Core economies whereas Italy scores a significantly lower 27.6). A simple exercise, where the GCI is computed for all countries using the non-core innovator equation (2) above, reveals the sensitivity of the GCI to this categorization. As suspected, those economies to benefit substantially from the unification of categories are those that ranked toward the lower boundary of the core-innovators (Hong Kong, Ireland and Luxembourg). It is likely that these economies will still benefit from aspects such as FDI and foreign licensing (captured in the TTSI specific to non-core innovators) and are less dependent on innovation and technology to maintain their growth 'competitiveness'. The results of this exercise are useful in demonstrating clearly that until economies are assigned weights dependent on their depth of technological-innovation then the CGI is not a consistent measure of growth competitiveness and the scores and rankings are not comparable throughout.

A further criticism questions the WEF's use, without any justification, of U.S. utility patents as a proxy for utility patents. Dermis and Khan (2004) clearly show that where patents are registered is highly dependent on the domestic geographical situation of a country and thus presents a high propensity for bias.[3] To help rectify the bias Dernis and Khan have compiled a proxy based on European, Japanese and U.S. utility patents. The "Triadic Patent Families" (TPF) comprises a set of patents that share one or more priorities at the European Patents Office (EPO), the Japan Patents Office (JPO) and the U.S. Patent and Trademark Office (USPTO). The share of countries patents in the TPF is much more uniform, with Japan, the EU and the U.S. accounting for 26.6%, 32.4% and 34% of patents respectively.

It therefore follows that the WEF's GCI hitherto discriminates against those countries not buying U.S. utility patents. Using data from 1998 from the USPTO and the OECD patent database, it is evident that European countries have systematically underscored whilst countries such as Taiwan and Republic of Korea have systematically achieved higher GCI scores. Changes in scores and ranks of utility patents will inevitably be reflected in GCI scores and rankings if an alternative, superior, utility patents variable is used instead of U.S. utility patents.

5 An Alternative Approach Using Structural Equation Modeling

One of the most surprising features of the calculation of the various indexes is the ad hoc and unjustified way the various weights are chosen and assigned to variables given their importance to the calculation of each index and sub-index and also the fact that the WEF consistently weight hard data items more heavily than survey data, except in one case.[4]

Because the created indexes and sub-indexes are latent variables which are indirectly represented by observed variables, it becomes important to select variables that are theoretically and intuitively appealing. The assignment of ad hoc weights coupled with an ad hoc selection of observed variables cast doubt on the reliability of the GCI and corresponding indexes and sub-indexes. In what follows,

[3]About 52.8% of U.S. utility patents are registered by residents of the U.S. whereas 46.6% of European Union patents are registered by EU residents. See Figure 1 (Dernis & Khan, 2004, p. 6).

[4]That one case involves the equal treatment given to CCR (hard data) and GW (survey data) each weighted equally at 1/4 in the calculation of MEI.

we present an alternative approach to assigning weights to the latent indexes and sub-indexes in representing the GCI. The procedure is completed via structural equation modeling (SEM). SEM exhibits properties similar to multiple regression modeling, but more robustly takes into account relationships between (a group or sub-group of) latent variables, including correlations, covariances, nonlinearities, and error terms (correlated and uncorrelated). SEM also allows for a set of observed variables to indirectly represent a composite latent variable in a relatively more objective fashion. A general description of the procedures used in deriving parameter estimates quantifying the causal relationships between a latent variable and a sub-set of observed variables is described below.

While SEM can play many roles, in this paper it is strictly confirmatory. The model provided by the WEF is not necessarily the best model to fit the data. However, the structural path model proposed by the WEF can be confirmed (or disconfirmed) by determining whether the variances and covariances in the data exhibit patterns which are consistent with the WEF's assumptions and findings. If the WEF approach is disconfirmed, then a new set of weights can be derived which ultimately lead to new (more robust) GCI scores and rankings.

Using the methodology described by Raykov and Marcoulides (2000), consider the following system of equations that represent the WEF's growth competitiveness drivers:

$$\begin{aligned} TI &= \lambda_1 GCI + \epsilon_1 \\ PII &= \lambda_2 GCI + \epsilon_2 \\ MEI &= \lambda_3 GCI + \epsilon_3 \end{aligned} \tag{6}$$

where λ_1 through λ_3 are factor loadings and ϵ_1 through ϵ_3 are error terms. Since all of these variables are latent, they can be expressed with respect to observed variables. The following is a system of equations representing the respective growth drivers for core innovators:

$$\begin{aligned} ISI &= \lambda_{11} TI + \epsilon_{11} \\ ICTSI &= \lambda_{12} TI + \epsilon_{12} \\ CLSI &= \lambda_{21} PII + \epsilon_{21} \\ CSI &= \lambda_{22} PII + \epsilon_{22} \end{aligned}$$

$$MSSI = \lambda_{31} MEI + \epsilon_{31}$$

$$CCR = \lambda_{32} MEI + \epsilon_{32}$$

$$GW = \lambda_{33} MEI + \epsilon_{33} \tag{7}$$

whereas non-core innovators are represented by all equations in system (7) plus the following equation:

$$TTSI = \lambda_{13} TI + \epsilon_{13} \tag{8}$$

From these systems of equations, we can derive a variance-covariance matrix first by deriving a series of covariances as follows:

$$\begin{aligned} Cov(TI, PII) &= Cov(\lambda_1 GCI + \epsilon_1, \lambda_2 GCI + \epsilon_2) \\ &= \lambda_1 \lambda_2 Cov(GCI, GCI) + \lambda_1 Cov(GCI, \epsilon_2) \\ &\quad + \lambda_2 Cov(\epsilon_1, GCI) + Cov(\epsilon_1, \epsilon_2) \\ &= \lambda_1 \lambda_2 \end{aligned} \tag{9}$$

A necessary, although not sufficient condition of SEM is for the model to be identified, which means that it must possess "fewer parameters than non-redundant elements in the covariance matrix" (Raykov and Marcoulides, 2000, p.31). This means that SEM therefore requires the regression weight of each residual parameter to be constrained equal to one. When this is done the SEM model is saturated which means it has an equal number of parameters to non-redundant elements, and therefore zero degrees of freedom. However, the iterative process that SEM employs relies on positive degrees of freedom to be able to converge to produce estimates which are both unique and admissible. Therefore, in order to achieve positive degrees of freedom, and fix the problem of unidentification, it is necessary to add an additional constraint to the model. The model is respecified with the variance of the three residual parameters constrained equal. Regression estimates are subsequently estimated by solving the system of equations represented by the variance-covariance matrix for the unknowns, namely the λs. To perform confirmatory SEM we split the WEF dataset into three separate datasets: one for core innovators; one for non-core innovators; and the third combines both core and non-core countries into a single dataset. In each case SEM produces regression estimates, λs, as well as their associated standard errors (SE), critical ratios (CR) and probability values (p label).

All estimates, apart from the CCR sub-index for the core innovating economies, are at least statistically significant at the 5% level. Therefore, according to SEM, CCR is not significantly different from zero and therefore should not be included in the GCI model for core innovating economies. The covariances and variances of the core countries' CCR scores are such that they explain none of the variation in variances and covariances of the core innovating countries' MEI scores. Thus, it follows that CCR is an unnecessary determinant of growth competitiveness for core innovating economies. This is the first important result from SEM, disconfirming the approach taken by the WEF to the creation of the MEI for core innovators.

The estimates produced by SEM may take any value and thus cannot be used in their raw format in estimating the weights for the GCI. However, given that the regression estimates measure the degree of causal importance in explaining a particular latent variable, the higher the coefficient estimate the more important a particular observed or latent independent variable is at explaining a corresponding latent dependent variable. These regression coefficients can therefore be used in a more compelling way to determine the different weights that are assigned to independent variables in explaining a dependent latent variable. For the remaining significant variables this can be done by simply summing up the different λs in a system of equations with the same independent variable, and assigning the ratios as weights.[5] To illustrate this more clearly consider the λs generated by SEM for core innovators. Figure (4) provides details of the various λs generated by SEM. In summary, the following values are: $\lambda_1 = 0.43$, $\lambda_2 = 0.21$, and $\lambda_3 = 0.62$ for the system of equations (6). The weights are therefore calculated as:

$$w_1 = \frac{\lambda_1}{\sum_{i=1}^{3} \lambda_i} = \frac{0.43}{1.26} = 0.34$$
$$w_2 = \frac{\lambda_2}{\sum_{i=1}^{3} \lambda_i} = \frac{0.21}{1.26} = 0.17$$

[5]In the calculation of weights using SEM, we have used the data generated by the WEF. That is, we have used their outlier adjusted method and we have used U.S. utility patents to emphasize the point that irrespective of data issues, the WEF choice of weights is totally arbitrary and unjustified.

$$w_3 = \frac{\lambda_3}{\sum_{i=1}^{3} \lambda_i} = \frac{0.62}{1.26} = 0.49 \tag{10}$$

where w_1, w_1, and w_3 represent the weights assigned respectively to TI, PII, and MEI in the composition of the GCI according to SEM. Figures (5) and (6) depict SEM estimations respectively for non-core innovators and for core and non-core innovators combined. Table (6) provides a comparison of the arbitrary weights used by the WEF for core and non-core innovators against the weights generated by SEM. There are substantial differences in every case and some are quite large.

Consider the core innovators first. According to the WEF, TI is weighted at 50% in the composition of the GCI for core innovators. However, SEM yields a lower estimate at about 34%. Furthermore, while the WEF weight PII and MEI at 25% each, SEM considers MEI as the most important sub-index and estimates the weights for PII and MEI respectively at 17% and 49%. Similar differences can also be observed for non-core innovators. Whereas the WEF weights each of TI, PII, and MEI at 0.33, SEM generates respective weights of 0.36, 0.43, and 0.21. In the case of non-core innovators, the WEF identify three drivers of technology represented by the ISI, TTSI, and ICTSI. However, because TTSI was perfectly correlated with the survey data items of ISI, these variables had to be dropped from the SEM. This means that the separation of the countries into core and non-core innovators and the exclusion of technology transfers variables from the calculation of the core innovators' GCI is an unnecessary contrivance. The perfect correlation detected by SEM emphasizes that technology transfer impacts are captured perfectly by the survey items used in the construction of the ISI. Hence we have a second important outcome from SEM which is unable to confirm the appraoch taken by the WEF to the treatment of technology transfers. As a consequence, we produce a third set of SEM weights whereby we combine all countries into a single group and generate weights using the model structure for core innovators. These weights are contained in the final column of Table (6).

The weights for TI, PII, and MEI are, respectively, 0.44, 0.34, and 0.22. In all cases, the weights generated by SEM are different from the arbitrary weights chosen by WEF. Table 6 highlights the effect that SEM has on determining weights in contrast to the arbitrary method of WEF. For instance in the case of core innovators the weight assigned to CLSI is greater using SEM while the weight for CSI falls compared to the 0.50 assigned by the WEF in each case. By contrast, for non-core innovators CLSI falls, while CSI rises compared to the WEF weights of 0.5. In the case of MSSI, the SEM weights are substantially lower, roughly half the WEF weight of 0.5 for core innovators, but little more than 1/3 of the 0.5 for non-core innovators. As noted above, in the case of CCR, this is dropped from the model and receives no weight in the case of core innovators, while it receives more than double the WEF's weight of 0.25 in the case of non-core innovators.There is also a dramatic difference for GW in the case of core innovators where the weight is more than double the 0.25 assigned by the WEF.

By using SEM we have been able to disconfirm the approach taken by WEF of arbitrary weight allocations. Moreover, SEM enables the calculation of a new set of alternative GCI scores and ranks. Table (7) presents three sets of GCI scores and ranks for the 117 countries. First, the WEF scores and ranks are reproduced. Second, scores and ranks generated by SEM after separating countries into core and non-core innovators categories are included. The third set of scores and rank orders are generated by SEM when all countries are combined into a single data set and treated equally. It is this third set of results that we believe represents the most accurate set of GCI scores and rank numbers after using SEM to generate weights appropriately. According to this approach, fifty five countries (47%) have improved ranks, fifty two (44%) have lower ranks, and ten (9%) have unchanged ranks.

Several important lessons may be drawn from Table (7). First, the WEF GCI scores are slightly higher than the SEM 'different weights' GCI scores in almost all cases, with the exceptions Slovenia and Greece. Second, both the WEF and SEM 'different weights' GCI scores are higher than the SEM 'same weights' scores for all non-core countries. However, for the majority of core innovating economies the SEM 'same weights' GCI scores are higher than both the others. The exceptions are Finland, Israel, Republic of Korea, Sweden and Taiwan who achieve their highest score on the WEF's GCI.

A third outcome is that, as shown in Table (8), there is high correlation between SEM 'same weights' GCI scores and SEM 'different weights' GCI scores. Fourth, although there is a reasonably high correlation between SEM 'same weights' GCI scores and WEF GCI scores, there are important case differences that affect ranks. For instance, Italy and the Russian Federation improve their rank by 16 points, jumping from 48th to 32nd and 75th to 63rd place respectively. Similarly, Bolivia moves from 101st to 86th, the Dominican Republic from 102nd to 91st, France from 30th to 19th and the Ukraine from 84th to 73rd place. The majority of countries that suffer a fall in rank under the new SEM weightings are Sub-Saharan African; Ghana, Mozambique, Nigeria, Uganda and Tanzania all fall more than 10 rank points. Similarly, the Arab countries, Qatar and the UAE, also witness substantial falls in rank, from 19th to 35th place and 18th to 29th respectively.

For core innovating countries most of the changes can be explained by the reduced weighting of MSSI in the GCI and increased weight allocated to CCR in MSSI for the 'core and non-core' combined group. MSSI previously under WEF weights accounted for 0.125 ($= 0.5 \times 0.25$) of the GCI score, under SEM this figure falls to 0.033 ($= 0.15 \times 0.22$) in the case of the SEM 'same weights'. Similarly, CCR previously accounted for 0.063 ($= 0.25 \times 0.25$) of the GCI but has now increased to 0.14 ($= 0.62 \times 0.22$). For instance, France and Italy have both witnessed a substantial increase in GCI rank primarily as a result of changes in the composition of their MEI and overall MEI score. Both countries' poorly scoring MSSI, 61st and 89th place respectively, no longer exerts such a negative impact on their GCI score. Additionally, their high CCRs, ranked 7th and 20th respectively, filter into the GCI with increased weight.

For non-core innovating economies the majority of changes in rank are attributed to the increased weight allocated to the TI and the change in the TI sub-index composition. The elimination of TTSI from the calculations and the increased weight on the ISI significantly changes TI scores. ISI previously, under WEF construction, accounted for a mere 4% ($= 0.125 \times 0.33$) of the GCI score. Under SEM this has increased substantially to above 20% ($= 0.47 \times 0.44$). In addition, the decrease in weight attached to the MEI, from 0.33 to 0.22, combined with the change in the weights of the constituent sub-indexes will undoubtedly have considerable influence over GCI scores. The importance of the MSSI for non-core innovating economies is reduced from 16.5% ($= 0.25 \times 0.33$) to 3.3% ($= 0.18 \times 0.21$) of the GCI, whilst the importance of CCR for growth competitiveness is seen to nearly double from 8.2% (= 0.25 × 0.33) to 13.6% (= 0.63 × 0.21). The majority of Sub-Saharan African countries formally discussed have suffered as a result of these changes. For example, Uganda's GCI rank falls from 87th to 101st. Uganda's TTSI was its best performing sub-index of the TI, ranked 32nd, whilst its ISI ranks extremely poorly at 104th. The reallocation of weights according to SEM substantially deflates Uganda's TI score whilst additionally allocating it greater representation in the GCI.

The use of SEM, a more rigorous methodology that allows the data itself to generate the weights, has resulted in a substantial change in GCI score calculations and substantial shifts in country rankings in some cases. This exercise highlights the arbitrariness of the weight selection by the WEF and how the choice of weights can affect the perception of a country's growth competitiveness. Using SEM, the Russian Federation and Italy are the big winners, whilst Uganda and Qatar are the big losers.

6 Latent Variable Reliability Analysis

Because of the inevitable heteroskedasticity in the data and potential presence of outliers, it is important to determine the extent to which the selected variables are related to each other. Since causal relationships between observed variables and a single latent variable cannot be established a priori, the validity of parameter estimates derived by SEM may be biased because of a potential poor fit between the variables used. Thus, in order to derive latent variables that are based on a plausible choice of observed variables, it becomes crucial to test for internal consistency of the measurement scale and the identification of unsuitable items. Internal consistency can be tested using Cronbach's alpha which is expressed as:

$$\alpha = \frac{V\bar{c}}{1 + (N-1)\bar{c}} \tag{11}$$

where V represents the number of variables and $\bar{c}$ represents the average inter-variable correlation. Internal consistency is generally supported when $\alpha > 0.80$ (see for example Fortune and Utley, 2005). It is evident that as V rises, α rises as well. Furthermore, when $\bar{c}$ is low, then α is also low.

As summarized in Tables (9) and (10), internal consistency is established for the survey data variables used in deriving GCI sub-indexes for core and non-core innovators. This may be due to the nature of the data and the strong correlation that exists among the different variables. The reported α values, being larger than 0.80, indicate that the different variables fit well together in explaining the different sub-indexes for core innovators. However, for non-core innovators, the survey data variables explaining the MSSI fit marginally well with $\alpha = 0.67$. Hard data, on the other hand, are problematic as in five out of the times they are used, internal consistency is violated. In fact, the hard data variables only fit well together for the ICTSI of the non-core innovators with $\alpha = 0.90$. In the other cases, α values range between 0.04 and 0.53. Moreover, when survey and hard data variables are used together, then Cronbach's alpha is driven down by the poor fit of hard data variables.

The arbitrary selection of variables in the composition of the different growth competitiveness indexes and sub-indexes is clearly put into question. The poor fit of hard data variables indicates that the variables selected in representing the ISI and MSSI for both core and non-core innovators and the ICTSI for core innovators cannot be reasonably combined. Rather, they could be treated independently of each other, with each hard data variable representing its own sub-index, thus making the task of determining weights, scores, and ranks even more challenging. It is also interesting to note that the WEF weights the hard data variables more heavily than survey data. Although this approach is intuitively appealing due to the higher objectivity of hard data, it fails to meet internal consistency requirements. This casts further doubt on the contrived procedures adopted by the WEF in selecting data variables and determining the proper weights assigned to each sub-index and corresponding observed variables.

7 Concluding Remarks

The WEF is an influential body that produces its *Global Competitiveness Report* annually. The purpose of these volumes is to determine and evaluate international country competitiveness, and to this end the WEF produces a comprehensive GCI which embodies three pillars of international growth competitiveness: technology readiness, macroeconomic environment, and public institutions.

The purpose of this study has been to evaluate carefully and comprehensively just how robust and defensible is the GCI and its various indexes and sub-indexes. In particular, the paper has identified three areas where the GCI is vulnerable to criticism. First, the treatment of outliers for hard data items. In several cases, we have identified alternative methods for dealing with outliers that are superior to the approach taken by the WEF. Second, the crucial role of the variable utility patents in the calculation of the GCI is questioned and serious doubts concerning the use of this variable are raised. Third, the paper suggests an alternative approach, based upon SEM, should be used for the determination of weights in the index calculation process. SEM is a robust statistical approach and overcomes the arbitrariness of the weight selection method used by the WEF.

Although there is merit in the approach of the WEF to assessing growth competitiveness of individual countries, this paper shows that considerable care needs to be taken when undertaking such analyses, particularly given the political sensitivity associated with creating league tables of country rank order. This paper highlights that the country rankings generated by the GCI are sensitive to change when alternative, more defensible and robust weights are applied to calculating the GCI and its constituent indexes and sub-indexes.

To avoid the stigma associated with ranking countries individually and given the imprecise nature of specifying individual scores and ranks, the WEF might consider allocating countries into broad groups. To illustrate the point, it is clear there is very little difference between the small group of countries at the very top. What does ranking Finland above the USA really mean, they are both outstanding by world standards? Similarly at the very bottom, it matters little whether a country is ranked 100th or 117th, in both cases they lag a long way behind the better performing countries in terms of their growth competitiveness.

Appendices

Table (A1) lists the 117 countries included in the WEF dataset.

Table (A2) lists the variables used in this study with their corresponding codes.

Table A1: Countries Included

Albania	Ghana	Nigeria
Algeria	Greece	Norway*
Argentina	Guatemala	Pakistan
Armenia	Guyana	Panama
Australia*	Honduras	Paraguay
Austria*	Hong Kong SAR*	Peru
Azerbaijan	Hungary	Philippines
Bahrain	Iceland*	Poland
Bangladesh	India	Portugal
Belgium*	Indonesia	Qatar
Benin	Ireland*	Romania
Bolivia	Israel*	Russian Federation
Bosnia and Herzegovina	Italy*	Serbia and Montenegro
Botswana	Jamaica	Singapore*
Brazil	Japan*	Slovak Republic
Bulgaria	Jordan	Slovenia
Cambodia	Kazakhstan	South Africa
Cameroon	Kenya	Spain
Canada*	Korea, Rep.*	Sri Lanka
Chad	Kuwait	Sweden*
Chile	Kyrgyz Republic	Switzerland*
China	Latvia	Taiwan*
Colombia	Lithuania	Tajikistan
Costa Rica	Luxembourg*	Tanzania
Croatia	Macedonia, FYR	Thailand
Cyprus	Madagascar	Trinidad and Tobago
Czech Republic	Malawi	Tunisia
Denmark*	Malaysia	Turkey
Dominican Republic	Mali	Uganda
East Timor	Malta	Ukraine
Ecuador	Mauritius	United Arab Emirates
Egypt	Mexico	United Kingdom*
El Salvador	Moldova	United States*
Estonia	Mongolia	Uruguay
Ethiopia	Morocco	Venezuela
Finland*	Mozambique	Vietnam
France*	Namibia	Zimbabwe
Gambia	Netherlands*	
Georgia	New Zealand*	
Germany*	Nicaragua	

The core innovators are marked with an asterisk.

Table A2: Description of the Variables Used

Variable #	Variable Description
2.01	Recession expectations
2.07	Access to credit cards
2.13	Government surplus/deficit, 2004
2.14	National savings rate, 2004
2.15	Real effective exchange rate, 2004
2.16	Inflation, 2004
2.17	Interest rate spread, 2004
2.20	Government debt, 2004
2.21	Country credit rating, 2005
3.01	Technological readiness
3.02	Firm-level technology absorption
3.03	Prevalence of foreign technology licensing
3.04	FDI and technology transfer
3.06	Company spending on research and development
3.07	University/industry research collaboration
3.11	Internet access in schools
3.12	Quality of competition in the ISP sector
3.13	Government prioritization of ICT
3.14	Government success in ICT promotion
3.15	Laws relating to ICT
3.17	Utility patents, 2004
3.18	Cellular telephones, 2003
3.19	Internet users, 2003
3.20	Internet hosts, 2003
3.21	Personal computers, 2003
4.17	Tertiary enrollment
5.08	Telephone lines, 2003
6.01	Judicial independence
6.03	Property rights
6.06	Wastefulness of government spending
6.08	Favoritism in decisions of government officials
6.16	Organized crime
6.19	Irregular payments in exports and imports
6.20	Irregular payments in public utilities
6.21	Irregular payments in tax collection

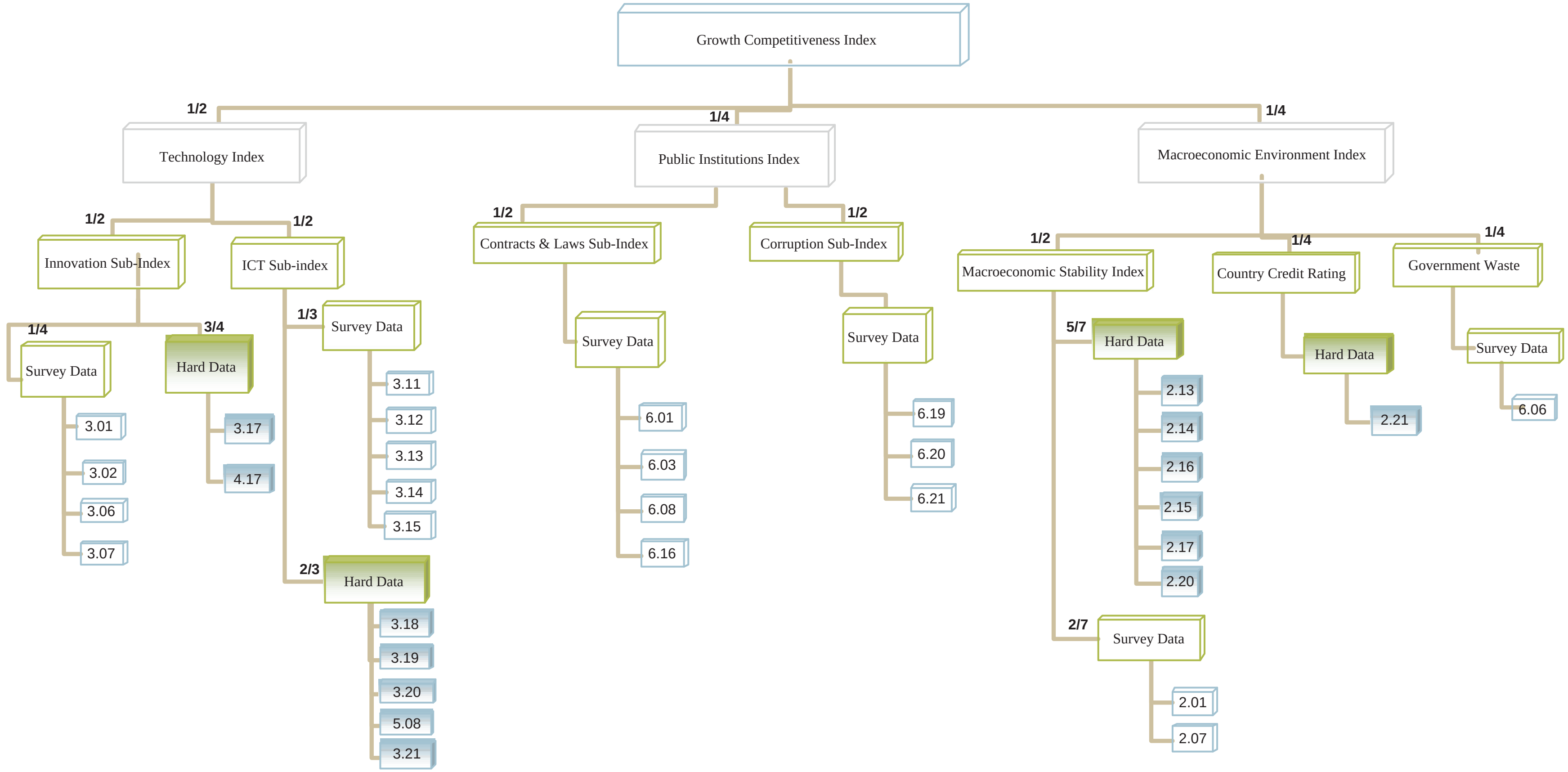

Figure 1: Growth Competitiveness Index for Core Innovators[a]

[a]Core Innovators are countries for which technological innovation is critical for growth. The WEF defines a core innovator as a country that has registered 15 or more US utility patents (patents for innovation) per million people in the most recent year. Non-Core Innovators are defined by WEF as those countries with less than 15 utility patents (patents for innovation) per million people in the most recent year. The numbers in boxes indicate the variable number from the WEF data set. The fractions indicate the weights assigned by WEF to each category of survey Data and hard data in the calculations of sub-indexes and indexes. Survey Data come from answers to questions in the WEF Executive Opinion Survey and all values are on a 1-7 scale. Hard data are sourced by WEF from reliable third parties, e.g. IMF. All hard data are converted to 1-7 scale using equation (5). WEF adjusts hard data variables 2.13, 2.14, 2.15, 2.16, 2.17, 2.20, 3.17, 3.20 for outliers before applying 1-7 scale conversion formula.

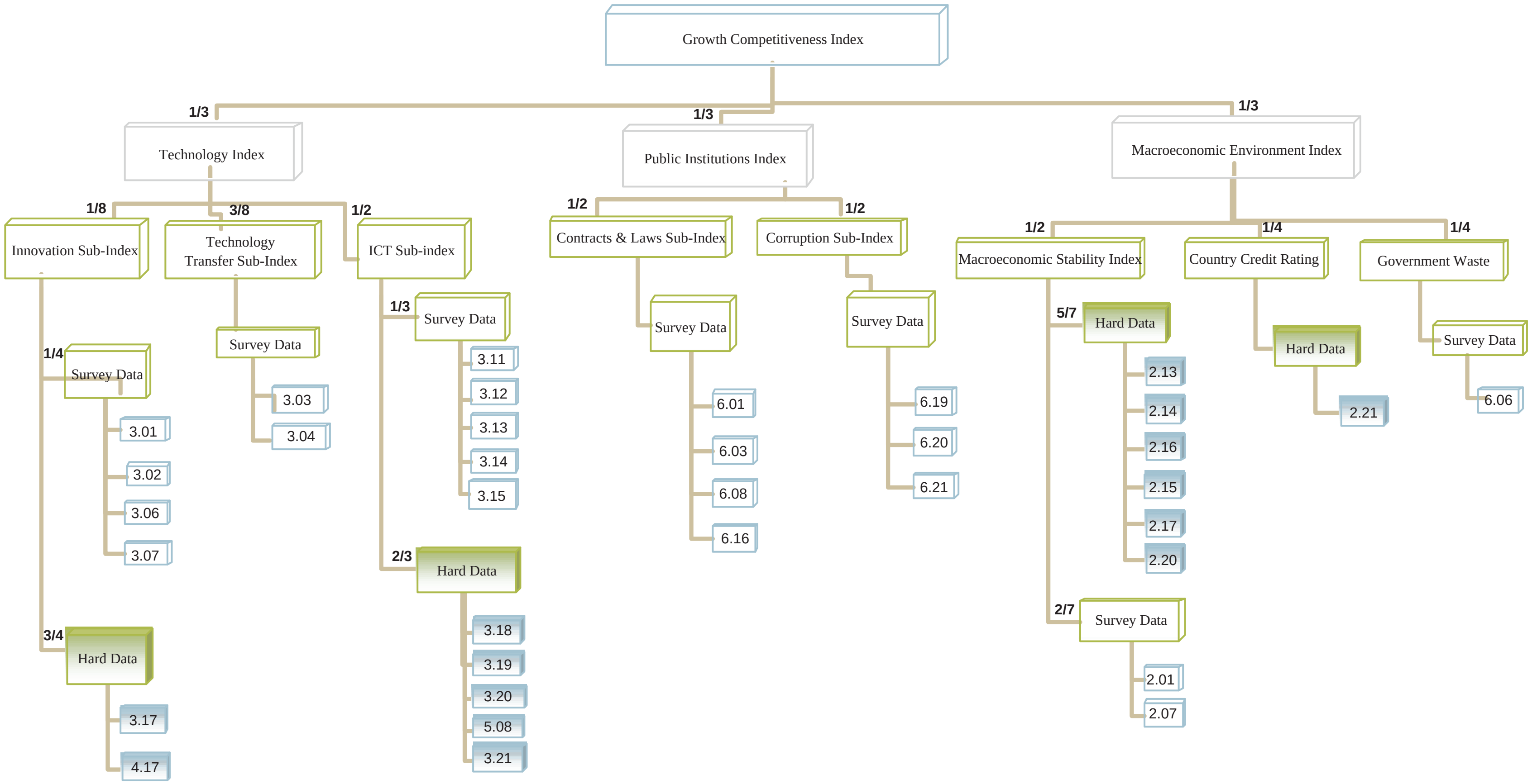

Figure 2: Growth Competitiveness Index for Non-Core Innovators

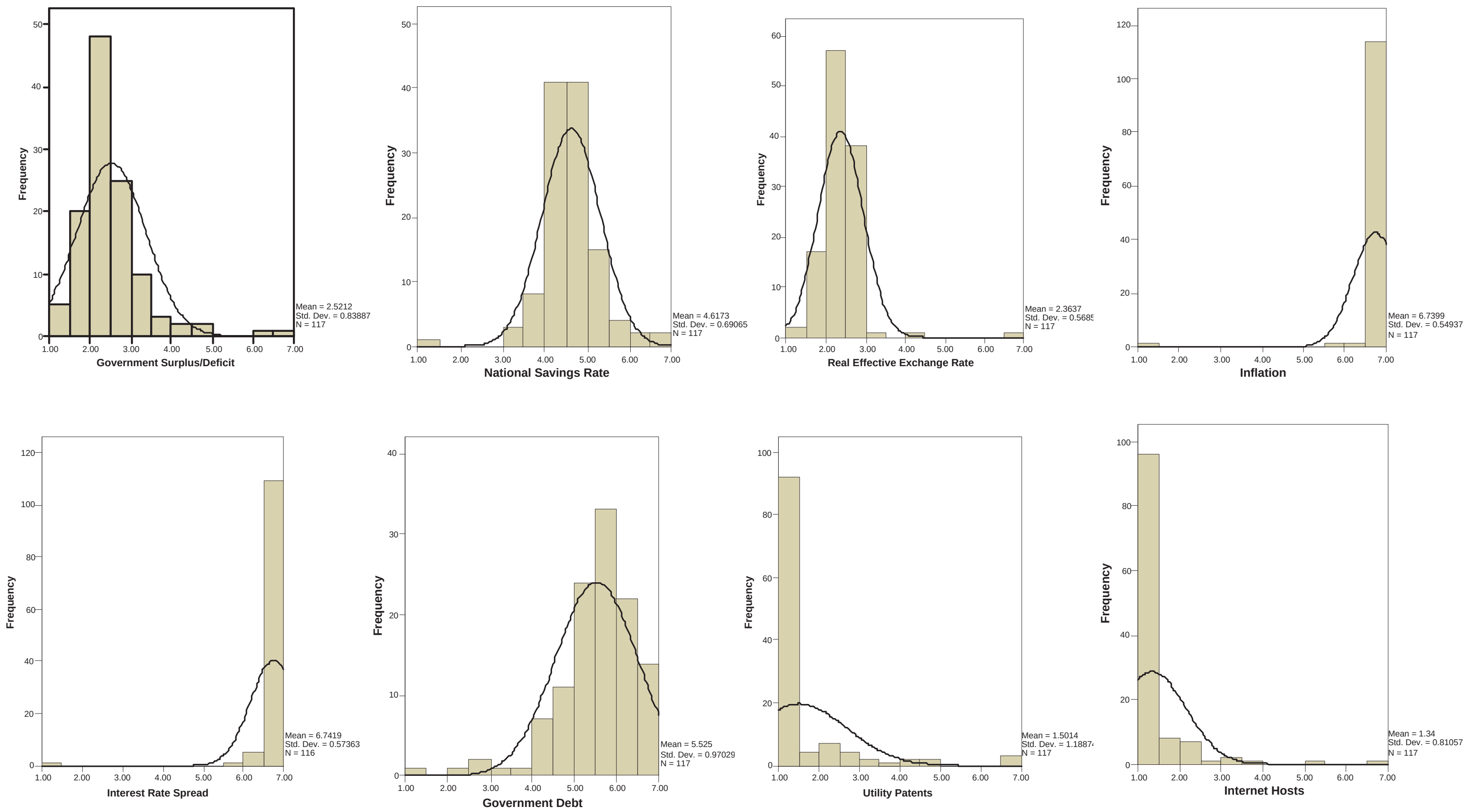

Figure 3: Hard Data Histograms

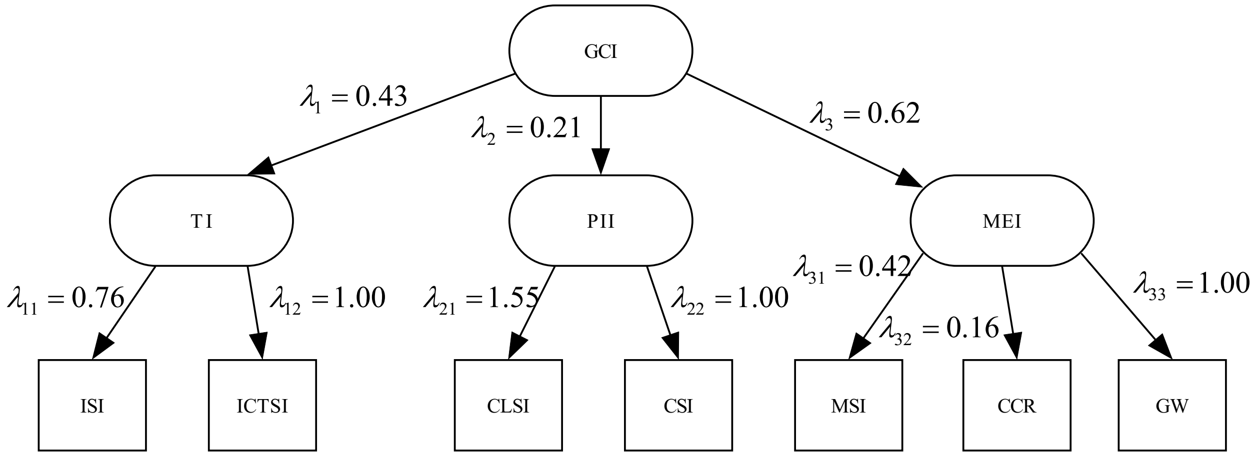

Figure 4: Structural Equation Modeling for Core Innovators

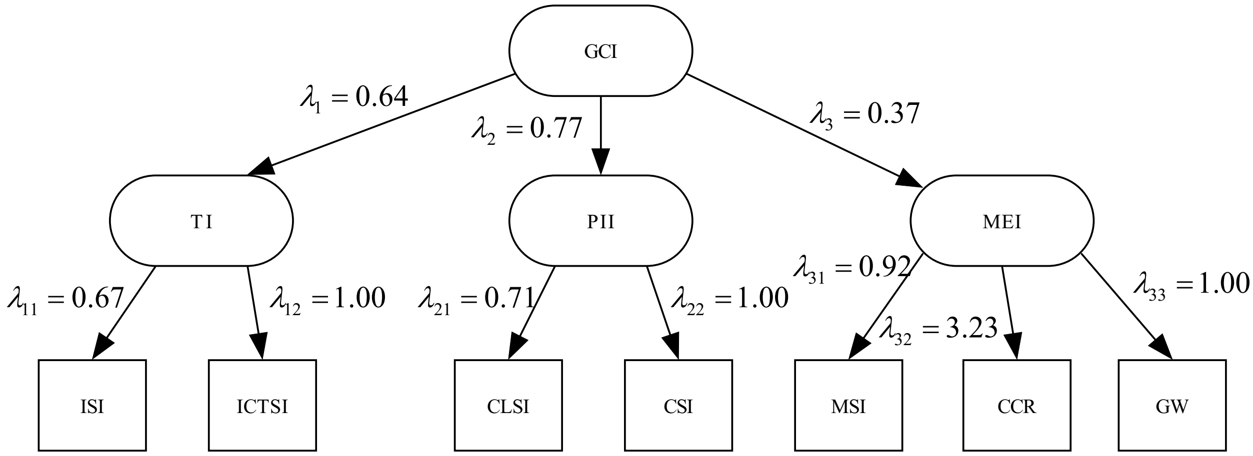

Figure 5: Structural Equation Modeling for Non-core Innovators

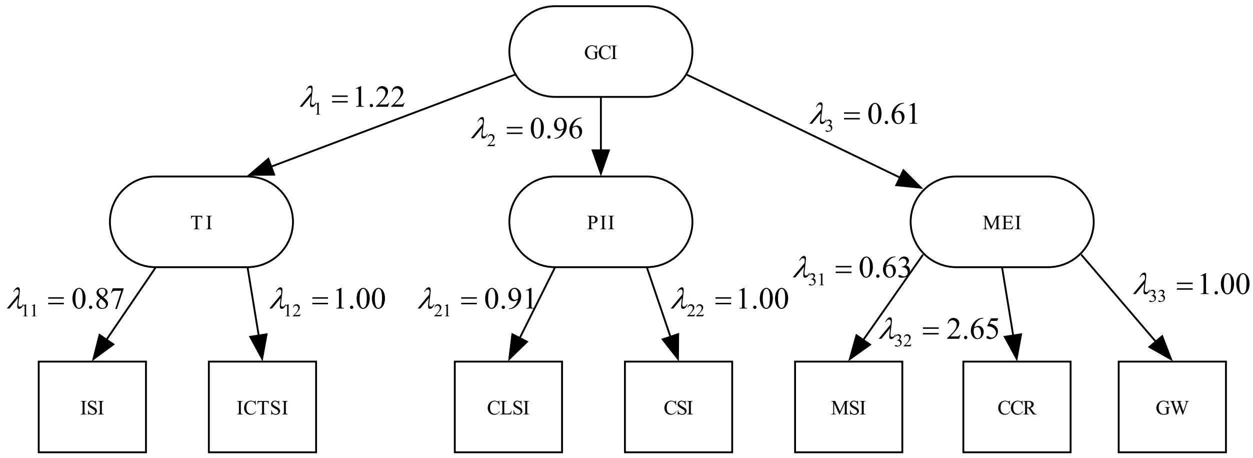

Figure 6: Structural Equation Modeling for Core and Non-core Innovators

Table 1: Growth Competitiveness Index

Country	GCI		TI		PII		MEI	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Top 20								
Finland	1	5.94	2	6.02	5	6.19	4	5.52
United States	2	5.81	1	6.19	18	5.77	23	5.07
Sweden	3	5.65	4	5.78	17	5.82	12	5.24
Denmark	4	5.65	5	5.30	2	6.35	3	5.64
Taiwan	5	5.58	3	5.85	26	5.47	17	5.15
Singapore	6	5.48	10	4.93	4	6.25	1	5.82
Iceland	7	5.48	9	5.16	3	6.33	11	5.24
Switzerland	8	5.46	6	5.29	9	6.02	13	5.23
Norway	9	5.40	13	4.87	6	6.13	2	5.76
Australia	10	5.21	14	4.82	10	6.01	14	5.21
Netherlands	11	5.21	11	4.88	16	5.83	10	5.26
Japan	12	5.18	8	5.24	14	5.84	42	4.40
United Kingdom	13	5.11	17	4.66	12	5.98	18	5.13
Canada	14	5.10	15	4.79	21	5.67	16	5.16
Germany	15	5.10	16	4.78	8	6.04	28	4.81
NewZealand	16	5.09	19	4.47	1	6.35	20	5.10
Korea Rep.	17	5.07	7	5.26	42	4.78	25	4.98
United Arab Emirates	18	4.99	33	4.04	24	5.52	5	5.43
Qatar	19	4.97	40	3.76	19	5.75	6	5.40
Estonia	20	4.95	18	4.62	25	5.51	30	4.73
Median 10								
Uruguay	54	3.93	63	3.19	33	5.19	84	3.40
Mexico	55	3.92	57	3.39	71	4.03	43	4.35
El Salvador	56	3.86	70	3.09	54	4.45	57	4.03
Colombia	57	3.84	74	3.01	49	4.55	61	3.95
Bulgaria	58	3.83	61	3.31	62	4.23	62	3.95
Ghana	59	3.82	69	3.11	51	4.54	66	3.82
Trinidad and Tobago	60	3.81	62	3.25	83	3.73	40	4.44
Kazakhstan	61	3.77	77	2.99	76	3.89	41	4.42
Croatia	62	3.74	51	3.48	73	3.99	68	3.76
Costa Rica	64	3.72	56	3.39	58	4.32	82	3.44
Bottom 10								
East Timor	108	2.93	109	2.42	108	3.20	93	3.18
Zimbabwe	109	2.89	98	2.62	80	3.79	117	2.25
Bangladesh	110	2.86	101	2.60	117	2.55	83	3.43
Cameroon	111	2.84	110	2.36	111	3.05	100	3.12
Cambodia	112	2.82	105	2.51	114	2.90	104	3.04
Paraguay	113	2.80	111	2.35	112	2.97	102	3.07
Benin	114	2.74	116	2.09	110	3.06	101	3.08
Guyana	115	2.73	112	2.34	109	3.10	113	2.77
Kyrgyz Republic	116	2.62	113	2.34	115	2.89	115	2.62
Chad	117	2.37	117	1.80	116	2.64	114	2.67

Table 2: Macroeconomic Environment Index

Country	MEI Rank	MEI Score	MSSI Rank	MSSI Score	GW Rank	GW Score	CCR Rank	CCR Score
Top 20								
Singapore	1	5.82	10	5.36	1	5.90	15	6.64
Norway	2	5.76	5	5.61	8	4.86	2	6.94
Denmark	3	5.64	11	5.31	4	5.12	8	6.83
Finland	4	5.52	13	5.30	10	4.61	4	6.87
United Arab Emirates	5	5.43	2	5.70	5	5.00	29	5.32
Qatar	6	5.40	4	5.66	3	5.13	33	5.17
Ireland	7	5.38	7	5.47	28	3.89	14	6.68
Hong Kong SAR	8	5.34	6	5.55	11	4.60	26	5.66
Luxembourg	9	5.30	26	5.04	18	4.25	3	6.88
Netherlands	10	5.26	39	4.69	9	4.81	9	6.82
Iceland	11	5.24	21	5.10	6	4.97	23	5.80
Sweden	12	5.24	16	5.20	31	3.77	11	6.79
Switzerland	13	5.23	37	4.76	13	4.43	1	7.00
Australia	14	5.21	25	5.05	16	4.34	18	6.39
Chile	15	5.20	3	5.66	19	4.23	32	5.25
Canada	16	5.16	23	5.07	33	3.76	13	6.74
Taiwan	17	5.15	17	5.15	12	4.53	24	5.76
United Kingdom	18	5.13	32	4.86	27	3.94	4	6.87
Malaysia	19	5.12	19	5.12	2	5.13	35	5.12
New Zealand	20	5.10	22	5.09	25	4.02	21	6.18
Median 10								
Poland	53	4.09	68	4.33	77	2.80	39	4.92
Egypt	55	4.07	59	4.47	34	3.75	64	3.57
Azerbaijan	56	4.05	18	5.13	57	3.19	78	2.74
El Salvador	57	4.03	63	4.42	35	3.71	62	3.58
Russian Federation	58	4.02	42	4.65	93	2.59	54	4.19
Mauritius	59	4.01	86	4.09	41	3.50	51	4.35
Vietnam	60	3.96	34	4.80	52	3.24	73	3.01
Bulgaria	62	3.95	51	4.59	89	2.65	56	3.96
Colombia	61	3.95	48	4.61	66	3.02	65	3.55
Hungary	63	3.91	95	3.93	73	2.88	40	4.90
Bottom 10								
Ethiopia	108	2.99	106	3.66	59	3.16	114	1.50
Madagascar	109	2.98	112	3.50	47	3.37	112	1.56
Nicaragua	110	2.96	97	3.88	101	2.38	105	1.72
Serbia and Montenegro	111	2.95	101	3.77	108	2.28	98	1.97
Dominican Republic	112	2.78	108	3.63	115	1.72	92	2.14
Guyana	113	2.77	115	3.13	86	2.67	92	2.14
Chad	114	2.67	110	3.56	114	1.80	104	1.73
Kyrgyz Republic	115	2.62	114	3.25	107	2.30	109	1.67
Malawi	116	2.47	117	2.83	92	2.60	110	1.62
Zimbabwe	117	2.25	116	3.00	112	2.00	117	1.00

Table 3: Technology Index

Country	TI		ISI		ICTSI		TTSI	
	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Top 20								
United States	1	6.19	1	6.66	3	5.72		
Finland	2	6.02	2	6.43	5	5.61		
Taiwan	3	5.85	3	6.19	6	5.51		
Sweden	4	5.78	4	5.89	4	5.66		
Denmark	5	5.30	10	4.70	1	5.90		
Switzerland	6	5.29	7	5.37	12	5.21		
Korea Rep.	7	5.26	8	5.29	11	5.23		
Japan	8	5.24	5	5.74	17	4.75		
Iceland	9	5.16	14	4.45	2	5.88		
Singapore	10	4.93	13	4.47	8	5.40		
Netherlands	11	4.88	17	4.33	7	5.43		
Israel	12	4.87	6	5.38	23	4.37		
Norway	13	4.87	12	4.62	14	5.12		
Australia	14	4.82	15	4.36	9	5.27		
Canada	15	4.79	11	4.69	16	4.89		
Germany	16	4.78	9	4.92	20	4.63		
United Kingdom	17	4.66	16	4.35	15	4.98		
Estonia	18	4.62	27	3.51	21	4.56	15	5.07
NewZealand	19	4.47	18	4.22	19	4.71		
Portugal	20	4.39	35	3.15	30	3.84	3	5.55
Median 10								
Philippines	54	3.43	65	2.34	63	2.42	11	5.15
India	55	3.42	76	2.13	67	2.33	6	5.32
Costa Rica	56	3.39	72	2.20	58	2.52	22	4.95
Mexico	57	3.39	73	2.20	57	2.57	27	4.88
Egypt	58	3.36	64	2.36	68	2.33	14	5.07
Argentina	59	3.35	34	3.18	59	2.51	39	4.54
Tunisia	60	3.35	57	2.41	56	2.61	34	4.64
Bulgaria	61	3.31	50	2.47	48	2.91	58	4.12
Trinidad and Tobago	62	3.25	92	1.77	61	2.43	30	4.84
Uruguay	63	3.19	49	2.50	49	2.71	63	4.07
Bottom 10								
Bolivia	108	2.42	59	2.38	106	1.81	86	3.25
East Timor	109	2.42	103	1.62	115	1.58	74	3.80
Cameroon	110	2.36	106	1.61	107	1.81	85	3.33
Paraguay	111	2.35	83	2.01	111	1.77	87	3.24
Guyana	112	2.34	111	1.48	94	1.90	88	3.22
Kyrgyz Republic	113	2.34	63	2.36	90	1.91	90	2.91
Algeria	114	2.29	84	2.01	110	1.80	89	3.03
Ethiopia	115	2.22	116	1.36	116	1.50	83	3.47
Benin	116	2.09	113	1.44	104	1.82	91	2.66
Chad	117	1.80	117	1.30	117	1.39	92	2.52

Table 4: Public Institutions Index

Country	PII		CLSI		CSI	
	Rank	Score	Rank	Score	Rank	Score
Top 20						
Denmark	1	6.35	1	6.17	4	6.54
New Zealand	2	6.35	2	5.97	2	6.74
Iceland	3	6.33	4	5.89	1	6.78
Singapore	4	6.25	5	5.88	3	6.62
Finland	5	6.19	3	5.90	5	6.49
Norway	6	6.13	7	5.80	6	6.45
Luxembourg	7	6.08	9	5.71	7	6.45
Germany	8	6.04	6	5.88	20	6.19
Switzerland	9	6.02	8	5.79	15	6.26
Australia	10	6.01	10	5.67	10	6.35
Austria	11	6.00	13	5.61	9	6.39
United Kingdom	12	5.98	12	5.62	12	6.33
Ireland	13	5.93	11	5.63	18	6.24
Japan	14	5.84	21	5.24	8	6.44
Netherlands	16	5.83	14	5.53	23	6.12
Portugal	15	5.83	16	5.46	19	6.20
Sweden	17	5.82	19	5.30	11	6.34
United States	18	5.77	20	5.27	14	6.27
Qatar	19	5.75	15	5.52	27	5.98
France	20	5.72	18	5.30	22	6.15
Median 10						
El Salvador	54	4.45	70	3.56	44	5.33
China	56	4.41	62	3.74	50	5.08
Mauritius	55	4.41	53	4.07	59	4.76
Namibia	57	4.38	54	4.06	63	4.69
Costa Rica	58	4.32	49	4.16	68	4.48
Peru	59	4.27	99	2.98	39	5.55
Tanzania	60	4.25	44	4.40	85	4.09
Turkey	61	4.25	59	3.82	64	4.68
Bulgaria	62	4.23	103	2.90	38	5.57
Moldova	63	4.20	93	3.12	47	5.28
Bottom 10						
East Timor	108	3.20	96	3.06	107	3.34
Guyana	109	3.10	110	2.74	105	3.45
Benin	110	3.06	95	3.12	113	3.00
Cameroon	111	3.05	91	3.15	114	2.95
Paraguay	112	2.97	117	2.17	95	3.77
Ecuador	113	2.93	115	2.30	101	3.56
Cambodia	114	2.90	102	2.91	115	2.89
Kyrgyz Republic	115	2.89	112	2.71	112	3.07
Chad	116	2.64	113	2.54	116	2.73
Bangladesh	117	2.55	104	2.88	117	2.22

Table 5: Hard Data Outlier Treatment

Variable	Grubbs' Test (GT) Results	Backward Engineering of WEF Adjustment Process
Government Surplus/Deficit	Four detected outliers: Kuwait, UAE, Norway, and Qatar	WEF drops the following countries: (upper limit) Kuwait, UAE, Norway, Qatar, Nigeria, Bahrain, Singapore, Algeria, Russia, New Zealand, Kazakhstan, Ecuador, Chile, Korea, Finland with Bulgaria being the highest; and (lower limit) Cambodia, Greece, Poland, Japan, Sri Lanka, Guyana, India, Turkey with Bolivia being the lowest. In addition to excluding these variables from its computations, the WEF manually adds rising increments to each of the indexes starting with the first value above 1.0 up to the second top value below 7.0. These increments ranged between 0.02 and 0.23.
National Savings Rate	Two detected outliers: East Timor and Qatar	WEF drops East Timor and Montenegro and uses 0 as the minimum value.
Real Effective Exchange Rate	No outliers detected	WEF drops Zimbabwe.
Inflation	Three outliers detected: Venezuela, Dominican Rep., and Zimbabwe	WEF procedure is consistent with GT. Countries with negative inflation rates d such that $0 < \lvert d \rvert \leq 3$ are treated as worse than those with an inflation rate i such that $0 \leq i < 3$. Once i exceeds 3%, then the negative inflation rates for d are ranked immediately after $i > 3$. When $d<-3$, then it is treated the same way as its absolute value. Negative rates between 0 and -1 are treated as worse than those between 0 and 3.
Interest Rate Spread	Six outliers detected: Kyrgyz Rep., Malawi, Georgia, Paraguay, Brazil, Zimbabwe	WEF drops the same countries plus the UK. Increments similar to those reported for government surplus/deficit appear to have been added.
Government Debt	Four detected outliers: Japan, Guyana, Gambia, and Malawi.	WEF procedure is consistent with GT.
Credit Rating	No outliers detected	No adjustments to the data are made by WEF.
Utility Patents	Thirty three outliers detected: USA, Japan, Taiwan, Switzerland, Finland, Israel, Sweden, Germany, Canada, Singapore, Korea, Luxembourg, Netherlands, Denmark, Austria, Iceland, Belgium, UK, France, Norway, Australia, Ireland, Hong Kong, New Zealand, Italy, Slovenia, Spain, Hungary, Malaysia, Czech Rep., Malta, S. Africa, Croatia	The reported figures appear to not have been adjusted properly for outliers. WEF drops USA and Japan and treats Taiwan as the highest. WEF procedure appears to be unclear and inconsistent with GT.
Cellular Phones	No outliers detected	No adjustments to the data are made by WEF.
Internet Users	No outliers detected	No adjustments to the data are made by WEF.
Internet Hosts	Twenty four detected outliers: USA, Iceland , Finland , Denmark, Netherlands, Australia, Norway, Taiwan, New Zealand, Singapore, Sweden , Japan, Canada, Hong Kong, Korea, Switzerland, Austria, Israel, Luxembourg, UK, Iceland, Estonia, France, Ireland, Hungary	WEF drops USA, Iceland , Finland , and Denmark (with Netherlands being the highest). Increments similar to those reported for government surplus/deficit and interest rate spread appear to have been added.
Personal Computers	No outliers detected	No adjustments to the data are made by WEF.
Tertiary Enrollment	No outliers detected	No adjustments to the data are made by WEF.
Telephone Lines	No outliers detected	No adjustments to the data are made by WEF.

Table 6: Weights of GCI Index and Sub-Indexes

Path	Core		Non-Core		Core & Non-Core
	WEF	SEM	WEF	SEM	SEM
GCI → TI	0.50	0.34	0.33	0.36	0.44
GCI → PII	0.25	0.17	0.33	0.43	0.34
GCI → MEI	0.25	0.49	0.33	0.21	0.22
TI → ISI	0.50	0.43	0.125	0.40	0.47
TI → ICTSI	0.50	0.57	0.50	0.60	0.53
PII → CLSI	0.50	0.61	0.50	0.41	0.48
PII → CSI	0.50	0.39	0.50	0.59	0.52
MEI → MSSI	0.50	0.27	0.50	0.18	0.15
MEI → CCR	0.25	0.10*	0.25	0.63	0.62
MEI → GW	0.25	0.63	0.25	0.19	0.23

Because of perfect correlation between the TTSI and ISI, the former is dropped from the estimations of the weights for non-core innovators. An asterisk * denotes a weight that is derived from a statistically insignificant coefficient estimate of λ_{32}.

Table 7: Comparative Rankings

Country	WEF Weights		SEM Different Weights		SEM Same Weights	
	Score	Rank	Score	Rank	Score	Rank
Albania	3.07	100	2.67	103	2.49	103
Algeria	3.46	78	3.08	79	2.92	77
Argentina	3.56	72	3.26	72	3.10	71
Armenia	3.44	79	3.11	77	2.89	80
Australia	5.21	10	5.08	10	5.31	12
Austria	4.95	21	4.85	18	5.16	17
Azerbaijan	3.64	69	3.24	73	3.03	74
Bahrain	4.48	37	4.20	40	3.94	42
Bangladesh	2.86	109	2.26	116	2.20	116
Belgium	4.63	31	4.47	34	4.84	23
Benin	2.74	114	2.42	114	2.28	114
Bolivia	3.06	101	2.94	85	2.76	86
Bosnia & Herzegovina	3.17	95	2.94	86	2.74	87
Botswana	4.21	47	3.90	46	3.62	49
Brazil	3.69	65	3.42	64	3.22	65
Bulgaria	3.83	58	3.71	53	3.47	54
Cambodia	2.82	112	2.33	115	2.21	115
Cameroon	2.84	111	2.44	112	2.32	112
Canada	5.10	14	4.82	20	5.18	16
Chad	2.37	117	2.09	117	1.96	117
Chile	4.91	23	4.64	28	4.38	30
China	4.07	49	3.77	51	3.55	51
Colombia	3.84	57	3.64	55	3.35	58
Costa Rica	3.72	64	3.51	61	3.32	61
Croatia	3.74	62	3.64	54	3.48	53
Cyprus	4.54	34	4.54	32	4.29	33
Czech Republic	4.42	38	4.20	39	4.02	39
Denmark	5.65	4	5.51	3	5.71	3
Dominican Republic	3.05	102	2.79	93	2.67	91
East Timor	2.85	110	2.43	113	2.28	113
Ecuador	3.01	103	2.55	107	2.41	108
Egypt	3.96	53	3.56	59	3.37	57
El Salvador	3.86	56	3.57	58	3.31	62
Estonia	4.95	20	4.87	17	4.66	25
Ethiopia	3.00	106	2.66	104	2.43	105
Finland	5.94	1	5.57	2	5.86	2
France	4.78	30	4.70	26	5.05	19
Gambia	3.18	94	2.79	94	2.60	94
Georgia	3.25	86	2.88	88	2.73	89
Germany	5.10	15	4.96	14	5.31	14
Ghana	3.82	59	3.29	71	3.07	72
Greece	4.26	46	4.34	36	4.21	36
Guatemala	3.12	97	2.76	97	2.58	96

Table 7: Comparative Rankings (Continued)

	WEF Weights		SEM Different Weights		SEM Same Weights	
Country	Score	Rank	Score	Rank	Score	Rank
Guyana	2.73	115	2.51	110	2.36	111
Honduras	3.18	93	2.84	91	2.62	93
Hong Kong SAR	4.83	28	4.77	21	4.88	22
Hungary	4.38	39	4.37	35	4.15	37
Iceland	5.48	7	5.45	4	5.56	5
India	4.04	50	3.60	56	3.41	55
Indonesia	3.53	74	2.98	83	2.86	81
Ireland	4.86	26	4.75	24	5.05	20
Israel	4.84	27	4.63	29	4.77	24
Italy	4.08	48	3.89	47	4.34	32
Jamaica	3.64	70	3.39	67	3.18	68
Japan	5.18	12	4.95	15	5.37	10
Jordan	4.28	45	4.02	44	3.77	46
Kazakhstan	3.77	61	3.40	66	3.27	63
Kenya	3.19	92	2.70	99	2.52	100
Korea, Rep.	5.07	17	4.75	23	4.92	21
Kuwait	4.58	33	4.24	37	3.99	41
Kyrgyz Republic	2.62	116	2.48	111	2.40	109
Latvia	4.29	44	4.14	41	4.01	40
Lithuania	4.30	43	4.22	38	4.04	38
Luxembourg	4.90	25	4.85	19	5.12	18
Macedonia, FYR	3.26	85	2.94	84	2.77	84
Madagascar	2.95	107	2.60	106	2.43	104
Malawi	3.00	105	2.79	95	2.54	98
Malaysia	4.90	24	4.55	31	4.36	31
Mali	3.22	90	2.90	87	2.70	90
Malta	4.54	35	4.51	33	4.28	34
Mauritius	4.00	52	3.74	52	3.54	52
Mexico	3.92	55	3.58	57	3.38	56
Moldova	3.37	82	3.16	76	2.90	79
Mongolia	3.16	96	2.86	90	2.73	88
Morocco	3.49	76	3.09	78	2.94	76
Mozambique	3.19	91	2.70	100	2.50	102
Namibia	3.72	63	3.39	68	3.15	69
Netherlands	5.21	11	5.06	11	5.31	13
New Zealand	5.09	16	5.00	12	5.25	15
Nicaragua	3.08	99	2.81	92	2.59	95
Nigeria	3.23	88	2.67	102	2.52	99
Norway	5.40	9	5.25	8	5.50	9
Pakistan	3.33	83	2.78	96	2.64	92

Table 7: Comparative Rankings (Continued)

Country	WEF Weights		SEM Different Weights		SEM Same Weights	
	Score	Rank	Score	Rank	Score	Rank
Panama	3.55	73	3.34	69	3.21	66
Paraguay	2.80	113	2.55	108	2.39	110
Peru	3.66	68	3.45	62	3.18	67
Philippines	3.47	77	2.99	81	2.90	78
Poland	4.00	51	3.86	49	3.74	47
Portugal	4.91	22	4.91	16	4.66	26
Qatar	4.97	19	4.56	30	4.27	35
Romania	3.67	67	3.41	65	3.25	64
Russian Federation	3.53	75	3.44	63	3.35	59
Serbia and Montenegro	3.38	80	3.19	74	2.96	75
Singapore	5.48	6	5.42	5	5.55	6
Slovak Republic	4.31	41	4.14	42	3.90	43
Slovenia	4.59	32	4.70	25	4.51	28
South Africa	4.31	42	3.87	48	3.66	48
Spain	4.80	29	4.76	22	4.57	27
Sri Lanka	3.10	98	2.72	98	2.57	97
Sweden	5.65	3	5.28	7	5.64	4
Switzerland	5.46	8	5.24	9	5.54	7
Taiwan	5.58	5	5.31	6	5.51	8
Tajikistan	3.01	104	2.55	109	2.42	106
Tanzania	3.57	71	3.06	80	2.85	82
Thailand	4.50	36	4.09	43	3.89	44
Trinidad and Tobago	3.81	60	3.31	70	3.13	70
Tunisia	4.32	40	4.00	45	3.79	45
Turkey	3.68	66	3.51	60	3.32	60
Uganda	3.24	87	2.67	101	2.51	101
Ukraine	3.30	84	3.18	75	3.07	73
United Arab Emirates	4.99	18	4.69	27	4.42	29
United Kingdom	5.11	13	4.99	13	5.32	11
United States	5.81	2	5.64	1	5.99	1
Uruguay	3.93	54	3.86	50	3.60	50
Venezuela	3.22	89	2.99	82	2.84	83
Vietnam	3.37	81	2.88	89	2.76	85
Zimbabwe	2.89	108	2.65	105	2.41	107

The scores and rankings under 'SEM with different weights' are calculated using the weights derived from SEM and in which the weights used for core innovators are different from those for non-core innovators. However, the scores and rankings under 'SEM with same weights' represent those derived through SEM when the GCIs for core and non-core innovators are assumed to be the same.

Table 8: One-Tailed Pearson Correlation Tests

	SEM Same Weights vs. Different Weights	WEF vs. SEM Same Weights
Correlation Coefficient	0.989	0.981
Significance	0.00	0.00
Observations	117	117

Table 9: Cronbach's Alpha for Core Innovators

Latent Variable	Survey Data	Hard Data	Survey and Hard Data
Innovation Sub-Index	0.92	0.33	0.81
ICT Sub-Index	0.81	0.53	0.72
Contracts & Laws Sub-Index	0.87		
Corruption Sub-Index	0.96		
Macroeconomic Stability Index	0.87	0.20	0.42

Table 10: Cronbach's Alpha for Non-Core Innovators

Latent Variable	Survey Data	Hard Data	Survey and Hard Data
Innovation Sub-Index	0.88	0.04	0.75
Technology Transfer Sub-Index	0.79		
ICT Sub-Index	0.84	0.90	0.90
Contracts & Laws Sub-Index	0.88		
Corruption Sub-Index	0.95		
Macroeconomic Stability Index	0.67	0.39	0.53

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