ANALYSIS

The Commitment to Development Index: An Information Theory approach

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ABSTRACT

Using statistical model selection criteria rooted in Information Theory which penalise complexity we show that there is little justification for relaxing the equal weights assumption underlying the Center for Global Development’s, Commitment to Development Index (CDI). The CDI is a composite index which combines metrics of aid, trade, investment, migration, environment, security and technology. A survey of researchers recently concluded that the CDI should not weight each of these six components equally. Specifically, it suggested that: trade and investment should be weighted higher; migration and aid should be weighted lower; with peacekeeping and environment not statistically different from equal weights. Generating hypothetical data around the weights proposed by the results of this survey we test an equally weighted CDI against two unequally weighted alternatives. Although the unequally weighted alternatives provide a superior goodness-of-fit to these hypothetical datasets, this is more than counteracted by the increased model complexity associated with these unequally weighted models according to most model selection criteria. The results of our analysis suggest that the CDI should not diverge from its equal weights assumption.

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1. Introduction

Composite indices of environment and development receive attention in the academic literature in order to elucidate: whether or not they include the right components; whether these components are mathematically related to one another in the best way; how changes to the components or the way they are related to one another changes the results (often rankings) produced by the indices; and thus whether or not the indices do what they set out to do — adequately convey a particular message in a simpler, more easily digestible form compared to, instead, referring to an array of non-aggregated indicators.

The Center for Global Development (CDG) is a non-profit think-tank established in 2001. The CDG first published its Commitment to Development Index (CDI) in Foreign Policy Magazine (FPM, 2003) and CDIs have since appeared in 2004, 2005 and 2006; presumably they will appear in future years as well. Therefore the CDI is a relative newcomer to the world of composite indices compared to, say, the United Nations Development Programme’s (UNDP) Human Development Index (HDI) which first appeared in 1990 (UNDP, 1990) and is now a well established indicator published every year.

Saltelli (2007) contends that an impetus for the creation of composite indices like the CDI is the demand for statistic-based narratives from the economically literate press. Whether via the press or not, the CDI could act as a yardstick for governmental and non-governmental organizations concerned with progress or lack of progress with respect to

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different aspects of development. There is some evidence to suggest that the CDI is being used as such a yardstick in the European Union (EU) because the CDI from 2004 appears in the 2006 EU Donor Atlas which aims to “derive rational and optimal redeployment of [...] activities and methods [related to development assistance]” (European Commission, 2006).

The CDI aims to measure, as the name suggests, how committed rich countries are to advancing the development of poorer countries. These ‘rich’ countries are defined in terms of 21 Organisation for Economic Co-operation and Development (OECD) countries. In 2003, the CDI assessed the commitment of these rich countries in terms of six different policy areas: aid; trade; investment; migration; peacekeeping; and environment. Importantly, it did this by attaching equal weights to each of these six components (Eq. (1)).

\[
\text{CDI} = (\alpha \cdot \text{Aid Score}) + (\alpha \cdot \text{Trade Score}) + (\alpha \cdot \text{Investment Score}) \\
+ (\alpha \cdot \text{Migration Score}) + (\alpha \cdot \text{Peacekeeping Score}) \\
+ (\alpha \cdot \text{Environment Score})
\]

where

\[\alpha = 0.167\]
\[6(\alpha) = 1\]

Comprehensive technical details about the construction of the CDI and the calculation of the scores in the six different policy areas in 2003 are available (Birdsall and Roodman, 2003). Following the calculation of CDIs, these 21 countries can then be ranked in order of how committed, or not, they are to advancing development. Although this equal weights assumption holds for CDIs published in subsequent years, other changes are apparent e.g. in 2005 the CDI comprises seven different policy areas instead of six.

As well as annual publication of CDIs in FPM, the CGD’s website also publishes CDI results (CGD, 2006). Each year, the results from previous years are updated on the CGD’s website based on, for example, improvements in the methodology for calculating the components of the index or, as alluded to above, changes in the way the index is specified in terms of which policy areas it includes. However, original results from previous years (using the methodology of that particular year) are also available from the website. We focus here on the CDI published in 2003 using the original methodology from 2003 which calculated the CDI based on six, not seven, policy areas (CDG, 2003) because we want to test the validity of a suggestion that the CDI should diverge from its equal weights assumption according to the results of a survey of researchers in 2003 which used the CDI from that year (Chowdhury and Squire, 2005).

Chowdhury and Squire (2005) surveyed 105 researchers in 60 different countries (from a population of 1547) in order to determine the weights they thought should be applied to the different components of both the CDI and the HDI. For the HDI the weights suggested by the survey were not statistically different from an equal weights assumption. For the CDI most of the weights suggested by the survey were statistically different from an equal weights assumption. Specifically the survey suggested that: trade and investment should be weighted higher; migration and aid should be weighted lower; with peacekeeping and environment not statistically different from equal weights (Table 1).

In this paper we use statistical model selection criteria rooted in Information Theory which penalise complexity in order to determine whether or not there is justification for differentiating the CDIs weights as per the suggestion in Chowdhury and Squire (2005). Therefore we outline a methodology (Section 2) present the results obtained from using this methodology (Section 3) and finally discuss and draw conclusions from this analysis (Section 4) which illustrate how our findings could be important to an array of different composite indices, not just the CDI.

### 2. Methodology

Historically, the performance of different models has been quantified using goodness-of-fit statistics such as $R^2$ or the residual sum of squares (RSS); the higher the value of the former and the lower the value of the latter indicates a closer agreement between model predictions and observations (i.e. data). Statistical model selection criteria rooted in Information Theory include a goodness-of-fit component via the maximum likelihood function which is akin to RSS but, additionally, they also penalise complexity. The rationale for penalising complexity can be viewed in terms of ‘assumptions’: The more complex a model, the more assumptions it makes and, unsurprisingly, assumptions don’t always turn out to be correct and as such should be limited. To give an example in context, differentiating the weights associated with the CDI based on the results of the survey discussed above would assume that those who responded to the survey were fully aware of what they were doing (specifically, what they were weighting). As Chowdhury and Squire (2005) note: “[…] though in our survey instrument we provided short definitions of each of the components included in each of the indices, some of the respondents might have been confused between flow and policy (e.g., trade flow versus trade policy)”.

Put differently, although more complex models often provide a closer fit to a particular dataset, not least because an increasing number of model parameters are adjusted for exactly this purpose, this improvement to one dataset won’t always generalise to other datasets.

<table>
<thead>
<tr>
<th>Component</th>
<th>Arithmetic Mean</th>
<th>Standard Error (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aid</td>
<td>0.142</td>
<td>0.0057</td>
</tr>
<tr>
<td>Trade</td>
<td>0.204</td>
<td>0.0047</td>
</tr>
<tr>
<td>Investment</td>
<td>0.193</td>
<td>0.0050</td>
</tr>
<tr>
<td>Migration</td>
<td>0.137</td>
<td>0.0053</td>
</tr>
<tr>
<td>Peacekeeping</td>
<td>0.157</td>
<td>0.0056</td>
</tr>
<tr>
<td>Environment</td>
<td>0.163</td>
<td>0.0048</td>
</tr>
</tbody>
</table>

* An asterisk indicates a weight which is statistically different from an equal weights assumption. Equal weights would be 1/6 = 0.166 for each of the six components. Abbreviation: Standard Error (SE).
In practice, penalising complexity in terms of model selection criteria amounts to either taking into account the number of adjustable parameters in a given model or a combination of this feature whilst taking into account the complexity of model functional form. Principle examples of the former are the Root Mean Squared Deviation (RMSD), the Akaike Information Criterion (AIC; Akaike, 1973, 1974) and the Schwarz Information Criterion (SIC; Schwarz, 1978). Principle examples of the latter are the Minimum Description Length (MDL; Rissanen, 1987) and the Information-Theoretic Measure of Complexity (ICOMP; Bozdogan, 1990, 2000). Therefore, a model which is selected by the majority of these statistics (Eq. (2)) could be described as parsimonious (striking a better balance between goodness-of-fit and complexity) relative to alternative models.

\[
\text{RMSD} = \sqrt{\frac{\text{SSE}}{n - p}}
\]

\[
\text{AIC} = -2 \log (\text{ML}) + 2p
\]

\[
\text{BIC} = -2 \log (\text{ML}) + p \log (n)
\]

\[
\text{MDL} = -\log(\text{ML}) + 0.5 \log |H(\theta)|
\]

\[
\text{ICOMP} = -\log(\text{ML}) + 0.5p \log \left[ \frac{\text{tr}(\Omega(\theta))}{p} \right] - 0.5 \log |\Omega(\theta)|
\]

where

- \( \text{ML} \) the maximised likelihood function
- \( p \) number of adjustable parameters
- \( n \) number of data points
- \( \text{SSE} \) model sum of squares error
- \( H(\theta) \) Hessian matrix of the likelihood
- \( \Omega(\theta) \) Covariance matrix of parameter estimates

It should be noted that an amended AIC, denoted as AICc (Eq. (3)) was proposed by Hurvich and Tsai (1989) for small sample sizes relative to the number of adjustable parameters.

\[
\text{AICc} = -2 \log (\text{ML}) + 2p + \frac{2p(p + 1)}{n - p - 1}
\]

Burnham and Anderson (2002) recommend using AICc instead of AIC where a specific inequality holds.

\[
\frac{n}{p} < 40.
\]

Briefly, using a range of model selection criteria instead of just one has an obvious advantage in that model selection is not limited to one view of what ‘complexity’ means or how it should be penalised. There has been some argument in the literature that the AIC can result in erroneously model selection because it overfits but this argument often revolves to wrongly using the AIC where \( p \) is high relative to \( n \) i.e. when AICc should have been used instead (Burnham and Anderson, 2004).

Composite indices of sustainable development could be regarded as models but models which fit the data perfectly; it’s not possible to go out into the field and measure these theoretical constructs directly in order to determine whether such models are an accurate representation of reality. Instead of an equal weighting approach let us assume that the true CDI lies about unequal coefficients. A CDI based on equal coefficients will necessarily have a lower goodness-of-fit to this true case but differentiating such coefficients adds complexity to the CDI model so that this improvement in goodness-of-fit might not justify this additional complexity according to model selection statistics (Eqs. (4a)–(4c)).

Model 1[current CDI] = \((x \cdot \text{Aid Score}) + (x \cdot \text{Trade Score}) + (x \cdot \text{Investment Score}) + (x \cdot \text{Migration Score}) + (x \cdot \text{Peacekeeping Score}) + (x \cdot \text{Environment Score})\) (4a)

where

\(x = 0.167\)

6,(a) = 1

Model 2[more complex CDI] = \((x_1 \cdot \text{Aid Score}) + (x_2 \cdot \text{Trade Score}) + (x_3 \cdot \text{Investment Score}) + (x_4 \cdot \text{Migration Score}) + (x_5 \cdot \text{Peacekeeping Score}) + (x_6 \cdot \text{Environment Score})\) (4b)

where

\(x_1, x_2, x_3, x_4 = \text{are all adjustable under model fitting}\)

\(x_5 = 0.167\)

\(x_1 + x_2 + x_3 + x_4 + 2(x_5) = 1\)

Model 3[most complex CDI] = \((x_1 \cdot \text{Aid Score}) + (x_2 \cdot \text{Trade Score}) + (x_3 \cdot \text{Investment Score}) + (x_4 \cdot \text{Migration Score}) + (x_5 \cdot \text{Peacekeeping Score}) + (x_6 \cdot \text{Environment Score})\) (4c)

where

\(x_1, x_2, x_3, x_4, x_5, x_6 = \text{are all adjustable under model fitting}\)

\(x_1 + x_2 + x_3 + x_4 + x_5 + x_6 = 1\)

Model 1 corresponds to the current (equally weighted) CDI (i.e. it is the same as Eq. (1)); Model 2 corresponds to a CDI suggested by Chowdhury and Squire (2005) where all weights, except those for peacekeeping and environment, differ from an equal weights assumption; and Model 3 allows all weights to be adjustable under model fitting.

Models 1–3 therefore have 1, 5 and 6 adjustable parameters respectively: although \( x \) in Model 1 and \( x_5 \) in Model 3 are both fixed values of 0.167 we consider them as adjustable in the calculation of model selection statistics (even though technically they will not be adjusted) because their values, although fixed, are specified for one particular purpose and would be different if there were more or less than the six policy areas which constituted the CDI in 2003. Cox et al. (2006) discuss the issue of supposedly fixed parameters in different terms: parameters which have actually been ‘tweaked’ (but not earmarked as adjustable) to minimise the deviation between observation and prediction.

Assume also that there are three CDI datasets (Eq. (5)) calculated by randomly adjusting the weights associated with the six policy metrics; the weights proposed (Table 1) by Chowdhury and Squire (2005) serve as the mean for each
Table 2 - Goodness-of-fit and model selection statistics where hypothetical data were generated for the 2003 Commitment to Development Index (CDI) around the weights posited in Chowdhury and Squire (2005) and then tested against: the 2003 CDI (Model 1), a more complex alternative with most coefficients set as adjustable (Model 2) and a most complex alternative with all coefficients set as adjustable (Model 3)*

<table>
<thead>
<tr>
<th>Model</th>
<th>Data</th>
<th>Parameters</th>
<th>SEs (±/-)</th>
<th>Data points</th>
<th>Degrees freedom</th>
<th>RSS</th>
<th>R²</th>
<th>RMSD</th>
<th>AICc</th>
<th>SIC</th>
<th>MDL</th>
<th>ICOMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>α = 0.167</td>
<td>0.001</td>
<td>21</td>
<td>20</td>
<td>0.646</td>
<td>0.968</td>
<td>0.152</td>
<td>2.674</td>
<td>3.508</td>
<td>4.990</td>
<td>0.232</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>α₁ = 0.142</td>
<td>0.007</td>
<td>21</td>
<td>16</td>
<td>0.640</td>
<td>0.997</td>
<td>0.050</td>
<td>14.04</td>
<td>15.26</td>
<td>13.33</td>
<td>1.325</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>g₁ = 0.148</td>
<td>0.016</td>
<td>21</td>
<td>15</td>
<td>0.614</td>
<td>0.999</td>
<td>0.030</td>
<td>18.01</td>
<td>18.29</td>
<td>15.08</td>
<td>1.589</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>α₂ = 0.138</td>
<td>0.005</td>
<td>21</td>
<td>16</td>
<td>0.381</td>
<td>0.971</td>
<td>0.154</td>
<td>14.38</td>
<td>15.60</td>
<td>13.50</td>
<td>1.495</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>g₂ = 0.146</td>
<td>0.003</td>
<td>21</td>
<td>15</td>
<td>0.276</td>
<td>0.979</td>
<td>0.137</td>
<td>18.27</td>
<td>18.54</td>
<td>15.21</td>
<td>1.720</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>α = 0.167</td>
<td>0.006</td>
<td>21</td>
<td>20</td>
<td>11.14</td>
<td>0.586</td>
<td>0.746</td>
<td>13.35</td>
<td>14.19</td>
<td>10.32</td>
<td>5.570</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>α₃ = 0.229</td>
<td>0.017</td>
<td>21</td>
<td>16</td>
<td>5.703</td>
<td>0.788</td>
<td>0.597</td>
<td>19.70</td>
<td>20.93</td>
<td>16.17</td>
<td>4.156</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>g₃ = 0.221</td>
<td>0.066</td>
<td>21</td>
<td>15</td>
<td>5.405</td>
<td>0.799</td>
<td>0.600</td>
<td>23.40</td>
<td>23.67</td>
<td>17.78</td>
<td>4.285</td>
</tr>
</tbody>
</table>

* Abbreviations: Standard Error (SE); residual sum of squares (RSS); Root Mean Squared Deviation (RMSD); Corrected Akaike Information Criterion (AICc); Schwarz Information Criterion (SIC); Minimum Description Length (MDL); Information-Theoretic Measure of Complexity (ICOMP). All statistics are unitless. Emboldened and underlined statistics indicate the best performing model with respect to each statistic and each dataset.

policy area with adjustment constrained by the standard errors of these proposed weights.

CDI Hypothetical Datasets = (x₁ - Aid Score) + (x₂ - Trade Score) + (x₃ - Investment Score) + (x₄ - Migration Score) + (x₅ - Peacekeeping Score) + (x₆ - Environment Score) (5)

where

\[ x₁ = 0.142 + / - \text{up to 3 SE} \]
\[ x₂ = 0.204 + / - \text{up to 3 SE} \]
\[ x₃ = 0.193 + / - \text{up to 3 SE} \]
\[ x₄ = 0.137 + / - \text{up to 3 SE} \]
\[ x₅ = 0.157 + / - \text{up to 3 SE} \]
\[ x₆ = 0.163 + / - \text{up to 3 SE} \]

Dataset 1 (somewhat variable weights between countries)

Dataset 2 (more variable weights between countries)

Dataset 3 (most variable weights between countries)

Put differently, although the weights in Table 1 are used as a basis for generating the three datasets, weights for
individual countries are allowed to vary around the SE of these weights or a multiple of the SE of these weights. The actual CDI assumes constant weights between countries and taking such an approach when generating data would not alter the fact that such weights should be considered as adjustable parameters given the remark made above concerning truly fixed parameters versus ‘specified for purpose’ parameters i.e. if the survey had been carried out in, say, 2005 then the weights proposed would not transfer because, for example, the CDI consists of seven, not six, policy area metrics.

Each of the three models (Eqs. (4a)–(4c)) is tested against each of the three datasets (Eq. (5)); the adjustable parameters in Models 2 and 3 are optimised using the Marquardt method (Press et al., 2002) in order to minimise the deviation between prediction and observation.

3. Results

For Dataset 1, Model 3 provides a closer fit compared to Models 1 and 2 in terms of $R^2$ and RSS. The RMSD also favours the most complex model but the AICC, BIC, MDL and ICOMP favour the least complex model, Model 1 i.e. the extra complexity of Models 2 and 3 does not justify the increased goodness-of-fit of these models (Table 2, Fig. 1a). Because the weights in Dataset 1 are allowed to vary up to $\pm 1 SE$ of the specified weights (Table 1, Eq. (5)) and further, because 21 (number of data points) $< \propto$, optimised weights for Models 2 and 3 converge around, but not absolutely to those specified weights.

For Dataset 2, again Model 3 provides the closest fit, in terms of goodness-of-fit statistics, compared to Models 1 and 2 and is also favoured by the RMSD but the other four model selection statistics favour Model 1, the least complex model (Table 2, Fig. 1b). Additionally, because the generated data was allowed to vary more about the specified mean weights (Table 1, Eq. (5)), the optimised values of these weights differ more compared to the optimised values of these weights in Dataset 1.

For Dataset 3, the pattern of results is somewhat different. $R^2$ and RSS still favour Model 3 but RMSD and ICOMP favour the intermediate model, Model 2. The AICC, BIC and MDL all still favour the least complex equal weights model, Model 1 (Table 2, Fig. 1c). Not surprisingly, because the generated data was allowed to vary most in this dataset (i.e. up to $\pm 10 SE$) the optimised weights tend to differ more from the mean specified weights (Table 1, Eq. (5)) compared to applications of the models to Datasets 1 and 2. As sample size increases, this variability would be lower i.e. the optimised weights would tend more towards the means.

The general preference for Model 1 by model selection statistics can’t be explained in terms of collinearity between the six different policy metrics which constituted the CDI in 2003, because this is low (Table 3). If the six different policy metrics ‘behaved’ similarly (e.g. increases in the investment metric were associated with increases in the environment metric) then differentiated weights would have less of an impact on the aggregate CDI and thus be even less likely to be favoured by model selection statistics. At its most extreme case where metrics are perfectly collinear then differentiating weights would be pointless: If we assume scores for all six policy metrics are 4.1 (although the choice of value is not important to the result here, this is the average score across all countries and all metrics in 2003)

![Fig. 1](image-url)
Table 3 – Pearson’s correlation matrix for the six policy metrics used to calculate the Commitment to Development Index for 21 countries in 2003

<table>
<thead>
<tr>
<th></th>
<th>Aid</th>
<th>Trade</th>
<th>Investment</th>
<th>Migration</th>
<th>Peacekeeping</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aid</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade</td>
<td>-0.266</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>0.043</td>
<td>-0.168</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Migration</td>
<td>0.132</td>
<td>-0.180</td>
<td>-0.038</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peacekeeping</td>
<td>0.166</td>
<td>-0.044</td>
<td>-0.132</td>
<td>-0.152</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>0.301</td>
<td>-0.009</td>
<td>0.337</td>
<td>0.054</td>
<td>-0.055</td>
<td>1</td>
</tr>
</tbody>
</table>

then equal weights makes no difference in terms of output compared to unequal weights as posited in Table 1 (Eq. (6)).

\[
0.167(4.1) + 0.167(4.1) + 0.167(4.1) + 0.167(4.1) + 0.167(4.1)
+ 0.167(4.1) + 0.167(4.1) = 4.1
0.142(4.1) + 0.204(4.1) + 0.193(4.1) + 0.137(4.1)
+ 0.157(4.1) + 0.163(4.1) = 4.1. \tag{6}
\]

4. Discussion

The preference for the least complex, equally weighted CDI in terms of model selection statistics is clearly significant. In total, across all three datasets Model 1 minimises the value of these statistics 11 out of 15 times compared to just twice each for Models 2 and 3. Furthermore, if we acknowledge that RMSD is only an informal model selection criterion which suffers from a lack of statistical justification for its use in this context (Myung, 2000) then the preference for Model 1 becomes even more pronounced. Discounting RMSD means that Model 1 is favoured by model selection statistics 11 out of 12 times compared to just once for Model 2 and never for Model 3.

In another paper (Stapleton and Garrod, 2007) we applied statistics rooted in Information Theory to the 2003 HDI. Similar to the results reported here we showed a general preference for an equally weighted HDI as opposed to a HDI with differentiated weights. However, the work presented here extends that work in five important ways: unlike the HDI, the CDI is a small sample indicator; the CDI is more complex than the HDI with six and three component indicators respectively; Chowdhury and Squire (2005) suggested that four of the CDI weights were statistically different from an equal weights assumption, compared to none of the weights associated with the HDI, which provides a basis for testing an unequally weighted CDI; the datasets generated for the CDI allow for varying degrees of between-country differences but the degree of between-country difference was fixed in the HDI analysis; the variables that constitute the CDI are not collinear unlike the variables that constitute the HDI.

These methodological differences between the two approaches could be useful for generalising the findings to other composite indices of environment and development and indeed composite indices in general i.e. increasing complexity in terms of differentiated weights should be viewed with caution for small and large sample indices, more or less complicated indices, with and without varying degrees of between-country differences and, finally, for cases where the component indicators of a composite index are or are not collinear.

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References


