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Construction of a Composite Indicator for Debt Sustainability Analysis
A Case of Sub-nationals in India

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Abstract

The size of fiscal deficits and sustainability of public debt levels remain a key macroeconomic policy problem in all emerging economies following the global financial crisis of 2008-09. In addition, the COVID-19 pandemic poses a considerable challenge to fiscal sustainability in developed and developing countries. Although the sustainability of public finances has been discussed for more than a century and studies have proposed several methods to define and assess debt sustainability, it remains an imprecise concept. This study proposes a new framework for public debt sustainability analysis by constructing a composite indicator, that is, a debt sustainability index. We emphasise the need for an explicit conceptual framework for constructing a composite index and usefulness of multivariate statistical analysis prior to the aggregation of individual indicators. The proposed approach can be used to analyse the debt sustainability of state governments (sub-nationals) in India.

Keywords: Composite Indicator, Debt Sustainability Analysis, Principal Components and Factor Analysis, Sub-sovereign Debt

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1. Introduction

Public debt vulnerabilities have increased globally in the aftermath of the global financial crisis, and this has highlighted the importance of prudent fiscal and debt management strategies for preventing financial shocks to the country. The build-up of debt substantially accelerated in developing countries following the severe COVID-19 pandemic shock.

Rising public debt levels have limited the ability of countries to mobilise resources for achieving sustainable development goals. With a rise in public debt levels, governments are likely to spend more on debt servicing and less on public goods, such as health, education, and infrastructure. A sustainability analysis of trends in primary surplus and growth–interest rate differentials can provide insights into the fiscal health of governments. In addition, the cost and risk characteristics of debt stocks can be considered for determining the stability and sustainability of public debt.

Debt sustainability analysis can help to assess the financial health of governments. The sustainability of debt requires governments to be both solvent and liquid, which refers to a country's ability to service all accumulated government debt at any point in time. The trade-off between the cost and risk of debt stock is crucial in debt sustainability analysis.

The government mainly functions as a service provider for the common man. Thus, both the inflow (revenue) and outflow (expenditure) of funds would be observed. However, the government is mostly in a deficit (higher expenditure than revenue) and to overcome extra expenses, the government borrows from the market by floating various securities, such as dated securities and treasury bills. The debt management strategy of the government is based on the principle of maintaining the public debt level within sustainable limits, and follows prudent debt management practices. The objective of the government is to reduce debt service burden and create fiscal space for economic development while minimising rollover risk[1].

In the context of India, debt sustainability analysis assumed importance during the late 1980s, when considerable fiscal deterioration occurred at the national and sub-national level. However, the majority of studies on debt sustainability in the Indian perspective have focused on central government finances or state finances only at a consolidated level. Because the constituent states of the Indian Union are highly heterogeneous in terms of their economic size, a state-specific assessment and comparison of debt sustainability status is required.

Different approaches have been employed to assess debt sustainability. The three common approaches are the analyses of the Domar debt stability condition, sustainability indicators, and present value budget constraints.

- According to the Domar debt stability condition, the growth of an economy must exceed the real interest rate.
- In the analysis of sustainability indicators, sustainability is evaluated with the consideration of different revenue and capital account parameters.

- The analysis of value budget constraints involves determining whether future surpluses are adequate to meet the current stock of debt.

This study contributes to the existing literature by proposing a composite debt sustainability index that can be used to evaluate debt sustainability. In addition, this index can be employed as a benchmark to measure the performance of the government and compare the performance of different governments or countries in terms of debt sustainability.

The remainder of this paper is organised as follows. Section 2 presents the literature review on different approaches used to analyse debt sustainability and discusses the literature available in the Indian context. Section 3 presents statistical methods used to construct the composite indicator. Section 4 discusses the empirical and analytical results. Section 5 concludes the study.

2. Literature Review

Studies have mainly used three approaches to analyse debt (fiscal) sustainability. In the pioneering work on debt sustainability based on post-Second World War US data, Domar (1944) reported that the primary deficit path can be sustained as long as the real growth of the economy remains higher than the real interest rate. Credit worthiness and liquidity indicators are considered in the analysis of sustainability indicators (Miller, 1982; Buiter, 1985, 1987; Blanchard, 1990; Buiter et al., 1993). In the analysis of present value budget constraints (Cuddington, 1999), debt sustainability is evaluated by the econometric testing of the validity of the present value of budget constraints.

Studies have examined the sustainability of public debt in the global context (Hamilton and Flavin, 1986; Trehan and Walsh, 1988; Wilcox, 1989; Bohn, 1998; IMF, 2002; Afonso, 2005; ADB, 2010). Debrun et al. (2019) performed a detailed survey on the practical aspects of debt sustainability assessments.

The sustainability of India's budget imbalance and public debt has been examined extensively at the national level (Parker and Kastner, 1993; Cashin et al., 2001; Reynolds, 2001; Jha and Sharma, 2004; Goyal et al., 2004; Rangarajan and Srivastava, 2005; Mohan et al., 2005; Buiter and Patel, 2006; Kannan and Singh, 2007; Topalova and Nyberg, 2010). The majority of the recent studies addressing the problem of public debt sustainability have demonstrated that the fiscal stance of the central government is unsustainable with regard to the future path of the public debt-to-GDP ratio (Akram and Rath, 2021).

Fiscal deficits and their implications for public debt sustainability at the subnational level in India have received considerably less attention, with some exceptions – Dholakia et al. (2004), Goyal et al. (2004), Rajaraman et al. (2005), Nayak and Rath (2009), Misra and Khundrakpam (2009) and Makin and Arora (2012). However, most of these studies have focused on subnational debt at the consolidated level.

Kaur et al. (2018) and Misra et al. (2021) have surveyed the up-to-date literature on debt sustainability analysis at the subnational level in India, and used the traditional indicator-based approach and empirical exercises. Most of the studies on this topic have limited their analysis to conventional debt sustainability.

In this context, this study aims to contribute to the literature on India's fiscal performance at the subnational level by constructing a debt sustainability index, a sound composite indicator based on different fiscal or debt indicators to assess the stability and sustainability of public debt. The proposed index can be used as a benchmark to measure and compare the performances of each sub-national units in terms of debt sustainability. Moreover, this index facilitates to gain a better understanding of how debt sustainability of different states changes through favourable and unfavourable economic and financial conditions, which lacks in the aggregate level debt sustainability analysis.

3. Construction of a Composite Indicator

A composite indicator is an index consisting of individual performance indicators. Composite indicators are typically used to summarise many underlying individual indicators or variables. The general public finds it easier to interpret composite indicators than to identify common trends across many indicators, and these indicators are useful for benchmarking the performance of a country (Saltelli, 2007).

However, the construction of composite indicators is challenging. If the associated technical and economic problems occurring during the construction of these indicators are not addressed, they can result in the misinterpretation or manipulation of potential composite measures. Greco et al. (2019) reviewed the literature on the methodological framework of the construction of composite indicators, specifically focusing on weighting, aggregation, and robustness steps.

Many steps are involved in the construction of composite indicators (for details, refer Greco et al. 2019), which are briefly discussed in this section.

i. *Theoretical framework*

   A theoretical framework should be developed to provide the basis for the construction of a composite indicator. A clear definition of the phenomenon to be measured is the prerequisite for the selection and combination of single indicators into a meaningful composite indicator under the fitness-for-purpose principle.

ii. *Indicator selection and data quality*

   Indicators should be selected on the basis of their analytical soundness, measurability, country coverage, relevance to the phenomenon being measured, and their relationship with each other. The use of proxy variables should be considered when data are unavailable. Different approaches should be considered for imputing missing values. Extreme values should be examined because they can become unintended benchmarks.

iii. Normalisation

Normalisation is necessary to ensure the comparability of data, because different indicators do not have a common meaningful unit of measurement, and differ in their range. For any aggregation and weighting methods, the effective weight of indicators depends on measurement units and their range. Therefore, normalisation affects the overall outcome. In this paper, min–max normalisation (or rescaling) was applied.

Let $y_{i,j}$ be the value of the individual indicator i for unit j, with $i=1,2,\ldots,N$ and $j=1,2,\ldots,M$. The normalised indicator $x_{i,j}$ is given by

$$x_{i,j}=\frac{y_{i,j}-min_j\{y_i\}}{max_j\{y_i\}-min_j\{y_i\}}.$$

The normalised indicators have a common range between 0 and 1, with 0 and 1 being the worst and optimal values, respectively, indicating a high degree of sustainability.

iv. Multivariate analysis

Multivariate analysis consists of a set of statistical methods that provide insights into the overall structure of indicators, the suitability of the dataset, and methodologies to be followed in next steps. Principal component analysis (PCA) is performed to transform a large set of correlated variables into a small set of uncorrelated variables, termed as principal components, that account for most of the variation in the original set of variables. PCA of subindices can overcome the difficulty regarding the random choice of weights in the construction of the composite index.

First, correlations between indicators are examined. We calculated the $N\times N$ correlation matrix R of normalised indicators. If indicators are uncorrelated, the principal component method would not be appropriate to evaluate weights to construct a composite indicator, because it is based on correlations. Moreover, correlations should not be too high, to ensure that indicators do not measure the same development.

The determinant equation $|R-\lambda I|=0$ is solved for λ, where I is the identity matrix of the same order as R. This provides a polynomial equation of order N in λ; therefore, N roots can be derived. These N roots are eigenvalues corresponding to R. λ values are arranged in the descending order of magnitude, $\lambda_1>\lambda_2>\ldots>\lambda_N$.

Corresponding to each value of λ, the matrix equation $(R-\lambda_i T)F_i'=0$ is solved, where $F_i=[f_{1,i},f_{2,i},\ldots,f_{N,i}]$ is a $1\times N$ eigenvectors corresponding to λ_i, subject to the condition that

$F_i' F_i = 1$. Thus, N eigenvectors $F_1, F_2, \ldots, F_N$ are generated, which corresponds to $\lambda_1 > \lambda_2 > \ldots > \lambda_N$.

The N principal components are computed by weighting normalised indicators with eigenvectors corresponding to eigenvalues $\lambda_1 > \lambda_2 > \ldots > \lambda_N$ as follows:

$$P_{1,j} = x_j F_1'$$
$$\vdots$$
$$P_{N,j} = x_j F_N{}'$$

where $x_j = \left[x_{j,1}, x_{j,2}, \ldots, x_{j,N} \right]$ is a vector of standardised indicators for unit j.

The first principal component accounts for the maximum variance of original indicators. The second principal component accounts for the maximum variation of the remaining variance. All principal components are mutually orthogonal. Eigenvalues calculated by performing PCA can be used to identify the number of principal components necessary to represent the variance in the dataset. A frequent practice is to select principal components that have an eigenvalue of ≥1, individually represent at least 10% of the overall variance, and cumulatively contribute to the explanation of the total variance by at least 60%.

v. *Weighting and aggregation*

Indicators should be weighted and aggregated in accordance with the underlying theoretical framework. Correlation and compensability2 problems among indicators should be considered, and either be corrected for or treated as the features of the phenomenon that need to be retained in the analysis. The choice of aggregation procedures is based on the weighting of indicators. We derive our weights from PCA and use the linear aggregation method to obtain the final index.

Selected principal components were rotated in order to obtain a clear pattern of loadings and a simpler structure of principal components. Following the study conducted by Nicoletti et al. (2000) and OECD (2008), varimax rotation is applied, which minimises the number of variables that have high loadings on a principal component and facilitates the interpretation of these components.

Let $r_{i,k}$ be the factor loadings of indicator i in the selected factor k and $r_{i,k}'$ is the rotated factor loading corresponding to the indicator i in the factor k. The construction of weights is based on the following formula:

The individual factor weight corresponding to indicator i in factor k is calculated as follows:

$$\vartheta_{i,k} = \frac{r'^{\,2}_{i,k}}{\sum_i \lambda_i}, \tag{1}$$

where $\sum_i \lambda_i$ is the total variation in normalised indicators.

Then, the final weight for each indicator i, $\omega_i = \sum_k \vartheta_{k,i}$

Equation (1) provides a weighting matrix, which included the individual weights of indicators in principal components. Each indicator was weighted in accordance with the proportion of its variance that was explained by the principal component it was associated with. Subsequently, each principal component was weighted according to its contribution to the explained variance in the dataset.

Finally, the composite indicator score for unit j was obtained using the following formula:

$$CI_j = \sum_i \omega_i x_{i,j} \tag{2}$$

where $x_{i,j}$ is the normalised individual performance measure of indicator i for unit j and ω_i is the weight attached to indicator i.

vi. *Robustness and sensitivity*

The robustness of the composite indicator, such as the inclusion or exclusion of indicators, the normalisation scheme, the imputation of missing data, and the choice of weights and the aggregation method, should be examined.

The Cronbach coefficient alpha (C-alpha) is used to estimate the internal consistency of a composite score (OECD, 2008). The C-alpha can be calculated as follows:

$$\alpha_c = \left(\frac{N}{N-1}\right)\frac{\sum_{i\neq j} Cov\left(x_i, x_j\right)}{Var\left(x_0\right)} = \left(\frac{N}{N-1}\right)\left(1 - \frac{\sum_j Var\left(x_j\right)}{Var\left(x_0\right)}\right), \; c = 1,2,\ldots,M;\; i,j = 1,2,\ldots,N \tag{3}$$

where M indicates the number of units considered, N is the number of individual indicators available, and $x_0 = \sum_j x_j$ is the sum of all individual indicators. The C-alpha measures the total variability of the sample of individual indicators based on its correlation with indicators. It increases with the number of individual indicators and with the covariance of each pair. If no correlation exists and individual indicators are independent, the C-alpha is equal to zero. If individual indicators are perfectly correlated, the C-alpha is equal to one.

4. Empirical Analysis

We constructed a debt sustainability index at the subnational level in India by using the methodology explained in section 3. We used time series data on state finances for the period from 2002-03 to 2019-20 to construct the composite indicator for debt sustainability analysis. The data were obtained from 'State Finances: A Study of Budgets' published by the Reserve Bank of India. Only those states with data available for all relevant variables for the entire study period were included.

On the basis of international practices, 11 fiscal/debt indicators were developed to evaluate the government's ability to manage and repay debt. Table 1 lists individual indicators used to construct the composite indicator, the recommended level of these indicators proposed by various Finance Commissions, Government of India, and abbreviations used in the rest of the paper.

Table 1. Indicators used to construct Debt Sustainability Index

Debt Indicators	Recommended Level	Abbreviation
Interest payment to GSDP	IP/GSDP ↓↓	Ipgsdp
Interest payments to revenue expenditure	IP/RE ↓↓	Ipre
Interest payments to revenue receipts	IP/RR ↓↓	Iprr
Primary balance to GSDP	PB/GSDP > 0	Pbgsdp
Primary revenue balance to GSDP	PRB/GSDP > 0	Prbgsdp
Public debt to revenue receipts	PD/RR ↓↓	Pdrr
Revenue receipts to GSDP	RR/GSDP ↑↑	Rrgsdp
Rate of growth of public debt to GSDP	PDG-GSDPG < 0	Pdg
Outstanding Liabilities to GSDP	OL/GSDP < 25%	Olgsdp
Gross fiscal deficit to GSDP	GFD/GSDP < 3%	Gfdgsdp
Revenue deficit to GSDP	RD/GSDP = 0	Rdgsdp

Source: Finance Commission Reports, Government of India

The first step in PCA is to examine the correlation structure of data, as explained in the section 3. The correlation matrix for the aforementioned 11 indicators is presented in Table 2. Coefficients higher than 0.5 indicates stronger relationships among individual indicators. The corresponding *p*-values of correlation coefficients are provided within parenthesis. To prevent one variable from affecting principal components, individual indicators should be normalised to obtain a common meaningful unit of measurement at the start of the analysis.

Table 2: Correlation matrix for individual indicators

	ipgsdp	ipre	iprr	pdgsdp	prbgsdp	pdrr	rrgsdp	pdg	ossgdp	gfdgsdp	rdgsdp
ipgsdp	1.0000										
ipre	0.1141	1.0000									
	(0.0139)										
iprr	0.1763	**0.9294**	1.0000								
	(0.0001)	(0.0000)									
pdgsdp	-0.0378	-0.0589	0.0281	1.0000							
	(0.4170)	(0.2050)	(0.5453)								
prbgsdp	-0.4185	0.4313	**0.5276**	0.2436	1.0000						
	(0.0000)	(0.0000)	(0.0000)	(0.0000)							
pdrr	0.0578	**0.8326**	**0.9232**	0.0362	**0.5838**	1.0000					
	(0.2136)	(0.0000)	(0.0000)	(0.4367)	(0.0000)						
rrgsdp	-0.5920	**0.5932**	**0.5546**	0.0517	**0.7736**	**0.5776**	1.0000				
	(0.0000)	(0.0000)	(0.0000)	(0.2665)	(0.0000)	(0.0000)					
pdg	0.0473	-0.0191	-0.0020	0.0762	0.0244	0.0026	-0.0494	1.0000			
	(0.3097)	(0.6818)	(0.9652)	(0.1010)	(0.6000)	(0.9553)	(0.2886)				
ossgdp	**0.8686**	-0.0659	0.0392	0.0333	-0.3602	-0.0156	**-0.6414**	0.0920	1.0000		
	(0.0000)	(0.1566)	(0.3990)	(0.4737)	(0.0000)	(0.7378)	(0.0000)	(0.0475)			
gfdgsdp	0.4042	-0.0370	0.0823	**0.7820**	0.0451	0.0567	-0.2415	0.1903	0.4621	1.0000	
	(0.0000)	(0.4268)	(0.0767)	(0.0000)	(0.3319)	(0.2226)	(0.0000)	(0.0000)	(0.0000)		
rdgsdp	-0.2285	0.4888	**0.6110**	0.2949	**0.9527**	**0.6182**	**0.7004**	0.0080	-0.2016	0.1808	1.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.8641)	(0.0000)	(0.0001)	

Source: Author's calculation

Table 3: Eigenvalues of individual indicators

PC	Eigenvalue	% of variation	Cumulative %
1	5.6667	51.52	51.52
2	2.0334	18.49	70.01
3	1.8289	16.63	86.64
4	0.7543	6.86	93.50
5	0.3605	3.28	96.78
6	0.2172	1.97	98.75
7	0.0805	0.73	99.48
8	0.0235	0.21	99.69
9	0.0202	0.18	99.87
10	0.0132	0.12	99.99
11	0.0017	0.01	100.00

Source: Author's calculation

Table 3 lists the eigenvalues[3] of the correlation matrix of the 11 individual indicators that were used to construct the debt sustainability index. The sum of eigenvalues is equal to the number of individual indicators. Given that the correlation matrix instead of the covariance matrix is used in PCA, all 11 individual indicators are assigned equal weights in forming principal components (Chatfield & Collins, 1980).

The first principal component explains the maximum variance (51.52%) in all individual indicators (eigenvalue of 5.67). The second principal component explains the maximum proportion (18.49%) of the remaining variance, with an eigenvalue of 2.03. The third principal component explains 16.63% of the variance, with an eigenvalue 1.83. The last eight principal components together explain the remaining 13.36% of the variance in the data set.

Table 4 presents component loadings for individual debt indicators. The component loadings indicate the correlation between principal components and each individual indicator. The high and moderate loadings indicate how individual indicators are related to principal components.

Table 4: Component loadings for individual indicators

	Principal Components										
Variables	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11
ipgsdp	-0.0349	0.2409	0.6540	-0.0696	0.4789	-0.0482	0.1694	-0.0062	-0.3986	0.1706	0.2444
ipre	0.0964	0.6775	0.0440	0.0742	-0.1160	-0.0443	0.0473	0.0144	-0.0723	0.0356	-0.7071
iprr	0.3599	0.1036	-0.2500	0.0714	0.5485	0.1759	0.0981	-0.5933	0.3126	0.0310	0.0033
pbgsdp	0.1150	0.6318	-0.1976	0.1044	-0.3017	-0.0303	0.0010	0.0231	0.0627	-0.0344	0.6634
prbgsdp	0.3676	-0.0791	0.2977	0.1799	-0.1345	0.2968	0.1137	-0.0101	-0.1086	-0.7788	-0.0056
pdrr	0.3513	-0.1204	0.3464	0.1095	-0.2150	-0.0119	0.4625	0.2342	0.5354	0.3582	0.0006
rrgsdp	0.3728	-0.0858	0.2298	0.1940	-0.2184	0.2759	-0.6679	-0.1510	-0.1485	0.3852	0.0086
pdg	0.3503	0.0157	-0.3461	0.0667	0.4092	0.1953	-0.0587	0.7205	-0.1476	0.0533	-0.0025
olgsdp	-0.2362	-0.0634	-0.0113	0.9345	0.1280	-0.2236	0.0116	0.0103	-0.0128	0.0025	-0.0002
gfdgsdp	-0.3795	0.0346	-0.0882	0.1103	-0.1135	0.8155	0.3135	-0.0405	-0.1252	0.2032	-0.0019
rdgsdp	-0.3559	0.1989	0.2823	-0.0422	0.2378	0.2154	-0.4297	0.2202	0.6133	-0.2002	0.0056

Source: Author's calculation

The first three principal components individually explain more than 10% of the total variance, and they together explain approximately 87% of variance. Thus, we retained the first three factors for further analysis without losing considerable information. To understand the meaning of these components, the rotated factor loadings of individual indicators determined through varimax rotation can be analysed (Table 5). The rotation is used to minimise the number of individual indicators that have a high loading on the same factor. The idea behind transforming the factorial axes is to obtain a "simpler structure" of the factors (ideally a structure in which each indicator is loaded exclusively on one of the retained factors).

Table 5: Rotated factor loadings of individual indicators based on principal components

	Factor Loading				Squared factor loading (Scaled to unity)		
Variables	Factor 1	Factor 2	Factor 3	Uniqueness	Factor 1	Factor 2	Factor 3
ipgsdp	0.0386	0.9486	-0.0094	0.0986	0.0003	0.3633	0.0000
ipre	0.9279	0.1163	-0.2032	0.0842	0.1899	0.0055	0.0212
iprr	0.9768	0.0808	-0.0398	0.0377	0.2104	0.0026	0.0008
pbgsdp	0.0895	0.0351	0.9125	0.1582	0.0018	0.0005	0.4269
prbgsdp	0.7342	-0.4380	0.3561	0.1423	0.1189	0.0774	0.0650
pdrr	0.9407	-0.0566	0.0485	0.1095	0.1952	0.0013	0.0012
rrgsdp	0.7709	-0.5574	-0.0175	0.0947	0.1311	0.1254	0.0002
pdg	-0.0042	-0.0324	0.3945	0.8433	0.0000	0.0004	0.0798
olgsdp	-0.1446	0.8877	0.1618	0.1649	0.0046	0.3181	0.0134
gfdgsdp	0.0176	0.4834	0.7797	0.1581	0.0001	0.0943	0.3117
rdgsdp	0.8184	-0.1659	0.3950	0.1467	0.1477	0.0111	0.0800
Expl. Var	4.5339	2.4772	1.9507				
Expl. Var/Total	0.5059	0.2764	0.2177				

Source: Author's calculation

In the last step, weights from the matrix of factor loadings after rotation are constructed, given that the square of factor loadings represents the proportion of the total unit variance of the indicator, which is explained by the factor.

Table 6: Weights of individual indicators for constructing composite indicator based on principal components

	Individual Factor weights			Final
Variables	Factor 1	Factor 2	Factor 3	Weights
ipgsdp	0.0002	0.1004	0.0000	0.1006
ipre	0.0961	0.0015	0.0046	0.1022
iprr	0.1065	0.0007	0.0002	0.1074
pbgsdp	0.0009	0.0001	0.0929	0.0939
prbgsdp	0.0602	0.0214	0.0141	0.0957
pdrr	0.0987	0.0004	0.0003	0.0994
rrgsdp	0.0663	0.0347	0.0000	0.1010
pdg	0.0000	0.0001	0.0174	0.0175
olgsdp	0.0023	0.0879	0.0029	0.0932
gfdgsdp	0.0000	0.0261	0.0678	0.0939
rdgsdp	0.0747	0.0031	0.0174	0.0952

Source: Author's calculation

Individual factor weights are obtained by assigning a weight to each squared factor loading, equal to the proportion of the explained variance. The final weights for individual indicators for constructing the debt sustainability index are calculated by adding individual factor weights corresponding to each individual indicator. The individual factor weights and final weights obtained on the basis of the principal component method are listed in Table 6.

Different methods used for the extraction of principal components provided different factor loadings, and thus different weights for individual indicators. The weights used for constructing the composite indicator by using different extraction methods, namely principal component factor (PCF), principal factor (PF), iterated principal factor (IPF), and maximum likelihood (ML), are listed in Table 7. As Table 7 shows, the weights are approximately equal for all the different extraction methods.

Table 7: Weights for constructing composite indicator based on different methods for the extraction of the common factors

Variable	PCF	PF	IPF	ML
ipgsdp	0.1006	0.1088	0.1153	0.1045
ipre	0.1022	0.1217	0.1271	0.1252
iprr	0.1074	0.1227	0.1244	0.1198
pbgsdp	0.0939	0.0851	0.0870	0.1230
prbgsdp	0.0957	0.0754	0.0562	0.0603
pdrr	0.0994	0.1029	0.1005	0.0995
rrgsdp	0.1010	0.1133	0.1109	0.1085
pdg	0.0175	0.0068	0.1008	0.0068
olgsdp	0.0932	0.0903	0.0018	0.1088
gfdgsdp	0.0939	0.0950	0.1136	0.0859
rdgsdp	0.0952	0.0781	0.0625	0.0576

Source: Author's calculation

Table 8 presents values of the Cronbach coefficient alpha and covariance with the total after deleting one individual indicator at a time. The C-alpha is a coefficient of reliability based on the correlation between individual indicators. If the correlation is high, individual indicators are measured under the same underlying construct. Therefore, a high C-alpha, or a equivalently high reliability, indicates that individual indicators effectively measure the latent phenomenon. Nunnally (1978) suggests 0.7 as an acceptable reliability threshold.

The C-alpha value of original indicator variables of the study is 0.8087, which implies that the consistency of indicator variables used for the construction of composite indicators is satisfactory. The variable 'pdg' is removed from final index because it is not correlated with most of the variables. The C-alpha is further increased to 0.8338 after its removal.

The final weights obtained after the removal of the indicator 'pdg' is listed in Table 9. The weights obtained from principal component factors are used to construct the composite indicator. The simplest additive aggregation method given in equation (2) is adopted to construct the final index.

Table 8: Cronbach coefficient alpha results for individual indicators

Deleted	Covariance	Cronbach coefficient alpha
ipgsdp	0.2975	0.8090
ipre	0.2613	0.7796
iprr	0.2507	0.7699
pbgsdp	0.3339	0.8337
prbgsdp	0.2380	0.7575
pdrr	0.2435	0.7630
rrgsdp	0.2364	0.7558
pdg	0.3341	0.8338
olgsdp	0.3004	0.8111
gfdgsdp	0.3374	0.8359
rdgsdp	0.2467	0.7661
All	0.2776	0.8087

Source: Author's calculation

Table 9: Final weights for constructing composite indicator based on different methods for the extraction of the common factors

Variable	PCF	PF	IPF	ML
ipgsdp	0.1019	0.1011	0.1010	0.1068
ipre	0.1038	0.1121	0.1077	0.1046
iprr	0.1085	0.1140	0.1096	0.1087
pbgsdp	0.0971	0.0784	0.0836	0.0788
prbgsdp	0.0974	0.1069	0.1054	0.1087
pdrr	0.1004	0.0987	0.0955	0.0916
rrgsdp	0.1019	0.1089	0.1062	0.1014
olsgdp	0.0939	0.0847	0.0898	0.1087
gfdgsdp	0.0981	0.0896	0.0982	0.0938
rdgsdp	0.0970	0.1057	0.1029	0.0969

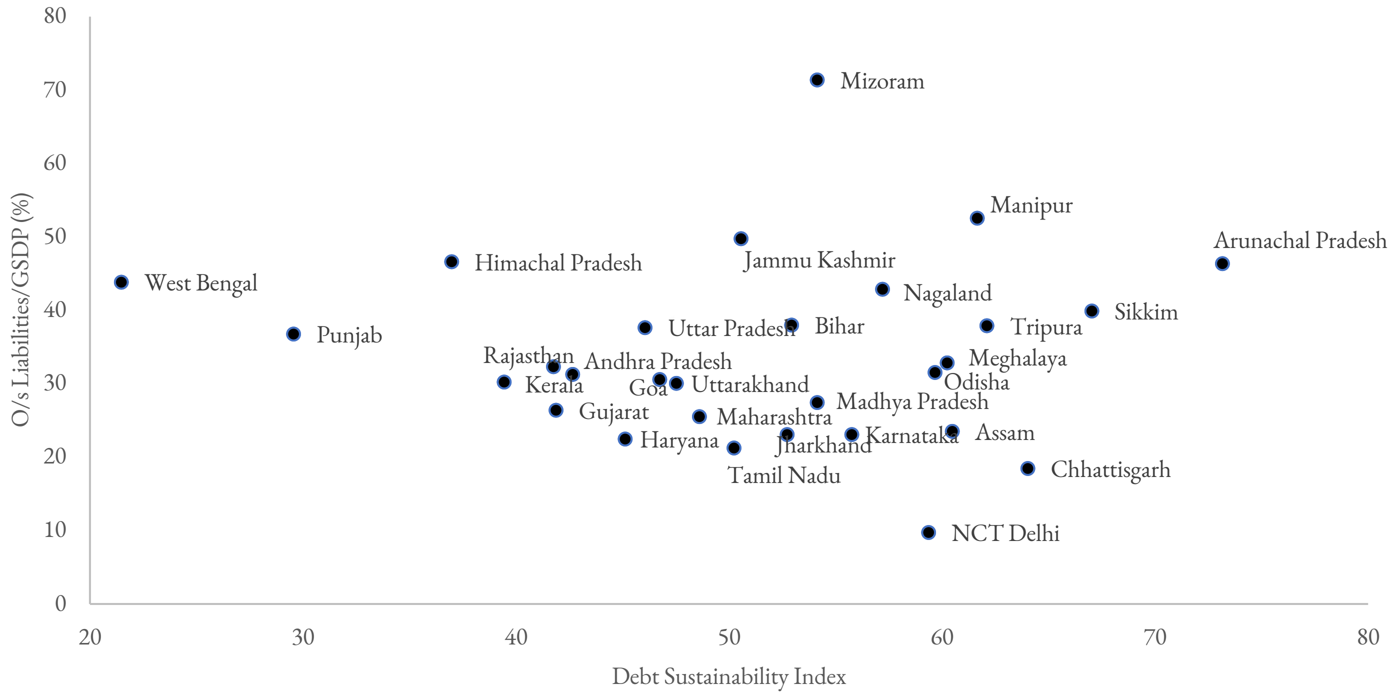
Source: Author's calculation

The resulting state-wise debt sustainability indices for the period from 2003-04 to 2019-20 are listed in Table 10. The higher the index value is, the better is the performance of the state in terms of debt sustainability.

Table 10: State-wise Debt Sustainability scores for the period 2003-04 to 2019-20

State	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	Average
Andhra Pradesh	51	42	43	46	46	43	45	49	47	40	42	31	36	36	47	48	33	43
Arunachal Pradesh	55	50	65	81	80	62	72	82	65	69	60	89	90	90	86	71	78	73
Assam	59	59	66	63	65	68	55	63	63	60	63	59	64	61	46	58	56	60
Bihar	46	54	44	50	53	56	56	59	59	57	60	54	53	55	52	55	37	53
Chattisgarh	58	62	66	65	65	66	69	73	72	65	67	60	63	66	64	59	49	64
Delhi	55	65	58	55	55	49	58	59	54	54	60	58	59	59	67	72	71	59
Goa	53	53	49	48	48	46	48	53	51	41	44	44	42	47	47	38	42	47
Gujarat	43	42	44	43	44	37	40	41	43	39	44	39	36	40	47	46	43	42
Haryana	55	59	60	60	57	48	50	53	49	42	47	36	25	28	38	33	28	45
Himachal Pradesh	27	31	44	42	44	31	35	43	45	35	39	34	40	39	38	32	29	37
Jammu & Kashmir	70	66	59	56	44	54	57	53	51	42	46	35	37	45	55	40	51	51
Jharkhand	60	53	49	47	40	48	59	53	58	53	58	52	47	51	59	51	57	53
Karnataka	59	63	61	57	57	54	56	57	59	54	59	53	52	52	55	51	50	56
Kerala	46	46	44	42	42	40	42	40	40	34	40	34	33	34	41	40	31	39
Madhya Pradesh	50	50	52	52	53	53	58	59	61	55	60	55	54	52	54	51	50	54
Maharashtra	50	49	48	49	55	48	48	49	49	48	50	44	43	45	50	54	49	49
Manipur	53	51	63	56	75	68	54	60	58	76	77	61	60	62	64	59	52	62
Meghalaya	64	59	62	61	60	57	67	63	57	64	67	55	57	59	61	55	59	60
Mizoram	48	50	43	48	39	62	53	46	59	42	50	50	71	73	68	67	51	54
Nagaland	71	62	61	61	55	58	56	64	59	53	62	59	53	58	51	50	40	57
Odisha	42	51	48	55	58	60	60	64	70	65	68	65	64	63	64	56	60	60
Punjab	43	42	45	37	38	31	38	38	28	27	33	24	16	7	19	20	16	30
Rajasthan	40	41	41	43	45	40	42	48	52	48	51	45	30	30	39	41	33	42
Sikkim	79	69	73	71	74	62	74	64	73	73	77	64	57	65	61	50	53	67
Tamil Nadu	55	59	60	56	56	54	55	54	55	51	54	46	41	37	41	44	36	50
Tripura	60	65	66	66	63	65	76	68	77	74	71	58	52	54	49	51	41	62
Uttar Pradesh	37	38	47	46	45	40	50	49	51	46	53	46	42	45	52	48	48	46
`Uttarakhand	50	39	48	52	48	48	49	54	53	49	56	46	42	43	49	40	41	48
West Bengal	23	25	23	19	20	18	14	20	19	16	19	16	20	23	30	33	27	21

Figure 1: Scatter plot of Debt Sustainability Index and outstanding liabilities to GSDP (average for the period 2003-04 to 2019-20)



This new index provides a starting point for debt sustainability analysis. Although this index can be used as a summary indicator to guide public debt policymaking, it can be decomposed such that the contribution of individual indicators in the final index can be identified and the state-wise performance can be analysed.

Moreover, the debt sustainability index can be linked with other variables and measures for further analysis. For example, in Figure 1, the debt sustainability index helps to assess the position of a state government relative to outstanding liabilities. The analysis of selected individual indicators can help to understand the relative position of state governments in the overall debt sustainability index. The detailed analysis of the performance of each state government by using the proposed composite indicator is not discussed here, leaving that for future research.

5. Concluding Remarks

Debt sustainability analysis frameworks provide an intertemporal consistency check that under current policies, a country or a government will be able to service its debts in the medium and long run without renegotiating or defaulting the policies. This paper proposes a new framework for public debt sustainability analysis by constructing the debt sustainability index, a sound composite indicator based on different fiscal or debt indicators of a country or a government. We emphasised the need for an explicit conceptual framework for the construction of a composite index and the usefulness of multivariate statistical analysis prior to the aggregation of individual indicators.

Most composite indicators rely on equal weighting, that is, all variables are assigned the same weight. This implies that all variables are the same in the composite, but it could reflect the absence of a statistical or an empirical basis. In the present study, statistical methods, such as PCA, are used to group individual indicators in accordance with their degree of correlation. However, weights cannot be estimated using these methods if no correlation exists between indicators. Thus, we selected 10 significantly correlated debt indicators, measuring the multiple aspects of fiscal or debt position of state governments in India, to construct the composite indicator.

PCA involves the use of the factor loadings of the first component to serve as weights for indicators. However, the first component alone is inadequate to explain a large proportion of the variance in indicators, thus requiring more components. In this study, the first three principal components were used for analysis. This paper uses PCA as the extraction method and varimax rotation to minimise the number of indicators with high loadings on each component. By considering the factor loadings of all retained factors, we could preserve the largest proportion of variation in the original dataset.

The final step involves the selection of weights used to construct the composite indicator. The approach followed in this paper was to weigh each individual indicator in accordance with the proportion of its variance that is explained by the factor it is associated to (i.e. normalised squared loading). Each factor was weighted according to its contribution to the portion of the explained variance in the dataset (i.e. the normalised sum of squared loadings). Finally, the additive aggregation method was adopted to construct the debt sustainability index.

To sum up, we constructed an index based on the composite indicator approach for the assessment of the debt sustainability of national/sub-national governments. The index was used to determine the comparative position of different Indian sub-nationals in terms of debt sustainability. The findings of this study are in accordance with those of previous studies on the debt sustainability of sub-national governments in India.

The proposed composite indicator can help summarise various debt indicators for assessing debt sustainability. Moreover, this index can be used as a benchmark to measure the performance and compare the performances of governments or countries in terms of debt sustainability. Future studies should determine the sustainable level of public debt based on the composite indicator.

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Notes

[1] The rollover risk mainly encompasses the possibility of rolling over debt at relatively higher cost and in extreme circumstances, failure to rollover debt completely/ partially.
[2] Compensability refers to the existence of trade-offs, i.e., the possibility of offsetting the poor performance in some indicators with outstanding performance in another.
[3] The eigenvalues are related to the variances of the indicators on which the correlation matrix is based. The eigenvalue for each principal component indicates the percentage of variation explained in the data by that principal component.