

Global Green Finance Index Methodology

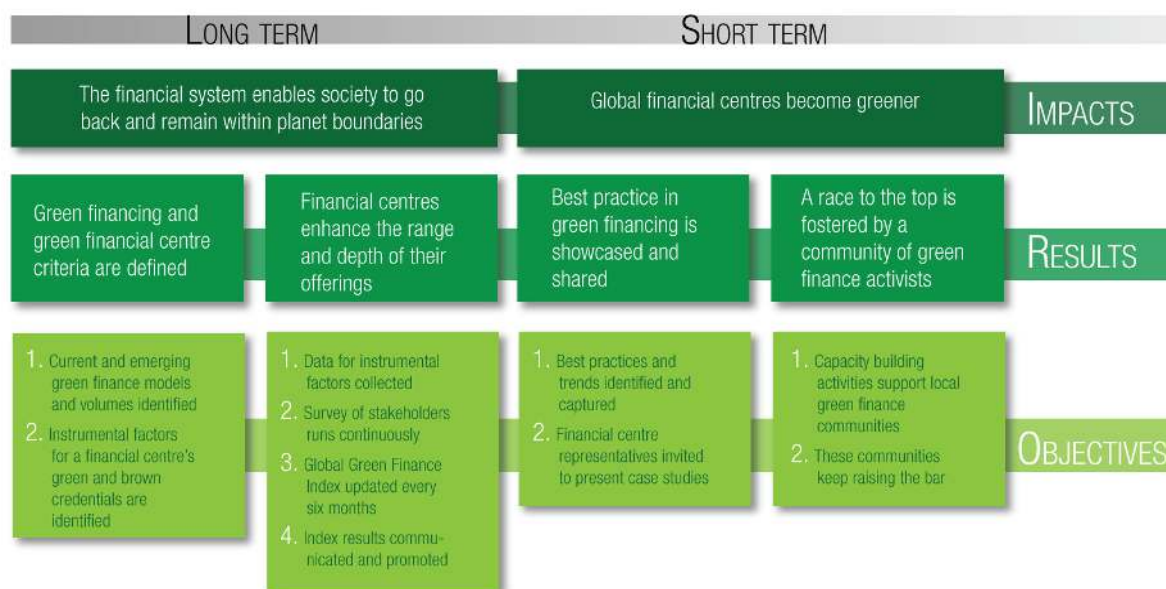
Introduction

1. This paper sets out the methodology underlying the construction of the Global Green Finance Index (GGFI). In summary, the process involves taking two sets of ratings – one from survey respondents and one generated by a statistical model – and combining them into a single table. For the first set of ratings, respondents are asked to rate financial centres that they are familiar with on a scale of 1 to 10. For the second, a support vector engine uses these ratings and a database of indicators to predict how each respondent would have rated the other financial centres. The respondents’ actual ratings and their predicted ratings for the centres they did not rate are then combined into a single table.

Background

2. The aims of the GGFI are to encourage financial centres to improve and expand their green finance offering and to focus developments in the financial system in ways that enable society to live within planetary boundaries.
3. The GGFI’s aims are set out in the diagram below.

Figure 1: GGFI Aims and Objectives



4. The GGFI will be published twice a year and uses qualitative ratings of financial centres’ green finance credentials combined with a number of instrumental factors to create an index of financial centres according to their green finance performance.

Approach

Inputs

5. The GGFI provides ratings for the green offering of financial centres calculated by a factor assessment model that uses two distinct sets of input:
 - **Financial centre assessments:** using an online questionnaire (<http://greenfinanceindex.net/survey>), respondents are asked to rate the penetration and quality of each financial centre's green finance offering using a ten point scale ranging from little penetration/very poor to mainstream/excellent. Responses are sought from a range of individuals drawn from the financial services sector, non-governmental organisations, regulators, universities and trade bodies.
 - **Instrumental factors:** these are a range of quantitative data about each financial centre. These instrumental factors draw on data from 113 different sources and include:
 - ◇ The development of financial service activities in that centre, including data on sustainable and green finance;
 - ◇ The business environment, including legal and policy factors and statistics on economic performance;
 - ◇ Human capital, reflecting educational development and social factors;
 - ◇ Environment and infrastructure data that reflect the physical attributes of the centre, such as air quality and local carbon emissions, or telecommunications and public transport.
6. A full list of the instrumental factors used in the model is attached at annex 1. Due to the way in which the factor assessment model operates, several indices can be used for each area of interest. Neither of these sets of inputs in themselves would allow the creation of a valid index and we use an approach which combines these data in creating the GGFI.

Factors Affecting the Inclusion of Centres in the GGFI

7. The questionnaire lists a total of 108 financial centres which can be rated by respondents. The questionnaire also asks whether there are other financial centres that will improve their green finance offering significantly over the next two to three years. Centres which are not currently within the questionnaire and which receive a number of mentions in response to this question will be added to the questionnaire for future editions.
8. With the initial publication of the GGFI, we will only give a financial centre a GGFI rating and ranking if it receives a statistically significant minimum number of assessments from individuals based in other geographical locations – at least ten in GGFI 1. This

means that not all 108 centres in the questionnaire will receive a ranking. We will keep this number under review for further editions of the index as the number of assessments increases.

9. We will also develop rules as successive indices are published as to when a centre may be removed from the rankings, for example if over a 24 month period, a centre has not received a minimum number of assessments.

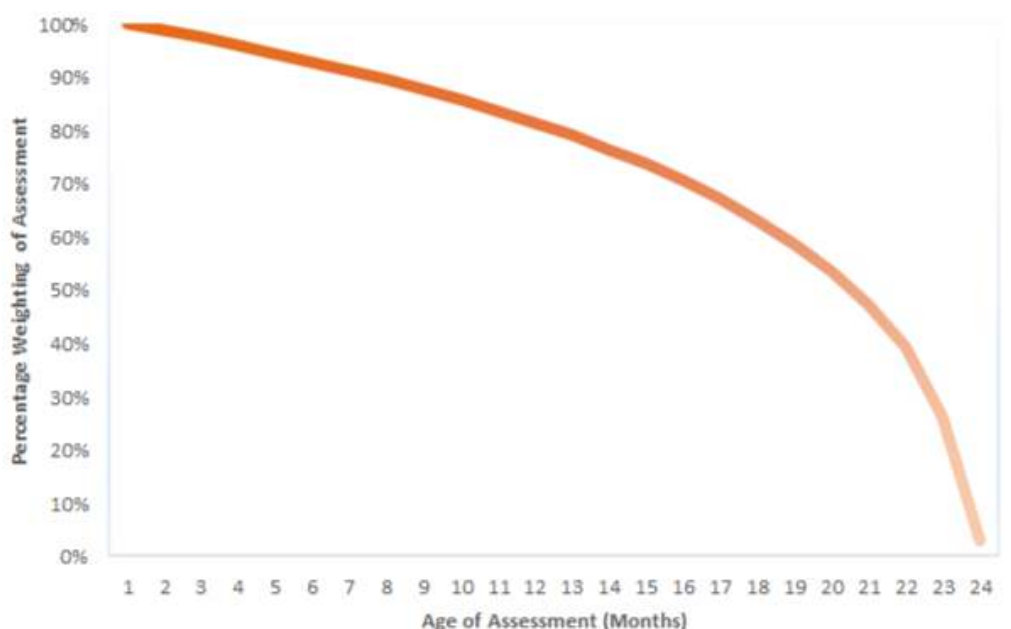
Financial Centre Assessments

10. Financial centre assessments are collected via an online questionnaire which will run continuously. A link to this questionnaire is emailed to a target list of respondents at regular intervals and other interested parties can complete the questionnaire by following the link given in GGFI publications.

11. For the first and subsequent editions of the GGFI:

- the score given by a respondent to their home centre and respondents who do not specify a home centre are excluded from the model – this is designed to prevent home bias;
- financial centre assessments will be included in the GGFI model for 24 months after they have been received – we consider that assessments still have validity for a period after they have been given; and
- financial centre assessments from the month when the GGFI is created will be given full weighting with earlier responses given a reduced weighting on a logarithmic scale as shown in Chart A – this recognises that older ratings, while still valid, are less likely to be up-to-date.

Chart A: Log Scale for Time Weighting



Instrumental Factor Data

12. For the instrumental factors, we have the following data requirements:

- data series should come from a reputable body and be derived by a sound methodology; and
- data series should be readily available (ideally in the public domain) and be regularly updated.

13. The rules on the use of instrumental factor data in the model are as follows:

- updates to the indices are collected and collated every six months;
- no weightings are applied to indices;
- indices are entered into the GGFI model as directly as possible, whether this is a rank, a derived score, a value, a distribution around a mean or a distribution around a benchmark;
- if a factor is at a national level, the score will be used for all centres in that country; nation-based factors will be avoided if financial centre (city)-based factors are available;
- if an index has multiple values for a city or nation, the most relevant value is used (and the method for judging relevance is noted);
- if an index is at a regional level, the most relevant allocation of scores to each centre is made (and the method for judging relevance is noted); and
- if an index does not contain a value for a particular financial centre, a blank is entered against that centre (no average or mean is used).

Factor Assessment

14. Neither the financial centre assessments nor the instrumental factors on their own can provide a basis for the construction of the GGFI.

15. The financial centre assessments rate centres on their green finance performance, but each individual completing the questionnaire will:
 - be familiar with only a limited number of centres - probably no more than 10 or 15 centres out of the total number;
 - rate a different group of centres making it difficult to compare data sets; and
 - consider differing aspects of centres' performance in their ratings.
16. The instrumental factors are based on a range of different models and using just these factors would require some system of totaling or averaging scores across instrumental factors. Such an approach would involve a number of difficulties:
 - indices are published in a variety of different forms: an average or base point of 100 with scores above and below this; a simple ranking; actual values, e.g., \$ per square foot of occupancy costs; or a composite 'score';
 - indices would have to be normalised, e.g., in some indices a high score is positive while in others a low score is positive;
 - not all centres are included in all indices; and
 - the indices would have to be weighted.
17. Given these issues, the GGFI uses a statistical model to combine the financial centre assessments and instrumental factors.
18. This is done by conducting an analysis to determine whether there is a correlation between the financial centre assessments and the instrumental factors we have collected about financial centres. This involves building a predictive model of the rating of centres' green financial offerings using a support vector machine (SVM).
19. An SVM is a supervised learning model with associated learning algorithms that analyses data used for classification and regression analysis. SVMs are based upon statistical techniques that classify and model complex historic data in order to make predictions on new data. SVMs work well on discrete, categorical data but also handle continuous numerical or time series data.
20. Academic studies have established SVMs as a robust statistical technique, with prediction accuracy rates often well above 90 per cent. Examples of studies on the effectiveness of SVM and explanations of the theory behind the technique can be found

at the links below.¹ SVMs have a variety of practical applications in addition to their use in surveys. For example, SVMs can be used to detect faults in diesel engines, or to set the sequence of traffic lights at road junctions. In medicine, they are used to predict whether particular individuals will develop heart disease or diabetes, how well they will recover after a stroke, or what sub-type of cancer they are likely to develop, helping doctors to prescribe more effective treatments.

21. The SVM is run in R, an open source programming language and software environment for statistical computing and graphics that is supported by the R Foundation for Statistical Computing. The R language is widely used among statisticians and data miners for developing statistical software and data analysis.
22. The SVM used for the GGFI provides information about the confidence with which each specific rating is made and the likelihood of other possible ratings being made by the same respondent.
23. The model then predicts how respondents would have assessed centres with which they are unfamiliar by answering questions such as:

If a respondent gives Singapore and Sydney certain assessments then, based on the instrumental factors for Singapore, Sydney and Paris, how would that person assess Paris?

Or

If Edinburgh and Munich have been given a certain assessment by this respondent, then, based on the instrumental factors for Edinburgh, Munich and Zurich, how would that person assess Zurich?

24. Financial centre rating predictions from the SVM are re-combined with actual financial centre assessments to produce the GGFI – a set of ratings for financial centres' green finance performance.
25. The process of creating the GGFI is outlined in Chart B below:

Chart B: The GGFI Process

¹ a. *An Idiot's Guide To Support Vector Machines (SVMs)*, R Berwick, MIT (<http://web.mit.edu/6.034/www/bob/svm-notes-long-08.pdf>)

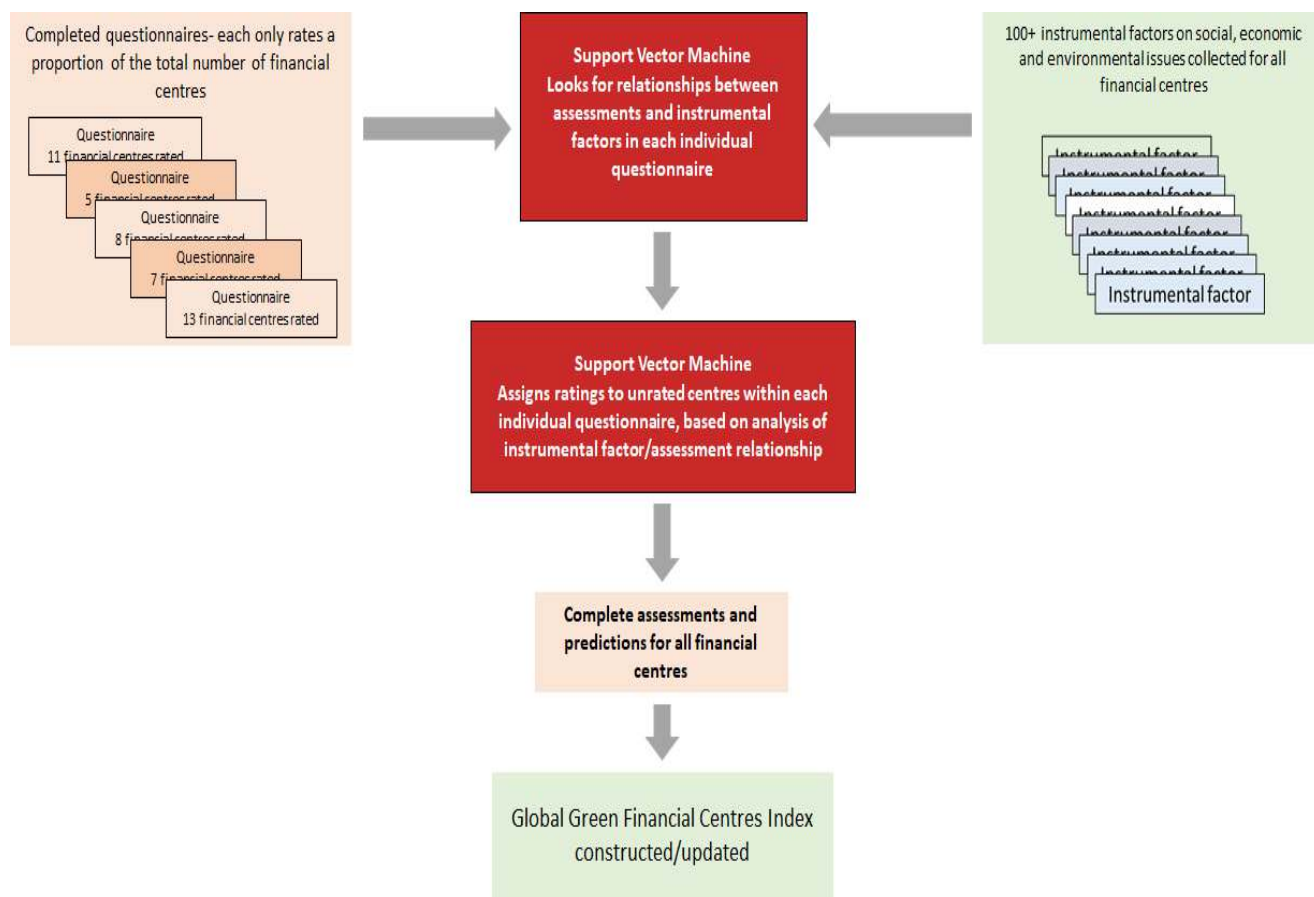
b. A Gentle Introduction to Support Vector Machines in Biomedicine, Statnikov, Hardin, Guyon and Aliferis (<https://www.eecis.udel.edu/~shatkay/Course/papers/UOSVMAlliferisWithoutTears.pdf>)

c. *Support Vector Machines*, Guenther and Schonlau, *Stata Journal* (http://www.schonlau.net/publication/16svm_stata.pdf)

d. Non-linear machine learning econometrics: SupportVector Machine

(https://circabc.europa.eu/webdav/CircaBC/ESTAT/ESTP/Library/2017%20ESTP%20PROGRAMME/29.%20Machine%20Learning%20Econometrics%20C%2012%20%E2%80%93%2014%20June%202017%20-%20Organiser_%20DEVSTAT/Materials_Machine_LEUC1502_Module4.pdf)

e. *An Introduction to Statistical Learning*, James, Witten, Hastie and Tibshirani (<http://www-bcf.usc.edu/~gareth/ISL/ISLR%20First%20Printing.pdf>)



Mathematical Model

26. The mathematical model underlying the process of factor assessment and the creation of the index is described at annex 2.

Validation

27. The rules on data use for both financial centre assessments and instrumental factors are a key part of data validation. In addition, we intend to scrutinise the data set for anomalous patterns, for example, exactly matching assessments given by respondents from the same region or multiple assessments given from the same source. Where there appears to be a discrepancy, we may ignore certain responses in compiling the index.

Updating the Index

The GGFI will be published twice a year and dynamically updated either by updating and adding to the instrumental factors or through new financial centre assessments.

Use of the Index

28. The GGFI produces a central index rating of financial centres' green finance credentials. The questionnaire collects other data and other analyses of the data are possible, for example:

- Sector-specific ratings are available using the business sectors represented by questionnaire respondents. This makes it possible to rate different centres in terms of their offering in, for example, insurance as opposed to their strength in debt capital.
- The factor assessment model can be queried in a 'what if' mode – for example, "how much would Singapore carbon emissions need to fall in order to increase Singapore's ranking against Paris?"

Annex 1: Instrumental Factors used in the Global Green Finance Index Model

Sustainability Factors		
Instrumental Factor	Source	Website
Air Quality Data	WHO	http://www.who.int/entity/phe/health_topics/outdoorair/databases/who-aap-database-may2016.xlsx?ua=1
Average precipitation in depth (mm per year)	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Buildings Energy Efficiency Policies Database	IEA	https://www.iea.org/beep/
CBI labelled green bonds by exchange (preliminary data)	CBI	https://www.climatebonds.net
City Commitment to Carbon Reduction (Cooperative Actions)	UNFCCC	http://climateaction.unfccc.int/cities
City Commitment to Carbon Reduction (Individual Actions)	UNFCCC	http://climateaction.unfccc.int/cities
Climate-aligned Bonds Outstanding by Country of Issuer	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
CO2 Emissions Per Capita	World Bank	https://data.worldbank.org/indicator/EN.ATM.CO2E.PC
Energy Intensity of GDP	Enerdata Statistical Yearbook	https://yearbook.enerdata.net/download/
Energy Sustainability Index	World Energy Council	http://www.worldenergy.org/data/sustainability-index/
Environmental Performance	Yale University	http://epi.yale.edu//epi/country-rankings
Financial Centre Carbon Intensity	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
Financial Centre Clean Revenue to Fossil-related	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
Financial Centre Sustainability Disclosure	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
Financial Institutions Conventional to New Energy Finance Data	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
Financial system green alignment	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
Forestry Area	World Bank	http://databank.worldbank.org/data/reports.aspx?source=2&series=AG.LND.FRST.ZS&country=
Global Sustainable Competitiveness Index	Solability	http://solability.com/the-global-sustainable-competitiveness-index/the-index
Green Bonds Issued by Country of Issuer	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
GREB Building Energy Intensity Score	Corporate Knights	http://www.finance-watch.org/our-work/dossiers?fid=192
IESE cities in motion index	IESE	http://citiesinmotion.iese.edu/indicecim/?lang=en
Protected Land Area as Percentage of Land Area	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=2&series=ER.LND.PTLD.ZS&country=
Quality of Life Index	Numbeo	http://www.numbeo.com/quality-of-life/rankings.jsp
Quality of Living City Rankings	Mercer	http://www.mercer.com
Share of renewables in electricity production	Enerdata Statistical Yearbook	https://yearbook.enerdata.net/download/
Shares of Wind and Solar in Electricity Production	Enerdata Statistical Yearbook	https://yearbook.enerdata.net/download/
Sustainable Cities Index	Arcadis	https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/
Sustainable Economic Development	Boston Consulting Group	https://www.bcgperspectives.com/content/interactive/public_sector_globalization_interactive_map_sustainable_economic_development/
Sustainable Stock Exchanges	UN Sustainable Stock Exchange Initiative	http://www.sseinitiative.org/sse-partner-exchanges/list-of-partner-exchanges/

Business Factors

Instrumental Factor	Source	Website
Best Countries for Business	Forbes	http://www.forbes.com/best-countries-for-business/list/#tab:overall
Bilateral Tax Information Exchange Agreements	OECD	http://www.oecd.org/document/7/0,3343,en_2649_33767_38312839_1_1_1_1,00.html
Business Environment Rankings	EIU	http://www.eiu.com/public/thankyou_download.aspx?activity=download&campaignid=bizenviro2014
Business Process Outsourcing Location Index	Cushman & Wakefield	http://www.cushmanwakefield.com/en/research-and-insight/2015/business-process-outsourcing-location-index-2015/
Capitalisation of Stock Exchanges	The World Federation of Stock Exchanges	http://www.world-exchanges.org/home/index.php/statistics/monthly-reports
City GDP composition (Business/Finance)	The Brookings Institution	http://www.brookings.edu/research/interactives/global-metro-monitor-3
Common Law Countries	CIA	https://www.cia.gov/library/publications/the-world-factbook/fields/2100.html
Corporate Tax Rates	PWC	http://www.doingbusiness.org/reports/thematic-reports/paying-taxes/
Domestic Credit Provided by Banking Sector (% of GDP)	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Ease of Doing Business Index	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=doing-business
External Positions of Central Banks as a share of GDP	The Bank for International Settlements	http://www.bis.org/statistics/bankstats.htm
FDI Confidence Index	AT Kearney	http://www.atkearney.com/research-studies/foreign-direct-investment-confidence-index
FDI Inward Stock as a Percentage of GDP	UNCTAD	http://unctad.org/en/Pages/DIAE/World%20Investment%20Report/Annex-Tables.aspx
Financial Secrecy Index	Tax Justice Network	http://www.financialsecrecyindex.com/
Foreign Direct Investment Inflows	UNCTAD	http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sRF_ActivePath=P,5,27&sRF_Expanded=P,5,27
Global Connectedness Index	DHL	http://www.dhl.com/en/about_us/logistics_insights/studies_research/global_connectedness_index/global_connectedness_index.html
Global Enabling Trade Report	World Economic Forum	http://www.weforum.org/issues/international-trade
Global Services Location	AT Kearney	http://www.atkearney.com/research-studies/global-services-location-index
Government Debt as % of GDP	CIA	https://www.cia.gov/library/publications/the-world-factbook/rankorder/2186rank.html
Net External Positions of Banks	The Bank for International Settlements	http://www.bis.org/statistics/bankstats.htm
Office Occupancy Cost	CBRE Research	http://www.cbre.com/research-and-reports/Global-Prime-Office-Occupancy-Costs-2016
Operational Risk Rating	EIU	http://www.viewswire.com/index.asp?layout=homePubTypeRK
Percentage of Firms Using Banks to Finance Investment	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Real Interest Rate	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Total Net Assets of Regulated Open-End Funds	Investment Company Institute	http://www.icifactbook.org/
Value of Bond Trading	The World Federation of Stock Exchanges	http://www.world-exchanges.org/home/index.php/statistics/monthly-reports
Value of Share Trading	The World Federation of Stock Exchanges	http://www.world-exchanges.org/home/index.php/statistics/monthly-reports
Volume of Share Trading	The World Federation of Stock Exchanges	http://www.world-exchanges.org/home/index.php/statistics/monthly-reports
World Competitiveness Scoreboard	IMD	http://www.imd.ch/research/publications/wcy/competitiveness_scoreboard.cfmue

Human Capital Factors		
Instrumental Factor	Source	Website
Citizens Domestic Purchasing Power	UBS	http://www.ubs.com/1/e/wealthmanagement/wealth_management_research/prices_earnings.html
Corruption Perception Index	Transparency International	http://www.transparency.org/policy_research/surveys_indices/cpi
Cost of Living City Rankings	Mercer	http://www.mercer.com
Crime Index	Numbeo	http://www.numbeo.com/crime/rankings.jsp#
GDP per Person Employed	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Global Cities Index	AT Kearney	https://www.atkearney.com/research-studies/global-cities-index
Global Innovation Index	INSEAD	http://www.globalinnovationindex.org/content.aspx?page=GII-Home
Global Intellectual Property Index	Taylor Wessing	http://www.taylorwessing.com/ipindex/
Global Peace Index	Institute for Economics & Peace	http://www.visionofhumanity.org/
Global Skills Index	Hays	http://www.hays-index.com/
Global Terrorism Index	Institute for Economics & Peace	http://www.visionofhumanity.org/
Good Country Index	Good Country Party	http://www.goodcountry.org/overall
Government Effectiveness	The World Bank	http://info.worldbank.org/governance/wgi/index.aspx#home
Graduates in social Science, Business and Law (as % of total graduates)	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=Education%20Statistics
Gross Tertiary Graduation Ratio	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=Education%20Statistics
Health Care Index	Numbeo	http://www.numbeo.com/health-care/rankings.jsp
Homicide Rates	UN Office of Drugs & Crime	https://data.unodc.org/
Human Development Index	UN Development Programme	http://hdr.undp.org
Human Freedom Index	Cato Institute	https://www.cato.org/human-freedom-index
ICT Development Index	United Nations	http://www.itu.int/net4/ITU-D/idi/2016/
Individual Income Tax Rates	KPMG	https://home.kpmg.com/xx/en/home/services/tax/tax-tools-and-resources/tax-rates-online/individual-income-tax-rates-table.html
Innovation Cities Global Index	2ThinkNow Innovation Cities	http://www.innovation-cities.com/
Legatum Prosperity Index	Legatum Institute	http://www.prosperity.com/#!/ranking
Linguistic Diversity	Ethnologue	http://www.ethnologue.com/statistics/country
Lloyd's City Risk Index 2015-2025	Lloyd's	http://www.lloyds.com/cityriskindex/locations
Number of High Net Worth Individuals	Capgemini	https://www.worldwealthreport.com/
Number of International Association Meetings	World Economic Forum	http://reports.weforum.org/travel-and-tourism-competitiveness-report-2015/
OECD Country Risk Classification	OECD	http://www.oecd.org/tad/xcred/crc.htm
Citizens Domestic Purchasing Power	UBS	http://www.ubs.com/1/e/wealthmanagement/wealth_management_research/prices_earnings.html
Open Data Barometer	The World Wide Web Foundation	http://opendatabarometer.org/?_year=2016&indicator=ODB
Open Government	World Justice Project	http://worldjusticeproject.org/rule-of-law-index
Personal Tax Rates	OECD	http://www.oecd.org/tax/tax-policy/tax-database.htm
Political Stability and Absence of Violence/Terrorism	The World Bank	http://info.worldbank.org/governance/wgi/index.aspx#home
Press Freedom Index	Reporters Without Borders (RSF)	http://en.rsf.org/
Prime International Residential Index	Knight Frank	http://www.knightfrank.com/wealthreport
Regulatory Quality	The World Bank	http://info.worldbank.org/governance/wgi/index.aspx#home
Tax as Percentage of GDP	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

Top Tourism Destinations	Euromonitor	http://blog.euromonitor.com/2016/01/top-100-city-destinations-ranking-2016.html
Visa Restrictions Index	Henley Partners	http://www.henleyglobal.com/citizenship/visa-restrictions/
Wage Comparison Index	UBS	http://www.ubs.com/1/e/wealthmanagement/wealth_management_research/prices_earnings.html
World Talent Rankings	IMD	http://www.imd.org/wcc/news-talent-report/

Infrastructure Factors		
Instrumental Factor	Source	Website
Crude oil input to refineries	Enerdata Statistical Yearbook	https://yearbook.enerdata.net/download/
Global Competitiveness Index	World Economic Forum	http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm
JLL Real Estate Transparency Index	Jones Lang LaSalle	http://www.jll.com/greti/Pages/Rankings.aspx
Liner Shipping Connectivity Index	The World Bank	http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
Logistics Performance Index	The World Bank	http://lpi.worldbank.org/international/global
Metro Network Length	Metro Bits	http://mic-ro.com/metro/table.html
Networked Readiness Index	World Economic Forum	http://reports.weforum.org/global-information-technology-report-2016/
Networked Society Index	Ericsson	https://www.ericsson.com/res/docs/2016/2016-networked-society-city-index.pdf
Quality of Domestic Transport Network	World Economic Forum	http://reports.weforum.org/travel-and-tourism-competitiveness-report-2015/
Quality of Roads	World Economic Forum	http://reports.weforum.org/travel-and-tourism-competitiveness-report-2015/
Railways per Land Area	CIA	https://www.cia.gov/library/publications/the-world-factbook/rankorder/2121rank.html
Roadways per Land Area	CIA	https://www.cia.gov/library/publications/the-world-factbook/rankorder/2085rank.html
Telecommunication Infrastructure Index	CIA	https://www.cia.gov/library/publications/the-world-factbook/rankorder/2085rank.html
TomTom Traffic Index	TomTom	https://www.tomtom.com/en_gb/trafficindex/list?citySize=LARGE&continent=ALL&country=ALL

Annex 2: Mathematical Model used in the creation of the Global Green Finance Index

1. This annex describes the model used to create the Global Green Finance Index.
2. The core methodology for creation of the index can be broken down into two parts:
 - i. Predicting assessment ratings for financial centres not rated by the survey respondent using support vector machine (SVM); and
 - ii. Combining the assessments submitted by survey respondents and the predicted assessments to obtain a comprehensive assessment score for each financial centre under consideration.

Prediction using Support Vector Machine (SVM)

3. Our training dataset consists of the instrumental factors data (attributes) and assessment scores (the 'label' with discrete integral values ranging from 1-10) for all financial centres being evaluated through the survey.
4. The test dataset consists of instrumental factor data for centres which have not been rated by our survey respondents.
5. The model is 'trained' on the training dataset to predict assessment rating values for all the financial centres in our test dataset.

Implementation

6. We use an R package called 'kernlab' to run 'ksvm' which is one of the many SVM methods available to 'train' the model. It supports classification, regression, native multi-class classification and bound-constraint SVM formulations. Ksvm supports class-probabilities output and confidence intervals for regression.
7. This is an instance of multiclass-classification with $k = 10$ classes (since our assessment scores can have discrete values ranging from 1-10). Ksvm uses the 'one-against-one' approach in which $\frac{k(k-1)}{2}$ binary classifiers are trained; the appropriate label is found by voting scheme.

Usage

8. The model we use can be described in the following string:

```
Model<-ksvm(CityAssessment~, data=Train, type= "C-svc", kernel="vanilladot",  
C= 0.1, prob.model=TRUE)
```

Parameter description

9. In this string:

- *CityAssessment*: the response vector with one label for each row of x /observation (that is, the assessment score for each financial centre given by the survey respondent);
- *data*: we 'train' our prediction model on the training dataset;
- *type: C-svc (C-classification)*: since the labels we are predicting have discrete values we use classification (classification is the problem of identifying to which discrete valued label a test observation belongs to);
- *kernel: vanilladot (linear kernel)*: this represents the kernel function used in training and predicting. The training dataset has several attributes (Instrumental Factors) which present a non-linear 'feature space' for prediction. Linear kernel transforms non-linear feature space into linear one for better separability (classification);
- *C: 0.1*: this defines the cost of constraint violation representing the 'C'-constant of regularisation term in Lagrange formulation. The regularization parameter (C) serves as a degree of importance that is given to miss-classifications. The SVM poses a quadratic optimization problem that looks for maximizing the margin between both classes and minimizing the amount of miss-classifications. However, for non-separable problems, to find a solution, the miss-classification constraint must be relaxed, and this is done by setting the mentioned "regularisation";
- *prob.model: true*: set to 'TRUE' builds a model for calculating class probabilities. Fitting is done on output data created by performing a 3-fold cross-validation on the training data and a sigmoid function is fitted on the resulting decision values f .

10. To obtain the class probabilities for our multi-class classification model just computed, we set the parameter type to 'probabilities' in the 'predict' function in R to

```
Pred<-predict(Model, Test, type="probabilities")
```

This gives probability value for each assessment score value (1-10) an individual might give a centre. The expected value ($\sum p_i x_i$) calculated for each row in this dataset gives us the assessment rating values for the observations (financial centres) in the test dataset.

Index Creation

11. The second step in the creation of the index consists of:

- calculation of interim weighted scores using probabilities obtained through the SVM process; and
- combining the assessment scores used in our training data with predicted assessments.

Interim weighted score calculation

12. As further editions of the index are produced, we intend to predict assessment ratings for all financial centres under consideration and only consider questionnaire assessments submitted in past two years. To account for the age of the data, we will multiply the assessment ratings calculated for financial centres in the test dataset by log value of time (calculated from the date the survey was submitted by respondent) to calculate a weighted assessment rating for each centre. The more recent assessments receive a higher weight than older ones.
13. Where a new financial centre is added to the questionnaire, predictions created for that centre based on questionnaire responses given before its inclusion will be multiplied by 0.85 to reduce the weighting of that assessment. Responses made after the date of the centre's inclusion will be given full weighting.
14. Similarly, the assessment scores in our training dataset (assessments for centres given by the survey respondents) are multiplied by discounted log value of time.

Combining the assessments used in our training data with predicted assessments

15. The final step is calculating a weighted mean score for each financial centre by summing all the weighted ratings (from training and test dataset) calculated for that financial

centre and dividing by the sum of log discount. This score value is multiplied by 100 to get the financial centre rating. According to the ratings we index the financial centres and generate individual rankings.

References:

1. <https://cran.r-project.org/web/packages/kernlab/kernlab.pdf>
2. https://escience.rpi.edu/data/DA/svmbasic_notes.pdf