**National ‘fair shares’ in reducing greenhouse gas emissions within the principled framework of international environmental law**

**Supplementary material**

Lavanya Rajamani1, Louise Jeffery2, Niklas Höhne2,3, Frederic Hans2, Alyssa Glass 1, Gaurav Ganti4, Andreas Geiges4

1: Faculty of Law, University of Oxford, UK

2: NewClimate Institute, Germany

3: Environmental Systems Analysis Group, Wageningen University, The Netherlands

4: Climate Analytics, Berlin, Germany

This document both provides additional supporting methodological description and describes additional results that are provided in tabular format.

1. Supplementary explanation – Dynamic interplay between principles
2. Supplementary quantitative methods
3. NDC analysis
4. Quantitative effort sharing results
5. Sensitivity of results to assumptions

Full references to the equity literature used in the quantitative analysis can also be found at the end of the document.

1. **Supplementary explanation – Dynamic interplay between principles**

Sustainable development is inextricably linked with other principles relating, inter alia, to:

* harm prevention, since sustainable development derives concrete content from norms of environmental protection (International Court of Justice, 1997, para. 140, 2010, pp. 75–77) ;
* equity, since, by definition, sustainable development requires a balance between equity across and within generations;
* common but differentiated responsibilities, as sustainable development captures a concern with equity within the same generation;
* Special circumstance, as vulnerability intersects with economic disadvantage and reflects levels of social and economic development; and,
* international cooperation, as sustainable development is best promoted in a supportive international economic system (United Nations, 1992, Principles 9 and 12; UNFCCC, 1998, Article 12).

The principle of special circumstances is closely linked to other principles, including:

* sustainable development, as discussed above;
* common but differentiated responsibilities, since it also provides criteria for differentiating between states;
* equity, in so far as prioritizing the needs of least developed and vulnerable states enhances equity within and between generations; and,
* international cooperation, as the loss and damage that accompanies vulnerability is a recognized subject of international cooperation (UNFCCC, 2015, Article 8)

The principle of common but differentiated responsibilities is closely linked with other principles, including:

* sustainable development, as indicated above;
* special circumstances, as indicated above;
* international cooperation, since the ‘common concern’ element of the common but differentiated responsibilities principle requires individual, cooperative, and collective efforts in service of the environmental goal; and,
* equity, since the common but differentiated responsibilities principle addresses intra-generational equity.

The principle of equity, given its open-ended nature, is closely linked with other principles, including:

* Sustainable development, in its expression as ‘equitable access to sustainable development;
* Common but differentiated responsibilities, since it overlaps with intra-generational equity;
* Special circumstances, as indicated above; and,
* International cooperation, as the provision of support, financial, technological and others to developing states, is an expression of equity.

1. **Supplementary quantitative methods**

## *Literature data*

The literature database for national emission levels based on effort sharing builds off that developed by Höhne et al. (2014) and used in the IPCC WGIII AR5 report (Clarke *et al.*, 2014) and used in the Climate Action Tracker (Ganti *et al., in prep*).

The accompanying supplementary excel file (Equity\_Literature\_Overview – 31-3-2021.xlsx) provides an overview of the equity literature that was considered and used in this study. There we indicate which studies, or allocation regimes within a study, are included in the overall dataset with an explanation of why some studies were not included.

All literature data is harmonised to up to date historic emissions data in the base year of the study on a country-by-country basis.

Since the 2014 Höhne et al. publication, the database has been curated to:

* Add additional studies that have been published since the AR5 report.
* Remove some studies that have target pathways that are no longer consistent with the long-term temperature goal.
* Replaced studies that have been updated with newer versions.
* Removed studies that are based on energy CO2 only.
* Remove some country specific datapoints from individual studies:
  + that include a large component (>20%) of LULUCF emissions in historic data
  + where historic data in the study deviates substantially from up-to-date reference historical emissions

These datapoints are removed because the harmonisation process cannot resolve the discrepancies between historic datasets which leads to results that are not consistent with the underlying equity principle, such as negative allocations that were positive in the original study.

Full references to all studies considered can be found at the end of this document and links to the studies in the excel file.

## *Supplementing data in categories with few datapoints*

As with the previous version of the dataset, the allocation regimes from all studies are separated into categories according to the type of approach that is used. The categories are: Responsibility, Capability-Need, Equality, Responsibility-Capability-Need, Equal cumulative per capita emissions, Capability-Costs, and Staged.

The equity literature does not cover these categories evenly, particularly for smaller economies. For purposes of this analysis, the dataset is therefore supplemented with additional datapoints in those categories. A version of the supplementary dataset is currently used in the Climate Action Tracker and is described in (Rocha *et al.*, 2017). An updated version, used here, is described in a forthcoming manuscript (Ganti *et al.*, *in prep*).

1. **NDC analysis**

The accompanying .csv file (NDC\_Database\_IntEnvLawPrinciples\_10-06-21.csv) contains the results of the NDC analysis.

1. **Quantitative effort-sharing results**

The accompanying .csv file (Intl\_Env\_Law\_results\_all\_countries - 31-3-2021.csv) contains results for all states, in addition to those G20 states shown in the main manuscript.

Emissions allocations in 2030 under different conditions are given as both absolute values (MtCO2e) and as a percentage of 2010 emissions. For each of the following conditions, explained in the main manuscript, a range is given.

* Below 1.8°C (with 66% probability)
* Below 1.5°C in 2100 and peak below 1.7°C
* International law fair-share
* Full equity literature range

Historic emissions in 2010 according to the PRIMAPhist dataset (Gütschow *et al.*, 2016, 2019) are also provided for reference and were used for quantifying the percent reductions relative to 2010.

From this dataset, one can see that the results for small countries can be quite extreme, which is a consequence of three components. First, that the low absolute emissions for these countries mean that a small absolute change can still translate into a large % change. Second, that there tend to be fewer data points for these countries meaning that the results are much more sensitive to outliers or spurious data points due to errors in historic emissions, for example. In addition, small countries usually have very special circumstances and can be very different to the average of all countries, which means that different approaches will lead to very different results. We recommend that the results are with caution for states with very low emissions (< 10 MtCO2e / year).

1. **Sensitivity of results to assumptions**

*1. The global emissions limit*

In the main paper we present and justify results derived from global emissions levels associated with 1.8°C (>66% probability) and 1.5°C (>66% probability) in 2100. The same methodology can be used to derive consistent state emissions for other global emissions totals, which one may wish to do to understand the implications of different warming limits or to understand the impact of the assumptions regarding LULUCF and international aviation and shipping.

Figure S1 (below) shows how a change in the 2030 global emissions limit would translate into the emissions allocated to each country. The % change in global emissions is shown for ‘World’ on the right-hand side and can be used to identify the corresponding changes for individual countries. Absolute global emissions (excluding LULUCF and bunkers) corresponding to each level in the range are listed in Table 1.

|  |  |
| --- | --- |
| **% from bottom of range** | **Global Emissions (excl. LULUCF and bunkers)  [Gt CO2e]** |
| 100 | 63.6 |
| 90 | 57.9 |
| 80 | 52.2 |
| 70 | 46.5 |
| 60 | 40.8 |
| 50 | 35.2 |
| 40 | 29.5 |
| 30 | 23.8 |
| 20 | 18.1 |
| 10 | 12.5 |
| 0 | 6.8 |

Table S1 Global emissions corresponding to % through equity ranges.

The consequences for different countries primarily depend on the size of the range for each country – a larger total range translates into a larger change in national emissions for the same change in total emissions. Of the G20 countries, the largest differences are found for India, Indonesia, and the EU members. Smaller changes are found for Canada, Australia, and Russia.

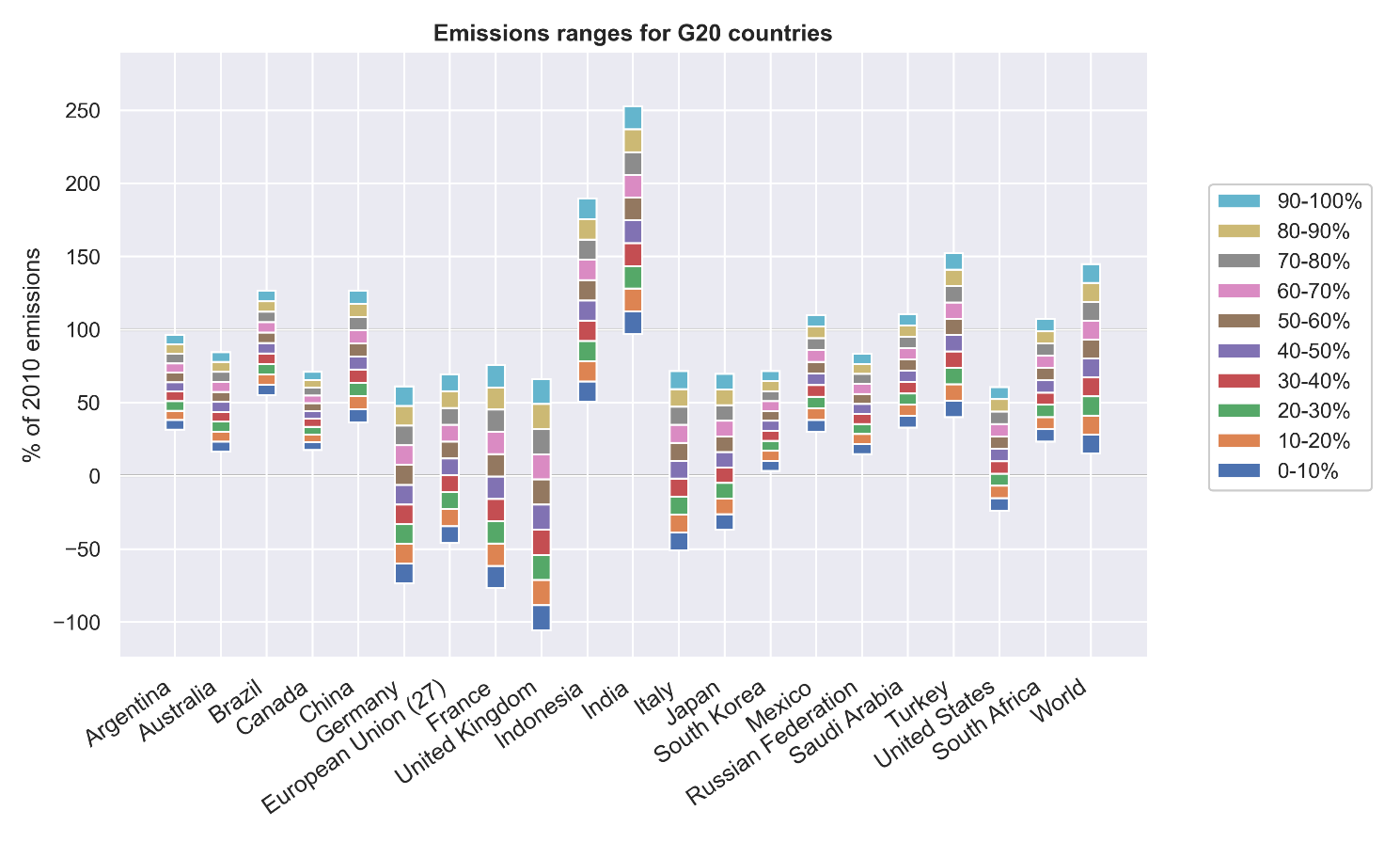


Figure S Relationship between national results and the targeted global emissions levels in 2030 with respect to the fair share range compatible with principles of international environmental law. Values here are expressed in % of 2010 emissions. See Table S1 for the corresponding global emissions in absolute terms. As an example, reducing global emissions (excl. LULUCF and bunkers) by 2030 to 50% of 2010 emissions would put ‘World’ emissions in the green band. Corresponding equal levels through the range for each country implies also reaching the same green band.

2. *Sensitivity to equality studies*

Of the various principles and indicators considered, we found that equality, particularly when expressed as equal per capita emissions, is less well founded in principled of international environmental law than some of the other approaches. A sensitivity test was therefore performed to check the impact of the literature data on equality approaches on the results. For that test all studies or data points that relied on a form of equal per capita emissions (e.g. contraction and convergence, common but differentiated convergence) were removed.

The results for individual G20 countries consistent with the 1.5C or well below 2C level are largely unaffected by the removal of these studies. Differences are mostly 1-2% of 2010 emissions levels, with the largest difference being 6% upwards (India).

The differences are, in most cases, minimal because the equal per capita results tend to (1) lie in the middle of the distribution and (2) are moderately spread out. They therefore do not affect the ends of the ranges or the shares between countries as much as some other analyses (such as cost-optimisation). As for all sensitivity tests, the countries that are far from the average are most affected, in this case India, with the lowest per capita emission of the G20 countries.

For more discussion on how data selection and availability impact the results of the methods, please see Ganti et al., (*in prep*).

**References cited above**

Clarke, L. *et al.* (2014) *Assessing Transformation Pathways*, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Asessment Report of the IPCC.* Edited by O. Edenhofer et al. Cambridge, UK and New York, NY, USA: Cambridge University Press.

Ganti, G. *et al.* (in prep) ‘Fair National Greeenhouse Gas Reduction Targets Under Multiple Equity Perspectives - A Synthesis Framework’, *under revision*.

Gütschow, J. *et al.* (2016) ‘The PRIMAP-hist national historical emissions time series’, *Earth System Science Data*, 8(2), pp. 571–603. doi: 10.5194/essd-8-571-2016.

Gütschow, J. *et al.* (2019) ‘The PRIMAP-hist national historical emissions time series (1850-2017). V. 2.1.’ Available at: http://doi.org/10.5880/PIK.2019.018.

Höhne, N., den Elzen, M. and Escalante, D. (2014) ‘Regional GHG reduction targets based on effort sharing: a comparison of studies’, *Climate Policy*, 14(1), pp. 122–147. doi: 10.1080/14693062.2014.849452.

International Court of Justice (1997) *The Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*. Available at: https://www.icj-cij.org/public/files/case-related/92/092-19970925-JUD-01-00-EN.pdf (Accessed: 8 December 2020).

Rocha, M. *et al.* (2017) *Climate Analytics equity methodology*. Available at: https://climateanalytics.org/media/ca\_equity\_methodology.pdf.

UNFCCC (1998) *Kyoto Protocol to the United Nations Framework Convention on Climate Change: UNFCCC. Entered into force 2005.* Bonn. Available at: http://unfccc.int/resource/docs/convkp/kpeng.pdf.

UNFCCC (2015) *Paris Agreement - Decision 1/CP.21: Adoption of the Paris Agreement. Doc. FCCC/CP/2015/10/Add.1. Entered into force 2016.* Paris. Available at: http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf [accessed on 9 October 2017].

United Nations (1992) *The Rio Declaration on Environment and Development*. Rio de Janeiro. Available at: http://www.unesco.org/education/pdf/RIO\_E.PDF (Accessed: 21 November 2018).

**Equity Literature References**

Baer, P. et al. (2008) The Greenhouse Development Rights framework. The right to development in a climate constrained world. Berlin. Available at: http://www.ecoequity.org/docs/TheGDRsFramework.pdf.

van den Berg, N. J. et al. (2020) ‘Implications of various effort-sharing approaches for national carbon budgets and emission pathways’, Climatic Change, 162(4), pp. 1805–1822. doi: 10.1007/s10584-019-02368-y.

Berk, M. M. and den Elzen, M. G. J. (2001) Options for differentiation of future commitments in climate policy: how to realise timely participation to meet stringent climate goals?, Climate Policy. Available at: http://www.sciencedirect.com/science/article/pii/S1469306201000377?np=y.

Bode, S. (2004) Equal emissions per capita over time - A proposal to combine responsibility and equity of rights for post-2012 GHG emission entitlement allocation, European Environment. doi: 10.1002/eet.359.

Böhringer, C. and Welsch, H. (2006) Burden sharing in a greenhouse: Egalitarianism and sovereignty reconciled, Applied Economics. doi: 10.1080/00036840500399453.

Bows, A. and Anderson, K. (2008) Contraction and convergence: an assessment of the CC Options model, Climatic Change. doi: 10.1007/s10584-008-9468-z.

Chakravarty, S. P. et al. (2009) Sharing global CO2 emission reductions among one billion high emitters, Proceedings of the National Academy of Sciences USA. Available at: http://www.pnas.org/content/106/29/11884.full.pdf.

Criqui, P. et al. (2003) Greenhouse gas reduction pathways in the UNFCCC Process up to 2025 - Technical Report. Grenoble; France. Available at: http://ec.europa.eu/clima/policies/package/docs/pm\_techreport2025\_en.pdf.

Edenhofer, O. et al. (2010) The economics of low stabilization: Model comparison of mitigation strategies and costs, Energy Journal. doi: 10.5547/ISSN0195-6574-EJ-Vol31-NoSI-2.

den Elzen, M. G. J. et al. (2007) ‘Differentiation of countries’ future commitments in a post-2012 climate regime: An assessment of the “South–North Dialogue” Proposal’, Environmental Science & Policy, 10(3), pp. 185–203. doi: 10.1016/j.envsci.2006.10.009.

den Elzen, M. G. J. et al. (2013) ‘Reduction targets and abatement costs of developing countries resulting from global and developed countries’ reduction targets by 2050’, Mitigation and Adaptation Strategies for Global Change, 18(4), pp. 491–512. doi: 10.1007/s11027-012-9371-9.

den Elzen, M. G. J., Höhne, N. and Moltmann, S. (2008) The Triptych approach revisited - A staged sectoral approach for climate mitigation, Energy Policy. Available at: http://www.sciencedirect.com/science/article/pii/S0301421507005289#.

Den Elzen, M. G. J. and Lucas, P. L. (2005) The FAIR model: A tool to analyse environmental and costs implications of regimes of future commitments, Environmental Modeling and Assessment. doi: 10.1007/s10666-005-4647-z.

den Elzen, M. G. J., Lucas, P. L. and van Vuuren, D. P. (2008) Regional abatement action and costs under allocation schemes for emission allowances for achieving low CO2-equivalent concentrations, Climatic Change. Available at: https://doi.org/10.1007/s10584-008-9466-1.

den Elzen, M. G. J., Lucas, P. and van Vuuren, D. P. (2005) Abatement costs of post-Kyoto climate regimes, Energy Policy. Available at: http://www.sciencedirect.com/science/article/pii/S0301421504001211#.

den Elzen, M. G. J. and Meinshausen, M. (2006) Meeting the EU 2°C climate target: global and regional emission implications, Climate P. Bilthoven; The Netherlands. Available at: http://www.rivm.nl/bibliotheek/rapporten/728001031.pdf.

Groenenberg, H., Blok, K. and van der Sluijs, J. P. (2004) Global Triptych: a bottom-up approach for the differentiation of commitments under the Climate Convention, Climate Policy. doi: 10.1080/14693062.2004.9685518.

Hof, A. F. and Den Elzen, M. G. J. (2010) The effect of different historical emissions datasets on emission targets of the sectoral mitigation approach Triptych, Climate Policy. doi: 10.3763/cpol.2009.0649.

Höhne, N. and Moltmann, S. (2008) Distribution of emission allowances under the Greenhouse Development Rights and other effort sharing approaches. Berlin. Available at: http://www.boell.de/downloads/ecology/GDR\_report\_for\_HBS\_2008-10-13\_endv\_2.pdf.

Höhne, N. and Moltmann, S. (2009) Sharing the effort under a global carbon budget. Cologne. Available at: http://www.ecofys.com/files/files/wwf\_ecofyscarbonbudget.pdf.

Holz, C., Kartha, S. and Athanasiou, T. (2018) ‘Fairly sharing 1.5: national fair shares of a 1.5 °C-compliant global mitigation effort’, International Environmental Agreements: Politics, Law and Economics, 18(1), pp. 117–134. doi: 10.1007/s10784-017-9371-z.

Jacoby, H. D. et al. (2008) Sharing the Burden of GHG Reductions. Massachusetts; USA. Available at: http://dspace.mit.edu/handle/1721.1/44625.

Jayaraman, T., Kanitkar, T. and Dsouza, M. (2011) Equitable access to sustainable development: An Indian approach, Equitable access to sustainable development: Contribution to the body of scinetific knowledge. A paper by experts from BASIC countries. Edited by H. Winkler et al. Available at: http://gdrights.org/wp-content/uploads/2011/12/EASD-final.pdf.

Knopf, B. et al. (2009) The economics of low stabilisation: Implications for technological change and policy. 1st edn, Making Climate Change Work for Us: European Perspectives on Adaptation and Mitigation Strategies. 1st edn. Edited by M. Hulme. Cambridge: ADAM synthesis book, Cambridge University Press. Available at: https://www.pik-potsdam.de/members/knopf/publications/knopf\_chapter11.pdf.

Knopf, B. et al. (2012) A global carbon market and the allocation of emission rights, Climate Change, Justice and Sustainability: Linking Climate and Development Policy. Edited by O. Edenhofer et al. Springer. doi: 10.1007/978-94-007-4540-7.

Kriegler, E. et al. (2014) Can we still meet 2°C with global climate action? The LIMITS study on implications of Durban Action Platform scenarios, LIMITS. Available at: http://www.feem-project.net/limits/docs/02. cce limits special issue\_paper1.pdf.

Kuntsi-Reunanen, E. and Luukkanen, J. (2006) Greenhouse gas emission reductions in the post-Kyoto period: Emission intensity changes required under the ‘contraction and convergence’ approach, Natural Resources Forum. doi: 10.1111/j.1477-8947.2006.00119.x.

Miketa, A. and Schrattenholzer, L. (2006) Equity implications of two burden-sharing rules for stabilizing greenhouse-gas concentrations, Energy Policy. Available at: http://www.sciencedirect.com/science/article/pii/S0301421504002861#.

Nabel, J. E. M. S. et al. (2011) Decision support for international climate policy - The PRIMAP emission module, Environmental Modelling and Software. Elsevier Ltd. doi: 10.1016/j.envsoft.2011.08.004.

Onigkeit, J., Anger, N. and Brouns, B. (2009) Fairness aspects of linking the European emissions trading scheme under a long-term stabilization scenario for CO2 concentration, Mitigation and Adaptation Strategies for Global Change. doi: 10.1007/s11027-009-9177-6.

Pan, X. et al. (2017) ‘Exploring fair and ambitious mitigation contributions under the Paris Agreement goals’, Environmental Science and Policy. Elsevier, 74(March), pp. 49–56. doi: 10.1016/j.envsci.2017.04.020.

Pan, X., Teng, F. and Wang, G. (2014) ‘Sharing emission space at an equitable basis: Allocation scheme based on the equal cumulative emission per capita principle’, Applied Energy. Elsevier Ltd, 113(January), pp. 1810–1818. doi: 10.1016/j.apenergy.2013.07.021.

Peterson, S. and Klepper, G. (2007) Distribution Matters – Taxes vs . Emissions Trading in Post Kyoto Climate Regimes. Kiel; Germany. Available at: https://www.ifw-members.ifw-kiel.de/publications/distribution-matters-taxes-vs-emissions-trading-in-post-kyoto-climate-regimes.

Robiou du Pont, Y. et al. (2017) ‘Equitable mitigation to achieve the Paris Agreement goals’, Nature Climate Change Change, 7(1), pp. 38–43. Available at: http://dx.doi.org/10.1038/nclimate3186.

Vaillancourt, K. and Waaub, J. P. (2004) Equity in international greenhouse gases abatement scenarios: A multicriteria approach, European Journal of Operational Research. doi: 10.1016/S0377-2217(03)00170-X.

van Vuuren, D. P. et al. (2009) Comparison of different climate regimes: the impact of broadening participation, Energy Policy. doi: 10.1016/j.enpol.2009.07.058.

Van Vuuren, D. P. et al. (2010) Low stabilization scenarios and implications for major world regions from an integrated assessment perspective, Energy Journal. doi: 10.5547/ISSN0195-6574-EJ-Vol31-NoSI-7.

WBGU (2009) Solving the climate dilemma: The budget approach. Berlin. Available at: http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/sondergutachten/sn2009/wbgu\_sn2009\_en.pdf.

Winkler, H. et al. (2011) Equitable access to sustainable development: Contribution to the body of scientific knowledge, Contribution to the body of scientific knowledge. Beijing, Brasilia, Cape Town and Mumbai. Available at: http://www.erc.uct.ac.za/Basic\_Experts\_Paper.pdf.