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Environmental, social and governance-efficient frontiers in an emerging market milieu

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Orientation: Environmental, social and governance (ESG) factors have evolved from peripheral significance (2000s) to a leading factor (2022) for many corporates. Most are now assigned ESG grades; which are increasingly scrutinised by investors.

Research purpose: An ideal milieu might involve rewards for responsible firms and penalties for culprits, but in a profit-driven world, this is not always true. Investors demand profitability so some trade-off is required.

Motivation for the study: Recent work to measure and optimise portfolio performance while observing corporate conscientiousness is promising: return/risk profiles comparable to those attained by unconstrained portfolios appear possible.

Research approach/design and method: Portfolio optimisation using Lagrangian calculus. As ESG scores worsen, portfolio performance should be adversely affected, and we then apply – for the first time – these portfolio optimising developments to emerging market corporates.

Main findings: ESG grades have improved over time, with both a statistically significant risk reduction and an increase in returns (the reverse for deteriorating ESG grades). As volatility increases, optimal ESG grades increase slowly as associated Sharpe ratios decrease. This could be due to an option-like reliance of inherent value upon underlying volatility.

Practical/managerial implications: With better knowledge of trends, asset managers who take ESG metrics into account can confidently assert that ESG compliant portfolios can generate healthy risk adjusted returns (Sharpe ratios) and that these values are improving over time.

Contribution/value-add: ESG compliant portfolios have become viable investments while adhering to sensible, responsible investment principles. ESG scores are improving globally, albeit at different rates.

Keywords: portfolio choice; ESG; socially responsible investing; sustainable investing; governance.

Introduction

Orientation

The devastating global economic impact of the coronavirus disease 2019 (COVID-19) pandemic, worrying accounts of corporate negligence and relentlessly accumulating evidence for climate change and its possible impact have all contributed to a growing awareness of individual and collective responsibility. Modern investors are increasingly calling corporations to account, punishing miscreants by reducing holdings in their stock or shunning them completely. To make informed decisions about these tactics, investors – the bulk of whom cannot possibly investigate and assess each potentially investable stock – rely on environmental, social and governance (ESG) scores provided by dozens of ratings providers – five of whom (MSCI, Refinitiv, Sustainalytics, RepRisk and Institutional Shareholder Services [ISS]) currently (2022) dominate the market (Sikochi & Serafeim 2021). Using self-disclosed corporate information (such as board diversity (social score), carbon emissions (environmental score) and safety policies (governance score) and firm's own, often concealed, analysis and algorithms, these providers formulate, synthesise and consolidate results into single ESG scores.

Sustainable investment increasingly relies on these ESG scores, but the investment strategies typically assemble investment portfolios using a ranked list of 'good' (high ESG score) stocks

while ignoring portfolio completeness. Although the field has begun to flourish, literature that investigates sustainable investment asset allocation remains limited and no consolidated best-practice approach has been proposed.

Developing economies are particularly impacted by climate change and perceptions of poor governance. The literature is replete with research, which has repeatedly demonstrated that developing countries are suffering, and will suffer, considerably more than their developed country neighbours from the effects of climate change (Huang & Tian 2021; Kompas, Ha Pham & Nhu Che 2018) and the ongoing toxic effects of poor governance (Kłosowicz 2019; Yahyaoui & Bouchoucha 2021). At the November 2021 COP26 summit in Glasgow, for example, South Africa (the world's 15th largest emitter of carbon dioxide [CO_2]) announced that it had secured commitments for US$8.5 billion in financing from 2022 to 2026 from France, the United Kingdom, Germany, the United States of America and the European Union to help install more clean energy and accelerate the country's transition away from coal power. The funds will also be used to mitigate the impact on workers affected by this transition. South Africa relies overwhelmingly on coal, which supplies 87% of the nation's electricity. This news was welcomed by investors, among others, wishing to capitalise on improved ESG scores and thus a wider universe of appropriate securities from responsible corporations.

Research purpose and objectives

Identifying and implementing an optimal investment solution in a mean-variance framework while heeding additional constraints (i.e. over and above 'traditional' constraints of simultaneously maximising excess returns and minimising associated risk) imposed by the new milieu such as selecting 'optimal' ESG scores for investable securities, remains. This article fills a gap in the literature by augmenting conventional portfolio selection models to embrace ESG constraints specifically for emerging markets where ESG scores are typically low compared with those observed in most developed markets. We aver that most investors still wish to generate risk-return performance obtained from conventional portfolio selection from portfolios constrained by ESG requirements and we find that for emerging economies, portfolio selection for sustainable investment and conventional portfolio selection are characterised by substantially different portfolio weights while achieving comparable levels of risk-adjusted returns. While this result has been demonstrated for developed markets, the results obtained from this research are important for sustainable investments because portfolio weights are the foundation of portfolio selection and investments. Using a sample of component stocks selected from South Africa's Johannesburg Stock Exchange Index from 2008 to 2020, the ESG-constrained efficient frontier and the traditional efficient frontier were found to produce similar levels of risk-adjusted returns, a fortuitous endorsement of sustainable investment.

The remainder of this article is structured as follows. The next section provides an overview of the relevant literature and discusses the limitations and conclusions reached by the relevant authors. A discussion of the data used, and the methodology adopted for this research, is presented in the 'Research design' section, and the 'Results and discussion' section sets out the results obtained and considers possible outcomes derived from these results. The 'Limitations and recommendations' section discusses the limitations of the current work and presents some suggestions for future work, while the 'Conclusion' section summarises the results and observations obtained and concludes the article.

Literature review

Socially responsible investing (SRI) is not a new concept. Centuries-old religious texts (such as the Jewish Torah – specifically the Islamic Quran and the biblical book of Leviticus) stipulate investment principles governing and regulating moral property ownership, fair taxation practices and appropriate interest charges for lenders. US Quakers were forbidden from profiting from the slave trade in the 18th century and US Methodists adopted the practice in the 19th century of only allowing investment in business that inflicted no harm on others (Marable 1974).

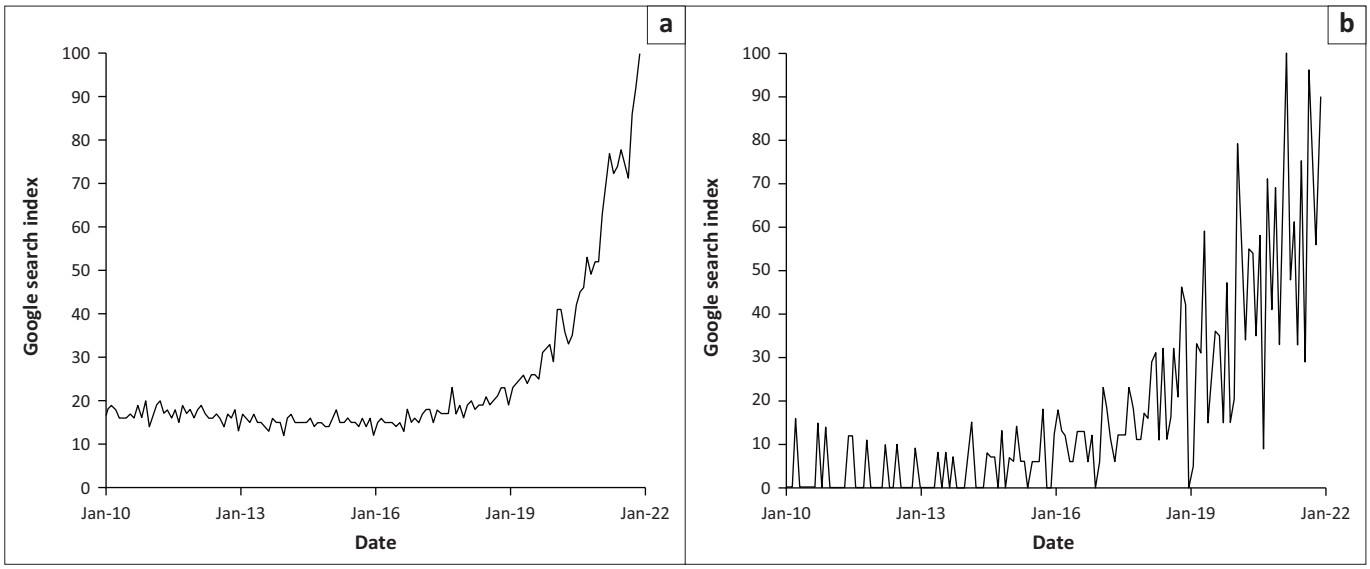
More recently, trade unions in the mid-20th century began to invest in socially relevant enterprises, such as medical facilities and housing developments; opponents of the Vietnam War in the 1970s boycotted companies that manufactured or distributed weapons (Rudd 1979), economic sanctions were imposed on apartheid South Africa in the 1980s, and the 1990s activists encouraged divestment and active avoidance of corporates involved in gambling, alcohol, tobacco, weapons, the 'adult industry' and nuclear energy (Ballestero et al. 2012; Dimson, Marsh & Staunton 2020). The United Nations Environmental Programme (UNEP) – the first organisation to do so – instituted a directive that required brokerage houses to disclose and classify their holdings into three categories: environmental, social and governance (later abbreviated to ESG). While these categories are somewhat broadly defined, some pertinent examples are provided in Table 1 (UNEP FI 2005).

Based on the premise that ESG factors materially affect corporate performance and market value, the rise of ESG assets has been astonishing. Reaching US$22.8 trillion in 2016,

TABLE 1: Examples of environmental, social and governance (ESG) issues – often called the ESG pillars.

Environmental issues	Social issues	Governance issues
Climate change and carbon emissions	Customer satisfaction	Board composition
Air and water pollution	Data protection and privacy	Audit committee structure
Biodiversity	Gender and diversity	Bribery and corruption
Deforestation	Employee engagement	Executive compensation
Energy efficiency	Community relations	Lobbying
Waste management	Human rights	Whistleblower schemes

Source: Dimson, E., Marsh, P. & Staunton, M., 2020, 'Exclusionary screening', *The Journal of Impact and ESG Investing* 1(1), 66–75. https://doi.org/10.3905/jesg.2020.1.1.066



ESG, environmental, social and governance.

FIGURE 1: Google search index for the phrase (a) 'environmental, social and governance' and (b) 'environmental, social and governance investing' since 2010. The value 100 represents maximal interest.

they increased by 34% to US$30.6tn in 2018; then another 14% to US35.0tn in 2020 – roughly one-third of current total global assets under management (Bloomberg Intelligence 2021). Assuming continued 15% annual growth in ESG assets (about half of the average pace calculated over the previous 5 years), ESG assets are projected to exceed US$50tn in assets under management by 2025, US$1tn in ESG ETFs and US$11tn in ESG debt (Global Sustainable Investment Association 2020). Figure 1 shows the extent of public enthusiasm in ESG and ESG investing as revealed by Google trend searches.

The techniques used in sustainable investing have also progressed beyond the early ethics-based approaches, such as negative screening. These novel strategies, while still embracing the significance of ethical concerns, now focus on a more conventional investment aim, that of maximising risk-adjusted returns (Bernow-, Klempner & Magnin 2017). It is erroneous and naïve to assume that investors will simply embrace ESG portfolios brimming with sustainable assets if they involve a trade-off between responsible, philanthropic environmentalism yet significantly diminished returns. Despite the proliferation of traditional analytical approaches being applied to measure ESG portfolio performance and despite data becoming more plentiful and reliable, the literature remains divided over whether high ESG-score portfolios outperform low ESG-score portfolios.[1]

Lower environmental, social and governance scores and higher returns

Hong and Kacperczyk (2009) found that 'sin' stocks generate higher average returns because they are rejected by ethical investors, and instead embraced by mutual and hedge funds (i.e. considerably larger investors). Investors are also willing to accept lower returns from socially responsible investments, a direct reflection of their investment motives which involve social signalling and preferences, rather than superior performance (Barnett & Salomon 2006; Barracchini 2012; Riedl & Smeets 2017). Lee et al. (2020) and Barber, Morse and Yasuda (2021) found that high ESG score venture capital funds generate returns which are 4.7% lower than funds with comparable geography and vintage. Investors were again found to be willing to accept these lower returns as compensation for social impact. Bolton and Kacperczyk (2020) found that companies which produce high CO_2 generate higher-than-average returns possibly because a carbon risk premium is included which compensates investors for the risks associated with future carbon pricing regulations (see also Bilbao-Terol, Arenas-Parra & Cañal 2012).

Higher environmental, social and governance scores and higher returns

Gompers, Ishii and Metrick (2003) found that portfolios which incorporate long stocks with high governance scores (e.g. those exhibiting strong shareholder rights) and those with low governance scores (e.g. those with poor employee satisfaction ratings) outperform the market by 8.5% annually. Core, Guay and Rusticus (2003) further explored Gompers et al.'s (2003) work and found that weak governance firms have worse operating performance and vice versa, which could explain the high market outperformance reported by Gomers et al. (2003, 2009) and Renneboog, Horst and Zhang (2008).

Using an extensive proprietary database of corporate social responsibility engagements with US public companies spanning from 1999 to 2009, Dimson, Karakas and Li (2015) found that those engagements which addressed ESG concerns generated positive abnormal returns. Engaged

1.An ESG score is a metric which reflects a company's performance based on several environmental, social and governance indicators. Generating an ESG score involves evaluating a company's adherence to and observance of these indicators using simple numerical scales and then aggregating these individual scores into a single appraisal. These are then mapped to an ESG rating much like a credit rating is assigned by credit rating agencies. Like credit ratings and the agencies that provide them, ESG ratings and ESG raters employ different approaches, thresholds, and scales and thus different outputs for the same company.

firms concerned about reputational issues and with an enhanced capacity to implement changes were more likely to be engaged and after engagement, accounting performance in the relevant companies improved and better governance led to increased institutional ownership.

Brav, Jiang, Partnoy, & Thomas (2008) found that, for activist funds at around the time of investment announcements, stock prices increased and exhibited abnormal returns of up to 7%. Alok, Kumar & Wermers (2020) found that money managers underweighted holdings in climate-change-affected geographies more than other managers. This was attributed to the psychological tendency to overestimate severe event probabilities in proportion to their proximity and emotional significance.

Friede, Busch and Bassen (2015) undertook a comprehensive review of primary research on the relationship, if any, between ESG criteria and corporate financial performance. They found that 90% of studies observed a positive ESG–corporate finance performance relation and that most studies reported positive findings. The positive ESG impact on corporate finance performance appeared to be stable over time.

Choi, Gao and Jiang (2020) found that investors reduced holdings of high emission companies after higher-than-average seasonal temperatures and that – after abnormally hot periods – high carbon intensity stocks underperform low carbon emission stocks.

Interest in ESG investing in emerging markets is also widespread and constantly gaining traction (Cole et al. 2020), although caution is frequently advised because of poor non-financial disclosure and a lack of fundamental research which typify these geographies (Chauhan & Kumar 2018; Mobius & Ali 2021).

Limited work has also been conducted on South African ESG investment. Johnson, Mans-Kemp and Erasmus (2019) investigated the relationship between ESG scores and corporate financial performance measures. McCallum and Viviers (2020) explored key barriers (as well as potential opportunities) to impact investment in an emerging market, and Johnson (2020) connected ESG disclosure to South African firms' capital costs. While these works are relevant and fill a gap in emerging market ESG literature, they did not assess empirical South African ESG performance, and ESG portfolio optimisation in an emerging market milieu was outside their ambits.

The environmental, social and governance-efficient frontier

Despite the often-inconclusive evidence that investment in ESG stocks generate superior returns, ESG investing remains immensely popular among institutional and private investors, with no signs of abating. It remains, however, an evolving field. No universally agreed process has been devised which optimally combines profit-maximising metrics with ESG ones.

Méndez-Rodríguez et al. (2013) proposed a flexible approach to measuring mutual funds' social responsibility score considering different dimensions and strategies of SRIs. Efficient frontiers corresponding to different SRI strategies and dimensions were plotted and the results show that including SRI constraints in the optimisation framework shifts the efficient frontier to the southeast in mean–variance space. Thus, for the same return (as portfolios on the traditional efficient frontier) the risk (on the ESG-constrained efficient frontier) tends to be greater as the level of social responsibility increases.

Beiting, Ioannou and Serafeim (2014) found that firms with better corporate social responsibility performance faced considerably lower capital constraints. No attempt was made to minimise capital or maximise risk-adjusted returns. Chen and Mussalli (2020) introduced an ESG investment framework which optimally collates the dual objectives of sustainability performance and α (excess market returns). While this work is important, we wished to explore optimal ESG risk-adjusted returns, not only the maximisation of α.

Qi and Li (2020) also extended the traditional portfolio selection model by imposing ESG constraints, computed the efficient frontier and found that the ESG-constrained frontier's portfolio weights all lie on a ray (half line). The authors showed that portfolios on the ESG-constrained frontier and those which constitute the traditional efficient frontier comprise substantially different portfolio weights. Because portfolio weights are the foundation of asset selection and portfolio composition, this result is important for sustainable investments. Using component stocks of the Dow Jones Industrial Average Index from 2004 to 2013, Qi and Li (2020) found that the ESG-constrained and traditional efficient frontiers were similar (i.e. both occupied very similar loci in mean-variance space) which demonstrated that investors can still obtain the risk-return profile of (or very similar to) traditional efficient portfolios after imposing strong ESG requirements, despite the considerable differences in portfolio weights.

Utz et al. (2014) and Pedersen, Fitzgibbons and Pomorski (2020) attempted to address this issue by installing an equilibrium asset pricing model with ESG preferences and then deriving an ESG-efficient frontier for use by investors to invest in stocks based on risk-adjusted performance and ESG scores. The authors found that optimal portfolios could be generated by combining the minimum variance portfolio, the risk-free asset, the maximum Sharpe ratio (SR) (optimal risk-adjusted) portfolio, and a novel 'ESG-tangency' portfolio, that is, analogous to the maximum SR portfolio on the traditional efficient frontier. Gupta, Mehlawat and Saxena (2013) and Pedersen et al. (2020) found that ESG portfolios benefit investors as they are used to update expectations of returns and risk which in turn raises the efficient frontier.

TABLE 2: Data summary by country and market sector.

Marketsector Country	Education	Materials	Cyclicals	Energy	Financials	Industrials	Technology	Total
Brazil	-	-	4	1	9	-	-	14
Caymans	-	-	-	-	-	-	1	1
Chile	-	-	1	-	3	-	-	4
China	4	-	30	1	54	7	54	150
Colombia	-	-	-	-	2	-	-	2
Czech Rep	-	-	-	-	2	-	-	2
Egypt	-	-	-	-	1	-	-	1
Greece	-	-	2	-	-	-	-	2
Hong Kong	1	-	3	-	3	-	3	10
India	-	1	10	-	18	-	6	35
Indonesia	-	-	1	-	4	-		5
South Korea	-	-	9	-	14	-	8	31
Kuwait	-	-	-	-	4	-	-	4
Luxembourg	-	-	-	-	1	-	1	2
Malaysia	-	-	1	-	7	-	-	8
Mexico	-	-	-	-	2	-	-	2
Pakistan	-	-	-	-	2	-	-	2
Peru	-	-	-	-	1	-	-	1
Philippines	-	-	1	-	3	-	-	4
Poland	-	-	1	-	4	-	-	5
Qatar	-	-	-	-	5	-	-	5
Russia	-	-	-	-	2	-	-	2
Saudi Arabia	-	-	1	-	10	1	-	12
Singapore	-	-	1	-	-	-	-	1
South Africa	-	-	2	-	9	-	1	12
Taiwan	-	-	6	-	17	1	36	60
Thailand	-	-	-	-	2	-	-	2
Turkey	-	-	1	-	5	-	-	6
UAE	-	-	-	-	4	-	-	4
Total	**5**	**1**	**74**	**2**	**188**	**9**	**110**	**389**

Source: Refinitiv, 2021, *An overview of Environmental, Social and Corporate Governance – ESG,* viewed 15 August 2021, from https://www.refinitiv.com/en/financial-data/company-data/esg-data

However, a cost arises from investor's pursuit of ESG preferences: they leave the traditional efficient frontier and do not obtain optimal SR portfolio returns or risk.

Research design

Research approach

The data comprised a sample of some 389 global emerging economy stocks grouped into seven business sectors (financials, industrials, basic materials, energy, consumer cyclicals, technology, and academic and educational services), sourced from Reuters *Refinitiv* database (Refinitiv 2021) and are summarised in Table 2.

While several ESG databases exist, *Refinitiv* was selected as it offers one of the most comprehensive ESG databases in the industry covering over 80% of global market capitalisation, providing details of more than 450 different ESG metrics over two decades, since 2002. This sample was used to ascertain broad insights into emerging economy ESG trends and patterns. A smaller sample comprising 12 South African stocks from three economic sectors, namely, financials (banks, insurance and reinsurance agencies, and asset managers), consumer cyclicals (retailers) and technology (software and IT services, Internet providers and mobile telecommunications) was used to focus on a single emerging economy's ESG evolution. Like most other countries, South African corporate ESG data only date from 2007, so the timespan used was 2007–2020 with an annual sampling frequency (at this stage) much like the reporting of credit rating agency grades. Several institutions have advocated for years for a more frequent assessment and reporting of ESG data (CFA Institute 2019) and as a direct result, ESG information is now a regular feature of quarterly earnings reports (AFME 2021).

The ESG information provided include, on a 0 – 100 numeric scale, an ESG score, an ESG controversies overlay, a combined ESG score and the mappings of these scores to grades on an A – D scale (with additional '±' notching identifiers). Environmental, social and governance scores provide a comprehensive evaluation of a company's ESG performance based on publicly available, reported information covered in the ESG pillars (see Table 1) with an ESG controversies overlay. The function of the ESG controversy overlay is based on 23 ESG controversy topics and captured from global media reports, and its function is to discount ESG performance scores based on negative media reporting. Such commentary increases the impact of material ESG controversies in the overall ESG score. If scandals occur, the affected company is penalised, which affects their overall ESG score and grading. Negative event impacts may be dragged into subsequent years if new developments related to the negative event occur, such as lawsuits, rolling legislation disputes or fines. The overall ESG score is determined as the weighted average of the two

component scores per fiscal period, with recent controversies reflected in the latest complete period. To account for this, only the overall ESG score was used in this work. We did not separate and independently investigate the individual components of the overall ESG score, mainly because controversy scores are relatively recent additions, so using only these would have constrained the somewhat limited data set even more. Note that different ESG scales, ranges and score methodologies are used by different ESG data providers.

Having selected the ESG-scored corporates, weekly share prices were assembled over the relevant period (as far back as 2007 in some cases). These share prices were then used to calculate share returns, volatility, portfolio variance-covariance matrices (where relevant) and SRs. These data were again gathered from Refinitiv (2021). Weekly risk-free rates (90-day rates of South African treasury securities) were sourced from the St Louis Federal Reserve Database (2021).

Research method

Efficient frontier

This section presents the formulae required to plot the efficient frontier and to determine the portfolios analysed in this work. The equations are valid for the following conditions:

- Short sales are allowed.
- Portfolios are fully invested, that is, the portfolio weights sum to 1.

The notation from Roll (1992) and Jorion (2003) was used with minor adaptations. The equations presented are primarily in matrix notation and therefore some definitions are provided before proceeding.

Portfolios on the efficient frontier have an expected return $\left(\mu^{U}_{frontier}\right)$ and variance $\left(\sigma^{U}_{frontier}\right)^2$ calculated, respectively, using:

$$\mu^{U}_{frontier} = \boldsymbol{w}^{U'}\boldsymbol{E} \qquad \text{[Eqn 1]}$$

$$\left(\sigma^{U}_{frontier}\right)^2 = \boldsymbol{w}^{U'}\boldsymbol{\Sigma}\boldsymbol{w}^{U} \qquad \text{[Eqn 2]}$$

where $\boldsymbol{w}^{U}$ is the row vector of weights for a portfolio of n assets:

$$\boldsymbol{w}^{U} = \begin{bmatrix} w^{U}_{1} \\ w^{U}_{2} \\ \vdots \\ w^{U}_{n} \end{bmatrix}$$

where U symbolises a universal efficient frontier, that is, unconstrained (component assets may be selected from the universe of available assets), $\boldsymbol{E}$ is the vector of expected asset returns and $\boldsymbol{\Sigma}$ is the variance-covariance matrix of asset returns. The subscript varies to indicate the relevant portfolio and the prime symbol (′) indicates the vector transpose such that the un-transformed vector is a row vector, and the transposed vector is a column vector.

Following Merton (1972), the following constants are defined: $a = \boldsymbol{E}'\boldsymbol{\Sigma}^{-1}\boldsymbol{E}$; $b = \boldsymbol{E}'\boldsymbol{\Sigma}^{-1}\mathbf{1}$; $c = \mathbf{1}'\boldsymbol{\Sigma}^{-1}\mathbf{1}$; $d = a - \frac{b^2}{c}$; where $\mathbf{1}$ is an n-dimensional row vector of 1s.

To plot the efficient frontier, the portfolio variance is minimised over the weights subject to a target expected return ($\boldsymbol{G}$), that is, minimise $\boldsymbol{w}^{U'}\boldsymbol{\Sigma}\boldsymbol{w}^{U}$ subject to $\boldsymbol{w}^{U'}\mathbf{1} = \mathbf{1}$ and $\boldsymbol{w}^{U'}\boldsymbol{E} = G$. Jorion (2003) showed that the solution is given by the following formula:

$$\boldsymbol{w}^{U'}\mathbf{1} = \left(\frac{a - bG}{d}\right)\boldsymbol{w}^{U}_{MV} + \left(\frac{bG - \frac{b^2}{c}}{d}\right)\boldsymbol{w}^{U}_{TG} \qquad \text{[Eqn 3]}$$

where $\boldsymbol{w}^{U}_{MV} = \boldsymbol{\Sigma}^{-1}\frac{\mathbf{1}}{c}$ is the vector of portfolio weights for the global efficient minimum variance portfolio, $\boldsymbol{w}^{U}_{TG} = \boldsymbol{\Sigma}^{-1}\frac{\mathbf{E}}{b}$ is the vector of portfolio weights for the tangent portfolio (the optimal portfolio in the absence of a risk-free asset), and the expected return and variance of these portfolios are: $\mu^{U}_{TG} = \frac{a}{b}$; $\left(\sigma^{U}_{TG}\right)^2 = \frac{a}{b^2}$; $\mu^{U}_{MV} = \frac{b}{c}$ $\left(\sigma^{U}_{MV}\right)^2 = \frac{1}{c}$.

Substituting [Eqn 3] into [Eqn 2] and setting G equal to μ_p, the equation for the efficient frontier is obtained:

$$\sigma^2_{frontier} = \frac{1}{d}\left(\mu_{frontier} - \mu^{U}_{MV}\right)^2 + \left(\sigma^{U}_{MV}\right)^2$$

From

$$\boldsymbol{w}^{U}_{TG} = \boldsymbol{\Sigma}^{-1}\frac{\boldsymbol{E}'}{b} = \boldsymbol{\Sigma}^{-1}\frac{\boldsymbol{E}}{\boldsymbol{E}'\boldsymbol{\Sigma}^{-1}\mathbf{1}}$$

the vector of portfolio weights for the tangent portfolio when $r_f \neq 0$ is obtained using the expected returns in excess of the risk-free rate, r_f:

$$\underset{r_f \neq 0}{\boldsymbol{w}^{U}_{TG}} = \boldsymbol{\Sigma}^{-1}\frac{\left(\boldsymbol{E} - r_f\right)}{\left(\boldsymbol{E} - r_f\right)\boldsymbol{\Sigma}^{-1}\mathbf{1}} \qquad \text{[Eqn 4]}$$

The return and risk for this portfolio are obtained by substituting [Eqn 4] into [Eqn 1] and [Eqn 2]: $\underset{r_f \neq 0}{\mu^{U}_{TG}} = \underset{r_f \neq 0}{\boldsymbol{W}^{U'}_{TG}}\boldsymbol{E}$ and $\underset{r_f \neq 0}{\left(\sigma^{U}_{TG}\right)^2} = \underset{r_f \neq 0}{\boldsymbol{W}^{U'}_{TG}}\boldsymbol{\Sigma}\underset{r_f \neq 0}{\boldsymbol{W}^{U}_{TG}}$.

ESG frontier

The investor's problem is that of assembling a portfolio from n possible ESG assets and a risk-free security (whose return is r_f) such that its risk-adjusted returns are maximised on the ESG frontier.

The investor commences with wealth W and chooses a portfolio of risky assets with weights given by the vector W:

$$\boldsymbol{w}^{ESG} = \begin{bmatrix} w^{ESG}_{1} \\ w^{ESG}_{2} \\ \vdots \\ w^{ESG}_{n} \end{bmatrix}$$

where w_i^{ESG} is the fraction of capital invested in security *i*, so the investor purchases $w_i^{ESG}W$ worth of security *i*. The returns of the risky assets are given by the vector of returns, *r*:

$$r = \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_n \end{bmatrix}$$

and the ESG scores of the component assets are given by the vector *s*:

$$S = \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_n \end{bmatrix}$$

The assets' average expected returns are given by

$$E^{ESG} = \begin{bmatrix} E_1^{ESG} \\ E_2^{ESG} \\ \vdots \\ E_n^{ESG} \end{bmatrix}$$

where $E_i^{ESG} = E(r_i \mid s_i)$.

The investor's utility depends on future wealth $(\widehat{W})$ and the portfolio's ESG characteristics, given by

$$\widehat{W} = W(1 + r_f + \boldsymbol{w}^{ESG'}\boldsymbol{r}).$$

where *W* is the current wealth. To maximise utility *U* over final wealth $\widehat{W}$ and average ESG score $\overline{s}$ (given by $\overline{s} = \frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}}$):

$$U = E\left(\widehat{W} \mid s\right) - \frac{\overline{\gamma}}{2} Var\left(\widehat{W} \mid s\right) + Wf(\overline{s})$$

where γ is the absolute risk aversion parameter and $f: R \to R \cup \{-\infty\}$ is the ESG preference function. The ESG preference function depends on the average ESG score among the risky asset positions (i.e. $\overline{s}$ is the weighted sum of ESG scores, scaled by the total position in risky assets, $\boldsymbol{w}^{ESG'}\boldsymbol{1}$), meaning that the investor enjoys no ESG utility from investing in the risk-free asset. The overall utility may then be written as

$$\begin{aligned} U &= W\left(1 + r_f + \boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG}\right) - \frac{\overline{\gamma}}{2} W^2 \boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG} + Wf\left(\frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}}\right) \\ &= W\left(1 + r_f + \boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG} - \frac{\gamma}{2}\boldsymbol{w}^{ESG'}\boldsymbol{\Sigma}\boldsymbol{w}^{ESG} + f\left(\frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}}\right)\right). \end{aligned}$$

where $\gamma = \overline{\gamma}W$ is the relative risk aversion. Omitting constant terms gives the utility maximisation problem:

$$\max_{w^{ESG} \in \Omega} = \left(\boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG} - \frac{\gamma}{2}\boldsymbol{w}^{ESG'}\boldsymbol{\Sigma}\boldsymbol{w}^{ESG} + f\left(\frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}}\right)\right) \quad \text{[Eqn 5]}$$

where the set of feasible portfolios is given by $\Omega = \left\{\boldsymbol{w}^{ESG} \in R^n \mid \boldsymbol{w}^{ESG'}1 > 0\right\}$, or all long-biased portfolios. Portfolios that invest at least as much long as short were considered because defining the overall ESG characteristic for a portfolio that is short overall is difficult, but, in principle, the framework can be defined more generally.

The ESG-motivated investor's portfolio problem may now be solved. The objective function depends on the ESG scores, *s*, so the optimal portfolio depends on these scores. In a standard mean-variance analysis, the investor optimally combines the tangency portfolio with the risk-free security. The tangency portfolio is the portfolio that maximises the SR, namely, the quotient of the expected excess returns and the standard deviation of excess returns. To generalise this idea, the maximum SR for each level of ESG score was considered. The maximum SR that can be achieved with an ESG score of $\overline{s}$ is denoted by the ESG-SR frontier, $SR(\overline{s})$: :

$$\begin{aligned} SR(\overline{s}) = \max_{\boldsymbol{w}^{ESG} \in \Omega} \left(\frac{\boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG}}{\sqrt{\boldsymbol{w}^{ESG'}\boldsymbol{\Sigma}\boldsymbol{w}^{ESG}}}\right) &= \max_{W} \left(\frac{\boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG}}{\sqrt{\boldsymbol{w}^{ESG'}\boldsymbol{\Sigma}\boldsymbol{w}^{ESG}}}\right) \\ s.t.\ \overline{s} = \frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}} & \qquad s.t.\ \boldsymbol{w}^{ESG'}\boldsymbol{1} = 1 \\ & \qquad \text{and } \boldsymbol{w}^{ESG'}\boldsymbol{s} = \overline{s} \end{aligned}$$

[Eqn 6]

To use this definition of the maximal SR for each ESG level, the utility maximisation problem [Eqn 5] must be rewritten

$$\max_{\overline{s}}\left[\max_{\sigma}\left\{\begin{array}{l} \max\limits_{\boldsymbol{w}^{ESG} \in \Omega} \left(\boldsymbol{w}^{ESG'}\boldsymbol{E}^{ESG} - \frac{\gamma}{2}\sigma^2 + f(\overline{s})\right) \\ s.t.\ \overline{s} = \frac{\boldsymbol{w}^{ESG'}\boldsymbol{s}}{\boldsymbol{w}^{ESG'}\boldsymbol{1}} \\ \sigma^2 = \boldsymbol{w}^{ESG'}\boldsymbol{\Sigma}\boldsymbol{w}^{ESG} \end{array}\right\}\right] \quad \text{[Eqn 7]}$$

Equation 7 may be thought of as first choosing the best portfolio given a level of risk σ and an ESG score $\overline{s}$ and then maximising over σ and $\overline{s}$. The former problem is solved by choosing the portfolio with the highest SR for the given ESG score, which gives

$$\max_{\overline{s}}\left[\max_{\sigma}\left\{SR(\overline{s})\sigma - \frac{\gamma}{2}\sigma^2 + f(\overline{s})\right\}\right] \quad \text{[Eqn 8]}$$

The optimal level of risk is given by

$$\sigma = \frac{SR(\overline{s})}{\gamma}$$

Inserting this risk level and simplifying [Eqn 8] gives the proposition which asserts how investors optimally trade off ESG and SRs, that is, investors should choose the average ESG score $\overline{s}$ to maximise the function in [Eqn 8] of the squared SR and the ESG preference function:

$$f:\max_{\bar{s}}\left[\left(SR(\bar{s})\right)^2+2\gamma f(\bar{s})\right] \quad \text{[Eqn 9]}$$

ESG affects optimal portfolio choice given that ESG is included in the utility function, but the interesting result here is that we can analyse this trade-off using a part that depends only on securities (the ESG-SR frontier, $SR(\bar{s})$ and another part that depends only on preferences: $2\gamma f(\bar{s})$. Standard Markowitz (1952) theory is powerful because the mean-variance frontier can be computed independent of preference parameters and then decisions about what portfolio to pick are based on risk aversion. In a similar way, the ESG-SR frontier can be computed independent of preferences and then the investor can decide in the end where to be placed on the frontier. Put differently, the ESG-SR frontier summarises all security-relevant information. The investor's problem is to first decide on a position on the ESG-SR frontier and then to decide on the amount of risk.

Understanding the ESG-SR frontier shows how differences in risk aversion and differences in ESG preferences can be distinguished. If a group of investors have no direct preferences for ESG ($f\equiv 0$) but differ in their risk aversion γ, then all these investors should invest in the same portfolio of risky assets (i.e. with the same SR and average ESG score), but the more risk tolerant should put a larger fraction of their wealth in this portfolio (i.e. own less cash instruments). If a group of investors have the same risk aversion but differ in their ESG preferences, then investors with stronger ESG preferences should buy a portfolio with lower SR, but higher average ESG score. Interaction effects also exist. If a group of investors care equally about ESG but differ in their risk aversion, then an investor with higher risk aversion not only increases investment in the risk-free asset, but also tilts the portfolio toward higher ESG and lower SR. Mathematically, this behaviour arises because the second term in [Eqn 4] is $(\bar{s})$, and economically, this interaction arises because SR matters less when an investor is more risk averse, so relatively speaking, ESG increases in importance. More generally, observing an investor's portfolio of risky assets and its placement on the ESG-SR frontier is revelatory about $\gamma f(\bar{s})$; considering the investor's cash position (or leverage), and risk aversion γ.

Using the notation $c_{ab}=a'\Sigma^{-1}b\in R$ for any row vectors $a,b\in R^n$, the maximum SR, $SR(\bar{s})$, that can be achieved with an ESG score of $\bar{s}$ is

$$SR(\bar{S})=\sqrt{C_{\mu\mu}-\frac{\left(C_{S\mu}-\bar{S}C_{1\mu}\right)^2}{C_{SS}-2\bar{s}c_{1s}+\bar{s}^2c_{11}}} \quad \text{[Eqn 10]}$$

Results and discussion

We begin by analysing the evolution of average ESG scores over time of several emerging economy countries, grouped into various regions, and shown in Figure 2(a) through (e). Figure 1(f) represents the overall emerging economy equally weighted average over all 389 stocks.

For all countries analysed, ESG scores increase over time, although at different rates. The average ESG score for emerging economies using the entire sample shows a pronounced linear trend, increasing at a rate of 1.63 per annum. At this rate, average emerging economy ESG scores will be comparable to current (2022) developed economy scores (~85) by the end of the 2030s. The average trend could, of course, be considerably different if rates accelerate or decelerate owing to the many contributing factors. So far, however, the slow but relentless improvement in ESG scores is encouraging.

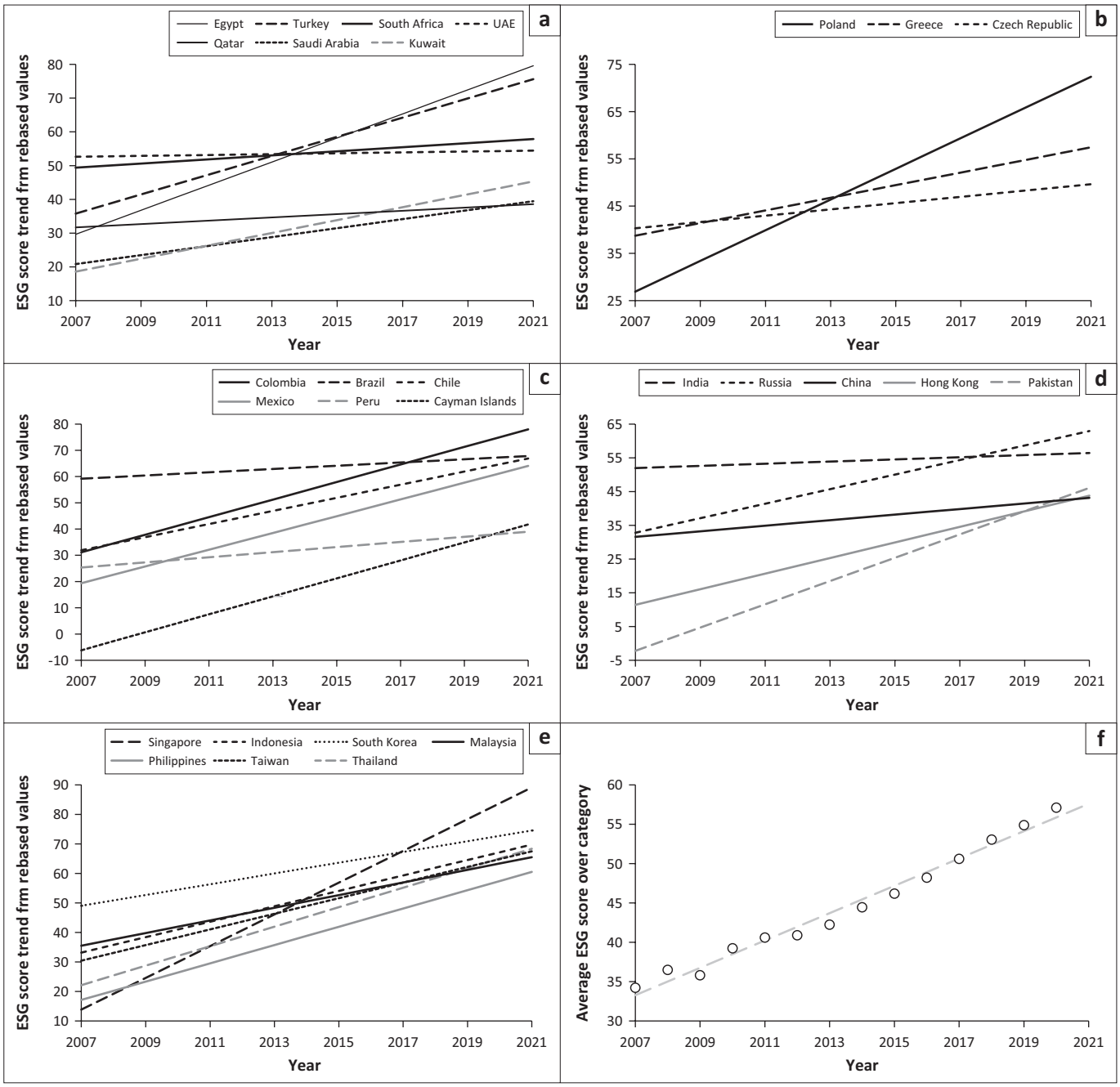
Corporate ESG scores at individual country level using actual ESG scores rather than regional averages display substantial volatility and – in some cases – decreasing scores. This is not unexpected: companies making progress on environmental issues may have deteriorating working conditions or be governed by a weak board. A representative sample of South African stocks is shown in Figure 3.

A well-diversified, multi-sector portfolio comprising 30 South African stocks with (current – 2022) ESG scores ranging from 14 to 81 was analysed using Equation 10. The results – shown in Figure 4 – display some important features.

The optimal SR for such a stylised portfolio occurs at an ESG score *which is not the maximum*. While construction of higher (~50 – 80) ESG-scored portfolios is possible (heavier weighting in higher-rated ESG score stocks), investment in these would not generate an optimal risk-adjusted return. The same is true for lower (~10 – 40) ESG-scored portfolios (higher weighting in lower-rated ESG score stocks): such portfolios would generate suboptimal performance. Both higher and lower ESG-scored portfolios are thus penalised in terms of risk-adjusted return performance.

Non-optimal SRs for low ESG-scored portfolios are explained by their generally higher volatility and lower returns (Sikochi & Serafeim 2021). Investors have begun to shun companies with poor environmental records, poor management and toxic corporate cultures resulting in poor return performance, and scandals, even if arising in different companies, tend to amplify negative public perceptions of already poorly rated firms, resulting in higher volatilities (Mobius & Ali 2021).

Non-optimal SRs for high ESG-scored portfolios require a more nuanced explanation. At this stage, however, a lack of relevant data and noisy samples prevent more than heuristic justification. It is possible that, broadly speaking, high ESG-scored companies are willing to accept lower profits in the interests of protecting the environment, improving working conditions and adhering to good governance. Note that this does not imply they are willing to forego *all* profits, rather that profits benefit the employees and community (rather than the company only) more so than lower ESG rated firms. Lower profits lead to lower returns, which lead to lower SRs.



Source: Reuters Refinitiv, Global Sustainable Investment Alliance (2020).

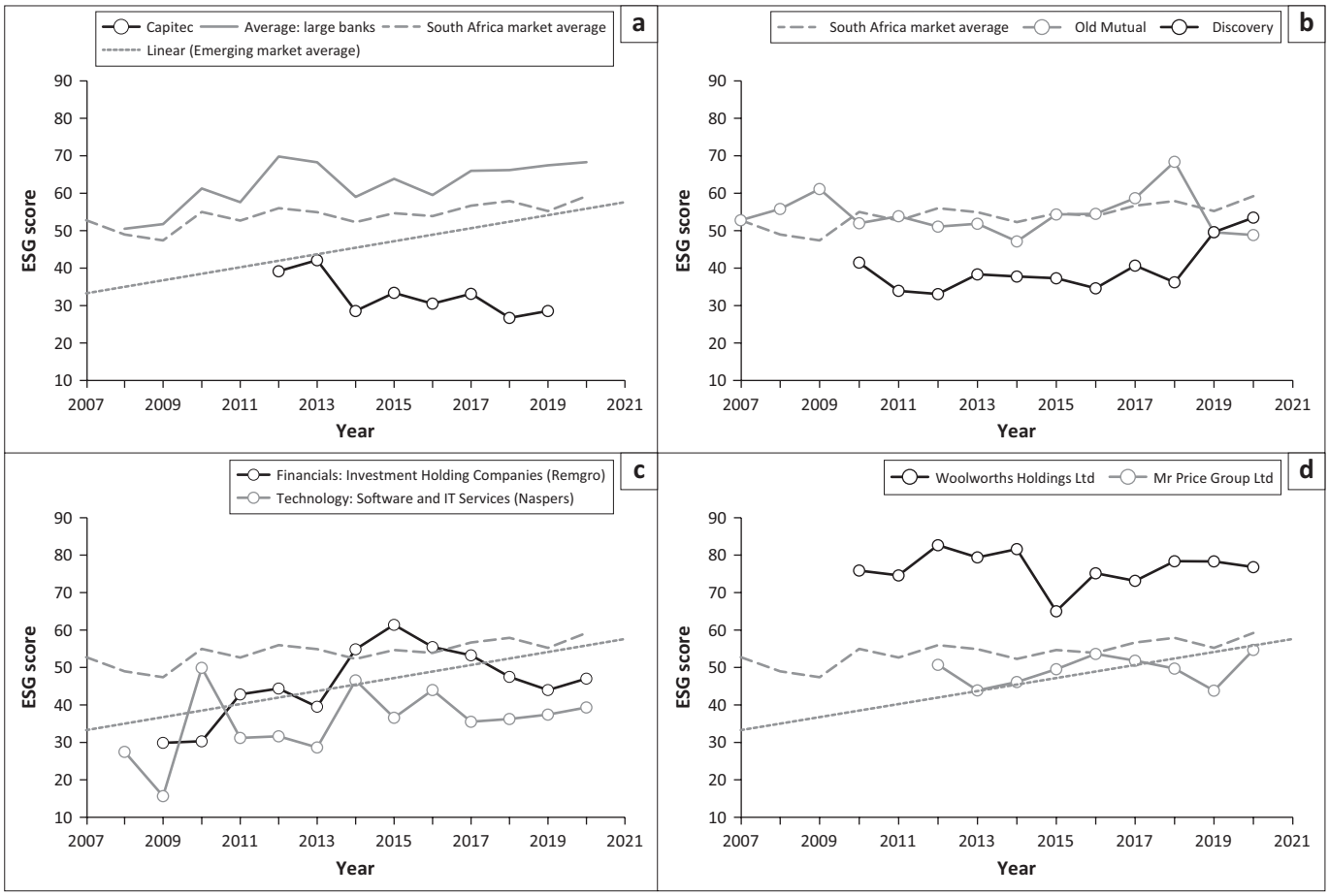
ESG, environmental, social and governance.

FIGURE 2: Environmental, social and governance (ESG) score trends for various global developing market regions: (a) Middle East and Africa, (b) Europe, (c) South America, (d) Asia, (e) Southeast Asia and (f) the emerging economy average ESG score over time. Vertical scales are different.

For the moment at least, then, ESG investors must decide between maximal ESG rating portfolios (and accept the associated suboptimal portfolio performance) and maximal risk-adjusted returns (and accept the associated reduction in the portfolio's ESG score).

As average portfolio risk decreases, the SR versus ESG score graph flattens (less variation in attainable SRs over the range of ESG scores). In addition, as portfolio risk decreases, the locus of the optimal SR versus ESG moves down (decreasing SR) and to the right (increasing ESG) as shown in Figure 5.

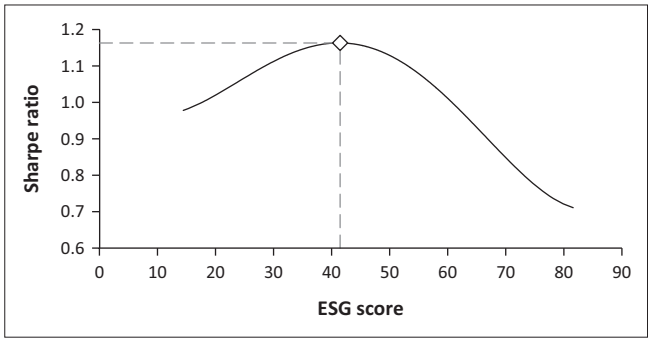
It is not obvious why the locus of the optimal SR/ESG score – as a function of portfolio volatility – should behave in this way. The results indicate that, unsurprisingly, portfolios with higher volatilities in general have lower ESG scores, but they also show that high volatility portfolios can generate higher SRs (all else being equal). It is possible that this could be an artefact of the risk/return relationship like that observed in option pricing (increases in volatility precipitate higher option prices because the option has a higher likelihood of exercise): higher volatility ESG portfolios generate higher SRs as they may generate higher returns. This possibility requires deeper interrogation when more data become available.



Source: Reuters Refinitiv and authors' calculations.

ESG, environmental, social and governance.

FIGURE 3: Environmental, social and governance scores (and relevant trends) for representative South African stocks selected from the (a) banking, (b) insurances, (c) technology and (d) consumer cyclicals sectors over 2007–2020. Vertical scales are identical for comparison.



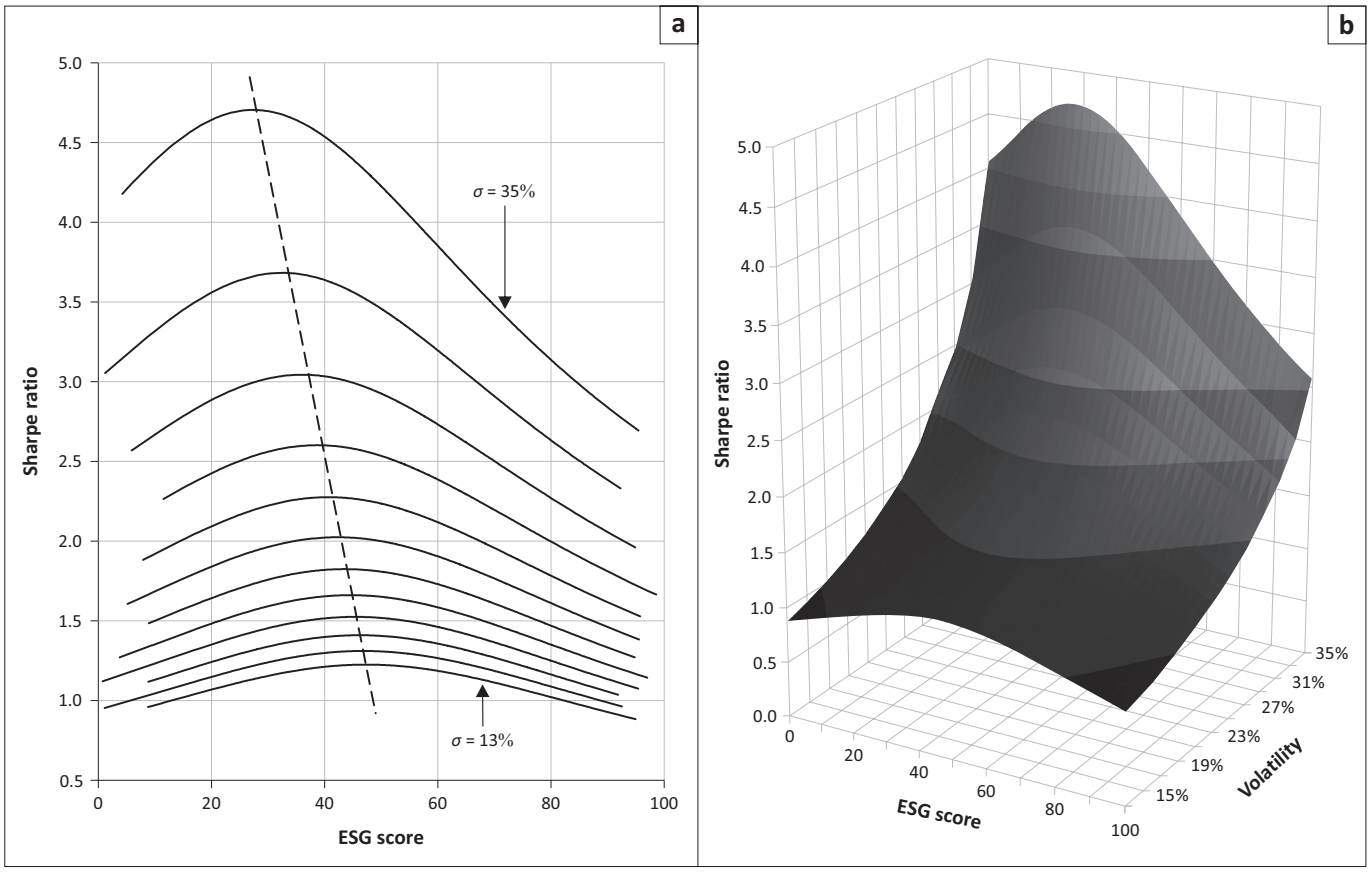
ESG, environmental, social and governance.

FIGURE 4: Sharpe ratio as a function of environmental, social and governance score for a portfolio of 30 South African stocks.

Using portfolio constituent weights from Equation 6, the ESG efficient frontier may be determined. Similar in shape to the 'global' efficient frontier, the ESG efficient frontier is generally characterised, nevertheless, by lower returns and higher risk, though variations are possible (Figure 6). The global efficient portfolio here is constructed using the Markowitz efficient asset allocation framework and the stocks which constitute the Johannesburg Stock Exchange's all share index (the ALSI40) over two 1-year periods between 2016 and 2020 (i.e. pre-COVID).

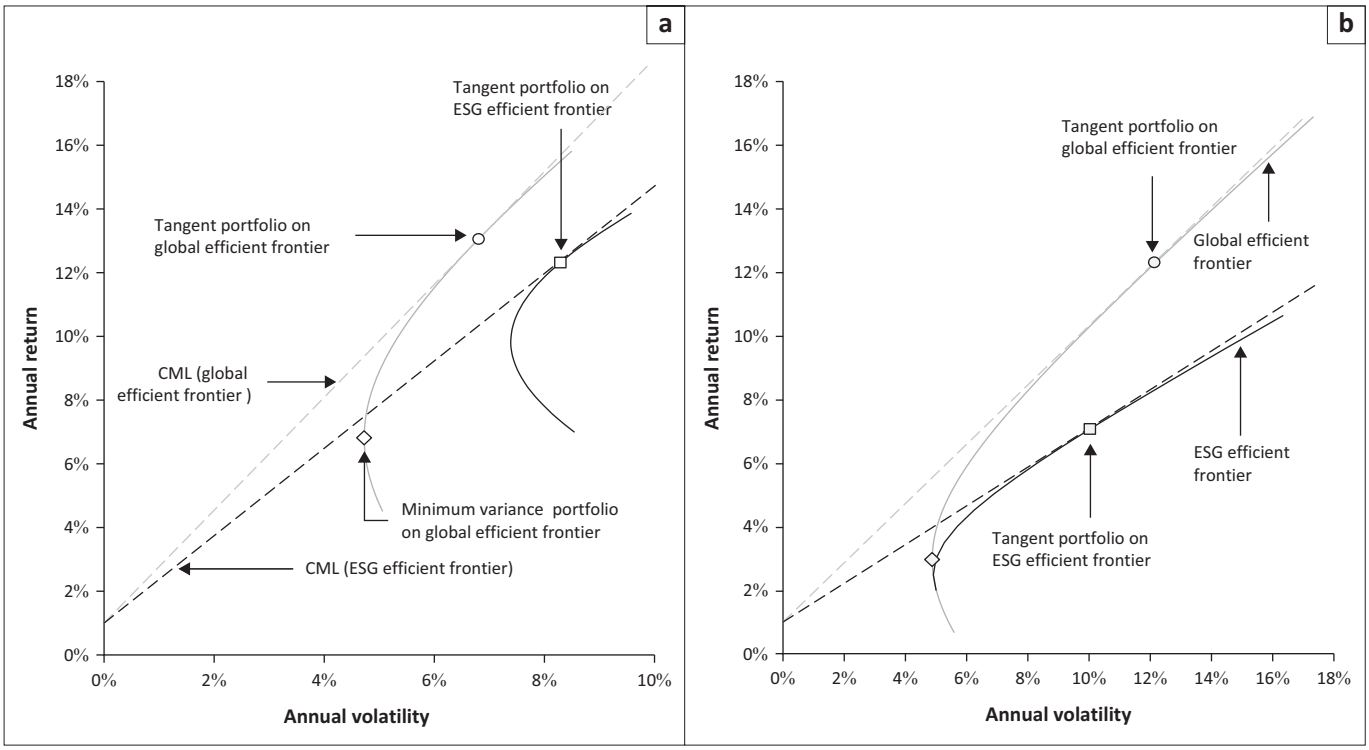
Empirical evidence shows that as portfolio ESG scores increase (all else equal), returns deteriorate and risk (volatility) increases. Examining country-specific portfolios comprising the ESG-rated companies in our sample, this was indeed found to be the case: the ESG-efficient frontier moves southeast (down and to the right) away from the global efficient portfolio (in each case comprising most – or all – of the stocks which constitute the country's principal stock exchange index). These shifts are illustrated in Figure 7(a). In all cases, these were again constructed using the standard Markowitz efficient asset allocation framework. Statistical results of tests to compare mean ESG scores, portfolio returns and variances are provided in Table 1 in Appendix 1.

Figure 7(b) shows a summary of the results of these tests using the South African portfolios described earlier over a period spanning over a decade of ESG scoring. For clarity, only ESG-efficient frontiers as at 2009, 2013, 2016 and 2020 are presented along with the global efficient frontier as it stood in 2020 using two prior years, in each case, of historical return data. The global efficient frontier has remained relatively static over these years – hence the decision to display only the latest (2020) frontier, again for the sake of clarity. Combining these observations with those displayed



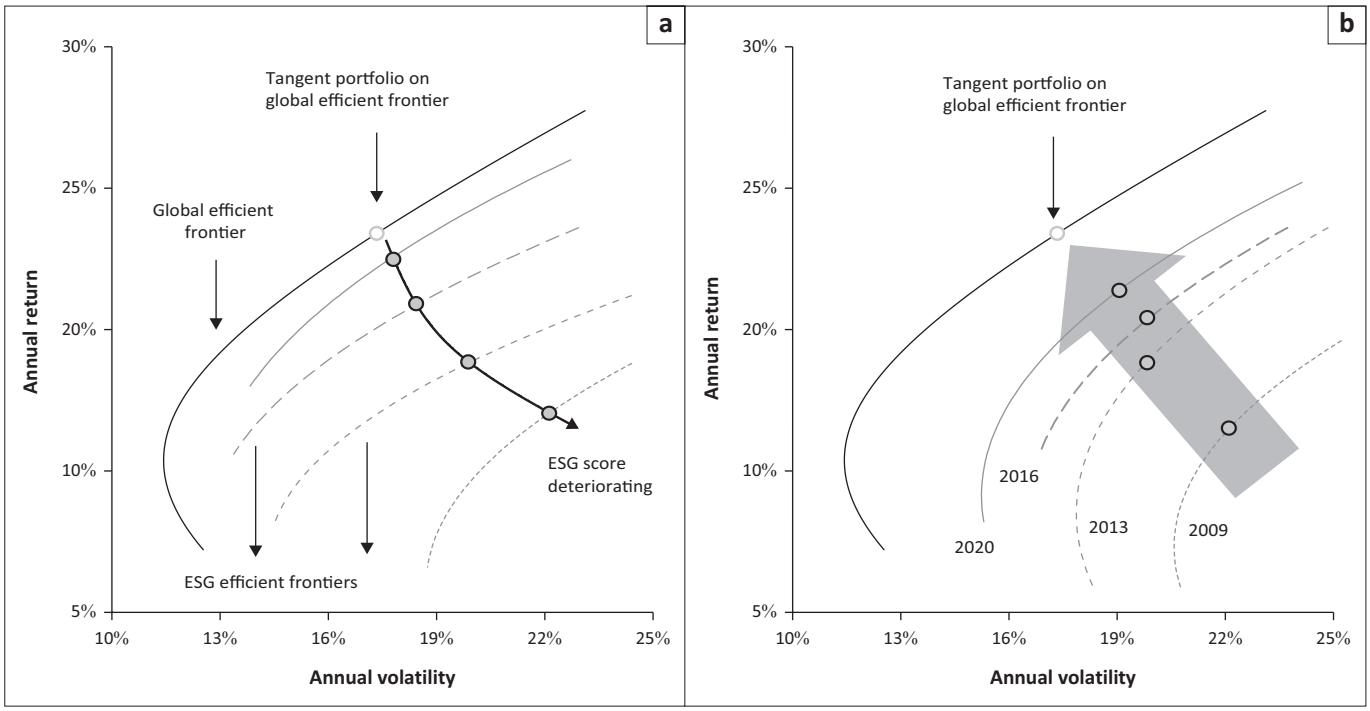
ESG, environmental, social and governance.

FIGURE 5: Sharpe ratio versus environmental, social and governance score as a function of volatility (increasing from the uppermost to lowest curve) in (a) two and (b) three dimensions.



ESG, environmental, social and governance.

FIGURE 6: Global and environmental, social and governance (ESG)-efficient frontiers with associated capital market lines (CMLs), minimum variance portfolios and tangent (optimal) portfolios. In (a) optimal portfolios have similar return levels but the ESG portfolio has higher volatility (lower Sharpe ratio) and in (b) optimal portfolios have similar risk levels, but the ESG portfolio has lower returns (again, a lower Sharpe ratio).



ESG, environmental, social and governance.

FIGURE 7: Return-risk loci for the global efficient frontier score and environmental, social and governance (ESG)-constrained frontiers as a function of ESG scores: (a) as the ESG score deteriorates, the maximal tangent portfolio moves down and right (southeast), that is, lower returns and higher risk and (b) time evolution of ESG-constrained efficient frontiers for South African portfolios. ESG monotonically increases over the period from 50 to 60. Grey arrow indicates the direction of improving ESG scores and their effect on the ESG efficient frontier's tangent portfolio.

in Figures 2(a) and 3 (i.e. a monotonically increasing ESG score), it is evident that the ESG-efficient frontier is approaching the global efficient frontier, and the locus of the optimal ESG portfolio is northwest – that is, up and to the left, edging ever closer to the global optimal portfolio over time (the ESG score for this South African portfolio increased over 2009–2020 from 50 to 60). These observations show statistically significant increases in returns and statistically significant reductions in risk over time (Table 1). We obtained similar results for all emerging economies in our sample.

Limitations and recommendations

The rise in significance of ESG criteria has become impossible to ignore. Social responsibility, once the purview of militant activists, has moved into the mainstream. Environmental, social and governance quantification is now widespread, which is an important development because management is impossible without measurement. Financial statements now analyse and report on ESG developments and investors avoid firms guilty of reckless behaviour. Asset managers must embrace these developments and structure portfolios accordingly, but in the absence of an established, robust mathematical structure, this has proved difficult to impossible.

The emergence of novel asset allocation techniques which borrow heavily from the tried and tested Markowitz efficient portfolio framework, then, is welcome, but acceptance and implementation have been slow. Like most new approaches to old-but-developing problems, many years of data are required to prove reliability and robustness. While such efforts are gathering steam in developing markets, emerging markets suffer from even fewer data and later installation. This work fills the gap by adapting new approaches and applying these to global emerging market data for the first time.

Future investigations should explore other ESG metrics and their ongoing impact on portfolio efficiency and risk-adjusted return optimality. A detailed comparison of the results obtained here and those assembled from developed economies would also be a welcome addition to the ongoing pursuit of profits while embracing responsibility to the planet, employees and the wider community.

Conclusion

We find that ESG scores have been improving inexorably (but slowly) in the emerging market milieu since ESG scores were introduced in 2007. At this current growth rate, emerging markets will enjoy similar ESG scores to their developed nation counterparts by the late 2030s, although many interacting factors could accelerate or slow that progress. We find that, at present (2022), optimal risk-adjusted portfolio returns are not necessarily associated with those portfolios having the highest ESG scores. There is a maximal SR portfolio attainable with a given portfolio ESG score, but both higher and lower ESG scores result in lower SR portfolios. We speculate that while the lower ESG/lower Sharpe ratio observation is intuitive, decreasing Sharpe ratios for increasing ESG scores is more nuanced and requires

further investigation. This observation could be due to diminished returns for very high ESG-scored firms who plough profits into employee working conditions and environmental projects, rather than their bottom lines. While good for the planet and their employees, such firms do not (yet) generate superior returns to their less responsible peers, but this is persistently improving over time and the distinction between global efficient portfolios (which ignore ESG scores) and ESG-efficient portfolios is constantly narrowing.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

F.B. was responsible for the conceptualisation, writing, analytics and visualisation of this article. G.v.V. was responsible for supervision, analytics and visualisation of the study.

Ethical considerations

This article followed all ethical standards for a research without direct contact with human or animal subjects.

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Data availability

All data are available from Reuters *Refinitiv* with subscription – no non-proprietary information was used.

Disclaimer

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Appendix 1: Environmental, social and governance statistics (ESG)

TABLE 1-A1: *t* statistics for comparison of ESG means, variances and return means.

Country	Comparison of means (ESG scores)	Comparison of variances	Comparison of means (returns)
	t	*t*	*t*
Egypt	2.54**	4.46***	2.99***
Kuwait	2.39**	2.76**	2.99***
Qatar	2.22**	5.11***	2.40**
Saudi Arabia	4.73***	4.35***	2.81***
South Africa	2.16**	3.41**	3.20***
UAE	2.92***	4.37***	1.98*
Turkey	4.54***	3.93***	4.01***
Czech Republic	3.98***	1.89*	4.20***
Greece	2.33**	4.67***	4.67***
Poland	3.65***	3.78***	3.96***
Chile	2.98***	4.97***	3.44***
Brazil	3.42***	2.32*	4.33***
Colombia	3.01***	4.07***	1.32*
Mexico	4.33***	3.31**	2.42**
Peru	4.21***	4.66***	2.35**
Cayman Islands	2.61**	3.08**	2.68**
China	2.59***	5.39***	2.46**
Hong Kong	3.95***	4.95***	4.82***
India	3.19***	3.27**	2.69**
Pakistan	2.32**	3.43**	2.75***
Russia	2.60**	4.92***	2.46**
Indonesia	3.91***	4.33***	2.17**
Malaysia	2.08**	4.93***	3.07***
Philippines	4.06***	2.53**	1.00*
Singapore	4.34***	3.74***	2.33**
South Korea	4.62***	4.61***	3.33***
Taiwan	2.16**	3.09**	4.00***
Thailand	2.95***	4.35***	2.82***

ESG, environmental, social and governance.

1%, 5% and 10% *p*-values of are indicated by ***, ** and *, respectively.