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ESG in Factors

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Environmental, Social, and Governance (ESG) signals are an important part of factor-based investing strategies as they can stem from the same economic rationales as general factor premiums. Because factors are broad and diversified, building portfolios by jointly optimizing factor exposures with ESG and carbon outcomes results in similar historical performance as benchmark factor portfolios which do not include those considerations. We show how sustainable signals, which often involve alternative data, can be integrated in the definitions of factors themselves: we offer two examples on green intangible value and corporate culture quality which enhance traditional financial value and quality factors, respectively.

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We integrate Environmental, Social, and Governance (ESG) data into factor-based investment strategies. We state upfront that this framework takes no view on whether ESG is a rewarded source of return in its own right: authors like Edmans (2011) and Eccles, Jaonnou, and Serafeim (2014) advocate that the predictive relation between ESG and firm returns is positive, whereas Hong and Kacperczyk (2009) and Cheng, Hong, and Shue (2013) document the relation is negative. In contrast, a voluminous asset pricing literature shows that factors—broad and persistently rewarded sources of returns like value, quality, and momentum—have historically outperformed market cap benchmarks over decades (Fama and French, 1993) and even over centuries (Goetzmann and Huang, 2018).¹ Different to most of the papers in a growing ESG literature, we show how to build factor portfolios with ESG signals—and because they are based first and foremost on factors, we can lean on the large theoretical and empirical factor literature to make a case on building factor strategies embedding ESG data for strategic allocation.²

Factor premiums result from economic rationales: rewards for bearing risk, structural or market impediments, and investors' behavioral biases. Some aspects of the “E” of ESG fall into the second category: whether a climate treaty is adopted, the imposition of a carbon tax, or potential legislation that may strand certain assets. The “S” of ESG may reflect behavioral biases of investors, employees, managers, or other market participants. Some “G” effects may be associated with increases or decreases in agency risk. But, since there is “aggregate confusion” and wide divergence of ESG ratings (see Berg, Koelbel, and Rigobon, 2019), some ESG variables may not meet these economic rationales. If certain ESG data are linked to risk or behavioral theories that are consistent with factor premiums, they may be useful in constructing factor portfolios.

First, the broad nature of factors means that their effects are observed across thousands of securities; in large portfolios, idiosyncratic risk is diversified away leaving exposure only to a few factors (see Ross, 1986). Not surprisingly, these factors, which have historically significantly forecasted excess returns, may be correlated with other firm characteristics that may not be systematically related to returns, or some of these characteristics may have data limitations giving low power to statistically reject that the null that they do not predict risk-adjusted returns. These conditions often apply to ESG data because of its sparse nature and lack of standardization.

¹ See Ang (2014) for a summary on style factors.

² Review summaries such as Clark, Feiner, and Viehs (2015) and Friede, Busch, Bassen (2015) and aggregate the findings of over 200 and 2200 studies, respectively, to examine the relationship between ESG and corporate performance.

Any locally convex optimization problem involving an objective function produces a weakly lower value of that objective function when constraints are imposed.⁴ This is the case for the standard utility functions used in finance, so practicing ESG by exclusionary screens or using other methods that shrink the investment universe can result in lower ex-ante returns, higher risk, or both. But, because ESG variables—which include carbon emissions as an “E” variable—are correlated with factors and the effects of factors are so broad, joint optimizations of ESG outcomes with factors result in portfolios with virtually identical realized returns and risk compared to factor portfolios optimized without ESG constraints which we show in Section 2.3. Intuitively, the optimizations trade off some ESG tilts that are positive for some factors (positive ESG scores for quality, for example) with those that are negative for other factors (negative ESG scores for small size) in a way that jointly maximizes the opportunity sets of the factors within the specified ESG improvements.

Even without joint ESG and carbon optimizations, we show a factor portfolio constructed from a global equity universe with five factors (value, quality, momentum, low volatility, and size) brings a 10% reduction in carbon emission intensity and has a modestly better ESG score than the market benchmark. The low volatility factor has a 6.6% better ESG profile, on average, than the market but the size factor has, on average, 5.9% lower ESG scores than the market. When we set ESG scores to improve, the low volatility factor is impacted least and the value factor is impacted most. The former is due to higher volatility stocks generally having lower ESG scores so excluding the lowest rated ESG stocks has little effect on a low volatility factor portfolio. Low priced stocks include some companies with very low ESG scores and thus we cannot hold some companies with the most attractive value exposures when there is a significant ESG improvement. Even so, the large diversification effects present in factor portfolios may allow investors to incorporate ESG constraints with no detrimental performance once the ESG conditions and the factors are jointly optimized.

⁴ A leading summary is Boyd and Vandenberghe (2004), who show how to transform many different optimizations into convex optimization problems. While the original optimization is performed from an ex ante perspective, an ex post realized portfolio with constraints may outperform a portfolio without constraints. As Jagannathan and Ma (2003) note, constraints may be useful in mitigating errors in the expected return and risk inputs. Guenster et al. (2011) argue that imposing ESG constraints results in superior performance because the effects of ESG are incorporated with a lag—and misspecified myopic problems with constraints may fare better in dynamic settings. The standard setting assumes these and other effects are captured by the objective function, where constraints can only make an investor weakly worse off.

The second way we incorporate ESG into factor strategies is to explicitly use ESG data in the factor definitions. Factors have historically been persistently rewarded over the long run but the way we measure them may change over time. Indeed, at the time of the publication of the first, seminal treatise on systematic investing, Graham and Dodd (1934), accounting practices were not standardized. The metrics to capture richness vs. cheapness (for the value factor), or high quality vs low quality companies (for the quality factor), have evolved over time.⁵ A large part of the literature, in fact, argues for the merits of one metric over another, while the underlying economic notions of value, quality, and other factors are stable.⁶

We use ESG data to evolve measures of factors beyond traditional balance sheet and earnings statement variables and treat ESG as a non-traditional data source to capture aspects of factors. We give two examples of non-financial value and quality. First, we measure a firm's output of innovation using green patent data—explicitly capturing long-term investment opportunities addressing climate change and other societal challenges. We extend quality beyond traditional financial quality, like accruals (Sloan, 1996) and profitability (Novy-Marx, 2013), to the quality of corporate culture using machine learning of textual data. Corporate culture reflects aspects of “S” and “G” of a firm such as human capital, innovation, customer satisfaction as well as corporate management.

1. Factors and ESG Data

We describe how we construct standard benchmark factor portfolios in Section 1.1 and summarize the ESG scores and carbon data in Section 1.2.

⁵ Generally Accepted Accounting Principles (GAAP) trace back to the standards established by the Community on Accounting Procedures in 1939, which was itself replaced in 1959 by the Accounting Principles Board. Since 1973, GAAP accounting standards are maintained by the Financial Accounting Standard Board. GAAP still differs materially from the international accounting standards (International Financial Reporting Standards), with still active discussions on reconciling the two standards (see Barth, Landsman, and Lang, 2008).

⁶ Value has moved from book value as a measure of intrinsic value from Graham and Dodd (1934) and used by modern authors like Fama and French (1993) and Lakonishok, Shleifer, and Vishny (1994), to other authors suggesting using different measures: past earnings (Basu, 1977), future earnings (Dechow and Sloan, 1997; Frankel and Lee, 1998), cash flow (Fama and French, 1996; Lettau and Wachter, 2007), return on equity (Haugen and Baker, 1996), and combinations of these and other variables (Piotroski, 2000).

1.1 Factor Data

We build theoretical factor portfolios of five factor strategies—value, momentum, quality, size and low volatility—in the MSCI World equity universe. Fundamental data from Worldscope and IBES are used to generate the momentum, value, quality, and size factors. For low volatility as well as momentum, we use equity returns and volatilities sourced from the MSCI Barra Global Equity Model (GEM3). We optimize the portfolios with MSCI GEM3 as the risk model. The simulation runs from December 1997 to September 2019 and rebalances monthly. The portfolios are constrained in terms of region, industry, and country to ensure risk is taken along the factor exposure dimension. In addition, we incorporate hypothetical transaction costs, with a similar model to Ratcliffe, Miranda, and Ang (2017), and control for turnover.

The signals we use for each factor are as follows:

Value: The value factor strategy combines three signals. The first two are forward-looking valuation metrics, using analysts' 12-months earnings forecasts with one divided by price and the other divided by enterprise value. The other valuation metric is a backward-looking measure: comparing a firm's cash flow from operations to its market capitalization.

Momentum: The momentum factor strategy combines two signals: price trend over the past 12 months (excluding the most recent one month to control for reversal effects as per Jegadeesh and Titman, 1993), and changes (up or down) in analysts' 12-month earnings forecasts.

Quality: In the quality factor strategy, we combine four signals: gross profitability, free cash flow to debt, an accruals measure, and capex growth.

Size: The size factor strategy uses the inverse of log of market capitalization.

Low Volatility: For the low volatility factor strategy, we use the inverse of idiosyncratic volatility.

Finally, we build a combined theoretical multi-factor portfolio which blends the single factor metrics with a bottom-up basis (see Grinold and Kahn, 2000; Bender and Wang, 2016). In this case, we first combine separate signals within each of the five factors above, and then compute a composite signal score for each individual stock equally combining the five factors.

Exhibit 1 reports summary statistics (Panel A) and a graph of cumulated returns (Panel B) of the factors from December 1997 to September 2019. All factors generate a positive information ratio over the sample period with momentum and quality having the highest active returns (portfolio return minus market benchmark) at 1.7% and 1.5% annualized, respectively.

While the information ratios are positive over the sample, there has been substantial cyclicalities for the factors, as Panel B of Exhibit 1 shows (see also Hodges et al., 2017). For example, the value factor's highest returns are from the beginning of the sample to the end of 2006, with an information ratio (IR) of 0.9. From January 2007 to September 2019, value has, on average, underperformed the market with an IR of -0.36 giving an IR of 0.12 over the full sample. Most recently since the beginning of 2017 to the end of the sample, quality, momentum, and low volatility have outperformed, and size and value have underperformed the market.

1.2 ESG and Carbon Data

We define the ESG score as the MSCI ESG industry-adjusted score. MSCI ESG Ratings aim to measure a company's resilience to long-term, financially relevant ESG risks (see MSCI ESG Ratings Methodology, 2019). Across 37 key ESG issues, material risks and opportunities such as human capital, climate change, or corporate behavior are measured for companies within the same industry. We use the industry-adjusted ESG scores to form industry ESG relative peer views.

The paucity of ESG data is well noted by many authors, but coverage has increased over time.⁷ Due to data availability, our ESG analysis uses data from 2015 onwards. In this period, almost 99% of the stocks in the MSCI World universe was covered. (For comparison, in 2004 only 63% of stocks carried ESG ratings, and in 2009 only 84% of stocks were covered.) In Section 3, we detail other proprietary ESG data which we deem suitable to incorporate in the definitions of the factors.

Our carbon emission intensity is defined as Scope 1 and Scope 2 carbon emission divided by sales. We use the MSCI database, which collates company-specific direct (Scope 1) and indirect (Scope 2) greenhouse gas (GHG) emissions data from company public documents and the Carbon Disclosure Project (CDP).⁸ Scope 1 emissions are those from sources owned by the company via

⁷ A good summary of the history of ESG ratings, as well as a broader industrial organization and "social construction" view of this data is provided by Eccles and Strohle (2018).

⁸ Scope 1 and Scope 2 need to be reported by companies as a minimum for GHG accounting for reporting purposes like the Kyoto protocol. Carbon emission intensity also plays an important role as ESG regulations become effective in the near future, such as carbon taxes or initiatives such as the Portfolio Decarbonization Coalition (see <https://unepfi.org/pdc/>).

company facilities or company vehicles, such as fleet vehicles or fuel combustion on site. Scope 2 emissions are those caused by the generation of electricity purchased by the company. At the company level, the carbon intensity (Scope 1 + 2 Emissions in tonnes/ \$M Sales) represents the company's most recently reported or estimated Scope 1 + Scope 2 GHG emissions normalized by sales in USD, which allows for comparison between companies of different sizes.

2. ESG and Carbon Profiles of Factors

This section investigates the ESG and carbon statistics of the factors. Section 2.1 documents how the factors fare along ESG and carbon intensity dimensions relative to the market—with certain factors like quality and low volatility having significantly better ESG scores and carbon reductions. Section 2.2 analyzes how factor efficacy varies as ESG and carbon constraints are imposed. The traditional factor portfolios are already ESG-friendly, and there is even more scope to trade off the ESG considerations with factor performance, which we explore in Section 2.3.

2.1 ESG and Carbon Characteristics of Factors

Exhibit 2 summarizes the ESG and carbon scores of the benchmark factors relative to the MSCI World market portfolio over January 2015 to September 2019. The origin represents the market portfolio, so the ESG scores represent percentage *improvements* relative to the market on the *x*-axis and we plot percentage carbon emission *reductions* on the *y*-axis. Thus, those factors in the top right-hand quadrant represent factors that have improved ESG scores and lower carbon emissions than the market as represented by the MSCI World Index.

Even without taking into account ESG considerations, Exhibit 2 shows that some style factor portfolios exhibit already a pro-sustainability profile: quality and low volatility portfolios are both higher in ESG ratings, at 2.3% and 6.6% relative to the market, respectively. Quality and low volatility portfolios also have lower carbon emissions than the market, at 30.6 and 20.6%, respectively. These results are not due to sector or country biases of the factors as we impose region and industry constraints in constructing the factors. The significantly positive ESG profile of quality has been noted by several authors, including Northern Trust (2014) and Melas, Nagy, and Kulkarni (2016). Dunn, Fitzgibbons, and Pomorski (2018) describe that ESG has important risk contributions, which are potentially captured directly in the low volatility factor.

The size and value factors are anti-ESG with 5.9% and 6.1% lower ESG ratings than the market, respectively. Part of the lower ESG score for smaller companies may be due to smaller

companies publishing less pertinent ESG information than larger companies. Looking within the individual E, S, and G components, the lower ESG score for the value factor is primarily due to the S and G scores. The value factor, but not the size factor, has a lower carbon profile than the market—contrary to some opinions that value companies use older, carbon-intensive technologies. Finally, the momentum factor has approximately the same ESG and carbon profile as the market benchmark. Part of this may be due to momentum being one of the largest factors present in the market portfolio itself (see Madhavan, Sobczyk, and Ang, 2018).

Finally, the theoretical multi-factor portfolio, shown in red in Exhibit 2, exhibits an 2.9% improvement in ESG and 9.4% lower carbon intensity relative to the market. Thus, investing in factors even without ESG considerations already produces a portfolio with above-average ESG and carbon characteristics.

2.2 Trading-Off Factor Efficacy and ESG/Carbon Performance

We now explore the effect of imposing ESG or carbon constraints on the long-only factor portfolios. Our procedure is as follows. So far, the factors are constructed using mean-variance optimization with the signals in Section 1.1 as expected returns, a risk model for the covariance, and various constraints to ensure there are no region or industry exposures away from the MSCI World Index, and we limit turnover. To this optimization we add constraints that specify that the ESG or carbon profiles must be improved by a certain level (see Appendix).

Exhibit 3 graphs the effects on the factor exposures resulting from improving the ESG scores (Panel A) and carbon emission intensities (Panel B) relative to the market. On the y-axis, we plot the percentage difference in active factor exposure between the optimal portfolio with ESG/carbon constraints and the optimum without constraints. This gives us an indication of how much the additional constraint moves us away from the optimal factor exposure. For example, we compute the value portfolio without ESG or carbon constraints as per the unconstrained factors in Exhibit 1. At each point in time, this benchmark factor portfolio has a value exposure, formally given in terms of z-scores using the valuation metrics detailed in Section 1.1. When we include ESG or carbon intensity constraints, the optimization produces a new value factor with lower value exposures. We graph the average value factor exposure of the constrained ESG or carbon portfolio as a percentage of the factor exposure of the unconstrained factor over the sample, from January 2015 to September 2019.

The x-axis in Exhibit 3 represents different percentage improvements in ESG scores or carbon intensity ranging from at least at benchmark levels (0%) to up to 50% better in ESG scores

(Panel A) or up to 80% better than benchmark in carbon intensity (Panel B). In both cases, the curves do not begin at the origin: as Exhibit 2 makes clear, certain factors (especially quality and low volatility) already have better-than-average ESG or carbon profiles than the market without any constraints, so the curves for those factors begin to the right of the origin. From then, the curves are downward sloping, indicating that as ESG or carbon improvements become tighter, the factor exposures decrease—which is as expected as when more and more stocks are removed from a portfolio, the more constrained space of the optimization can result in inferior factor exposure.

Panel A, Exhibit 3 shows that the low volatility portfolio, which is the curve lying on top, is the least affected by the additional ESG constraint and exhibits the least change in factor exposure. At the 20% ESG improvement level relative to the market, the low volatility exposure decreases by 1.2%, and at the 50% improvement level, the exposure decreases by 15.9%. Some of this is due to a size interaction because larger stocks have tended to be less volatile (see Ang et al., 2006), and larger stocks are also more likely to furnish ESG data. But not all. If we exclude the top 10% largest stocks by market capitalization, the exposures decrease to 1.5% and 20.7% at the 20% and 50% ESG improvement levels, respectively.

The value and quality portfolios are the most affected as ESG profiles improve. For the value factor, the decreases in factor exposure are 4.1% and 26% at the 20% and 50% ESG improvement levels, respectively. The decrease for the quality factor exposures are 3% and 27%, respectively. None of the factor portfolios, however, sees a meaningful change in factor exposure to achieve a 20-30% higher ESG portfolio than the market benchmark.

We perform a similar analysis in Exhibit 3, Panel B but now add an explicit carbon emission improvement relative to benchmark. Carbon emission intensity is far from normally distributed and it is feasible to achieve a strong improvement in carbon emissions with minimal changes to the portfolio's factor exposures. (Note especially the scale on the y-axis in Panel B relative to Panel A.) The size factor exhibits the smallest decrease in factor exposures and is the curve that lies on the top. Reducing carbon emissions by 50% results in a reduction in small size exposure of only 0.11%! But all the factors exhibit small decreases: the factor with the largest decrease in factor exposure is quality at the 50% carbon reduction level, which decreases its exposure by 0.66%. Again, none of the factor portfolios sees a meaningful change in factor exposure when the aim is to achieve a 40-60% lower carbon emission intensity portfolio than the benchmark.

What is driving these results is that there are a few, often very large, companies which account for the bulk of carbon emissions. Certainly a few industries and sectors account for outsized

carbon emissions—but this is true also *within* the industries and sectors. Carbon emissions tend to be driven by three sectors: utilities, materials and energy. Within materials, the metals and mining industry has the highest carbon emissions, while within utilities, companies within power and renewable electricity producers are the largest emitters.⁹ Even companies within the same industry can have very different carbon intensity values.

2.3 Jointly Optimizing Factors, ESG, and Carbon Outcomes

We now construct optimized factor portfolios with simultaneous ESG and carbon intensity outcomes, using the same region, industry, and country constraints as the benchmark factor portfolios. We impose an *ex-ante* 20% improvement in ESG ratings *and* a 40% reduction in carbon intensities for each individual factor—value, quality, momentum, size, and low volatility—and the multi-factor version containing all five factors.

Exhibit 4 reports *ex-post* ESG and carbon scores of the factor portfolios, together with performance statistics over January 2015 to September 2019. In each panel, we plot two columns: one for the benchmark factor portfolio without the additional ESG and carbon improvements and the other for the jointly optimized factors with ESG and carbon intensity improvements. Panel A reports ESG scores, showing the ESG/carbon optimized factor achieves ESG scores in excess of 6.6, compared to the benchmark factor scores around 5.6 to 5.8. In particular, the benchmark multi-factor portfolio has an ESG score of 5.7 vs. the market of 5.3. (Note the multi-factor portfolio already improves upon the ESG profile of the market as Exhibit 2 shows.)

Panel B of Exhibit 4 plots carbon intensities. To interpret the units, recall the carbon intensity is defined as (Scope 1 + 2 Total Emissions tonnes CO₂/ \$M Sales). The ESG/carbon optimized factor portfolios can further improve their carbon efficiency from 166 tn/\$ to 115 tn/\$ on average. Momentum, size, and low volatility see the largest improvements, while quality has the lowest—but the improvement for quality is still reduces emissions from 135 tn/\$ to 108 tn/\$.

Panel C of Exhibit 4 reports the factor exposures given in terms of z-scores for the benchmark factor portfolios and the factor portfolios with ESG/carbon improvements. This is similar to Exhibit 3, which plots a ratio of the factor exposures, but Exhibit 4 displays the factor exposures for the specific *ex-ante* targets of 20% ESG improvement and 40% carbon emission

⁹ [https://www.msci.com/documents/10199/2043ba37-c8e1-4773-8672-fae43e9e3fd0Standard Board. GAAP still differs materially from the international accounting standards \(International Financial Reporting Standards\), with still active discussions on reconciling the two standards \(see Barth, Landsman, and Lang 2008\).](https://www.msci.com/documents/10199/2043ba37-c8e1-4773-8672-fae43e9e3fd0Standard Board. GAAP still differs materially from the international accounting standards (International Financial Reporting Standards), with still active discussions on reconciling the two standards (see Barth, Landsman, and Lang 2008).)

reduction. On average, by jointly optimizing ESG scores and carbon emission, the factor portfolios' active exposures reduce only by approximately 3%. Low volatility sees a very muted exposure change of only -0.7%.

Finally, Panel D shows the in-sample performance of the raw factors compared to the optimized ESG/carbon factors. We acknowledge that our sample, over January 2015 to September 2019 is short, but it is notable how similar the IRs are for both portfolios. For example, the sample period is not kind to the value factor portfolio, which has an IR of -0.23 without ESG/carbon improvements and -0.09 optimizing with ESG and carbon. For the multi-factor portfolio, the IRs are 0.66 and 0.78, respectively. The ex-post tracking errors between the factor portfolios with and without ESG improvements range from 0.60% for the momentum factor portfolio to 0.96% for the size factor portfolio. Of course, we expect that ex ante, any additional constraint will cause the objective function to be weakly lower, so these apparent improvements are likely attributable to sampling error—the important point is that the ex-post performance is very similar constructing factor portfolios with and without ESG and carbon improvements.

Overall, these results suggest that the marginal cost of trading one stock over another based on only style factor exposures is relatively low, while the marginal benefit to ESG improvement is high. This is a fundamental characteristic of factor portfolios that makes them a potentially effective way of achieving ESG goals with limited impact on investment performance.

2.3 Comparing the Jointly Optimized Factor, ESG, and Carbon Portfolio

Exhibit 5 compares the joint optimized multi-factor portfolio with the 20% ESG improvement and 40% carbon reduction (“multi-factor portfolio with ESG/carbon improvements”) with portfolios optimizing only ESG and carbon emissions. We construct two versions of the latter: using the ESG score as an alpha input to our optimization (“max ESG”) and using the carbon intensity as an alpha input (“min carbon”).

Panel A plots the ESG improvement (x-axis) and the reduction in carbon emission intensities (y-axis) for the three portfolios above, together with some comparable ESG strategies. First, the orange dot is the multi-factor portfolio constructed with the 20% ESG improvement and the 40% reduction in carbon. This is comparable to the MSCI World ESG Screened Index, which achieves an almost 40% reduction in carbon with a minimal ESG improvement, and the MSCI World SRI Index, which has a 60% reduction in carbon emissions with a 30% improvement in ESG ratings. These two indices are market-cap weighted indices on an ESG screened universe and are therefore less diversified portfolios. The MSCI World ESG Enhanced Focus Index aims to

maximize the overall ESG score with a 30% improvement in carbon intensity relative to benchmark and sees an ESG improvement of 20%.

The min carbon portfolio exhibits a very large reduction of carbon intensity of over 90% along with a small ESG improvement. The very high reduction in carbon emission is due to the distribution of the carbon emission intensity which we also encountered in Section 1. The max ESG obtains a 40% improvement in ESG with a 20% reduction in carbon, but while the sustainability profile is better than the multi-factor portfolio with ESG/carbon improvements, the factor exposures are unsatisfactory. The min carbon portfolio has, with the exception of a size tilt, no other factor exposures as shown in Panel B of Exhibit 5.

The max ESG portfolio, however, has some interesting factor loadings: the positive momentum and negative value exposure suggest that good ESG companies have seen trending prices in the recent past. The mildly positive exposure to quality re-confirms that there is a correlation between ESG scores and a company's quality characteristics. Notwithstanding the negative correlation of (-20%) between ESG scores and size factor exposures, the max ESG portfolio results in a large size exposure alongside a high volatility exposure. This is counterintuitive but shows how constructing a long-only factor portfolio with only one variable can result in unintended biases.¹⁰ In contrast, the multi-factor portfolio with ESG/carbon improvements has a much more balanced exposure to targeted style factors, which are a rewarded source of return. In Exhibit C of Panel 5, this results in a positive IR of 0.23 from 2015 to September 2019, while the min carbon and max ESG portfolios have IRs of 0.03 and -0.41, respectively.

3. ESG in Factors

While Section 2 shows how to take advantage of the correlation between ESG ratings, carbon scores, and factor exposures to construct factor portfolios that jointly optimize all three—we have so far taken the sustainability data to be exogenous. In this section, we give two examples of how innovative ESG data can be incorporated in the factor definitions themselves. Section 3.1 shows how to use ESG data in a value factor by using green patent information. Section 3.2 describes how to incorporate corporate culture into a quality factor. Incorporating non-traditional ESG data to

¹⁰ Within the portfolio optimization we have a maximum asset weight constraint which the optimizer tries to utilize as much as possible by selecting the few companies with an ESG score of, or close to, 10. If we modify the upper asset weight constraint to be the minimum of 2% and four times the benchmark weight, the size exposure reduces significantly while the other factor exposures remain similar and the IR increases but at the expense of the portfolio level ESG score.

capture salient aspects of factors, but not relying solely on ESG as a source of return, may mitigate the data limitations traditionally associated with ESG data.

3.1 Green Intangible Value

More economists now recognize the role of intangible capital as an important component of firm assets (see, for example, Corrado, Hulten, and Sichel, 2009; Crouzet and Eberly, 2018). The rise of intangible assets is particularly stark: Crouzet and Eberly (2018) report that the fraction of intangibles as a fraction of total firm assets was around 10% in 1990 rising to close to 15% in 2016, and for high-tech firms, the fraction of intangible assets is now over 40% of total assets. Patents are one way of capturing intangible asset information: since at least Hall, Griliches, and Hausman (1984), economists have estimated intellectual property using patent data, providing valuation information complementary to financial valuations captured using traditional earnings statements and balance sheets. In particular, several authors, like Hirshleifer, Hsu, and Li (2013), Bekkerman and Khimich (2017), and Lee et al. (2019) demonstrate the predictive power of patent data for cross-sectional equity returns.

In this section, we concentrate on “green” patents and show how they can be included as a measure of value. We collect data on global patents via Google Patents Data, which is a rich database dating back to the 1980s.¹¹ We focus on green patents, which are patents promoting ESG-friendly innovations. These are defined as filing International Patent Classification (IPC) codes defined by the World Intellectual Property Organization if they meet UN Sustainable Development Goals (SDGs).¹² Examples of green patents include inventions around water and waste treatment, life-saving devices, fire-fighting advances, and clean energy. We take the two-year rolling sum of the number of green patents owned by each company divided by market capitalization. We match company names from the patent database to the standard financial databases using the methodology described in the Appendix. We build a portfolio with green intangible value along the same lines as Section 1.

¹¹ There are hundreds of years of patent data. The first patent in the UK was issued in 1449 for the manufacture of stained glass and the first patent in the US was issued in 1790 for a process for making potash.

¹² For IPC codes, see <https://www.wipo.int/classifications/ipc/en/> and for SDGs, see <https://sustainabledevelopment.un.org/sdgs>. The SDGs are no poverty; zero hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation, and infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; peace, justice, and strong institutions; and partnerships for the goals.

Economic Intuition

The economic intuition of using green patents as an intangible measure of firm intrinsic value is as follows. First, patents are an important form of innovative output and they are traded and licensed in intellectual property markets (see Griliches, 1990). Exhibit 6 shows the link between the patent signal and research and development (R&D) spending. R&D itself predicts future stock returns (see, for example, Lev, Sarath, and Sougiannis, 2005). In some cases, patents are the direct product of R&D spending, but the lead-lag correlations between patents and R&D spending in Exhibit 6 suggest that R&D spending increases before the issuance of a patent (event time zero), and then there is continued spending in R&D after the patent is issued—suggesting a continued focus on innovation once the innovation is recognized in a patent.

The innovative output captured in patents is risky, however, as not all R&D results in commercial success. If we interpret patents as the capitalization of certain investments, with R&D devoted to patents being a form of investment following Cochrane (1991), then investors should earn returns for these additional risks in new, unproven inventions. The special focus on green patents is that the SDGs are not only areas that are important to society as recognized by the UN, efforts to solve them should also naturally result in large profitable opportunities by firms.

Relation to Benchmark Value

Exhibit 7 documents the economic performance of intangible green value. As part of the portfolio optimization model described in Section 1, both factors are sector, industry, and country controlled. For example, although patents tend to be issued more in certain sectors such as healthcare, the patents signal identifies companies within the same sector that have more green patents than their peers.

Panel A graphs the cumulative relative performance of the green patents value factor portfolio versus the MSCI World Index from January 2000 to September 2019. As a comparison, we also graph the performance of the benchmark value factor portfolio. The intangible green value factor has an IR of 0.5 and has its strongest period from 2003 to 2011 with an IR of 0.94. There is a notable difference in performance with the benchmark value factor portfolio, based only on financial measures in the more recent period: from January 2007 to the end of the sample, the green value factor IR is 0.08 compared to -0.36 for regular value (see also Exhibit 1). This underperformance of the benchmark value factor portfolio coincides with the increasing importance of intangible capital noted by Crouzet and Eberly (2018).

Panel B reports some characteristics of the green value factor portfolio. The correlation of excess returns between green value and benchmark value is 15.7%, and thus there is some relation between the two. The fact that the correlation is much lower than one indicates that green value is not subsumed by regular value. We can test formally whether intangible green value is additive to the benchmark value factor by running a Britten-Jones (1999) spanning test, which yields a p-value of 0.003. Panel B also shows that the green patents factor portfolio has better sustainability characteristics than the benchmark value factor portfolio with the ESG score improved by 6.4% and the carbon emission intensity by 11%.

3.2 Corporate Culture Quality

Since Kreps (1980) and more recently Bolton, Brunnermeier, and Veldkamp (2013), economists have recognized the role of corporate culture in contributing to the production and value of firms.¹³ Aspects of culture tend to be more qualitative compared to the more quantitative notions of financial quality, but recent advances by Guiso, Sapienza, and Zingales (2015) and Li et al. (2019), among others, show that textual analysis (machine learning) techniques can be used to estimate corporate culture. In economic models, culture is relevant because it is a form of social norms and embeds values which are typically not formally specified, unlike contracts and legal norms—but they form an important part of “G” in ESG for firm value. Culture helps alleviate moral hazard: from employees’ point of view, it helps internalize behaviors that accrue to the organization. For managers, corporate culture mitigates the urge to divert profits as breaches of trust lead to a breakdown of corporate norms. Because contracts are incomplete in the real world, culture matters. Not surprisingly, CEOs place the creation and maintenance of corporate culture as one of the most important facets in running companies (see Graham et al., 2019).

We follow Li et al. (2019) and use the word embedding model of Mikolov et al. (2013) to estimate the quality of corporate culture using conference call transcripts. We work with the five core corporate culture values identified by Guiso, Sapienza, and Zingales (2015): innovation, integrity, quality, respect, and teamwork. Exhibit 8 illustrates how the word embedding model works. For each of the five core pillars, we specify a list of seed words. For example, a seed list containing words similar to “innovation” includes: creativity, excellence, passion, pride, etc. The

¹³ A much larger organizational behavioral literature, building on social anthropology, has long studied positive and toxic corporate cultures. The classic textbook is Kotter and Heskett (1992). Zingales (2015) provides a literature review in the finance literature.

word embedding algorithm finds words that are “similar” to the seed list using a deep neural network (for example LeCun, Bengio, and Hinton, 2015). For example, related words to “passion” in the “innovation” pillar are found by analyzing call reports and are identified by the algorithm, with some examples being “dedication” and “creativity.” The full procedure then results in a dictionary of words based on the five culture pillars. We then count how often these words are mentioned in the call transcripts, adjusting for the total number of words within the transcript.

Relation to Benchmark Quality

Panel A of Exhibit 9 graphs the relative performance statistics of the corporate culture quality measure versus the MSCI World Index from January 2007 to September 2019. Similar to our analysis for green intangible value (see Exhibit 7), Exhibit 9 also overlays benchmark quality which is constructed using only financial market data. The IR for corporate culture quality over the sample period is 0.29 with an annualized active risk of 2.4%. This compares with an IR of 0.7 with active risk of 2.3% for the traditional financial quality factor. We see relatively better performance during the recovery post the global financial crisis, perhaps consistent with good corporate culture fostering cooperative opportunities among employees that tend to fare better during periods of recovery. Corporate culture quality fares worse going into the global financial crisis—a period where companies that focus more on cost reductions and operational efficiency, which are captured well by benchmark quality, tend to do better.

In Panel B, we report some characteristics of the corporate culture quality factor. Reflecting the overall similar payoff patterns in Panel A, the excess return correlation between governance corporate culture quality and traditional financial quality is 0.22, which suggests that corporate culture quality is related to, but different from, benchmark financial quality. We test the additivity of corporate culture to the benchmark quality factor by running the Britten-Jones (1999) statistic which has a corresponding p-value of 0.068, which is close to, but not significant at the 5% level. Economically, the low correlation and the different dynamic behavior in Panel A indicate there are diversification benefits of the corporate culture quality factor to benchmark quality. Finally, we report the ESG and carbon characteristics of the corporate culture quality factor. The ESG score is similar to the quality benchmark (2% better) and while the carbon emission intensity is 9.6% lower, but it is still better than the market benchmark with an 18% improvement.

4. Conclusion

Environmental, Social, and Governance (ESG) risks can originate from the same economic rationales as regular style factors, like value, momentum, quality, size, and low volatility: a reward for bearing risk, economic structural impediments, and behavioral biases. Certain ESG data may be linked to risk or behavioral sources of return that are consistent with factor premiums, and can be used together with traditional factor signals to obtain efficient factor exposure. While traditional benchmark factors, which do not incorporate ESG information, are already ESG-friendly, the commonality between ESG and factor signals means that we can jointly optimize ESG, carbon, and factor exposures to form a multi-factor portfolio with a 20% better ESG profile and 50% lower carbon reductions without exhibiting any detracting performance in historical data. We show that ESG data can be incorporated into the factor definitions themselves, with green intangible value, using green patents, and corporate culture quality, using machine learning on textual data, are additive to traditional value and quality benchmark factors.

Appendix

A.1 Portfolio Optimization

We construct benchmark factor portfolios using mean-variance optimization:

$$\begin{aligned} \text{Max } \alpha_p - \frac{1}{2} \lambda \sigma_p^2 \\ \text{s.t. } w'1 = 1 \\ l_i \leq w'b_i \leq u_i \\ w \geq 0 \end{aligned} \quad (1)$$

where α_p is the portfolio's active alpha; σ_p^2 is the portfolio's active risk; λ is a risk aversion parameter; w are the portfolio weights; 1 is a vector of ones; l_i , u_i are lower and upper bounds, respectively, with respect to characteristics i : country, sector, industry and beta; and b_i are corresponding exposures of characteristic i . The scores are produced using standardized scores of the individual data items in Section 1.1 and converted to alphas by multiplying by idiosyncratic volatility and a constant information coefficient (IC) of 0.05 following Grinold and Kahn (2000). For the multi-factor portfolio, we use weights of 20% each to value, momentum, quality, size, and low volatility in the combined signal score of each stock.

To construct jointly optimized ESG and carbon improved factors, the optimization in equation (1), we add constraints that specify that the ESG or carbon emissions (CE) must be improved by at least a certain minimum level, given by l_{ESG} and l_{CE} , respectively:

$$\begin{aligned} w'ESG &\geq l_{ESG} \\ w'CE &\leq l_{CE} \end{aligned} \quad (2)$$

A.2 Matching Names

The Google Patents data comes with a large number of named entities holding patents, ranging from individuals to large corporations. The company names are not standardized and have different naming conventions to other traditional standardized data sets. We address this by first truncating the text into $k = 3$ length characters, shifting across by one character at a time, with the trigram length of three typically used for matching names/entities. We removed special characters and generic terms like "Corp" or "Inc" to help with the matching process.

We follow the term frequency inverse document frequency (TFIDF) procedure to convert the trigrams into vectors (see Jones, 1972), which counts the frequency of each trigram. Similar company names will have a similar distribution of trigrams, which are formally matched with a cosine similarity measure. Multiple entries can also be accepted if the data used shows potential of

different naming schemes/practices of the same entity. We perform manual checks and also check robustness with different thresholds on the cosine similarity measure.

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Exhibit 1

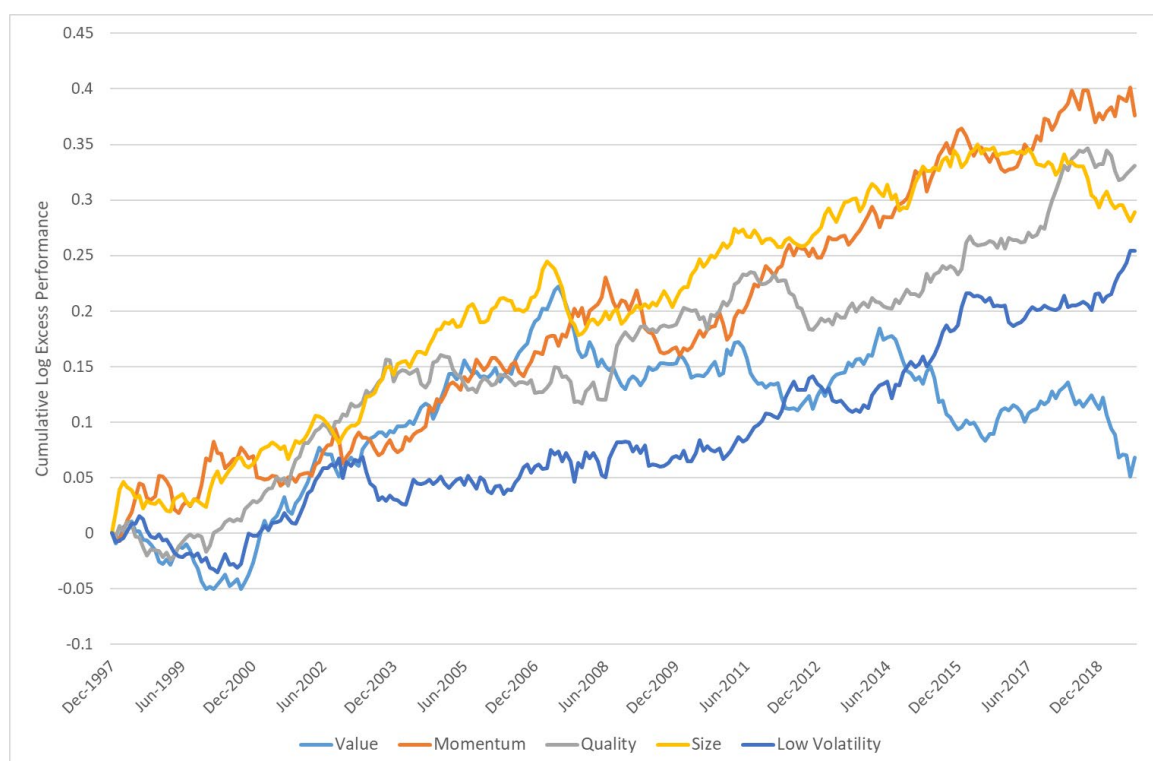
Summary Statistics of Benchmark Factor Portfolios (Without ESG)

Panel A: Summary Statistics

Strategy	Information Ratio (IR)	Annualised Active Return	Annualised Active Risk
Value Factor	0.12	0.30%	2.60%
Momentum Factor	0.61	1.70%	2.80%
Quality Factor	0.67	1.50%	2.30%
Size Factor	0.59	1.30%	2.20%
Low Volatility Factor	0.62	1.40%	2.30%

Calculations by BlackRock. Data from Worldscope, IBES and Barra, period of returns shown: January 1998 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

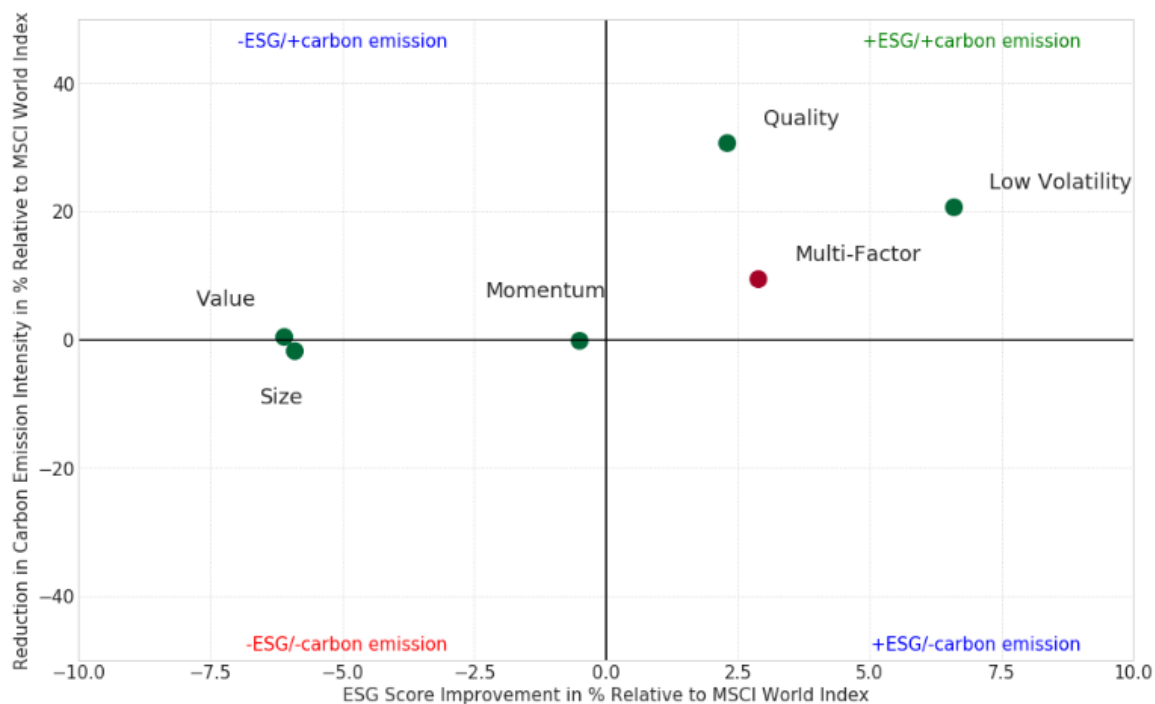
Panel B: Cumulative Active Returns



Calculations by BlackRock. Data from Worldscope, IBES and Barra, period of returns shown: January 1998 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

Exhibit 2

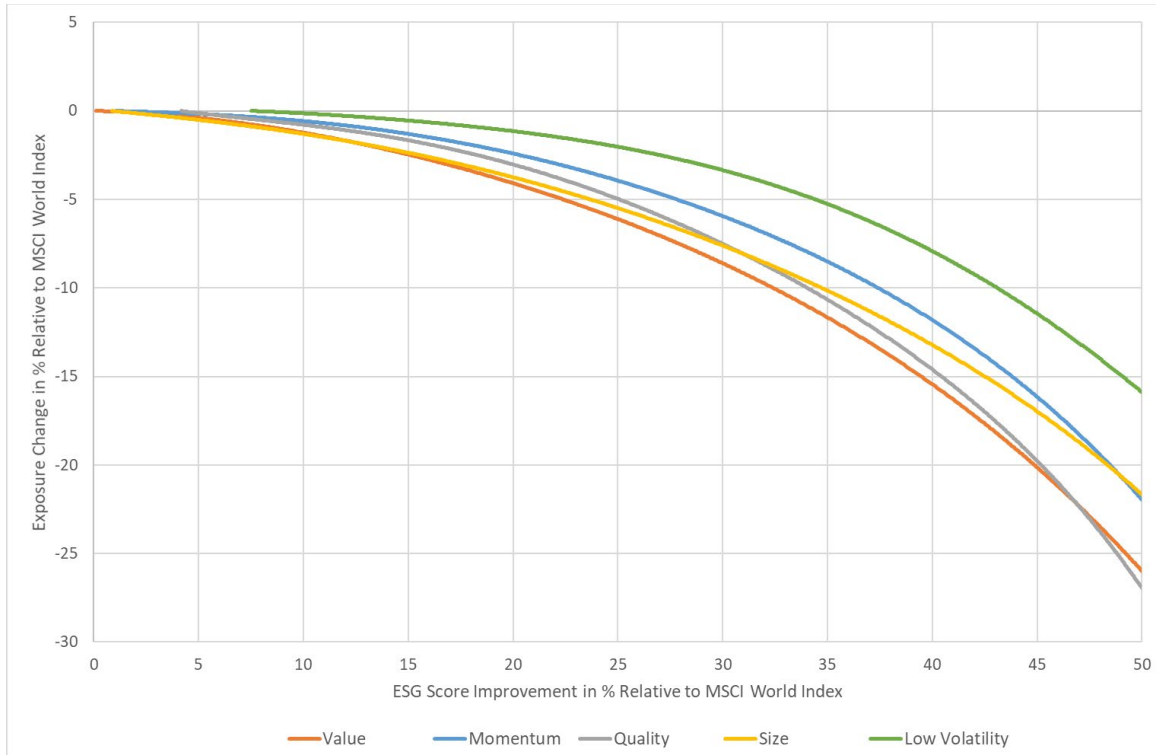
ESG Score and Carbon Emission Intensity of Benchmark Factor Portfolios



Calculations by BlackRock,. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Exhibit 3 Factor Efficacy as ESG and Carbon Outcomes Improve

Panel A: ESG Score Improvement Relative to MSCI World Index

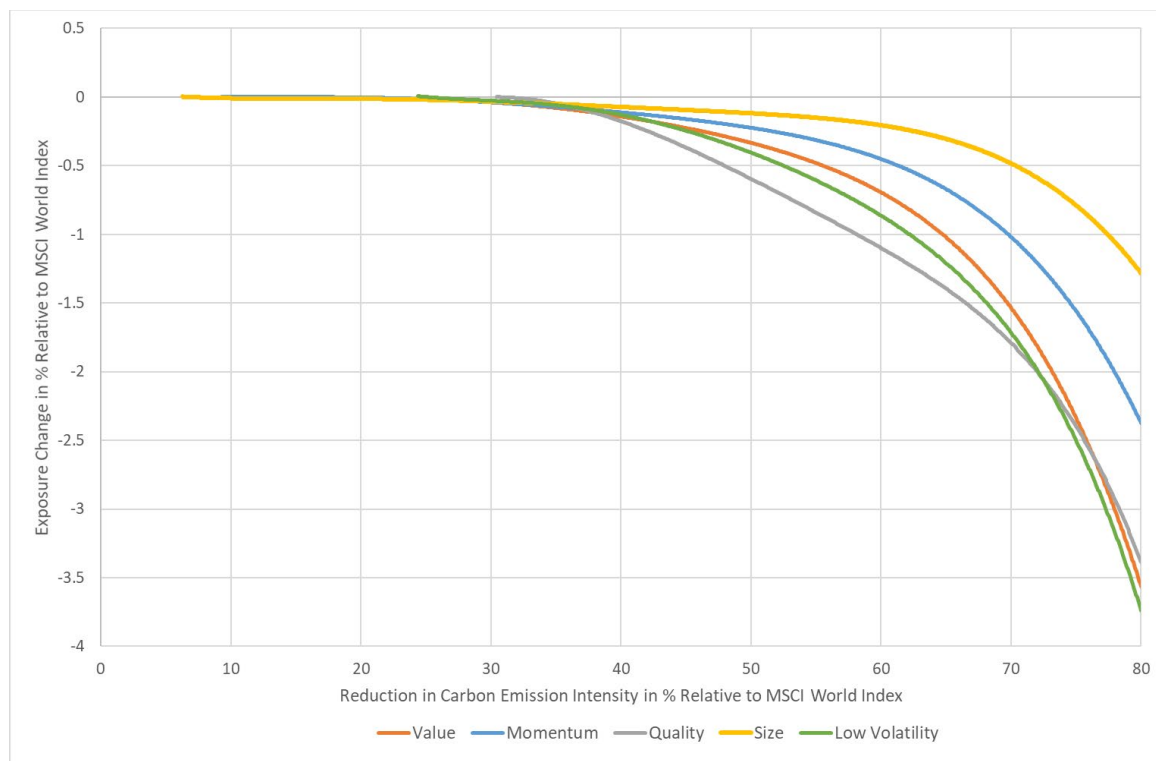


Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Exhibit 3 Continued

Factor Efficacy as ESG and Carbon Outcomes Improve

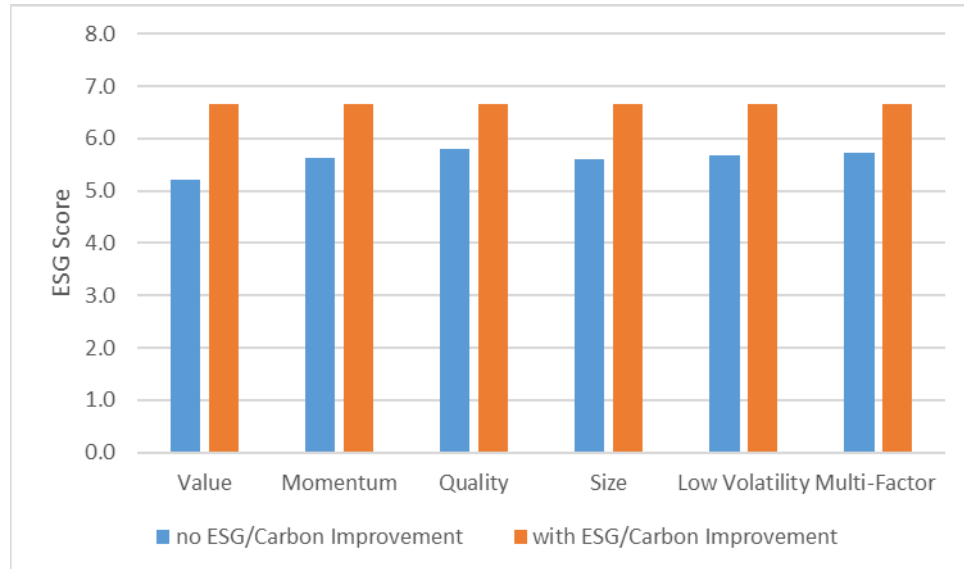
Panel B: Carbon Intensity Improvement Relative to MSCI World Index



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

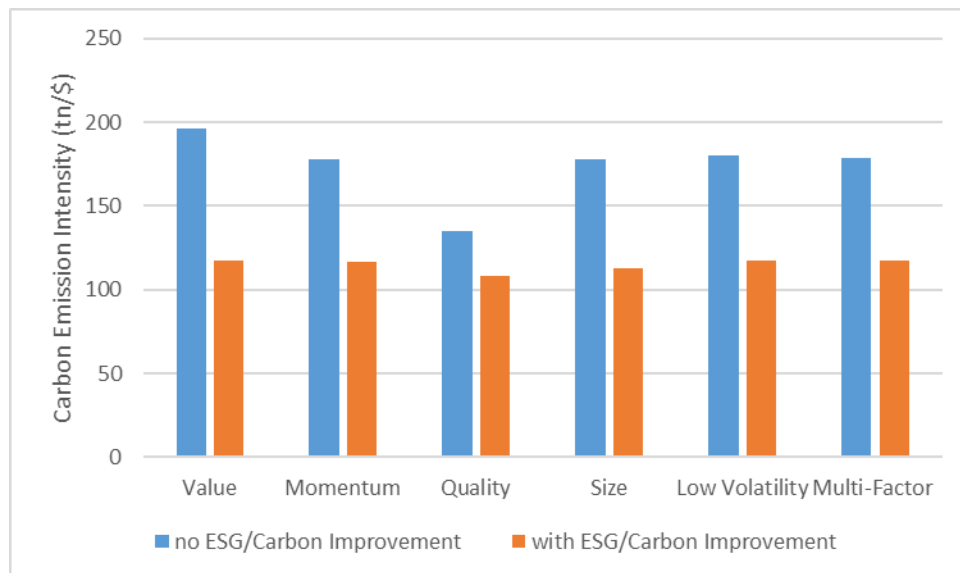
Exhibit 4 Statistics with and without ESG and Carbon Improvements

Panel A: ESG Scores



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Panel B: Carbon Emission Intensities

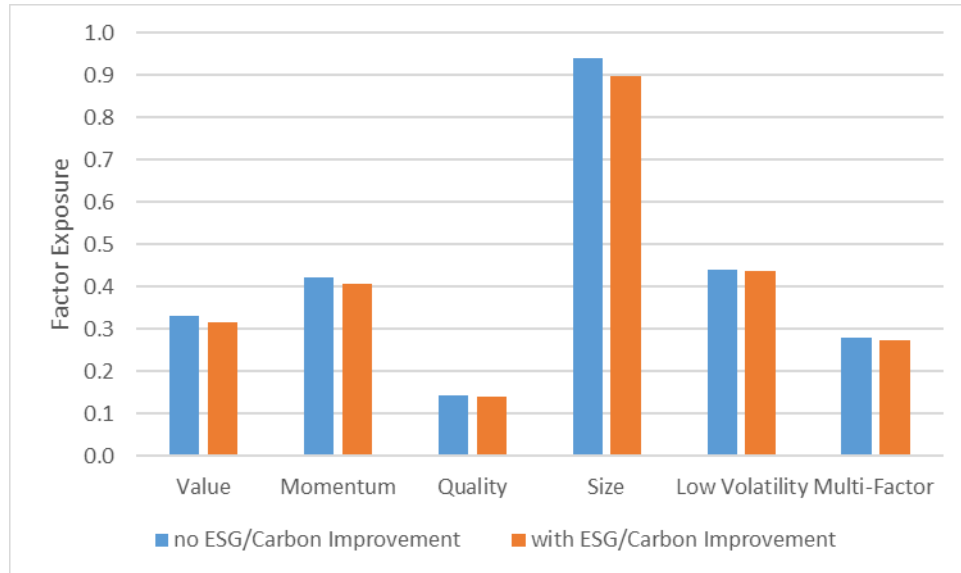


Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Exhibit 4 Continued

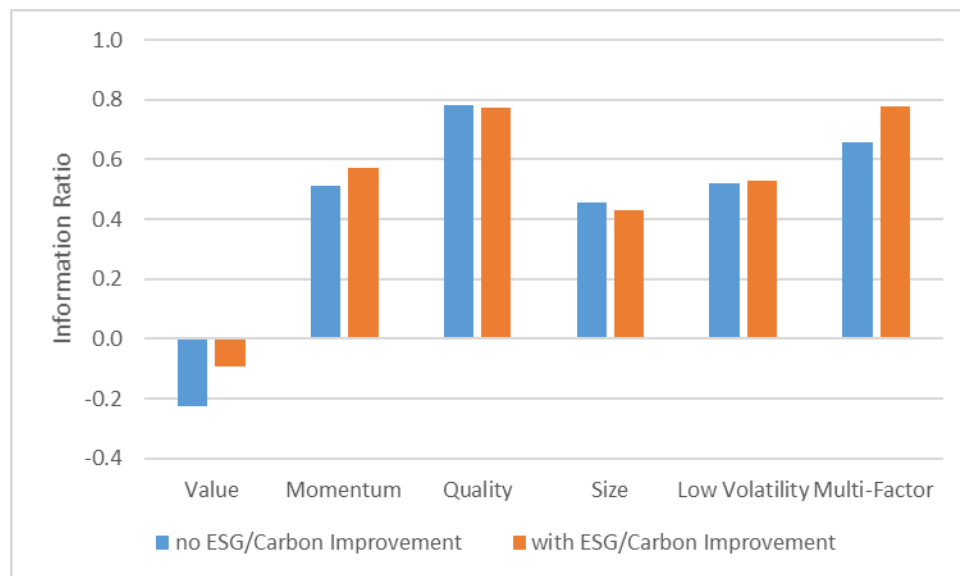
Statistics with and without ESG and Carbon Improvements

Panel C: Factor Exposures



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

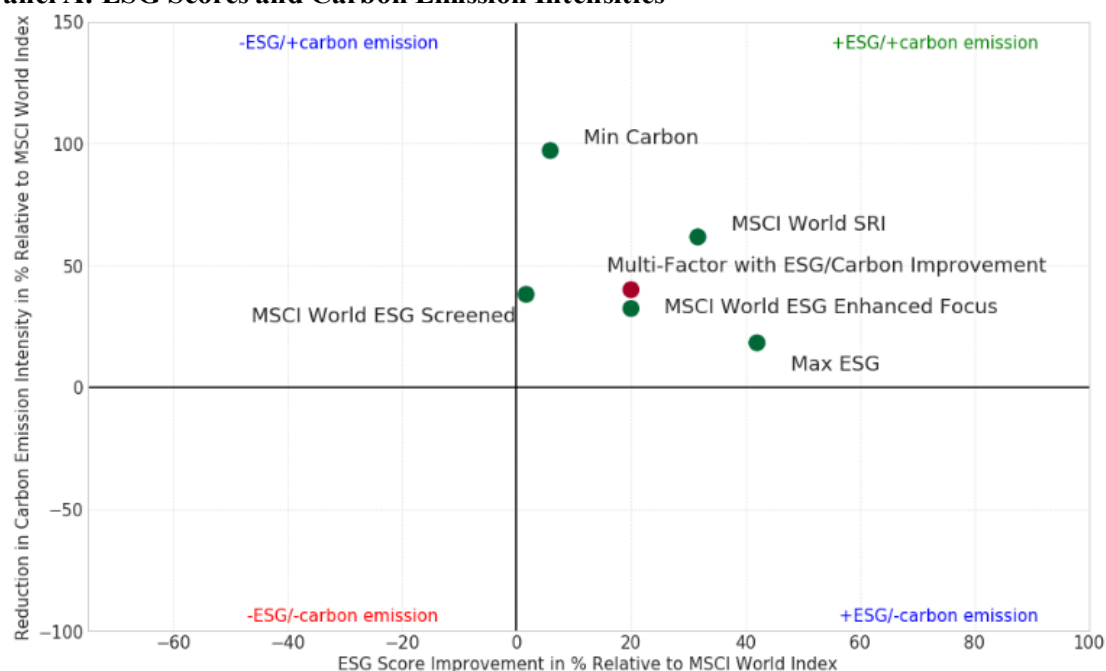
Panel D: In-Sample Information Ratios



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

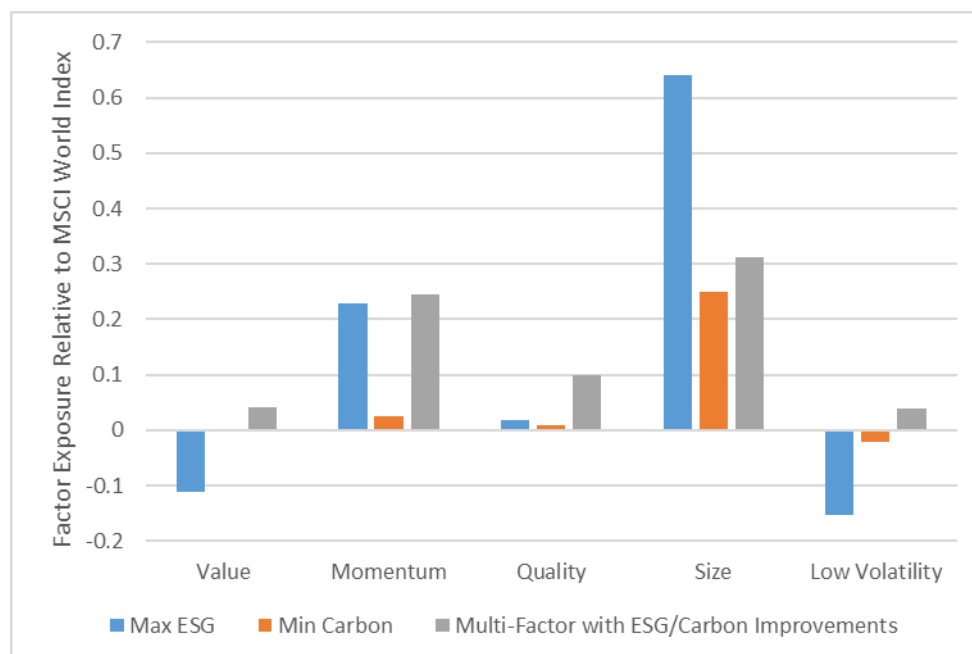
Exhibit 5 Comparing Optimized ESG/Carbon Factor Portfolios

Panel A: ESG Scores and Carbon Emission Intensities



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Panel B: Factor Exposures

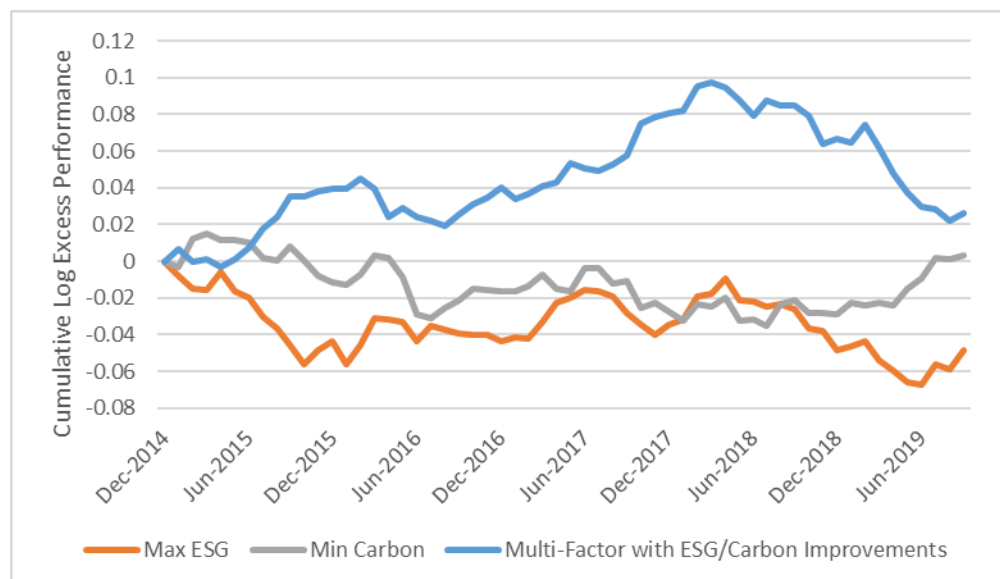


Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. Factors portfolios shown are hypothetical and do not represent actual investible strategies.

Exhibit 5 Continued

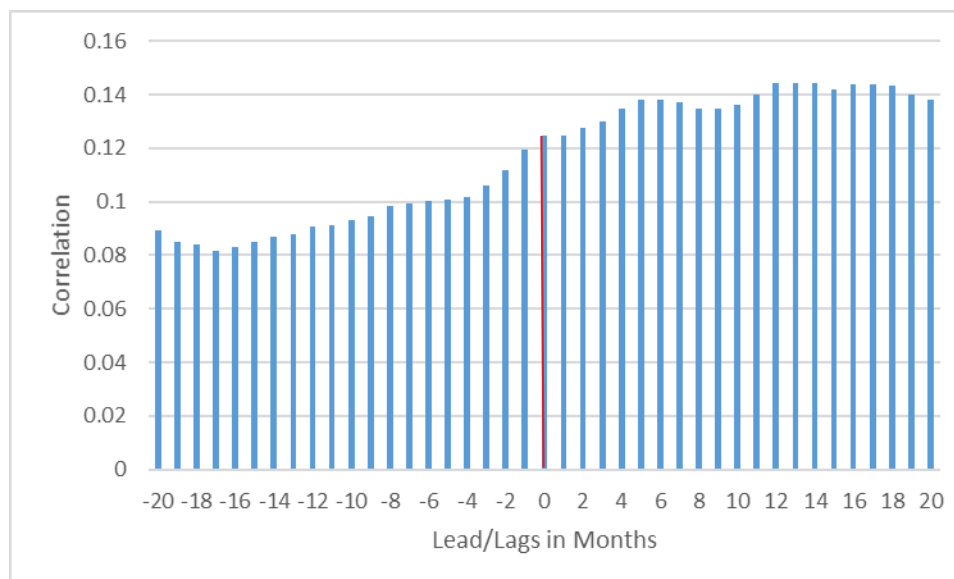
Comparing Optimized ESG/Carbon Factor Portfolios

Panel C: Cumulative Returns



Calculations by BlackRock. Data from Worldscope, IBES, MSCI ESG and Barra, period of returns shown: January 2015 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

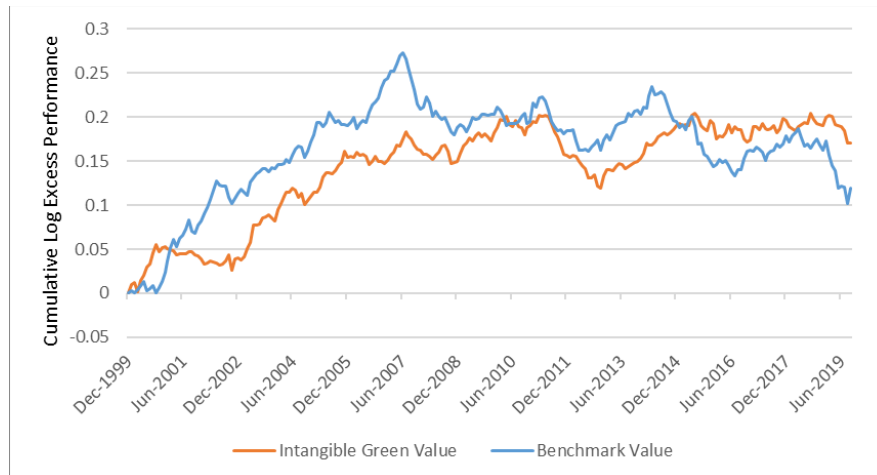
Exhibit 6 Relationship between Patents and R&D Spending



Calculations by BlackRock. Data from Worldscope and Google, period of returns shown: January 2000 – September 2019.

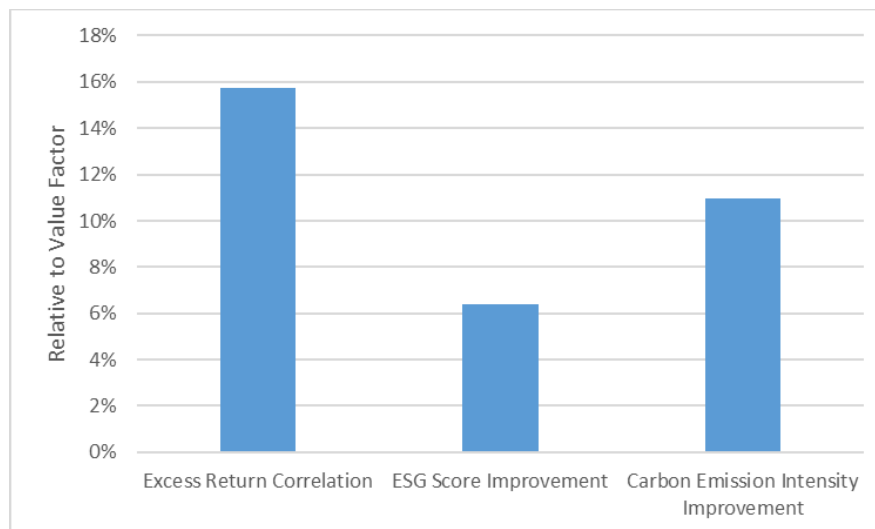
Exhibit 7 Intangible Green Value

Panel A: Cumulative Returns



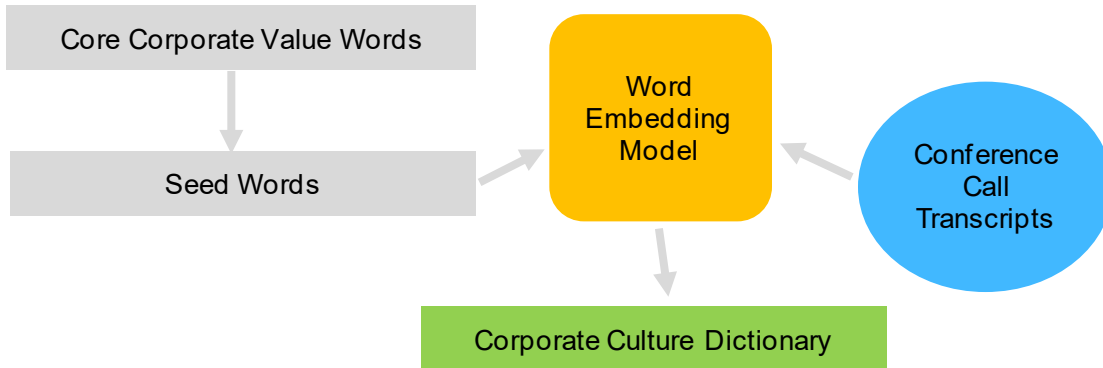
Calculations by BlackRock. Data from Worldscope, IBES, Google and Barra, period of returns shown: January 2000 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

Panel B: Characteristics of Intangible Green Value Factor Portfolio



Calculations by BlackRock, data from Worldscope, IBES, Google and Barra, period of returns shown: January 2000 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

Exhibit 8
Schematic of Measuring Corporate Culture Quality

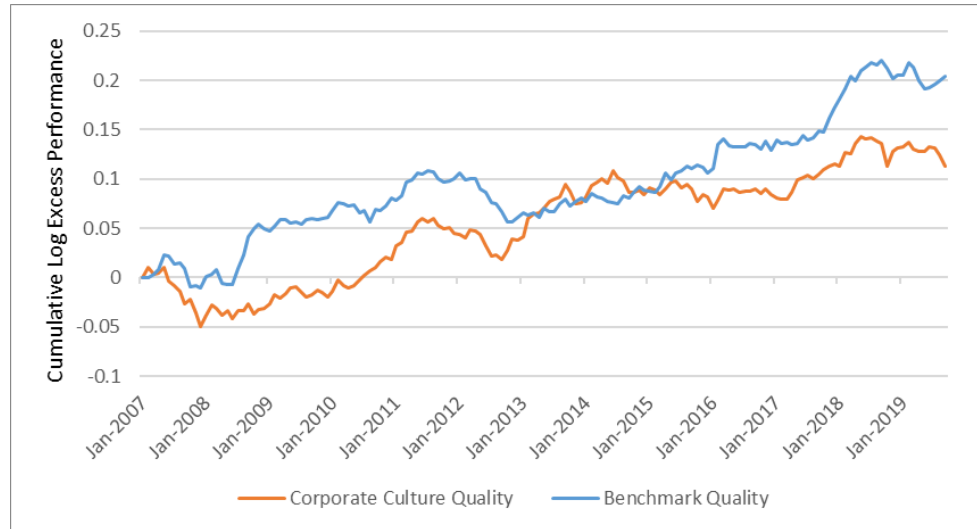


Core Corporate Values	Seed Words
Innovation	Creativity, Excellence, Passion, Pride, Leadership, Growth, Performance, Efficiency, Results, Innovation
Integrity	Integrity, Ethics, Accountability, Honesty, Fairness, Responsibility, Transparency
Quality	Quality, Customer, Commitment, Dedication, Value, Expectations
Respect	Respect, Diversity, Inclusion, Development, Talent, Employees, Dignity, Empowerment
Teamwork	Teamwork, Collaboration, Cooperation

Source: BlackRock as of January 2020. Words are derived from Guiso et al. 2015. For illustrative purposes only.

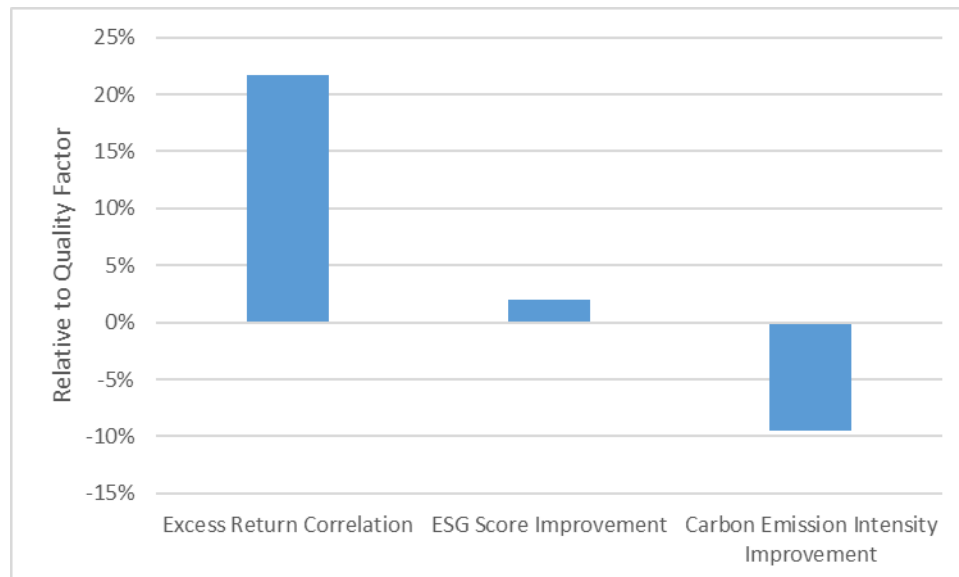
Exhibit 9 Corporate Culture Quality

Panel A: Cumulative Returns



Calculations by BlackRock. Data from Worldscope, IBES and Barra, period of returns shown: January 2007 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

Panel B: Characteristics of Corporate Culture Quality



Calculations by BlackRock. Data from Worldscope, IBES and Barra, period of returns shown: January 2007 – September 2019. **Past performance is not a guarantee of future results.** Performance shown is hypothetical and does not represent an actual investible strategy. Performance does not take into account the impact of fees. If fees were included, performance would be lower.

Capital at risk: The value of investments and the income from them can fall as well as rise and are not guaranteed. The investor may not get back the amount originally invested.

Past performance is not a reliable indicator of current or future results and should not be the sole factor of consideration when selecting a product or strategy.

Changes in the rates of exchange between currencies may cause the value of investments to diminish or increase. Fluctuation may be particularly marked in the case of a higher volatility fund and the value of an investment may fall suddenly and substantially. Levels and basis of taxation may change from time to time.

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