Understanding the Global Equity Greenium

G. Andrew Karolyi, Ying Wu, and William W. Xiong*

Abstract

We offer new evidence on how the application of environmental, social, and governance (ESG) criteria has affected international stock returns. We estimate the market-based equity greenium in a cross-section of 21,902 firms from 96 countries. We find reliable evidence that green stocks earned higher returns than brown stocks around the world. This outperformance is associated with lower stock returns of energy firms but not higher returns of technology stocks. Decomposing this outperformance further into five regions, including North America, Europe, Japan, Asia Pacific, and Emerging Markets, demonstrates that the equity greenium effect mostly occurs in North America and during the period before 2016. Most of the equity greenium performance cannot be explained by exposures to return factors prominent in the asset pricing literature.

Key words: ESG, sustainable investing, environment, climate change, international stock returns
JEL Classification Codes: F30, G12, G14, G15.
This Version : April 9th, 2023

* Karolyi is a Professor of Finance and the Harold Bierman Jr. Distinguish Professor of Management at the Cornell S.C. Johnson College of Business, Cornell University, Wu is an Associate Professor at the School of Business, Stevens Institute of Technology, and Wei (William) Xiong is a Ph.D. student at the Cornell S.C. Johnson College of Business, Cornell University. The authors deeply appreciate the insightful comments and invaluable feedback from René Stulz, Ľuboš Pástor, Luke Taylor, Jeffrey Wurgler, Malcolm Baker, Daniel Bergstresser, Andrew Ang, Nick Guest, Shaojun Zhang, Julian Kölbel, Lucia Alessi, Jitendra Aswani; conferences participants at the 2023 FMA meetings; and seminar participants at the Cornell Finance Faculty Brown Bag. Special thanks are given to Xiaoqing Eleanor Xu, the discussant and session chair at the 2023 FMA meetings, for constructive critiques and valuable suggestions. The authors also extend their heartfelt gratitude to Luke Taylor for generously sharing his code. Karolyi may be reached at gak56@cornell.edu, Wu may be reached at ying.wu@stevens.edu, and Xiong may be reached at wx98@cornell.edu. Address correspondence to: Ying Wu, School of Business, Stevens Institute of Technology, Hoboken, NJ 07030, U.S.A. Phone: (201) 216-3510, Fax:(201) 216-5385.

1. Introduction.

Sustainable investing, which applies environmental, social, and governance (ESG) criteria in investment decisions, has experienced an impressive development throughout the past two decades. According to the Global Sustainable Investment Review, the total assets under management for sustainable investing reached $35.3 trillion in 2020. The emerging theoretical literature predicts that green assets should have lower *expected* returns than brown assets. (e.g., Pastor, Stambaugh, and Taylor, 2021; Baker, Bergstresser, Serafeim, and Wurgler, 2022). The reasons include that investors with green tastes are willing to sacrifice financial returns for social benefits, and that green assets are a better hedge against climate risk. However, empirical studies often find inconclusive evidence on the correlation between ESG characteristics and equity returns (Alessi, Ossola, and Panzica, 2021; Bolton and Kacperczyk, 2021, 2022; Pastor, Stambaugh, and Taylor, 2022; Aswani, Raghunandan, and Rajgopal, 2023; Zhang, 2023). In this study, we quantify the impact of ESG characteristics on asset prices by exploiting the time-series and the cross-sectional variations of international stock returns. Especially, we focus on the environmental (or greenness) pillar and whether there are notable differences in the greenness-return relation between the equities in the U.S. market and those in the non-U.S. markets.

We examine the pricing dynamics of green equity and their conventional counterparts using a cross-section of 21,902 firms in 96 developed and emerging market countries. We estimate the market-based greenium, which is associated with the MSCI ESG ratings. We follow Pastor, Stambaugh, and Taylor (hereafter PST, 2022) and assign the greenness measures to individual stocks. Our sample begins in December 2012, when MSCI started to offer a more complete and balanced global data coverage, and ends in December 2021. Over this period, the value-weighted portfolio of stocks in the top third of greenness outperformed the bottom third by a cumulative return difference of 70 bps per month. This return spread, which we denote as GMB (green-minus-brown), has a monthly Sharpe ratio of 0.16. This is comparable with the stock market's Sharpe ratio during this bull-market period.

We perform a comprehensive analysis on the time-series and cross-section dynamics of the equity greenium effect around the world. Using monthly returns of over 52,000 stocks from 46 countries, we examine whether green stocks have generally performed differently from brown stocks in the first round of global experiments. We find that the strong performance of global GMB returns cannot be explained by exposures to global return factors prominent in the asset pricing literature. Interestingly, brown stocks have started to outperform green stocks in the past year of 2021 around the world. Even in the U.S. market, the GMB spread portfolio yield a negative average return of -30 bps per month for the past year. Next, we investigate whether this outperformance stems from the undue influence of specific industries. We find that most of the equity greenium effect is associated with lower stock returns of energy firms but not higher returns of technology stocks. In the U.S. market, the global GMB spread portfolio returns has dropped down to only 25 bps per month, which is not significant at the 10% level, if the energy sector is stripped down from the portfolios. Further, we examine how the GMB returns perform when they are constructed from regional test asset portfolios. We find that out of the five regions (North America, Europe, Japan, Asia Pacific, and Emerging Markets, the GMB returns from North America carry the most weight into the global GMB returns. For North America, its monthly GMB return averages 58 bps, which is significant at the 1% level. In contrast, the monthly GMB returns from the other four regions are rarely distinguishable from zero on the average. There are some critical instabilities on the greenium effect over time and across regions.

The next logical question is whether the ESG risk priced globally or locally in international stock markets. There exists a long-standing debate in the international asset pricing literature as to whether securities are priced locally in segmented markets or globally in a single, integrated market (Karolyi and Stulz (2003), Lewis (2011)). Most empirical evidence evaluating partial-segmentation models to date has focused only on whether aggregate market or consumption risks are priced locally or globally. However, more recent research has uncovered that the cross section of average returns in global markets is importantly linked to firm characteristics, such as size, book-to-market-equity ratios, or momentum (Bekaert, Hodrick, and Zhang (2009), Hou et al. (2011)). An important debate has emerged over whether the explanatory power of these characteristics arises locally or globally. We are interested in how our answer on the pricing of the ESG risk in international stock markets depends on whether we account for common sources of return covariation related to firm-level attributes so prevalent in equity markets. To answer these questions, we perform a variety of asset pricing tests for a given region of interest. Specifically, we consider a purely global, perfected integrated multi-factor model, a purely local, perfectly segmented multi-factor model, and a partial segmentation hybrid model as suggested in Griffin (2002). We find that the regional GMB alphas are robust to the benchmark models considered in the test. While the performance of the GMB returns varies across region, there has been shown a relatively stronger performance of the GMB returns in North America. For the other four regions, the performance of the GMB returns depends on whether we account for the common sources of return covariation related to firm-level attributes, such as size, value, and momentum.

An interesting feature of the monthly GMB returns is that they have been positive for an extended run, both globally and across region, but then was completely neutralized in the most recent years, especially for the regions of Europe, Asia Pacific, and Emerging Markets. During the sub-period from December 2012 to December 2015, almost all of the five regions experience substantially higher GMB returns. The monthly GMB return averaged 89 bps per month, 49 bps per month, 123 bps per month, and 102 bps per month in North America, Europe, Asia Pacific, and Emerging Markets, respectively. All of the alphas are statistically significant, regardless of what the benchmark model is considered. Their monthly Sharpe ratio of GMB goes up to 0.45 in three regions (North America, Asia Pacific, and Emerging Markets), and stays at a relatively median level of 0.33 in Europe. All of them are higher than the stock market's Sharpe ratios during this bull-market period. In contrast, there is a completely different picture on the GMB performance from January 2016 to December 21. Green stocks have started to deliver lower returns than brown stocks for three regions except North America and Japan. The monthly GMB return averaged -34 bps per month, -56 bps per month, and -55 bps per month in Europe, Asia Pacific, and Emerging Markets, respectively. For North America and Japan, the monthly GMB returns averaged 42 bps per month and 7 bps per month, respectively, and none of them are distinguishable from zero. These underperformances still cannot be explained by exposures to local return factors prominent in the asset pricing literature.

We acknowledge, of course, that it is hard to draw a clear line of demarcation between green stocks and brown stocks. Yet, despite being potentially coarse, such a distinction from the MSCI ESG score ratings provides a natural framework to test our hypotheses. Further, there are some positive signs that we can learn from our experiments to guide future research.

2. Data and Summary Statistics.

We compute the stock-level environmental scores based on MSCI ESG Ratings, following the procedures specified in PST (2022). The MSCI ESG Rating is a successor to the MSCI KLD data. MSCI is documented to be the world's largest provider of ESG ratings (Eccles and Stroehle, 2018; PST, 2022). MSCI covers more firms than other ESG raters, such as Asset4, KLD, RobecoSAM, Sustainalytics, and Vigeo Eiris (Berg et al., 2020). Further, Berg et al. (2021) find that MSCI's ESG scores are the least noisy among the eight ESG data vendors they consider. MSCI's ESG research unit employs more than 200 analysts and incorporates artificial intelligence, machine learning, and natural language processing into its methodology. MSCI generates its ratings based on a variety of sources and updates those ratings at least annually. Due to its comprehensive coverage and advanced methodology, the MSCI ESG Ratings data has been used by more than 1,700 institutional clients around the world.

In particular, we use the MSCI variables "Environmental pillar score" (*E_score*) and "Environmental pillar weight" (*E_weight*). *E_score* is a number between 0 and 10 measuring the firm's weighted-average score across 13 environmental issues related to climate change, natural resources, pollution and waste, and environmental opportunities. These scores are designed to measure a company's resilience to long-term environmental risks. *E_weight*, which is typically constant across firms in the same industry, is a number between 0 and 100 measuring the importance of environmental issues relative to social and governance issues.

Following PST (2022), we compute the unadjusted greenness score of firm *i* at the beginning of month *t* as

$$G_{i,t-1} = -(10 - E\_score_{i,t-1}) \times E\_weight_{i,t-1} / 100, \quad \text{(a)}$$

where $E\_score_{i,t-1}$ and $E\_weight_{i,t-1}$ are from company *i*'s most recent MSCI ratings date before month *t*, looking back no more than 12 months. The quantity $10 - E\_score_{i,t-1}$ measures how far the company is from a perfect environment score of 10. The product $(10 - E\_score_{i,t-1}) \times E\_weight_{i,t-1}$

measures how brown the firm is, specifically, the interaction of how badly the firm scores on environmental issues and how large the environmental impacts are for the industry's typical firm (i.e., $E\_weight_{i,t-1}$). The initial minus sign converts the measure from brownness to greenness.

The environmental score we use in our analysis is

$$g_{i,t} = G_{i,t} - \bar{G}_t \,, \tag{b}$$

where $\bar{G}_t$ is the value-weighted average of $G_{i,t}$ across all firms i. Since we subtract $\bar{G}_t$, $g_{i,t}$ measures the company's greenness relative to the market portfolio, as in PST. If w_t and g_t denote the vectors containing stocks' market weights and $g_{i,t}$ values in month t, then

$$w'_t g_t = 0, \tag{c}$$

a condition imposed by PST (2021). Here equations (a) to (b) are the same as equations (1) to (3) in PST (2022).

We compute $g_{i,t}$ for all stocks with non-missing MSCI data and trading data from Datastream. The sample period begins in December 2012 and ends in December 2021.[1] Our sample begins with all firms with non-missing MSCI ESG ratings data. We merge MSCI and Datastream by using a combination of ISIN, SEDOL, CUSIP, and company name. We filter out those that fail to be matched with the corresponding stocks in the Datastream equity database, for example, private firms and firms that are not listed as equity. These filters leave 21,902 firms in 96 countries. To construct our final sample, we confine the list of countries to be consistent with those in Fama and French (2012) and Karolyi and Wu (2018). As in Fama and French (2012), 23 developed markets are combined into four regions: i) North America, including the United States and Canada; ii) Japan; iii) Asia-Pacific, including Australia, New Zealand, Hong Kong, and

[1] We follow several screening procedures for monthly returns from Datstream as suggested by Ince and Porter (2006), and Hou et al. (2011). The beginning date of our sample is partly dictated by the availability of the MSCI ESG ratings data.

Singapore (but not Japan); and iv) Europe, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. The remaining 23 countries are combined into Emerging Markets, the fifth region in our tests; it includes Israel, Turkey, Pakistan, South Africa, Czech Republic, Poland, Hungary, Russia, China, India, Indonesia, Malaysia, Philippines, South Korea, Taiwan, Thailand, Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela. There are ultimately 21,198 stocks from 46 countries, referred to as our base sample.[2]

Graph A of Figure 1 plots the counts for the base sample, in which the total number has increased sharply in December 2012, from roughly 2,000 to over 8,000. Graph A of Figure 1 also plots the number of stocks on a region-by-region basis. All five regions have experienced a sharp in late 2012. The number of stocks from North America has remained at around 4,000 since September 2013 while those from the other four regions have continued to rise. For example, the number of European stocks has increased from roughly 1,500 in September 2013 to over 2,500 in December 2021. Likewise, the number of stocks from Emerging Markets has risen up from less than 1,700 in September 2013 to over 3,100 in December 2021.

Graph B of Figure 1 plot the counts for the U.S. sample only. Here we report two variants, one is on the full U.S. sample and the other on the restricted sample which only includes primary quote and major securities. The restricted sample resembles that in PST (2022), and yields very close results on the count. Graph C of Figure 1 plot the count for the global sample excluding the U.S. Consistent with the counts by regions, we notice a very steady increase on the coverage on the non-U.S. stocks with the MSCI ESG ratings. This rise further justifies the need to conduct

[2] Most of the firms and monthly observations are concentrated in the 46 markets considered for our base sample. There are only 704 stocks coming from the other 50 markets and being filtered out here. They account for 3% of the initial sample by count, and their monthly observations account for 2% of the total observations.

more comprehensive research on the impact of the application of ESG criteria on stock returns in the international setting.

3. The Equity Greenium.

PST (2022) documented that green stocks strongly outperformed brown in the U.S. We replicate their study for the U.S. sample and further extend it to the international setting. We examine whether the green stocks have performed differently from the brown stocks for our global sample in the first round of experiments in this section. Next, we examine whether the green stocks have performance differently from the brown stocks for the regional samples in the second round of experiments to follow.

3.1 global equity greenium.

Figure 2 displays the performance of green and brown stocks from November 2012 to December 2021. The connected scatter plot of green solid dots, representing green stocks, shows the cumulative value-weighted return on the portfolio of stocks with greenness scores in the top third. The connected scatter plot of brown solid triangles, representing brown stocks, displays the corresponding cumulative return for stocks with greenness scores in the bottom third. From Graph A which represents the global sample, we see that green stocks strongly outperformed brown stocks in the 2010s, with a cumulative return difference of 70% over our 110-month sample period. We also report the cumulative returns on the GMB portfolio (green-minus-brown) in Figure 3 following the calculation procedure in PST (2022). The monthly GMB return averaged 29 bps per month (*t*-statistic: 1.94), as reported in the first column of Table 1.

Among the 46 countries considered in the sample, the stocks from U.S. have created to a monthly GMB returns of, on average, 50 bps (*t*-statistic: 2.76), as reported in the second column of Table 1. The result is consistent with the findings in PST (2022). PST (2022) study the GMB portfolio for the period between November 2012 and December 2020 and document a 65 bps per month (*t*-statistic: 3.23) on the GMB portfolio in the U.S. Our replication reaches a 60 bps per month (*t*-statistic: 3.33) on the GMB portfolio in the U.S. when we also limit the sample period as from December 2012 to December 2020. Interestingly, brown stocks have strongly outperformed green stocks in the past year of 2021 for the U.S. market. Different from the first eight years, the GMB portfolio has started to yield negative returns in the U.S. since February 2021. Overall, the downturn has resulted in a -30 bps per month for the past year.

For the remaining 45 countries, the corresponding GMBs yield only 6 bps per month, with a *t*-stat of 0.36, as reported in the third column of Table 1. The GMB portfolio performed fairly well during the first eight years, with the average of 14 bps per month, but its performance gets substantially worse afterwards in the sense that the monthly return has averaged a negative 58 bps per month in the past year.

Table 1 shows that most of the global GMB returns comes from the U.S. sample rather than the remaining 45 countries. For the global GMB portfolio, its Sharpe ratio is 0.16, smaller than the market portfolio's Sharpe ratio of 0.24 but larger than that of the global SMB, 0.07, as well as the global HML portfolio's Sharpe ratio of -0.07. For the U.S. sample, its monthly Sharpe ratio of the GMB portfolio goes up to 0.26. In contrast, the monthly Sharpe ratio of the GMB portfolio only reaches 0.03 for the remaining 45 markets in the sample. Table 1 also reports the correlations among the variety of GMB portfolios. The global GMB is closely correlated with both the GMB portfolio in the U.S., with a correlation coefficient of 0.84, and the GMB portfolio in the non-U.S. countries, with a correlation coefficient of 0.89. The U.S. market and the remaining 45 markets are fairly correlated on the GMB portfolios, and the correlation coefficient is 0.53.

Can the strong performance of global GMB returns be explained by exposures to global return factors prominent in the asset pricing literature? To answer this question, the critical research design choice is about the benchmark factor models for the global GMB returns. The benchmark models considered here include the global versions of the Capital Asset Pricing model (CAPM), of the Fama–French (1993) three-factor, of the Carhart (1997) four-factor, and of the Fama–French (FF, 2017) five-factor models:

$$r^{\$}_{W,t} - r_{f,t} = \alpha^{i}_{WFF3} + \beta^{i}_{W}{}' \, [WMKT] + \varepsilon_{t} \qquad \text{(CAPM)} \quad (1_W)$$

$$r^{\$}_{W,t} - r_{f,t} = \alpha^{i}_{WFF3} + \beta^{i}_{W}{}' \, [WMKT_t, WSMB_t, WHML_t] + \varepsilon_{t} \qquad \text{(Fama-French 3-factor)} \quad (2_W)$$

$$r^{\$}_{W,t} - r_{f,t} = \alpha^{i}_{WFF4} + \beta^{i}_{W}{}' \, [WMKT_t, WSMB_t, WHML_t, WMOM_t] + \varepsilon_{t} \qquad \text{(F-F-Carhart 4-factor)} \quad (3_W)$$

$$r^{\$}_{W,t} - r_{f,t} = \alpha^{i}_{WFF5} + \beta^{i}_{W}{}' \, [WMKT_t, WSMB_t, WHML_t, WRMW_t, WCMA_t] + \varepsilon_{t} \qquad \text{(F-F 5-factor)} \quad (4_W)$$

$$r^{\$}_{W,t} - r_{f,t} = \alpha^{i}_{WFF5} + \beta^{i}_{W}{}' \, [WMKT_t, WSMB_t, WHML_t, WMOM_t, WRMW_t, WCMA_t] + \varepsilon_{t} \qquad \text{(F-F 6-factor)}, \quad (5_W)$$

where $r^{\$}_{W,t} - r_{f,t}$ is the excess return of the global GMB portfolio at time t expressed in dollars relative to the dollar-denominated risk-free rate, $r_{f,t}$. All five models include: *WMKT,* defined as the excess return on the world equity market portfolio, denominated in U.S. dollars, for which the superscript "*W*" implies that they are constructed from all stocks around the world; *WSMB*, the difference between the returns of globally diversified portfolios of small stocks and big stocks; and *WHML,* the difference between the returns on globally diversified portfolios of high B/M (value) stocks and low B/M (growth) stocks. Eq. (3_W) adds *WMOM* as the difference between the returns of globally diversified portfolios of winner stocks and loser stocks. In Eq. (4_W), *WRMW* is the difference between the returns on globally diversified portfolios of robust operating profitability stocks and weak operating profitability stocks and *WCMA* is the difference between the returns on globally diversified portfolios of conservative investment stocks and aggressive investment stocks. β^{i}_{W} is a vector of factor loadings that correspond to the respective global factors.

Panel A of Table 2 reports results of regressing the global GMB portfolios on various factors. Overall, the strong performance of the global GMB portfolio cannot be explained by exposures to return factors prominent in the asset pricing literature. The factors considered include a market factor (Mkt-Rf), a size factor (SMB), a book-to-market-equity factor (HML), a momentum factor (UMD), a profitability factor (RMW), and an investment factor (CMA). Here we consider a variety of the global benchmark models. The first column of the table reports the estimated coefficient as well as the robust *t*-statistics (in the parentheses) for the global CAPM model, as reported in (1) in the table. The remaining four columns report the estimated results for the global Fama-French (1993) three-factor model, the global version of the Fama-French-Carhart (1999) four-factor model, the global version of the Fama-French (2017) five-factor model, and the global version of the Fama-French (2017) five-factor model augmented with the momentum factor, respectively, as (2) - (5) from left to right in the table. The alpha of the global GMB is 36 bps per month ($t = 2.37$) for the global CAPM model, 31 bps per month ($t = 2.39$) for the global Fama and French (1993) three-factor model, 29 bps per month ($t = 2.13$) for the global Carhart (1999) four-factor model, 30 bps per month ($t = 2.20$) for the global Fama and French (2015) five-factor model, and 28 bps per month ($t = 1.97$) for the global Fama and French (2015) five-factor model augmented with the global momentum factor. In all cases, the global GMB's alpha (regression constant) is economically and statistically significant. GMB's lowest alpha in Table 1 occurs in Column 5, where we adjust for the global variant of the Fama and French (2015) five-factor model augmented with the momentum factor. Its exposures to the market factor, the size factor, the value factor indicate that the global GMB portfolio tilts toward stocks with negative market beta, large stocks, and growth stocks.

Factor model regressions with useful factors should have higher R^2s. The highest value of the adjusted R^2s in Table 1 occurs in Columns 2 and 3, where we adjusted for the global variants of the Fama and French (1993) three-factor model, and of the Carhart (1999) four-factor model. This indicates that the market factor, the size factor and the value factor are more useful for explaining time-series variation in the global GMB portfolio returns.

Panel B of Table 2 reports results of regressing the GMB portfolio returns in the U.S. on a variety of global benchmark models. In all cases, GMB's alpha in the U.S. is economically large and statistically reliable, ranging from 43 to 54 bps per month, with *t*-statistics between 2.42 and 2.94. The U.S. GMB's lowest alpha occurs in column 5, where we adjust for the global Fama and French (2015) five-factor model augmented with the global momentum factor. Its exposure to SMB, HML, and UMD indicate that the GMB portfolio in the U.S. tilts toward large stocks, growth stocks, and recent winners. Net of those exposures, the alpha of GMB is 43 bps per month (t = 2.42). The U.S. GMB's highest alpha occurs in column 1, where we adjust for the global CAPM. The alpha of GMB is 54 bps per month (t = 2.89). The highest value of the adjusted R^2s in Panel B occurs in Columns 3 and 5, where we adjusted for the global variants of the Fama and French (1993) three-factor model, and of the Fama and French (2015) five-factor model. This indicate that all the fundamental factors linked to firm characteristics are useful for explaining time-series variation in the U.S. GMB portfolio returns.

Panel C of Table 2 reports the regression results for the returns of the GMB portfolio from the remaining 45 markets. In contrast to the results for the global sample and the U.S. sample, the estimates of the GMB's alphas decrease substantially for the global sample excluding the U.S., and become insignificantly different from zero in all experiments. For example, the alpha of the GMB portfolio shrinks to an insignificant 9 bps per month in the test of the global version of the

Fama and French (2015) five-factor model augmented with the momentum factor. In addition, its exposures to the market factor, the size factor, the value factor indicate that the GMB portfolio from the other 45 countries tilts toward stocks with negative market beta, large stocks, and growth stocks. This is similar with the results for the global GMB portfolio. The adjusted R^2s range from 0.04 for the global CAPM to 0.15 for the global Fama and French (1993) three-factor model. This result corroborates the estimates of the exposures, indicating that the market factor, the size factor and the value factor are the most useful factors in explaining time-series variation in the global GMB portfolio returns excluding the U.S.

The relatively disappointing performance of the GMB portfolio from the non-U.S. markets suggests the need to further explore the sensitivity of our inference on the time-series regression tests to alternative multi-factor asset pricing models. Following a key prescription of Fama and French (2012), we consider the purely local factor model when regressing the GMB portfolio returns in the U.S. on various factors, and report the estimation results in Table 3. All regression tests give qualitatively similar results to those reported in Panel B of Table 2. On the other hand, by the purely local factor model, the magnitudes of these GMB's alphas become smaller, regardless of what estimation models are employed. The U.S. GMB's lowest alpha occurs in Column 3, where we adjusted for the local version for the Carhart (1999) four-factor model. Its exposures to the market factor, the size factor, the value factor, and the momentum factor suggest that GMB tilts toward stocks with negative beta, large stocks, growth stocks, and recent winners for the U.S. market. Net of those exposures, the alpha of GMB is 31 bps per month, which is not statistically significant at the 5% level.

At first sight, these results appear at odds with those of PST (2022), who find that green stocks strongly outperformed brown unanimously in the U.S. However, PST (2022)'s sample period, 2012 to 2020, is shorter than ours, 2012 to 2021. As mentioned earlier, the past year of 2021 is the period when the GMB portfolio has performed poorly around the world. Without loss of generality, we conduct a sub-period analysis to provide a head-to-head comparison with PST (2022). In this experiment, the sample period is set as the same with PST (2022), 2012 to 2020, and we re-conduct the time-series regression on the GMB portfolio in the US on various local factors. Panel B of Table 3 shows our replication results on PST (2022) and Panel C of Table 3 is exactly Table 3 in PST (2022). It is clear that our replication provides very close results with PST (2022). Like PST (2022). GMB's alpha in the U.S. remains economically large and statistically reliable for all cases. For example, when the local version of the Fama and French (2015) five-factor model is used as the benchmark model, its exposures to the market factor, the size factor, the value factor, the profitability factor, and the investment factor are 0.06, -0.22, -0.13, -0.25, -0.12, respectively, in our replication. PST (2022) reports the exposures are 0.04, -0.26, -0.21, -0.39, -0.10, respectively. Further, all of the estimated coefficients come with a similar significance level. They indicate that GMB tilts toward large stocks, growth stocks and stocks with high profitability. Net of those exposures, we report the alpha of GMB as a value of 43 bps per month (t = 2.41) and PST (2022) report a 50 bps per month (t = 2.38). Overall, our replication results reassured us that green stocks did strongly outperformed brown in the first eight years but not as well as before during the year of 2021.

3.2 industry equity greenium

As pointed out by PST (2022), the GMB portfolio has been correlated with two different types of greenness, the greenness of the firm's industry and the relative greenness of the firm within its industry. Does the equity greenium stem from the influence of some specific industries? To investigate this question, we further collect the GICS industry classification data codes from

Datastream and merge them with our MSCI ESG Rating datasets. The GICS industry codes classify stocks into eleven general sector categories: (1) Energy, (2) Materials, (3) Industrials, (4) Consumer Discretionary, (5) Consumer Staples, (6) Health Care, (7) Financials, (8) Information Technology, (9) Communication Services, (10) Utilities, and (11) Real Estate. We redo the main experiments on the construction of green and brown portfolios but strip down one sector out of the eleven sectors of stocks in each round of the experiments. Using the energy sector as an example, we first exclude stocks from the energy sector from the complete equity sample and create a refined equity sample which only include the remaining ten sectors. Then we follow the procedure specified in Section 2 and construct a new set of the green portfolio and the brown portfolio, for a given region, which aggregate individual stocks representing all sectors except for the sector of energy.[3]

Figure 4 displays the performance of green and brown stocks for the industry carving-out experiments. Panel A shows the results for the global sample, Panel B shows the results for the U.S. only, and Panel C shows the results for the global sample excluding U.S. For a given region, the left figure demonstrates how the green portfolios and the brown portfolios have performed over time when both portfolios include all sectors of stocks. Using stocks in the energy sector as the representative for the brown stocks, the middle figure reports how the green and brown portfolios have performed if we carve out stocks in the energy sector. Using stocks in the information technology sector as the representative for the green stocks, the right figure reports how the green and the brown portfolio have performed if we strip down stocks in the sector of

[3] We also consider the ICB and TRBC industry classifications in the industry experiments. Our empirical results are very close and consistent cross the three industry systems (GICS, ICB, and TRBC). For the sake of brevity, we mainly report and discuss the results which are based on the GICS industry classification. The results for the other two industry classification are available upon request.

information technology. We also report the cumulative returns on the GMB portfolios in Figure 5 for the leave-one-sector-out experiments.

As shown in Figures 4 and 5, the brown portfolio seems to perform better when we remove out the stocks from the energy sector. The US brown portfolio without the energy sector stocks has delivered a much higher return, which almost doubles that of the original US brown portfolio which include all stocks from the eleven sectors. It indicates that the energy sector, especially in the U.S., has delivered a lower return in general, when compared with other brown stocks. As a consequence, leaving them out would make the US brown return higher and the GMB spread shrink down.

As mentioned in PST (2022), the technology industry, especially "big tech", has delivered higher stock returns in recent years. Then, are our results driven by big tech? Figures 4 and 5 indicates that the outperformance of the green portfolio over the brown portfolio does not get weaken or disappear when we strip down the stocks in the sector of information technology, regardless of which specific region is considered in the experiments. It is clear that we notice a substantial difference between the GMB spread in the U.S. and the GMB spread in the non-U.S. countries. In particular, the U.S. green portfolios have performance substantially better than those in the non-U.S. countries. Are the higher U.S. green returns driven by the higher returns from the large technology companies in the U.S.? Removing the sector of information technology, the U.S. green portfolio continues showing a much higher returns than that from the non-U.S. countries. The difference between the U.S. and the global excluding U.S. are not driven by the undue influence of technology sector.

Table 4 reports the risk-adjusted returns on the global GMB portfolios, the GMB portfolios in the U.S. and the GMB portfolios in the non-U.S. countries when the global Fama-French (2015) five-factor model is considered as the benchmark model.[4] The very left column reports the regression results on the global GMB portfolios. The estimated alpha is 34 bps per month for the complete GMB portfolio including all sectors of stocks, which is very close to 30 bps per month reported in Table 2.[5] When we remove the energy sector out of the sample, the GMB alpha has decreased to 25 bps per month and it is no longer statistically significant at the 10% level. The weaken GMB performance also occurs in the U.S. sample as well as in the Global excluding U.S. sample. Take the U.S. sample as the example, the GMB alpha has dropped down substantially from 49 bps per month (*t*-statistic: 2.62) to 31 bps per month (*t*-statistic: 1.63). When we remove the sector of information technology out of the sample, the GMB alphas has slightly decreased to 32 bps per month, which is still significant at the 5% level, for the global sample. In the U.S. the GMB alpha has barely changes, from 49 bps to 50 bps, and both of them are still statistically significant. Stocks in the sector of communication service is another example of the green stocks. The GMB alphas have generally increased and remained reliably significant when we carve out the sector of communication service from the complete equity sample. For the global excluding U.S. sample, removing the financial sector helps to increase the GMB alpha from 12 bps per month (*t*-statistic: 0.70) to 27 bps per month (*t*-statistic: 1.68). At the same time, the poor GMB performance does not seem to be correlated with some specific sectors. Further, it is worthy to note that the substantial difference between the GMB spread in the U.S. and that in the global excluding U.S. still remain in the carving-out sectoral experiments.

Overall, there are three main findings in the industry greenium experiments. First, the equity greenium is associated with the lower returns of energy firms. Second, the equity greenium

[4] Internet Appendix Table 2 report the full set of regression results on the experiments, including the estimated alphas, the estimated coefficients associated with the fundamental factors in the model, as well as the regression fits.

[5] The minor difference is driven by the fact that some stocks in the original data sample have missing GICS codes from Datastream and have to be removed from the portfolio construction in the industry experiments.

is not simply a manifestation of premium on technology. Third, the big difference on the GMB spread from one region to another, like from U.S. firms to non-U.S. firms, does not stem from the undue influence of specific industries.

3.3 regional equity greenium.

To further explore the equity greenium effect, we conduct the second round of experiments. Specifically, how do the GMB returns perform when they are constructed from equivalent regional test asset portfolios? We construct the spread portfolio that longs the green stocks and shorts the brown stocks for a given region, and examine whether there are some critical instabilities on the equity greenium effect over time and across regions.

Table 1 reports the summary statistics for the regional spread portfolios (regional GMBs) for North America, Europe, Japan, Asia Pacific, and Emerging Markets, respectively. The GMB return is 58 bps per month for the region of North America, which is similar with the results in the U.S. It is obvious that excluding North America lowers the global GMB returns so that the monthly GMB returns from the other four regions are hardly significant from zero on the average. For example, we find that the green stocks of European firms earn lower returns than the brown stocks of European firms. The GMB returns averaged -6 bps per month for the entire sample period. Likewise, we find insignificantly negative GMB returns for the region of Emerging market, with an average of -2 bps per month. For the regions of Japan and Asia Pacific, the GMB returns share the same sign with those in North America, although the magnitude is much smaller and not reliably different from zero. For example, the average of the monthly GMB in Asia Pacific is only 5 bps and the *t*-value yields only 0.18. Table 1 also reports the correlations among these regional GMBs over time. Most correlations are positive in the sign. For example, the monthly GMB in North America has the correlations as high as 0.52 with the monthly GMS in Europe and down to

0.07 with that in Japan. The exception is the region of Japan, which tends to be negatively correlated with the three regions other than North America. Its correlation runs as -0.04, -0.07, and -0.05 with Europe, Asia Pacific, and Emerging Markets, respectively. Interestingly, the monthly GMB in Emerging Markets seems equally correlated with those in North America (correlation = 0.37), Europe (correlation = 0.36), and Asia Pacific (correlation = 0.38). We also report the cumulative returns on the green portfolio, the brown portfolio, and the GMB portfolio in Figures 6 and 7.

Is the ESG risk priced globally or locally? And how does our answer depend on whether we account for common sources of return covariation related to firm-level attributes so prevalent in equity markets? There exists a long-standing debate in the international asset pricing literature as to whether securities are priced locally in segmented markets or globally in a single, integrated market (Karolyi and Stulz, 2003; Lewis, 2011). Karolyi and Wu (2018) investigate how reliably investigate how reliably do multifactor models that include size, value, and momentum factor portfolios capture return covariation globally when the factor portfolios are built to allow (i) for only local variation (segmented markets), (ii) for global variation (integrated markets), and (iii) in the intermediate case of what they call partial segmentation, for both local and global variation. Their findings demonstrate how models of partial segmentation achieve the lowest pricing errors and rejection rates relative to the pure segmentation or pure integration models, especially when emerging markets are included among the tests asset portfolios. To answer the question as to whether the ESG risk is priced in a way that depends on the degree of market segmentation or integration, we repeat the time-series regression-based tests of multifactor models above but on the monthly GMB returns, which are built on a region-by-region basis.

For a given region of interest, we perform three sets of asset pricing tests, which are the regional test, the partial segmentation test, and the global test, respectively. The purely global, perfected integrated multi-factor models specified above are examined for the regional GMB portfolios. At the same time, we adopt the purely local, perfectly segmented factor models as the new benchmark for the regional test asset portfolios, as suggested in Fama and French (2012) and Karolyi and Wu (2018). The purely local benchmark models considered here include the purely local versions of the Capital Asset Pricing model (CAPM), of the Fama–French (1993) three-factor, of the Carhart (1997) four-factor, and of the Fama–French (FF, 2017) five-factor models:

$$r^{\$}_{i,t} - r_{f,t} = \alpha^{i}_{DFF3} + \beta^{i}_{D}{}' [DMKT] + \varepsilon_t \quad \text{(CAPM)} \quad (1_D)$$

$$r^{\$}_{i,t} - r_{f,t} = \alpha^{i}_{DFF3} + \beta^{i}_{D}{}' [DMKT_t, DSMB_t, DHML_t] + \varepsilon_t \quad \text{(Fama-French 3-factor)} \quad (2_D)$$

$$r^{\$}_{i,t} - r_{f,t} = \alpha^{i}_{DFF4} + \beta^{i}_{D}{}' [DMKT_t, DSMB_t, DHML_t, DMOM_t] + \varepsilon_t \quad \text{(F-F-Carhart 4-factor)} \quad (3_D)$$

$$r^{\$}_{i,t} - r_{f,t} = \alpha^{i}_{DFF5} + \beta^{i}_{D}{}' [DMKT_t, DSMB_t, DHML_t, DRMW_t, DCMA_t] + \varepsilon_t \quad \text{(F-F 5-factor)}, \quad (4_D)$$

where $r^{\$}_{i,t} - r_{f,t}$ is the excess return of the GMB portfolio for region i at time t expressed in dollars relative to the dollar-denominated risk-free rate, $r_{f,t}$. The subscript designation of "D" on the market and factor portfolios implies that they are constructed only from domestic - or regional, in our experiments – stocks. β^{i}_{D} is a vector of factor loadings that correspond to the respective local factors.[6]

Table 5 reports the regression results on the regional GMB returns, in which the regressions shown in Panel A consider the purely global model as the benchmark model and the regressions shown in Panel B use the purely local benchmark model. The top left section, for both Panel A

[6] We consider the partial segmentation model as the third benchmark model for regional test asset portfolios, as suggested in Griffin (2002). Griffin (2002) proposed a variant of the three-factor model of Fama and French (1993), (1998), which includes a market factor, a size factor, and a book-to-market-equity factor, for four countries (the United States, the United Kingdom, Canada, and Japan). He decomposes the global factor model into its domestic and foreign components so that the partial segmentation hybrid model allows domestic and foreign factors to have a different impact on stocks returns. Empirical results show that the regional GMB alphas are generally robust to the benchmark models considered in the test. For the sake of brevity, we report the results for both the purely global models and the purely local models in Table 5.

and Panel B, reports the risk-adjusted GMB returns in the region of North America. The regression results on the purely global model are very similar to those reported in Panel B of Table 2 for the U.S. market. All of the GMB's alphas in North America are economically large, ranging from 51 to 62 bps per month, at a 1% significance level. When the benchmark model is shifted from the purely global model to the purely local model, the magnitude of the GMB's alpha has been shrunk. Take the Fama–French Carhart (1997) four-factor model as the example, the risk-adjusted GMB returns has dropped from 51 bps per month to 29 bps per month, although the *p*-value is still lower than 5%. Further, when the partial segmentation hybrid model is considered in the regressions, a few GMB's alphas turn economically small and hardly reliable. For example, GMB's alpha has further dropped to only 15 bps per month for the Fama–French Carhart (1997) four-factor model, and its *p*-value equals to 0.34. At the same time, when we only adjust for the market factor, the alpha is estimated to be 53 bps per month, which is still statistically significant. Admittedly, although the addition of foreign factors to the benchmark model does help reduce the magnitude of the alphas, it barely yields significant improvements in the model explanatory power. There seems to be only a slight increase in the regression R^2s.

The middle-left section, for both Panel A and Panel B of Table 5, reports the risk-adjusted GMB returns in the region of Europe. The regression results on the purely global model are clearly different from those for North America. All of the GMB's alphas are statistically indistinguishable from zero, regardless of what benchmark model is employed. When the purely local factor model is considered as the benchmark model, its exposures to SMB, HML, and UMD indicate that GMB no longer tilts toward large stocks, growth stocks, and recent winner. On the other than, GMB is negatively exposed to the local market factor. When the benchmark model is shifted from the purely local model to the purely global model, the regression R^2s have been increased substantially.

Take the Fama–French (1993) three-factor model as the example, the adjusted R^2 have been improved from 0.10 for the purely local model to the 0.17 for the purely global model. Further, its exposures to MKT and HML indicate that GMB in Europe tilts toward stocks with negative betas and growth stocks. We the partial segmentation hybrid model is considered as the benchmark model, almost all of the coefficients with respect to the domestic factor are insignificant while most of the coefficients with respect to the foreign factors are statistically reliable. This evidence is consistent with the findings for the purely global factor model in the sense that foreign factors help explain a reliably large proportion of the total variation in the GMB returns for Europe.

The middle right section of Table 5 reports the risk-adjusted GMB returns in the region of Japan. For the estimated coefficients associated with the fundamental factors in the benchmark models, most of the estimations are not distinguishable from zero for the purely global model. When we regress the GMB portfolios returns on the purely local models, the estimations become very similar to those for the region of North America. Its exposure to the local SMB, HML and CMA indicate that GMB tilts toward large stocks, growth stocks and stocks with high investment in the region of Japan. Net of these exposures, the alphas of GMB are statistically indifferent from zero, regardless of whether the benchmark model is the purely global model or the purely local model. Overall, the equity greenium effect does not to exist in the region of Japan.

The bottom left section of Table 5 shows the regression results on the GMB portfolio returns in the region of Asia Pacific. The adjusted R^2s are generally larger for the purely local models than that purely global model. When it comes to the coefficients with respect to the fundamental factors, the GMB portfolio in Asia Pacific tilts toward large stocks, growth stocks and past winners, especially when the purely local model is considered as the benchmark model. Net of these exposures, the alpha of GMB is 2 bps per month for the local CAPM model, 6 bps per month for the local Fama and French (1993) three-factor model, -18 bps per month the local Carhart (1999) four-factor model, and 13 bps per month for the local Fama and French (2015) five-factor model, respectively. In none of these cases, the local GMB's alpha (regression constant) is economically large and statistically significant. In all, the inference on the greenium effect in the U.S. does hinge on, to some extent, on the empirical asset pricing models considered in the tests.

The bottom right section of Table 5 shows the regression results on the GMB portfolio returns in the region of Emerging Markets. The adjusted R^2s are equally small between the purely global models and that purely local model. When the purely local model is used as the benchmark model, the GMB portfolio in Emerging Markets tilts toward stocks with negative market beta and growth stocks. The purely global model help decrease the alpha of GMB when compared with the purely local model. Using the Fama–French Carhart (1997) four-factor model as the example, the model intercept goes down from 14 bps per month for the purely local model to 2 bps per month for the purely global model. Admittedly, neither of them is statistically distinguishable from zeros. The return factors prominent in the asset pricing literature do help explain the GMB returns in the region of Emerging Markets.

Overall, the performance of the GMB returns varies across region. We find stronger performance of GMB in North America. For the other four regions, the performance of the GMB returns depends on whether we account for the common sources of return covariation related to firm-level attributes, such as size, value, and momentum.

4. Robustness Checks.

All of our tests up to now have been unconditional and have taken into account the total variation across countries and over the entire period from November 2012 through December

2021. We next investigate how the GMB returns varies over time, on a cross-region basis and on the region-by-region basis. As shown in Figures 2 to 7, the GMB returns, both globally and regionally, have been positive for an extended run and then was completely neutralized in the most recent years, especially for the regions of Europe, Asia Pacific, and Emerging Markets.

Panel A of Table 6 reports summary statistics on the regional GMB returns between two sub-periods, one is from December 2012 to December 2015 and the other from January 2016 to December 2021. For the first three years of the sample period, green stocks delivered higher returns than brown stocks for almost all of the regions except Japan. The monthly GMB return averaged 89 bps per month (*t*-statistic: 2.71), 49 bps per month (*t*-statistic: 1.99), 11 bps per month (*t*-statistic: 0.40), 123 bps per month (*t*-statistic: 2.76), 102 bps per month (*t*-statistic: 2.73) in North America, Europe, Japan, Asia Pacific, and Emerging Markets, respectively. Accordingly, the monthly Sharpe ratio of GMB goes up to 0.45 in three regions (North America, Asia Pacific, and Emerging Markets), and stays at a relatively median level of 0.33 in Europe. The lowest monthly Sharpe ratio occurs in Japan as the level of 0.07. In terms of the correlations among regions, there is still relatively co-movement in the GMB returns between North America and Europe (a correlation level of 0.54). The next region which is positively correlated with Europe is Asia Pacific with the correlation coefficient of 0.40. For both Asia Pacific and Emerging Markets, they are equally positively correlated with the other regions except Japan. Similar to the case for the whole sample period, Japan is the region in which the GMB returns behave negatively correlated with the other regions.

As shown in the second half of Panel A, the more recent six years display a different picture on the GMB performance. Green stocks have started to deliver lower returns than brown stocks for three regions except North America and Japan. The monthly GMB return averaged -34 bps per month (*t*-statistic: -1.79), -56 bps per month (*t*-statistic: -1.65), and -55 bps per month (*t*-statistic: -2.34) in Europe, Asia Pacific, and Emerging Markets, respectively. For North America and Japan, the monthly GMB returns averaged 42 bps per month and 7 bps per month, respectively, and none of them are distinguishable from zero. In terms of the correlations among regions, the GMB returns in North America have still remained highly correlated with the other four regions. On the other hand, the co-movement between Asia Pacific with most of the regions is getting weaker compared with the first three years. It is correlations have dropped from 0.34 to 0.18, from 0.40 to 0.28, and from -0.20 to 0.03 with North America, Europe, and Japan, respectively, while its correlation with Emerging Markets has increased from 0.18 to 0.38.

Panel B of Table 6 reports the regressions result for the regional GMB returns for the first three years and those for the more recent six years. For sake of simplicity, here we follow the suggestion of Fama and French (2015) and focus on the local version of the Fama-French (2017) five-factor model. As shown in the top panel for the first three years, there are generally strong GMB performance across region which cannot be explained by exposures to local return factors prominent in the asset pricing literature. For the region of North America, the exposures to the MKT, SMB, HML, WML, and other factors related with the firm-level attributes are quantitatively similar to those reported in Table 5. Net of all the exposures, the alpha of the GMB yields a significant 37 bps per month. For the region of Europe, the risk-adjusted GMB returns remains economically large and statistically reliable, with the average level of 54 bps per month, for both the local CAPM model and the local three-factor model of Fama and French (1993). The magnitude of the alphas reduces to 27 bps per month for the local Fama–French Carhart (1997) four-factor model and 42 bps per month for the local Fama and French (2015) five-factor model. The GMB's alphas in Japan go as high as 30 bps per month for the local Fama and French (2015) five-factor model and drops down to 14 bps per month for the local CAPM. However, all of them are statistically indistinguishable from zero. It is worthy to note that the monthly GMB has shown much stronger performance in the regions of Asia Pacific and Emerging Markets. Using the local Fama and French (2015) five-factor model as the benchmark model, the alphas of the GMB returns remains 154 bps per month for Asia Pacific, and 142 bps per month for Emerging Markets. Both of them are significant at the 1% level.

Consistent with the summary statistics shown in Panel A, there are generally weaker GMB performance across region as shown in the bottom rows in Panel B. During the more recent six years, green stocks seem to underperform brown in the regions of Europe, Asia Pacific, and Emerging Markets. These underperformances cannot be explained by exposures to local return factors prominent in the asset pricing literature. Take the region of Europe as an example, the exposures to the MKT, SMB, HML, RMW, and CMA indicates that the GMB in Europe tilts to stocks with negative market beta. Net of all the exposures, the alpha of the GMB yields a significant -30 bps per month. Likewise, the alpha of the GMB in Emerging Markets yields -51 bps per month, which is significant at the 5% level. On the other hand, the GMB's alpha remains positive in North America but the magnitude becomes much smaller, from 37 bps per month to only 5bps per month, in the alpha estimates.

In all, there is strong co-movement on the greenium effect across region for the first three years of our sample period. Surprisingly, the co-movement has been much weaker since 2016. More importantly, the equity greenium effects in Europe, Asia Pacific, and Emerging Markets have disappeared in the sense that green stocks have started to underperform brown stocks in these regions.

5. Conclusions.

We offer new evidence on how the application of environmental, social, and governance (ESG) criteria has affected international stock returns. We estimate the market-based equity greenium in a cross-section of 21,902 firms from 96 countries. We find reliable evidence that green stocks earned higher returns than brown stocks around the world. This outperformance is associated with lower stock returns of energy firms but not higher returns of technology stocks. Decomposing this outperformance further into five regions, including North America, Europe, Japan, Asia Pacific, and Emerging Markets, demonstrates that the equity greenium effect mostly occurs in North America and during the period before 2016. Most of the equity greenium performance cannot be explained by exposures to return factors prominent in the asset pricing literature.

Over time, there is strong co-movement in the greenium effect across region for the first three years of our sample period. Surprisingly, the co-movement gets much weaker starting from 2016. More importantly, the equity greenium effects in Europe, Asia Pacific, and Emerging Markets have disappeared in the sense that green stocks have started to underperform brown stocks in these regions. The performance of the GMB returns varies across regions. We find a stronger performance of the GMB spread portfolio in the region of North America. For the other four regions, the performance of the GMB returns depends on whether we account for the common sources of return covariation related to firm-level attributes, such as size, value, and momentum.

References

Alessi, L., Ossola, E. and Panzica, R. (2021) What greenium matters in the stock market? The role of greenhouse gas emissions and environmental disclosures, *Journal of Financial Stability* 54, https://doi.org/10.1016/j.jfs.2021.100869.

Aswani, J. and Raghunandan, A. and Rajgopal, S. (2023) Are Carbon Emissions Associated with Stock Returns? *Review of Finance*, https://doi.org/10.1093/rof/rfad013.

Baker, M., Bergstresser, D., Serafeim, G., Wurgler, J. (2022) The Pricing and Ownership of U.S. Green Bonds. *Annual Review of Financial Economics* 14, https://doi.org/10.1146/annurev-financial-111620-014802.

Bekaert, G., Hodrick, R. J., and Zhang, X. (2009) International stock return comovements, *Journal of Finance* 64, 2591–2626.

Berg, F., Koelbel, J. F., and Rigobon, R. (2020) Aggregate Confusion: The Divergence of ESG Ratings, Working paper, MIT.

Berg, F., Koelbel, J. F., Pavlova, A., and Rigobon, R. (2021) ESG Confusion and Stock Returns: Tackling the Problem of Noise, Working paper, MIT.

Bolton, P., and Kacperczyk, M. (2022) Global Pricing of Carbon-Transition Risk. *Journal of Finance*, forthcoming.

Bolton, P., and Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics* 142, 517-549.

Carhart, M. M. (1997) On persistence in mutual fund performance, *Journal of Finance* 52, 57–82.

Eccles, R. G., and Stroehle, J. C. (2018) Exploring Social Origins in the Construction of ESG Measures, Working paper, University of Oxford.

Fama, E. F., and French, K. R. (1993) Common Risk Factors in the Returns on Stocks and Bonds, *Journal of Financial Economics* 33, 3–56.

Fama, E. F., and French, K. R. (1998) Value versus Growth: The International Evidence, *Journal of Finance*, 53, 1975-1999.

Fama, E. F., and French, K. R. (2012) Size, Value, and Momentum in International Stock Returns, *Journal of Financial Economics* 105, 457–472.

Fama, E. F., and French, K. R. (2017) International Tests of a Five–factor Asset Pricing Model, *Journal of Financial Economics* 123, 441–463.

Griffin, J. M. (2002) Are the Fama and French Factors Global or Country Specific? *Review of Financial Studies*, 15, 783–803.

Hou, K., Karolyi, G. A., and Kho, B. C. (2011) What factors drive global stock returns? *Review of Financial Studies* 24, 2527–2574.

Ince, O., and R. B. Porter. (2006) Individual Equity Return Data from Thomson Datastream: Handle with Care! *Journal of Financial Research* 29, 463–479.

Karolyi, G. A., and Stulz, R. M. (2003) Are Assets Priced Locally or Globally? In the Handbook of *the Economics of Finance*, G. Constantinides, M. Harris and R. Stulz (eds.), North Holland.

Karolyi, G. A., and Wu, Y. (2018) A New Partial–segmentation Approach to Modeling International Stock Returns, *Journal of Financial and Quantitative Analysis* 53, 507–546.

Lewis, K. K. (2011) Global Asset Pricing, *Annual Review of Financial Economics* 3, 435–466.

Pastor, L., Stambaugh, R. F., and Taylor, L. A. (2021) Sustainable Investing in Equilibrium. *Journal of Financial Economics* 142, 550–571.

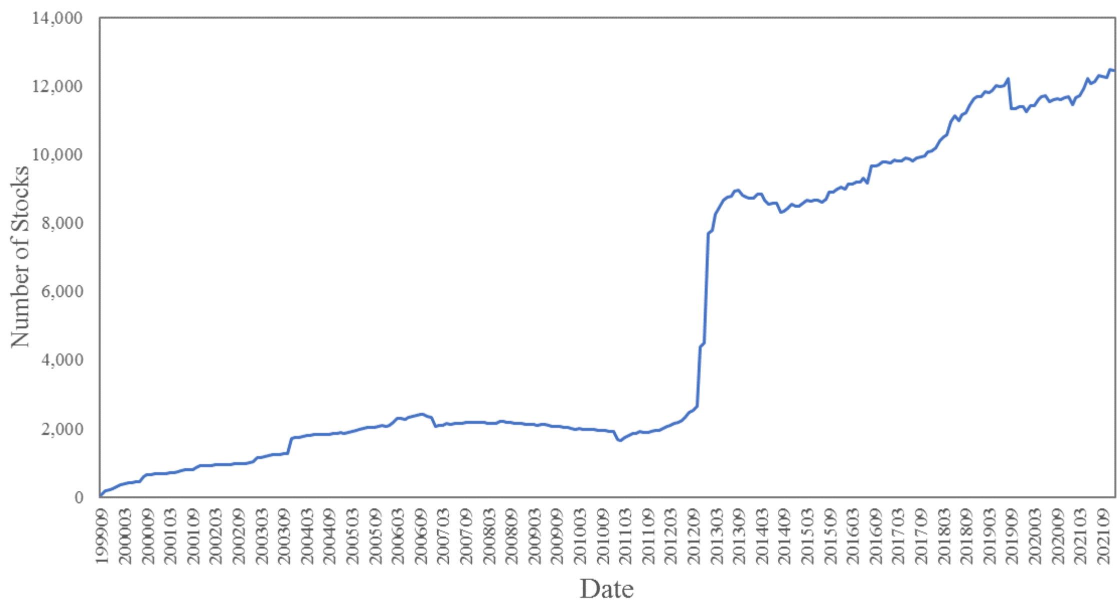
Pastor, L., Stambaugh, R. F., and Taylor, L. A. (2022). Dissecting Green Returns. *Journal of Financial Economics* 146, 403–424.

Zhang, S. (2023). Carbon Returns Across the Globe, Working paper, OSU Fisher.

Figure 1. MSCI Coverage.

The figures plot the number of stocks with non-missing MSCI environmental scores and Datastream trading records from 46 developed and emerging market countries. Graph A shows the counts, overview and by region, for the global sample, Graph B shows the overview for the U.S. Here we report two variants, one is on the full sample and the other on the restricted sample which only includes primary quote and major securities. Graph C shows the count for the global sample excluding U.S.

Graph A.1. Global Overview



Graph A.2. Count by Region

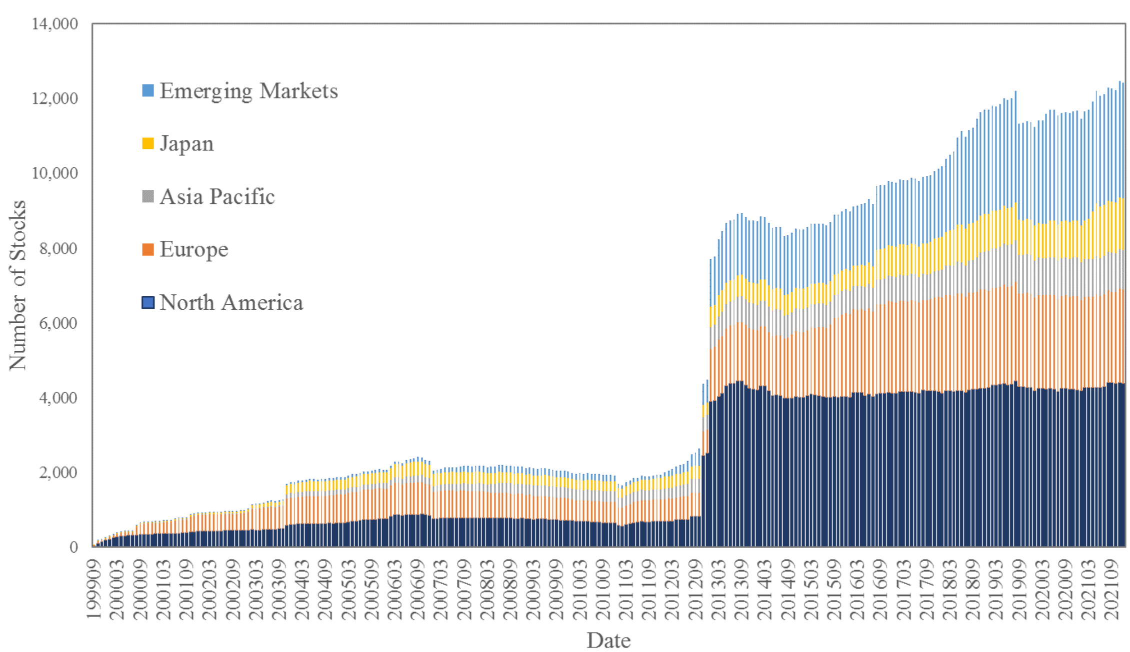
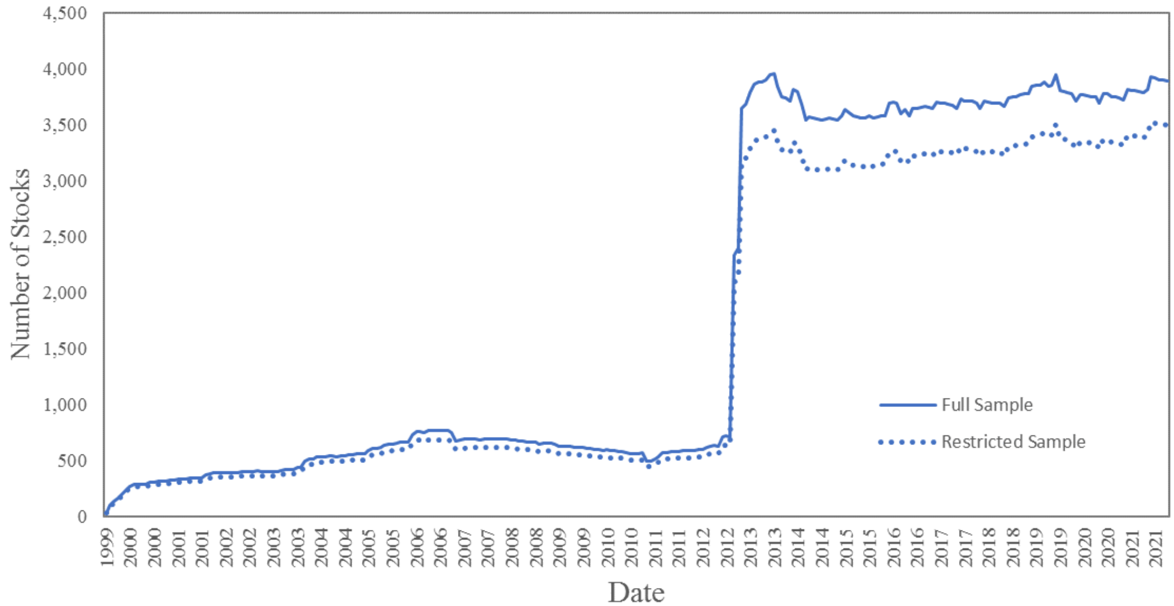


Figure 1. MSCI Coverage. Continued

Graph B. the U.S.



Graph C. Global excluding U.S.

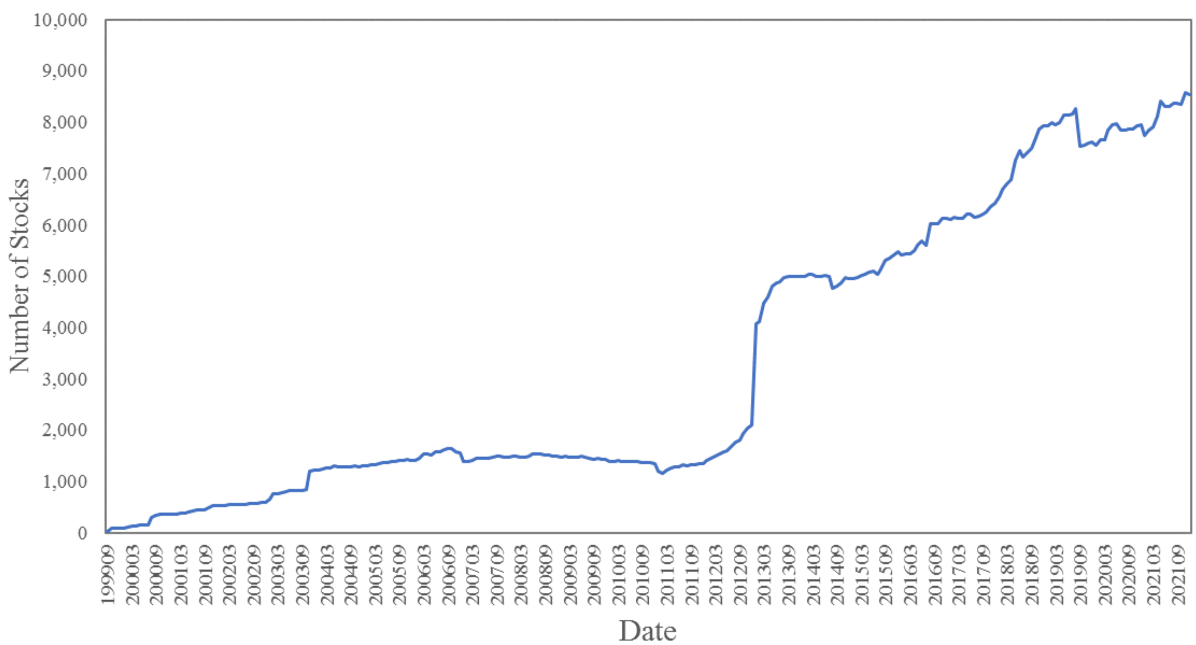


Figure 2. Returns on Value-weighted Green and Brown Portfolios.

The figures plot the green and brown portfolios' cumulative returns. The sample period is between November 2012 and December 2021. The cumulative returns are computed from the Datastream-MSCI ESG Ratings merged dataset. Graph A shows the results for the global sample, Graph B shows the results for the U.S. only, and Graph C shows the results for the global sample excluding U.S.

Graph A. Global Overview

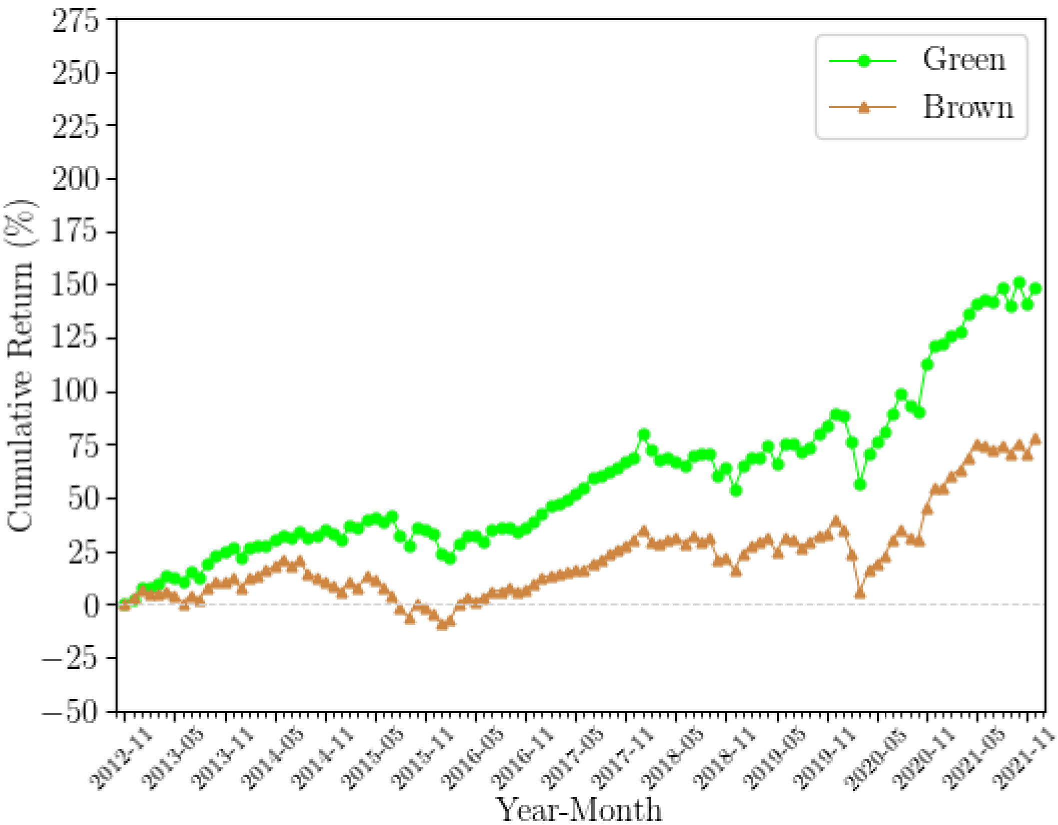
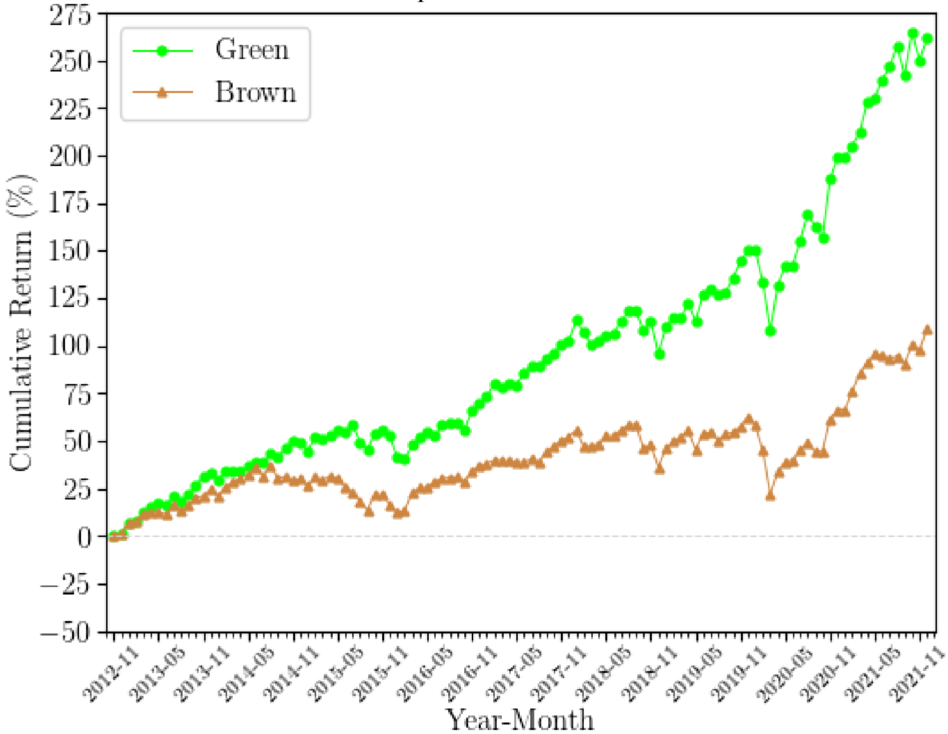


Figure 2. Returns on Value-weighted Green and Brown Portfolios, continued.

Graph B. the U.S.



Graph C. Global excluding U.S.

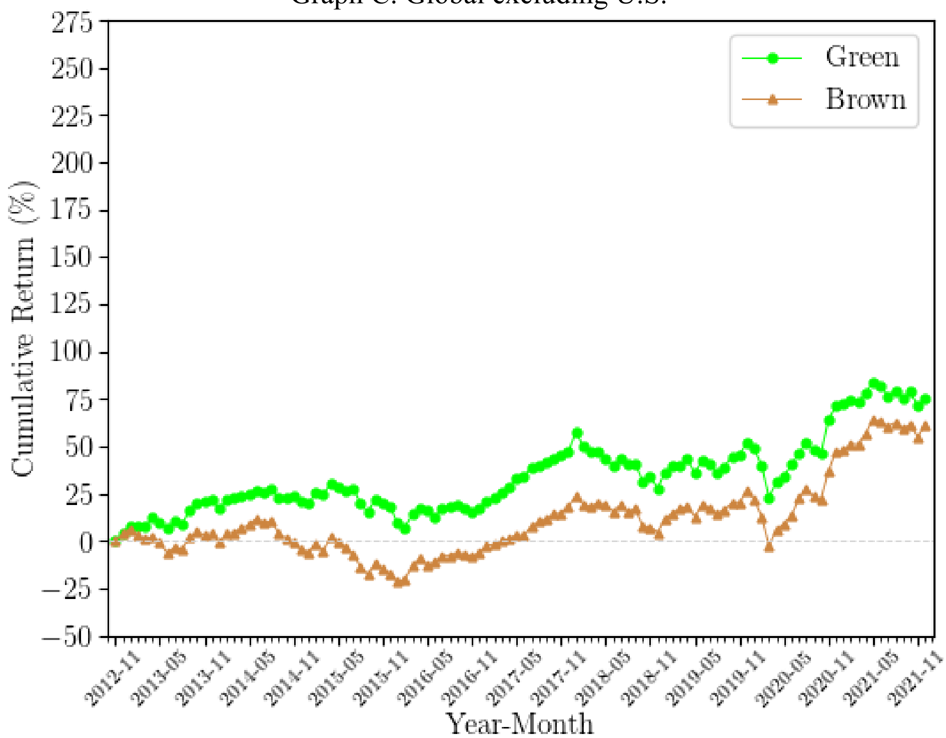


Figure 3. Cumulative GMB Returns.

The figures plot the cumulative returns on the GMB portfolios. The GMB portfolios long green stocks and short brown stocks. The sample period is between November 2012 and December 2021, and the cumulative returns are computed from the Datastream-MSCI ESG Ratings merged dataset.

Graph A. Global Overview

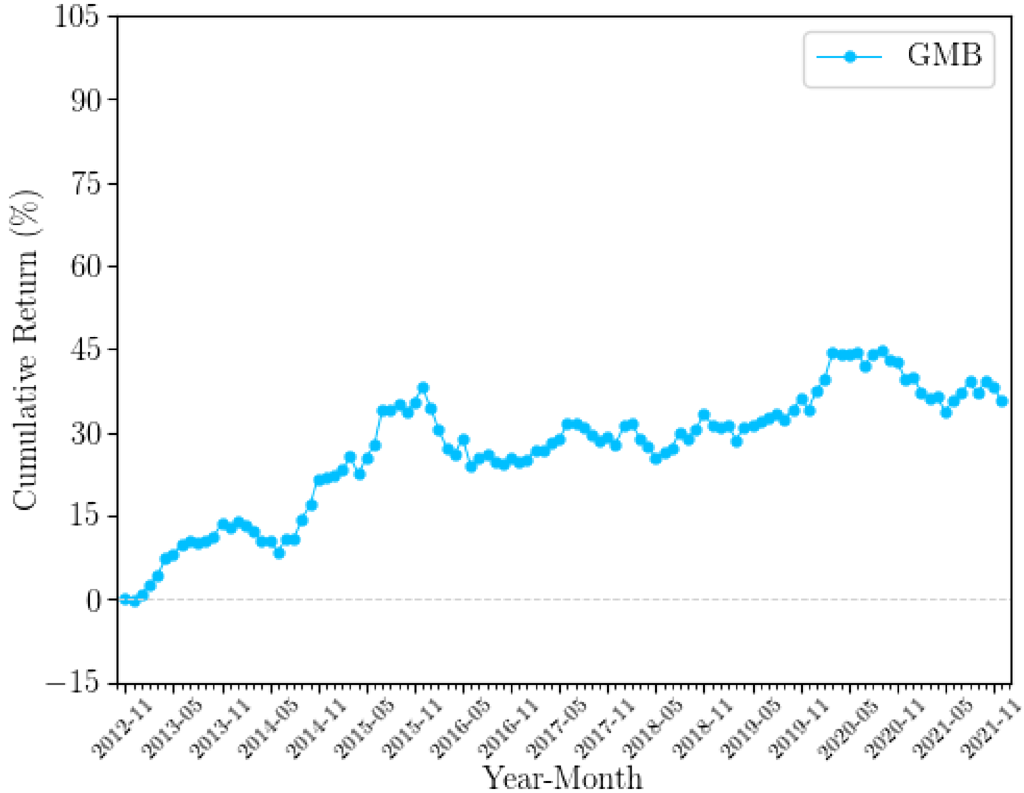
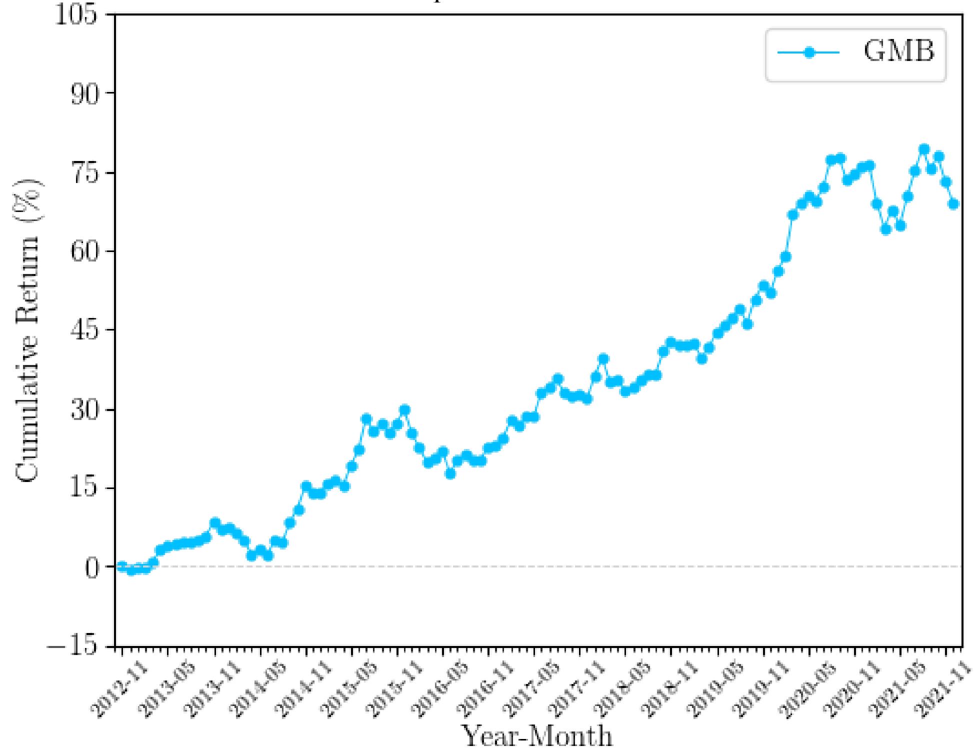


Figure 3. Cumulative GMB Returns, continued.

Graph B. the U.S.



Graph C. Global excluding U.S.

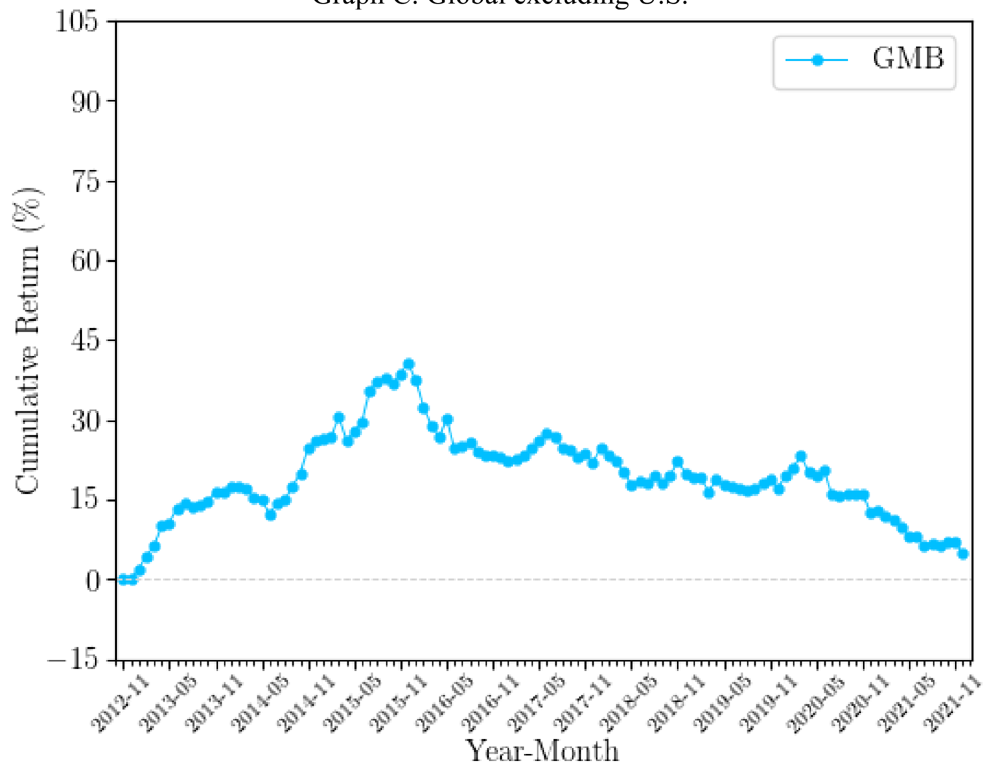
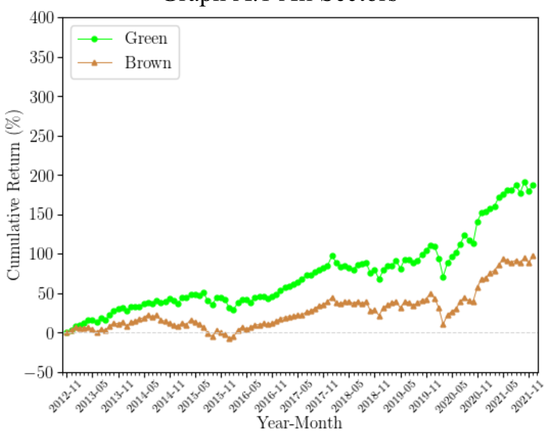


Figure 4. Returns on Leave-one-sector-out Green and Brown Portfolios.

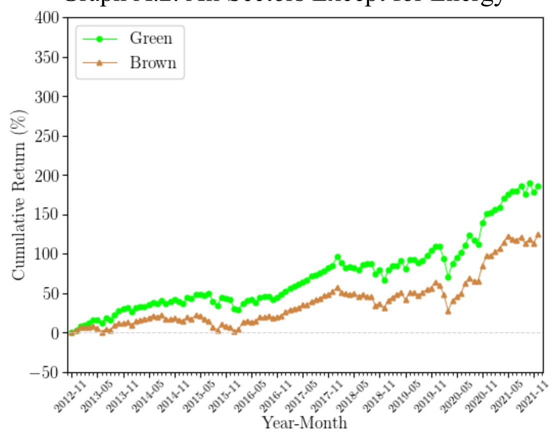
The figures plot the green and brown portfolios' cumulative returns, in which the stocks have both valid observations from the Datastream-MSCI ESG Ratings merged dataset and valid GICS codes from Datastream. In addition to the complete green and brown portfolios including all sectors of stocks, the two leave-one-sector-out portfolios are constructed by using the GICS industry classification system to aggregate individual stocks representing all industries except for Energy and Information Technology ("Info. Tech." in the table), respectively, for a given region. Panel A shows the results for the global sample, Panel B shows the results for the U.S. only, and Panel C shows the results for the global sample excluding U.S.

Panel A: Global Overview

Graph A.1 All Sectors



Graph A.2. All Sectors Except for Energy



Graph A.3. All Sectors Except for Info. Tech.

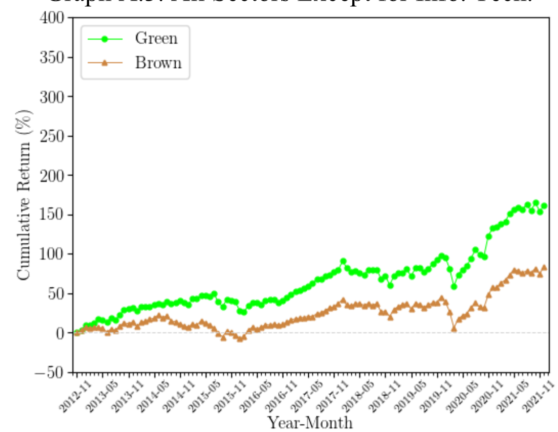
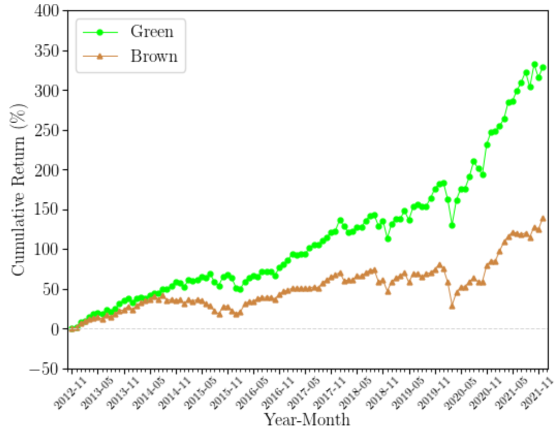


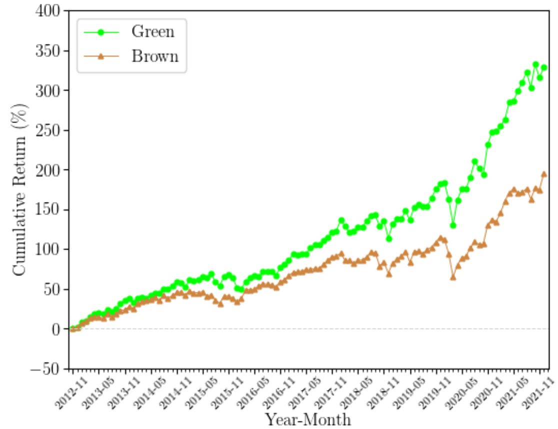
Figure 4. Returns on Leave-one-sector-out Green and Brown Portfolios, continued

Panel B: The U.S.

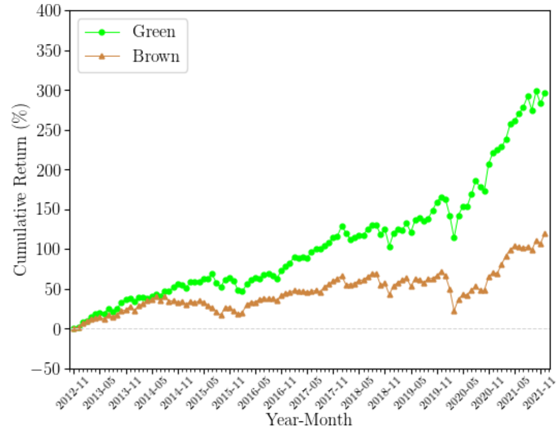
Graph B.1 All Sectors



Graph B.2. All Sectors Except for Energy

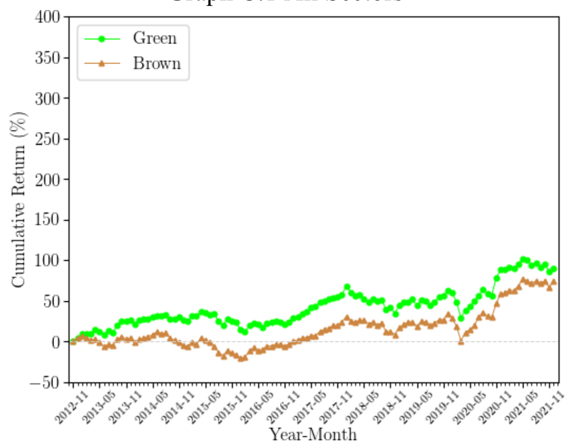


Graph B.3. All Sectors Except for Info. Tech.

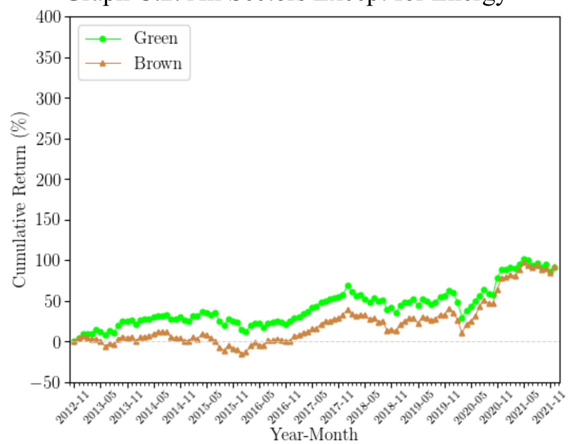


Panel C: Global excluding U.S.

Graph C.1 All Sectors



Graph C.2. All Sectors Except for Energy



Graph C.3. All Sectors Except for Info. Tech.

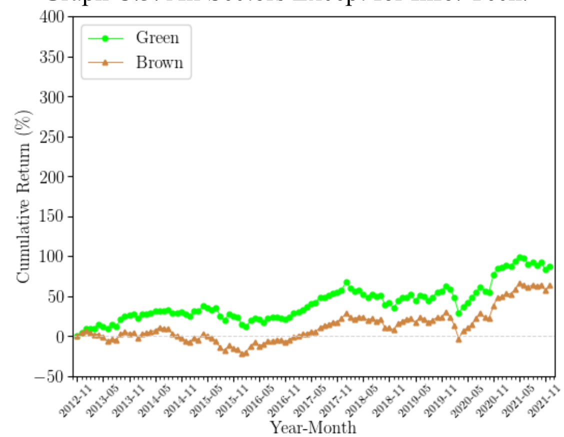
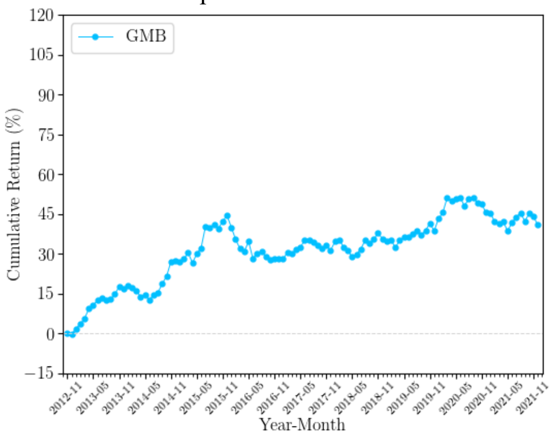


Figure 5. Leave-one-sector-out Cumulative GMB Returns.

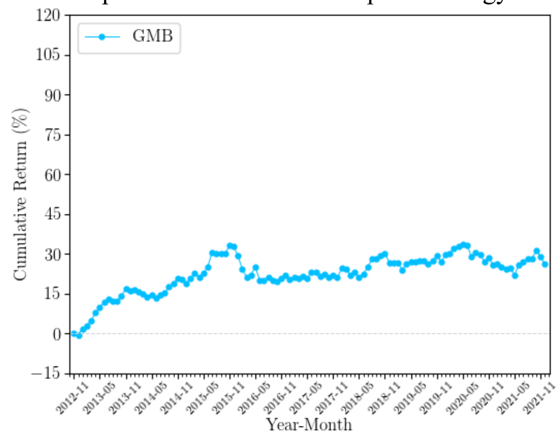
The figures plot the cumulative returns on the GMB portfolios, in which the stocks have both valid observations from the Datastream-MSCI ESG Ratings merged dataset and valid GICS codes from Datastream. In addition to the complete green and brown portfolios including all sectors of stocks, the two leave-one-sector-out portfolios are constructed by using the GICS industry classification system to aggregate individual stocks representing all industries except for Energy and Information Technology ("Info. Tech." in the table), respectively, for a given region. Panel A shows the results for the global sample, Panel B shows the results for the U.S. only, and Panel C shows the results for the global sample excluding U.S.

Panel A: Global Overview

Graph A.1 All Sectors



Graph A.2. All Sectors Except for Energy



Graph A.3. All Sectors Except for Info. Tech.

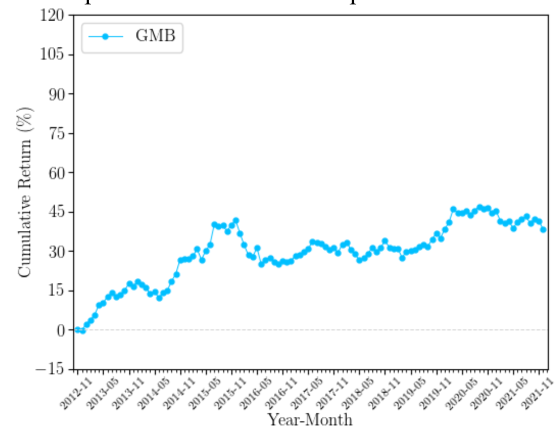
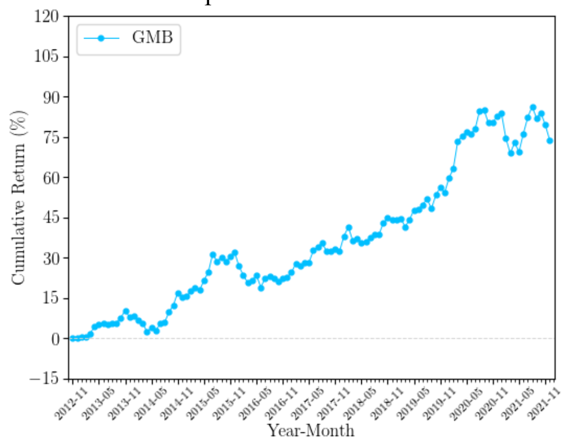


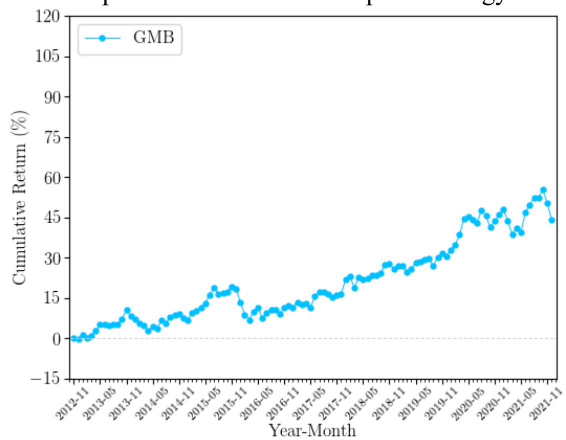
Figure 5. Leave-one-sector-out Cumulative GMB Returns, continued

Panel B: The U.S.

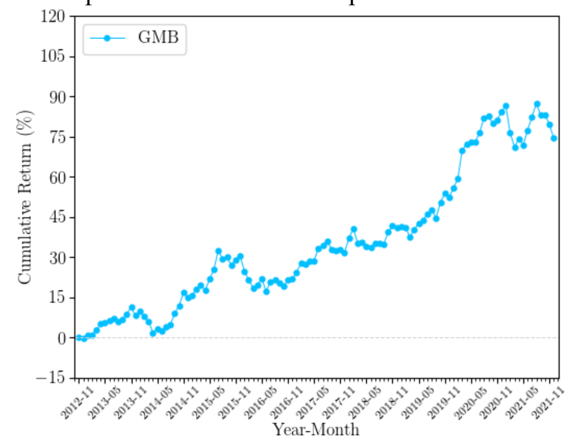
Graph B.1 All Sectors



Graph B.2. All Sectors Except for Energy

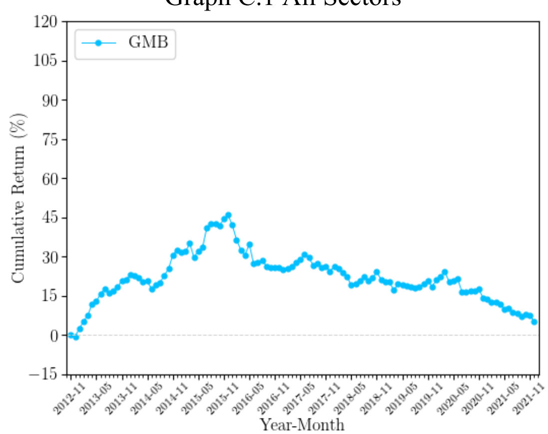


Graph B.3. All Sectors Except for Info. Tech.

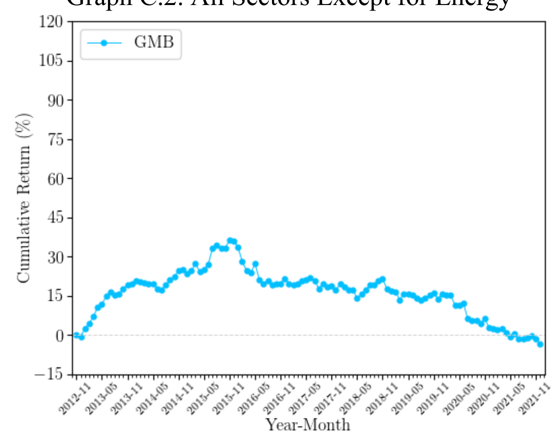


Panel C: Global excluding U.S.

Graph C.1 All Sectors



Graph C.2. All Sectors Except for Energy



Graph C.3. All Sectors Except for Info. Tech.

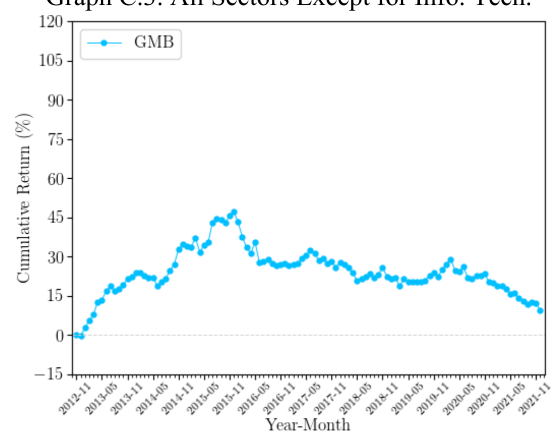
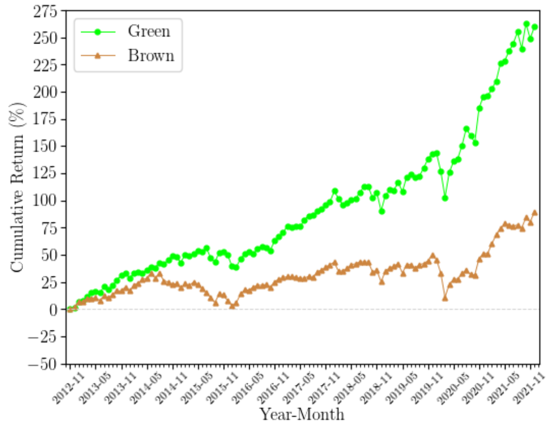


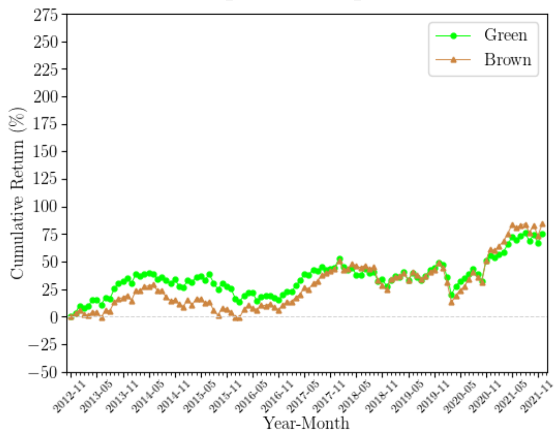
Figure 6. Returns on Value-weighted Green and Brown Portfolios by Region.

The figures plot the green and brown portfolios' cumulative returns on a region-by-region basis. The sample period is between November 2012 and December 2021. The cumulative returns are computed from the Datastream-MSCI ESG Ratings merged dataset.

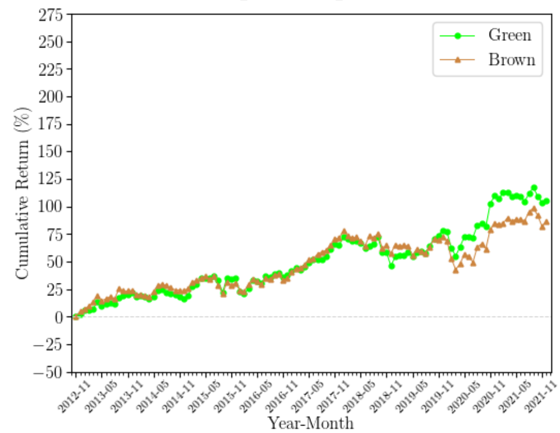
Graph A. North America



Graph B. Europe



Graph C. Japan



Graph D. Asia Pacific

Graph E. Emerging Markets

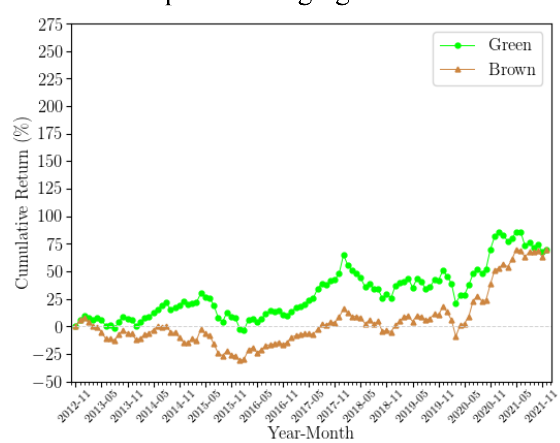
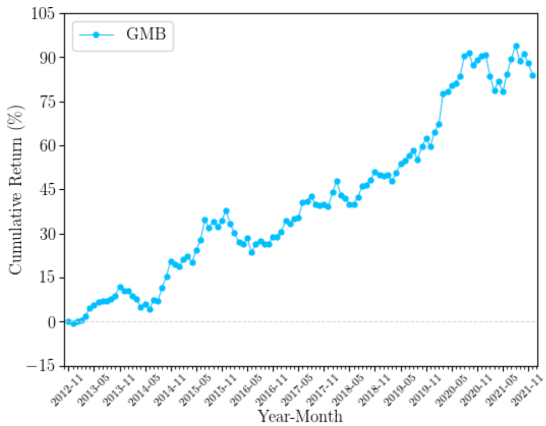


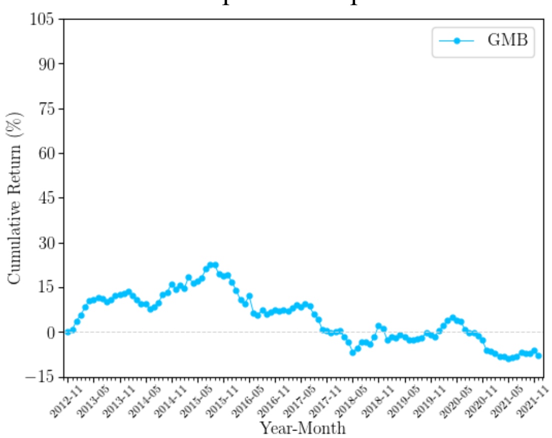
Figure 7. Cumulative GMB Returns by Region.

The figures plot the cumulative GMB returns on a region-by-region basis. The sample period is between November 2012 and December 2021, and the cumulative returns are computed from the Datastream-MSCI ESG Ratings merged dataset.

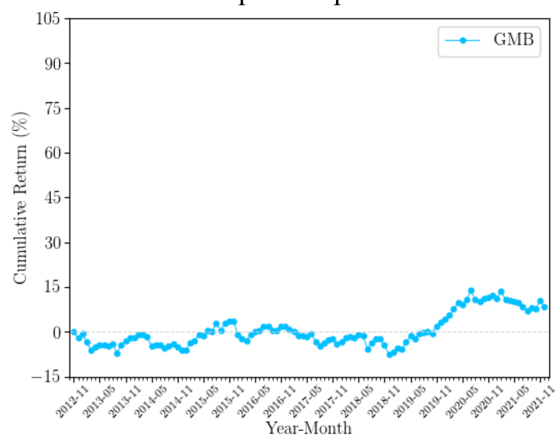
Graph A. North America



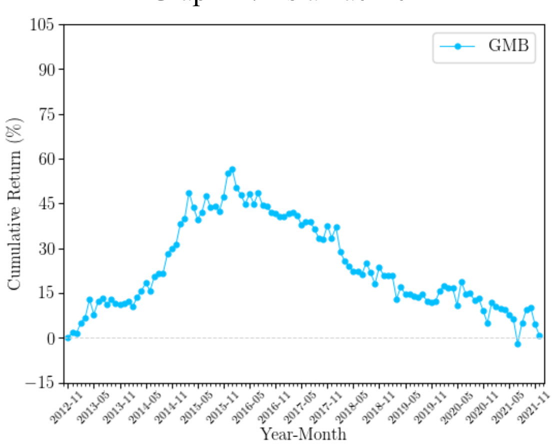
Graph B. Europe



Graph C. Japan



Graph D. Asia Pacific



Graph E. Emerging Markets

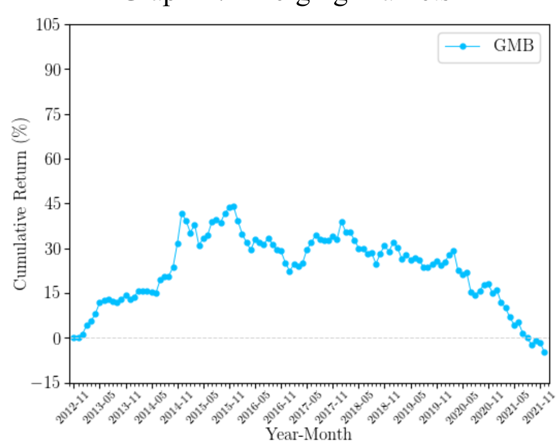


Table 1. Summary Statistics on the GMB Portfolios

This table reports the summary statistics on the GMB portfolios. The set of GMB portfolios are for the global sample ("Global" in the table), for the U.S. only ("U.S."), for the global sample excluding the U.S. ("Global ex. US"), and for five regional samples ("North America", "Europe", "Japan", "Asia Pacific", and "Emerging Markets"), respectively. Section 2 provides the descriptions on the constructions of the GMB portfolios. The sample period is December 2012 to December 2021.

	Global	U.S.	Global ex. US	North America	Europe	Japan	Asia Pacific	Emerging Markets
Mean returns (%)	0.29	0.50	0.06	0.58	-0.06	0.09	0.05	-0.02
Std. Dev (%)	1.57	1.89	1.64	2.02	1.62	1.60	2.93	2.22
t-statistic	1.94	2.76	0.36	3.01	-0.40	0.56	0.18	-0.10
Sharpe ratio	0.19	0.26	0.03	0.29	-0.04	0.05	0.02	-0.01
Correlation								
Global	1							
U.S.	0.84	1						
Global ex. US	0.89	0.53	1					
North America	0.89	0.97	0.61	1				
Europe	0.73	0.49	0.76	0.52	1			
Japan	0.06	0.08	0.04	0.07	-0.04	1		
Asia Pacific	0.46	0.19	0.58	0.25	0.37	-0.07	1	
Emerging Markets	0.61	0.33	0.75	0.37	0.36	-0.05	0.38	1

Table 2. Global GMB's Alphas

We estimate time-series regressions on the global GMB portfolios. Mkt-Rf is the global excess market return. SMB and HML are the global version of the size and value factors of the Fama and French (1993) model. UMD is the global version of the momentum factor of Carhart (1997). RMW and CMA are the global version of the profitability and global investment factors of Fama and French (2015). See Equations (1_W) - (5_W) in Section 3.1 for details on the model specifications. Returns are in percentage per month. Robust *t*-statistics are in parentheses.

Panel A. Global Sample

	(1)	(2)	(3)	(4)	(5)
Constant	0.36	0.31	0.29	0.30	0.28
	(2.37)	(2.39)	(2.13)	(2.20)	(1.97)
Mkt-Rf	-0.08	-0.06	-0.06	-0.07	-0.07
	(-1.95)	(-1.73)	(-1.70)	(-1.85)	(-1.82)
SMB		-0.21	-0.21	-0.21	-0.22
		(-3.45)	(-3.49)	(-3.20)	(-3.22)
HML		-0.43	-0.40	-0.38	-0.35
		(-6.42)	(-5.26)	(-3.86)	(-3.35)
UMD			0.05		0.05
			(0.84)		(0.82)
RMW				0.03	0.03
				(0.21)	(0.21)
CMA				-0.09	-0.09
				(-0.72)	(-0.71)
Observations	109	109	109	109	109
R-squared	0.03	0.31	0.31	0.31	0.31
Adj. R-squared	0.03	0.29	0.29	0.28	0.27

Table 2. Global GMB's Alphas, continued

Panel B. Sub-sample of the U.S.

	(1)	(2)	(3)	(4)	(5)
Constant	0.54	0.48	0.43	0.48	0.43
	(2.89)	(2.94)	(2.55)	(2.78)	(2.42)
Mkt-Rf	-0.05	-0.02	-0.02	-0.03	-0.02
	(-0.90)	(-0.54)	(-0.50)	(-0.54)	(-0.49)
SMB		-0.22	-0.23	-0.22	-0.23
		(-2.90)	(-3.00)	(-2.67)	(-2.76)
HML		-0.49	-0.43	-0.48	-0.42
		(-5.95)	(-4.60)	(-3.97)	(-3.28)
UMD			0.10		0.10
			(1.43)		(1.42)
RMW				0.00	0.00
				(0.02)	(0.03)
CMA				-0.02	-0.01
				(-0.10)	(-0.09)
Observations	109	109	109	109	109
R-squared	0.01	0.26	0.27	0.26	0.27
Adj. R-squared	0.00	0.24	0.24	0.22	0.23

Panel C. Sub-sample of Global ex. US

	(1)	(2)	(3)	(4)	(5)
Constant	0.15	0.11	0.10	0.11	0.09
	(0.93)	(0.77)	(0.67)	(0.67)	(0.58)
Mkt-Rf	-0.11	-0.09	-0.09	-0.11	-0.11
	(-2.46)	(-2.26)	(-2.24)	(-2.40)	(-2.38)
SMB		-0.15	-0.15	-0.15	-0.16
		(-2.16)	(-2.16)	(-2.04)	(-2.05)
HML		-0.29	-0.28	-0.22	-0.21
		(-3.88)	(-3.24)	(-2.03)	(-1.78)
UMD			0.02		0.02
			(0.35)		(0.34)
RMW				0.02	0.02
				(0.18)	(0.18)
CMA				-0.12	-0.12
				(-0.86)	(-0.85)
Observations	109	109	109	109	109
R-squared	0.05	0.17	0.17	0.18	0.18
Adj. R-squared	0.04	0.15	0.14	0.14	0.13

Table 3. GMB Performance in the U.S.

We estimate time-series regressions on the GMB portfolios for the U.S. market. Mkt-Rf is the excess market return for the U.S. market. SMB and HML are the size and value factors of the Fama and French (1993) model for the U.S. market. UMD is the momentum factor of Carhart (1997) for the U.S. market. RMW and CMA are the profitability and investment factors of Fama and French (2015), again, for the U.S. market. Returns are in percentage per month. Robust *t*-statistics are in parentheses.

Panel A. U.S. GMB's alphas

	(1)	(2)	(3)	(4)	(5)
Constant	0.50	0.35	0.31	0.39	0.37
	(2.61)	(2.05)	(1.87)	(2.40)	(2.23)
Mkt-Rf	0.00	0.06	0.09	0.08	0.10
	(0.02)	(1.43)	(1.93)	(1.92)	(2.22)
SMB		-0.13	-0.11	-0.25	-0.23
		(-1.91)	(-1.72)	(-3.31)	(-3.04)
HML		-0.26	-0.21	-0.18	-0.15
		(-4.76)	(-3.40)	(-2.78)	(-2.13)
UMD			0.10		0.07
			(1.72)		(1.29)
RMW				-0.28	-0.27
				(-2.97)	(-2.76)
CMA				-0.08	-0.08
				(-0.75)	(-0.71)
Observations	109	109	109	109	109
R-squared	0.00	0.26	0.28	0.32	0.34
Adj. R-squared	-0.01	0.24	0.25	0.29	0.30

Table 3. GMB Performance in the U.S., continued.

Panel B. Our Replication of PST (2022)

	Mean	(1)	(2)	(3)	(4)	(5)
Constant	0.60	0.62	0.43	0.42	0.43	0.42
	(3.33)	(3.27)	(2.40)	(2.34)	(2.41)	(2.35)
Mkt-Rf		-0.02	0.05	0.07	0.06	0.08
		(-0.36)	(1.07)	(1.49)	(1.33)	(1.63)
SMB			-0.14	-0.12	-0.22	-0.20
			(-1.89)	(-1.62)	(-2.75)	(-2.43)
HML			-0.19	-0.14	-0.13	-0.10
			(-3.07)	(-1.96)	(-1.77)	(-1.24)
UMD				0.09		0.07
				(1.54)		(1.22)
RMW					-0.25	-0.24
					(-2.03)	(-1.90)
CMA					-0.12	-0.09
					(-0.88)	(-0.69)
Observations	97	97	97	97	97	97
R-squared	0.00	0.00	0.17	0.19	0.21	0.22

Panel C. PST (2022)

	Mean	(1)	(2)	(3)	(4)	(5) - n.a.
Constant	0.65	0.71	0.50	0.47	0.50	
	(3.23)	(2.91)	(2.23)	(2.14)	(2.38)	
Mkt-Rf		-0.05	0.02	0.05	0.04	
		(-0.78)	(0.32)	(0.87)	(0.77)	
SMB			-0.14	-0.11	-0.26	
			(-1.49)	(-1.23)	(-2.59)	
HML			-0.26	-0.18	-0.21	
			(-3.36)	(-1.99)	(-2.60)	
UMD				0.13		
				(2.00)		
RMW					-0.39	
					(-2.90)	
CMA					-0.10	
					(-0.60)	
Observations	98	98	98	98	98	
R-squared	0.00	0.01	0.19	0.22	0.26	

Table 4. Leave-one-sector-out GMB's Alphas

We estimate time-series regressions on the global GMB portfolios which are composed of stocks with valid GICS codes from Datastream. Here we consider the global Fama-French (2015) five-factor model. See Equations (4_W) in Section 3.1 for details on the model specifications. Alphas are in percent per month. Robust *t*-statistics are in parentheses. In addition to the complete GMB portfolio including all sectors of stocks, the 11 leave-one-sector-out GMB portfolios are constructed by using the GICS industry classification system to aggregate individual stocks from the specific region for which the test is performed into 11 groups representing all industries except for Energy, Materials, Industrial, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, Real Estate, respectively. We report the three cases, the Global, the U.S. and Global excluding U.S., in the table.

		Global		U.S.		Global ex. U.S.	
		Alphas	*t-stat.*	Alphas	*t-stat.*	Alphas	*t-stat.*
All Sectors		0.34	*(2.23)*	0.49	*(2.62)*	0.12	*(0.70)*
All Sectors Except for	Energy	0.25	*(1.70)*	0.31	*(1.63)*	0.08	*(0.47)*
	Materials	0.27	*(1.68)*	0.48	*(2.42)*	0.04	*(0.21)*
	Industrial	0.38	*(2.29)*	0.54	*(2.72)*	0.13	*(0.70)*
	Consumer Discretionary	0.32	*(1.91)*	0.44	*(2.27)*	0.11	*(0.58)*
	Consumer Staples	0.37	*(2.46)*	0.53	*(2.72)*	0.16	*(0.92)*
	Health Care	0.25	*(1.52)*	0.44	*(2.14)*	0.04	*(0.20)*
	Financials	0.50	*(3.57)*	0.56	*(2.77)*	0.27	*(1.68)*
	Information Technology	0.32	*(2.04)*	0.50	*(2.52)*	0.16	*(0.91)*
	Communication Service	0.38	*(2.23)*	0.56	*(2.75)*	0.14	*(0.75)*
	Utilities	0.37	*(2.27)*	0.55	*(2.86)*	0.13	*(0.66)*
	Real Estate	0.34	*(2.19)*	0.50	*(2.59)*	0.13	*(0.69)*

Table 5. Regional GMB's Alphas

We estimate time-series regressions on the regional GMB portfolios. Panel A reports the regression results using the purely global model as in Equations (1_W) - (4_W), and Panel B reports those using the purely local model as in Equations (1_D) - (4_D). Section 3.2 for details on the model specifications. Returns are in percentage per month. ** denotes significance at the 5% level, and * for the 10% level.

Panel A. Purely Global Model

a. North America	(1)	(2)	(3)	(4)
Constant	0.62**	0.55**	0.51**	0.53**
Mkt-Rf	-0.05	-0.02	-0.02	-0.03
SMB		-0.27**	-0.28**	-0.26**
HML		-0.58**	-0.53**	-0.56**
UMD			0.09	
RMW				0.06
CMA				-0.05
R^2	0.01	0.32	0.33	0.32
Adj. R^2	0.00	0.30	0.30	0.29

	b. Europe				c. Japan			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	0.05	0.01	0.03	0.00	0.08	0.05	0.08	0.08
Mkt-Rf	-0.13**	-0.12**	-0.12**	-0.12**	0.01	0.01	0.01	-0.03
SMB		-0.03	-0.03	-0.02		0.00	0.00	-0.05
HML		-0.23**	-0.26**	-0.27**		-0.13	-0.16*	0.10
UMD			-0.04				-0.06	
RMW				0.03				-0.09
CMA				0.05				-0.37**
R^2	0.08	0.17	0.17	0.17	0.00	0.03	0.04	0.10
Adj. R^2	0.07	0.15	0.14	0.13	-0.01	0.00	0.00	0.06

	d. Asia Pacific				e. Emerging Markets			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	0.07	0.06	-0.09	0.11	0.06	0.03	0.02	0.08
Mkt-Rf	-0.03	-0.02	-0.01	-0.02	-0.09	-0.08	-0.08	-0.10*
SMB		-0.12	-0.14	-0.15		-0.17*	-0.17*	-0.22**
HML		-0.18	-0.01	-0.15		-0.28**	-0.26**	-0.11
UMD			0.28**				0.02	
RMW				-0.16				-0.17
CMA				-0.02				-0.25
R^2	0.00	0.02	0.06	0.02	0.02	0.08	0.08	0.11
Adj. R^2	-0.01	-0.01	0.02	-0.03	0.01	0.05	0.04	0.06

Table 5. Regional GMB's Alphas, continued.

Panel B. Purely Local Model

a. North America

	(1)	(2)	(3)	(4)
Constant	0.60**	0.27*	0.29**	0.15
Mkt-Rf	-0.01	0.02	0.01	-0.01
SMB		-0.13**	-0.13**	-0.04
HML		-0.51**	-0.54**	-0.69**
UMD			-0.06	
RMW				0.18*
CMA				0.27**
R^2	0.00	0.55	0.56	0.59
Adj. R^2	-0.01	0.54	0.54	0.57

	b. Europe				c. Japan			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	0.01	-0.03	0.01	-0.07	0.09	0.08	0.09	0.10
Mkt-Rf	-0.13**	-0.11**	-0.11**	-0.10**	-0.01	-0.03	-0.03	-0.05
SMB		0.05	0.05	0.09		-0.23**	-0.23**	-0.22**
HML		-0.10	-0.13	-0.17*		-0.17**	-0.19**	-0.10
UMD			-0.04				-0.06	
RMW				0.06				0.01
CMA				0.18				-0.19*
R^2	0.08	0.10	0.10	0.11	0.00	0.10	0.11	0.12
Adj. R^2	0.07	0.07	0.07	0.07	-0.01	0.07	0.08	0.08

	d. Asia Pacific				e. Emerging Markets			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Constant	0.02	0.06	-0.18	0.13	0.03	0.16	0.14	0.06
Mkt-Rf	0.09	0.05	0.04	0.07	-0.08*	-0.11**	-0.12**	-0.15**
SMB		-0.29**	-0.32**	-0.33**		-0.11	-0.12	-0.12
HML		-0.24**	-0.17	-0.18		-0.16**	-0.15**	-0.02
UMD			0.19*				0.04	
RMW				-0.20				0.02
CMA				-0.06				-0.20*
R^2	0.02	0.13	0.16	0.15	0.03	0.07	0.07	0.10
Adj. R^2	0.01	0.11	0.13	0.11	0.02	0.04	0.04	0.05

Table 6. Sub-period Experiments on Regional GMBs

We report the summary statistics and estimate time-series regressions for two sub-periods, from December 2012 to December 2015 and from January 2016 to December 2021. For a given region, the purely local model as in Equation (4_D) is considered as the benchmark model. Section 3.2 for details on the model specifications. Returns are in percentage per month. ** denotes significance at the 5% level, and * for the 10% level.

Panel A Summary Statistics

	North America	Europe	Japan	Asia Pacific	Emerging Markets
			Sub-period I: 2012-2015		
Mean returns (%)	0.89	0.49	0.11	1.23	1.02
Std. Dev (%)	2.00	1.49	1.60	2.72	2.27
t-statistic	2.71	1.99	0.40	2.76	2.73
Sharpe ratio	0.44	0.33	0.07	0.45	0.45
			Sub-period II: 2016-2021		
Mean returns (%)	0.42	-0.34	0.07	-0.56	-0.55
Std. Dev (%)	2.02	1.63	1.61	2.87	2.01
t-statistic	1.77	-1.79	0.39	-1.65	-2.34
Sharpe ratio	0.21	-0.21	0.05	-0.19	-0.28
Correlation					
			Sub-period I: 2012-2015		
North America	1				
Europe	0.54	1			
Japan	-0.07	-0.17	1		
Asia Pacific	0.34	0.40	-0.30	1	
Emerging Markets	0.34	0.28	-0.20	0.18	1
			Sub-period II: 2016-2021		
North America	1				
Europe	0.50	1			
Japan	0.14	0.02	1		
Asia Pacific	0.18	0.28	0.03	1	
Emerging Markets	0.36	0.32	0.02	0.38	1

Table 6. Sub-period Experiments on Regional GMBs, continued.

Panel B. Regional GMB's Alphas

	North America	Europe	Japan	Asia Pacific	Emerging Markets
			Sub-period I: 2012-2015		
Constant	0.37*	0.42*	0.30	1.54**	1.52**
Mkt-Rf	-0.05	-0.16*	-0.02	0.04	-0.31**
SMB	-0.12	-0.01	-0.29**	-0.26	-0.47
HML	-0.88**	-0.24	-0.43*	-0.33	-0.23
RMW	0.40**	0.04	-0.39	0.03	0.09
CMA	0.40**	0.75**	0.30	0.32*	-0.25
Observations	37	37	37	37	37
R-squared	0.78	0.26	0.16	0.32	0.17
Adj. R-squared	0.74	0.14	0.03	0.21	0.04
			Sub-period II: 2016-2021		
Constant	0.05	-0.33*	0.04	-0.57*	-0.51**
Mkt-Rf	0.01	-0.13**	-0.06	0.12	-0.11**
SMB	-0.05	0.09	-0.21*	-0.23	-0.24*
HML	-0.56**	-0.11	-0.06	-0.03	0.13
RMW	0.05	0.06	0.05	-0.25*	-0.05
CMA	0.14	-0.02	-0.31**	-0.21	-0.29**
Observations	72	72	72	72	72
R-squared	0.58	0.11	0.19	0.23	0.14
Adj. R-squared	0.54	0.04	0.13	0.17	0.08

INTERNET APPENDIX

Understanding the Global Equity Greenium

Internet Appendix Table 1. Summary Statistics of Global Equity Universe by Country

	Initial: 1989-2011			Now: 1973-2022		
Country	Beginning Date	Total Number of Stocks	Size (U.S. $ mills.)	Beginning Date	Total Number of Stocks	Size (U.S. $ mills.)
North America		9,438			12,607	
United States	1989/11	6,494	252.53	1973/01	8.624	336.52
Canada	1989/11	2,944	9.71	1973/01	3,983	20.81
Europe		8,630			10,430	
Austria	1989/11	240	182.04	1973/01	135	82.26
Belgium	1989/11	178	105.91	1973/01	202	89.88
Denmark	1989/11	205	65.72	1973/01	263	56.42
Finland	1989/11	157	134.50	1973/01	224	133.96
France	1989/11	1,170	70.54	1987/01	1,452	97.55
Germany	1989/11	1,109	77.73	1973/01	1,261	91.88
Greece	1989/11	332	47.72	1973/01	341	34.37
Ireland	1989/11	78	183.24	1988/01	81	70.27
Italy	1989/11	351	181.87	1973/01	549	114.90
Netherland	1989/11	203	221.79	1973/01	245	114.04
Norway	1989/11	347	100.56	1973/01	494	76.11
Portugal	1989/11	100	76.89	1973/01	115	61.78
Spain	1989/11	169	427.10	1988/01	265	342.31
Sweden	1989/11	571	51.30	1976/07	904	60.12
Switzerland	1989/11	265	189.44	1982/01	293	182.55
UK	1989/11	3,155	54.25	1973/01	3,606	46.29
Asia Pacific		3,914			5,853	
Hong Kong	1989/11	977	67.65	1973/01	2,035	85.45
Australia	1989/11	2,012	21.13	1973/01	2,728	39.83
New Zealand	1989/11	170	51.09	1988/01	196	70.18
Singapore	1989/11	755	69.29	1973/01	894	70.52
Japan	1989/11	4,301	174.90	1973/01	4,906	165.08
Emerging Markets		11,116			18,685	
Israel	1989/11	326	21.45	1986/01	431	37.04
Turkey	1989/11	241	57.61	1988/01	367	53.13
Pakistan	1989/11	129	35.75	1988/01	384	10.23
South Africa	1989/11	567	65.03	1973/01	633	115.77
Czech Republic	1993/07	76	1.00	1993/07	83	65.58
Poland	1992/01	348	31.41	1991/04	681	25.28
Hungary	1991/01	45	39.06	1991/01	59	42.87
Russia	1994/06	292	108.65	1994/06	398	91.91
China	1991/01	1,550	249.07	1991/01	3,999	465.17
India	1989/11	1,455	38.71	1981/01	3,309	13.42
Indonesia	1990/04	312	38.75	1990/04	255	81.40
Malaysia	1989/11	993	60.00	1973/01	1,169	61.60
Philippines	1989/11	158	32.13	1976/11	199	60.30
South Korea	1989/11	1,757	40.54	1980/01	2,717	50.82
Taiwan	1989/11	1,344	166.91	1987/09	2,317	147.25
Thailand	1989/11	483	35.95	1987/01	746	46.45
Argentina	1989/11	84	68.83	1988/01	106	55.43
Brazil	1993/01	404	97.73	1990/02	252	245.97

Internet Appendix Table 1. continued

Country	Initial: 1989-2011 Beginning date	Total number of Stocks	Size (U.S. $ mills.)	Now: 1973-2022 Beginning Date	Total Number of Stocks	Size (U.S. $ mills.)
Chile	1990/12	179	119.92	1989/07	206	108.22
Colombia	1992/01	85	65.86	1992/01	64	122.18
Mexico	1989/11	150	321.80	1988/01	169	196.72
Peru	1991/01	111	10.93	1991/01	128	18.23
Venezuela	1990/01	27	46.91	1990/01	13	27.97
Total All		37,399			52,481	

This table reports summary statistics of our sample stocks for each country. We exclude financial firms and to be included in the analysis, each stock has to have at least 12 monthly returns, is listed in its country's major exchange(s), and has sufficient information to calculate market value of equity (Size). We also apply several screening procedures for Datastream data errors in monthly returns as suggested by Ince and Porter (2003) and others, as detailed in the text. The beginning date for each country is as shown. The total numbers of unique stocks are reported for each country. Also reported are the time-series average of annual medians for size. Here the detailed sample selection criteria are described in Appendix A of the Internet Appendix.

Internet Appendix Table 2. Leave-one-sector-out GMB's Alphas

We estimate time-series regressions on the global GMB portfolios which are composed of stocks with valid GICS codes from Datastream. Mkt-Rf is the global excess market return. SMB and HML are the global version of the size and value factors of the Fama and French (1993) model. RMW and CMA are the global version of the profitability and global investment factors of Fama and French (2015). See Equations (4_W) in Section 3.1 for details on the model specifications. Returns are in percentage per month. ** denotes significance at the 5% level, and * for the 10% level.

In addition to the complete GMB portfolio, the 11 leave-one-sector-out GMB portfolios are constructed by using the GICS industry classification system to aggregate individual stocks from the specific region for which the test is performed into 11 groups representing all industries except for Energy, Materials, Industrial, Consumer Discretionary, Consumer Staples, Health Care, Financials, Information Technology, Communication Services, Utilities, Real Estate, respectively. We report the three cases, the Global, the U.S. and Global excluding U.S., in the table. The list below shows the leave-one-out GICS Sector Name in the ascending order of GICS Sector Code, respectively.

(1) All industries except for Energy (code: 10);
(2) All industries except for Materials (code: 15);
(3) All industries except for Industrial (code: 20);
(4) All industries except for Consumer Discretionary (code: 25);
(5) All industries except for Consumer Staples (code: 30);
(6) All industries except for Health Care (code: 35);
(7) All industries except for Financials (code: 40);
(8) All industries except for Information Technology (code: 45);
(9) All industries except for Communication Services (code: 50);
(10) All industries except for Utilities (code: 55);
(11) All industries except for Real Estate (code: 60).

Internet Appendix Table 2. Leave-one-sector-out GMB's Alphas, continued

	Complete GMB	Leave-one-sector-out GMBs (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A. Global												
Constant	0.34**	0.25*	0.27*	0.38**	0.32*	0.37**	0.25	0.50**	0.32**	0.38**	0.37**	0.34**
Mkt-Rf	-0.07	-0.01	-0.04	-0.07	-0.08*	-0.10**	-0.03	-0.12**	-0.06	-0.05	-0.12**	-0.07
SMB	-0.27**	-0.26**	-0.22**	-0.28**	-0.24**	-0.30**	-0.22**	-0.43**	-0.25**	-0.25**	-0.28**	-0.28**
HML	-0.45**	-0.22**	-0.40**	-0.47**	-0.42**	-0.55**	-0.26**	-0.78**	-0.40**	-0.44**	-0.53**	-0.47**
RMW	0.02	-0.14	0.06	0.02	0.09	0.02	0.07	0.00	0.00	0.01	0.05	0.01
CMA	-0.10	-0.13	-0.15	-0.14	-0.09	-0.06	-0.21	0.03	-0.10	-0.13	-0.01	-0.08
R^2	*0.33*	*0.18*	*0.29*	*0.33*	*0.27*	*0.41*	*0.19*	*0.59*	*0.28*	*0.28*	*0.35*	*0.33*
Adj. R^2	*0.30*	*0.14*	*0.25*	*0.29*	*0.24*	*0.38*	*0.15*	*0.56*	*0.24*	*0.25*	*0.32*	*0.29*
Panel B. U.S.												
Constant	0.49**	0.31	0.48**	0.54**	0.44**	0.53**	0.44**	0.56**	0.50**	0.56**	0.55**	0.50**
Mkt-Rf	-0.04	0.05	-0.03	-0.02	-0.04	-0.07	0.00	-0.08	-0.03	-0.02	-0.12	-0.03
SMB	-0.26**	-0.20**	-0.22**	-0.29**	-0.25**	-0.27**	-0.26**	-0.35**	-0.24**	-0.25**	-0.28**	-0.27**
HML	-0.53**	-0.19	-0.53**	-0.58**	-0.46**	-0.60**	-0.36**	-0.82**	-0.54**	-0.52**	-0.67**	-0.56**
UMD	0.03	-0.14	0.08	0.03	0.05	0.05	0.06	0.12	0.00	0.02	0.05	0.04
CMA	-0.08	-0.21	-0.11	-0.09	-0.16	-0.04	-0.22	0.07	-0.05	-0.14	0.06	-0.07
R^2	*0.29*	*0.14*	*0.27*	*0.29*	*0.26*	*0.31*	*0.19*	*0.39*	*0.25*	*0.27*	*0.35*	*0.29*
Adj. R^2	*0.25*	*0.10*	*0.24*	*0.26*	*0.22*	*0.28*	*0.15*	*0.36*	*0.22*	*0.23*	*0.31*	*0.25*
Panel C. Global ex. U.S.												
Constant	0.12	0.08	0.04	0.13	0.11	0.16	0.04	0.27	0.16	0.14	0.13	0.13
Mkt-Rf	-0.09*	-0.06	-0.04	-0.10**	-0.12**	-0.13**	-0.05	-0.17**	-0.09*	-0.06	-0.12**	-0.10*
SMB	-0.21**	-0.21**	-0.16*	-0.19**	-0.16*	-0.26**	-0.14	-0.38**	-0.21**	-0.19**	-0.21**	-0.21**
HML	-0.27**	-0.10	-0.21*	-0.26*	-0.27*	-0.41**	-0.09	-0.60**	-0.27**	-0.25*	-0.32**	-0.28**
RMW	-0.03	-0.16	-0.03	-0.02	0.11	-0.02	-0.01	-0.06	-0.05	-0.05	-0.01	-0.04
CMA	-0.09	-0.07	-0.13	-0.14	-0.06	-0.05	-0.15	-0.04	-0.10	-0.10	-0.02	-0.07
R^2	*0.16*	*0.08*	*0.11*	*0.16*	*0.15*	*0.25*	*0.05*	*0.45*	*0.16*	*0.12*	*0.16*	*0.16*
Adj. R^2	*0.12*	*0.04*	*0.07*	*0.12*	*0.11*	*0.22*	*0.01*	*0.43*	*0.12*	*0.08*	*0.12*	*0.12*