



Climate policy uncertainty and the price dynamics of green and brown energy stocks

Elie Bouri ^a, Najaf Iqbal ^{b,*}, Tony Klein ^c

^a School of Business, Lebanese American University, Lebanon

^b School of Finance, Anhui University of Finance and Economics, Anhui, PR China

^c Queen's Management School, Queen's University Belfast, UK

ARTICLE INFO

JEL classification:

G22

G10

Keywords:

Climate policy uncertainty
Green and brown energy stocks
Green equity
Crisis periods
Climate change

ABSTRACT

Using the newly proposed textual-based climate policy uncertainty index of Gavriilidis (2021), we provide the first empirical evidence that climate policy uncertainty is a significant determinant of the performance of green energy stocks relative to brown energy stocks. The climate policy uncertainty effect is positive and driven by crisis periods. The findings highlight the predictive information of climate policy uncertainty for price dynamics of green and brown energy equity and underline its influence on the preference of investors for green energy stocks, which matters for asset pricing, style rotation strategies, and asset allocation.

1. Introduction

Climate risk has been shown to influence firms' investment decisions (Engle et al., 2020) and evidence indicates that a firm's decision to diminish its carbon footprint is positively affected by uncertainty about climate policy regulation (Rodríguez Lopez et al., 2017).¹ This implies that investors switch from *brown* firms to *green* firms when worries around climate change rise, leading to green stocks outperforming brown stocks (Pástor et al., 2021). Furthermore, Choi et al. (2020) show that retail investors unload carbon-intensive firms when temperatures are abnormally high. Hsu et al. (2020) find evidence of a significant effect of uncertainty in environmental policies and regulations on the cross-section of emission portfolios' returns.

Based on the above discussion and considering the universe of green and brown energy stocks, we argue that higher levels of climate policy uncertainty might be associated with a rise in the ratio measuring the relative performance of green energy firms over brown energy firms. However, the validity of this hypothesis remains vague despite growing academic literature on climate economics and finance (e.g. Choi et al., 2020; Engle et al., 2020; Pástor et al., 2021). Interestingly, the recent construction of the monthly index of climate policy uncertainty (CPU) by Gavriilidis (2021) that is based on a textual analysis of several US newspapers allows us to empirically address this question. Implications of these findings are manifold and cover portfolio analysis, style rotation strategies between green energy and brown energy stock investments, as well as asset pricing.

In this paper, we provide first empirical evidence that the news-based uncertainty index related to climate policy (Gavriilidis, 2021) affects the performance of green energy stocks relative to brown energy stocks. The effect is significantly positive at the mean but becomes stronger at higher quantiles of the ratio distribution, reflecting stronger predictive power of the CPU index for the ratio

* Corresponding author.

E-mail address: Najaf@aufe.edu.cn (N. Iqbal).

¹ The opposite can happen in non-green firms where intensified uncertainty in general makes firms postpone investment in new machinery and R&D, which is manifested via the real options channel (Bloom, 2009).

of green to brown energy stocks, if this ratio is high. Given previous evidence on the effect of global financial and health crises on the price dynamics of clean and brown energy stocks, and given that the CPU index does not reflect uncertainty arising from these two types of crises, we include these crises in our empirical analysis. Our results are robust to the nature of the crisis (2008 Global Financial Crisis (GFC) and COVID-19 outbreak). Further analysis shows the robustness of our results to the choice of the exchange traded fund (ETF) data on green and brown energy stocks.

Our contribution is two-fold. Firstly, we extend the academic literature on environmental economics and finance, which has recently examined how climate risk influences the investment decisions of firms (Engle et al., 2020) and investors (Choi et al., 2020; Hsu et al., 2020). In that sense, our paper is also related to the literature on the performance of environmental, social, and governance (ESG) firms (Huang, 2021) and the high risk exposure of polluting firms (Bolton and Kacperczyk, 2021).

Secondly, we add to studies indicating that textual-based uncertainty measures such as economic policy uncertainty and geopolitical risk can affect asset prices and the correlation across asset returns (Ko and Lee, 2015; Demirer et al., 2018; Alqahtani and Klein, 2021). Specifically, we show that uncertainty related to climate policy is a significant driver of the relative performance of green energy stocks to brown energy stocks.

The remainder of this note is structured as follows. Section 2 outlines the analyzed data set and the regression methodology. Section 3 discusses our results with a reflection on existing literature. Section 4 concludes this discussion on the impact of climate uncertainty on relative equity performance.

2. Data & methodology

We measure the price performance of green energy stocks by two ETFs, the *Invesco Global Clean Energy ETF* (PBD) and the *Invesco WilderHill Clean Energy ETF* (PBW). For brown energy stocks, we use three ETFs, the *Energy Select Sector SPDR fund* (XLE), the *iShares Global Energy ETF* (IXC), and the *iShares US Energy* (IYE). The Global Clean Energy index, tracked by PBD, focuses mainly on alternative energy firms, having more than 60% of its sector allocation in Oil & Gas, Utilities, and Industrials.² XLE represents the energy sector of the S&P 500 Index and thereby provides an exposure to companies in the oil, gas and consumable fuel, energy equipment and services industries (e.g., top holdings are Exxon Mobil Corporation with a share of 23% and Chevron Corporation with a share of 20%). IXC contains global equity in the energy sector such as Exxon Mobil Corporation (13.62%), Chevron Corporation (11.12%), TotalEnergies (6.29%), ConocoPhillips (5.12%), and BP PLC (4.83%). IYE captures the performance of US equities in the energy sector, covering Oil & Gas Refining and Marketing (46.97%), Oil & Gas Exploration and Production (27.00%), and Oil & Gas Transportation (10.98%). The main constituents are Exxon Mobil Corporation (20.90%), Chevron Corporation (17.17%), ConocoPhillips (7.87%), EOG Resources (4.78%), and Schlumberger (4.05%).

We sample daily price data in U.S. Dollar quotation from Refinitiv and aggregate to monthly measures. The sample period spans July 2008 to March 2021, where the beginning date is dictated by the availability of PBD. The ending date is dictated by the availability of the CPU index recently constructed by Gavrilidis (2021) based on the scaled frequency of articles in eight major US newspapers covering exclusively news about climate policy. Data on the CPU index are sampled from <https://www.policyuncertainty.com>.

Following Huang and Kilic (2019), who use the ratio of gold to platinum prices to study US and international stocks, we compute the ratio of green stock to brown stock prices (Ratio G/B) and test our hypothesis.

Fig. 1 plots the CPU index and the dynamics of the ratio of green energy to brown energy stocks, which shows some spikes in the climate policy uncertainty index when President Trump announced that the US “will withdraw from” the Paris Agreement, but generally shows the index coinciding with spikes in the ratio, suggesting a somewhat positive relationship between the level of CPU and the ratio of green energy to brown energy stocks. Notably, the ratio moves upward from early Q1 2020 to the end of the sample period, which overlaps with the COVID-19 outbreak.

To determine the relationship between climate policy uncertainty and the ratio of green to brown energy stocks, we estimate the following regressions:

$$Ratio_t = \alpha + \beta_1 CPU_t + \varepsilon_t, \quad (1)$$

as well as with an interaction term

$$Ratio_t = \alpha + \beta_1 CPU_t + \beta_2 D_t^{90CPU} \cdot CPU_t + \varepsilon_t, \quad (2)$$

where $Ratio_t$ denotes the ratio of green over brown energy stock prices (Ratio G/B), and CPU_t denotes the climate policy uncertainty index of Gavrilidis (2021). The regression in Eq. (2) accounts for a possible interaction of CPU_t with a dummy variable (D_t^{90CPU}) that takes a value of 1 if the CPU is elevated. We choose a threshold value of the 90th percentile of the distribution of CPU, such that the dummy variable is 1 if CPU is higher than that value, and 0 otherwise. This is based on the hypothesis to be tested that investors might increase their switching behavior from brown energy firms to green firms when worries or awareness of climate risks are high.

Further, we estimate a model reflecting the possible interaction of the CPU with the Global Financial Crisis (GFC) and COVID-19 pandemic, which reads

$$Ratio_t = \alpha + \beta_1 CPU_t + \beta_3 D_t^{GFC} \cdot CPU_t + \beta_4 D_t^{COVID} \cdot CPU_t + \varepsilon_t, \quad (3)$$

² The WilderHill clean energy index, tracked by the PBW ETF, is diverse in scope and covers the space of wind, solar, biofuels, and geothermal firms.

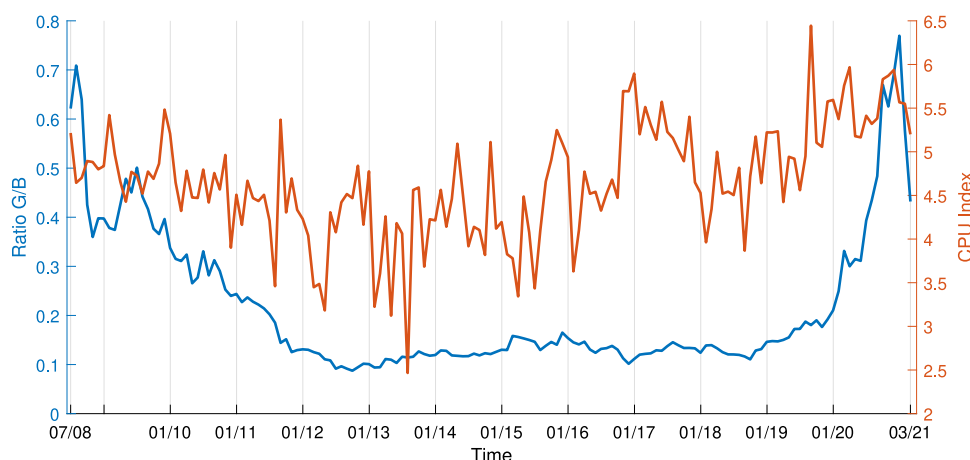


Fig. 1. Dynamic ratio of green energy to brown energy equity prices (Ratio G/B) and climate policy uncertainty index (CPU) of Gavrilidis (2021), sampled from July 2008 to March 2021. The CPU is plotted as logarithmic values.

where D_t^{GFC} is a dummy variable taking the value of 1 during the GFC period (July 2008 to September 2009) and 0 otherwise. Similarly, the dummy variable D_t^{COVID} takes the value of 1 during the COVID-19 outbreak (February 2020 to March 2021) and is 0 otherwise.

3. Results

We show the effect of CPU on the performance of green energy stocks relative to brown energy stocks based on the regressions outlined in Eq. (1)–(3).

The estimation results for the baseline regression in Eq. (1) are presented in Table 1. The results provide clear evidence that CPU has a significant explanatory power over the ratio of green over brown energy stocks. This is true regardless of whether we use the *Wilderhill ETF* or the *Global clean ETF* as a proxy for green stocks and whether we use XLE, IXC, or IYE as a proxy for brown stocks. The coefficient estimates are significantly positive, establishing a higher level of the ratio at higher levels of CPU, with the largest impact shown for IYE. This result is in line with a market situation in which a higher level of climate policy uncertainty is associated with investors moving funds out of brown energy stocks into green energy stocks, leading to a better performance of green stocks relative to brown stocks, which has been demonstrated in existing literature (Rodríguez Lopez et al., 2017; Pástor et al., 2021). Considering that stock prices are affected by cash flows and discount rates, the above results suggest that the dislike of investors for unexpected deterioration in the climate or awareness of the risks associated with climate change—and thus for brown stocks which have large exposures to climate risk—affects the performance of green stocks to brown stocks. This observation complements (Pástor et al., 2021) and establishes a link between climate policy uncertainty and the price dynamics of green and brown stocks.³

When estimating the regression with interaction terms in Eq. (2), the results are positive and significant for both coefficients β_1 and β_2 , reflecting that higher levels of CPU are positively related with the ratio. This is also highlighted in the increase in the level of adjusted R^2 for all models involving at least one proxy for green energy stock prices (e.g. PBD).⁴

For additional robustness, we also determine the relationship between climate policy uncertainty and the ratio of realized volatility of green energy stocks to brown energy stocks, where the monthly realized volatility of each energy ETF is computed as the sum of squared daily returns within each month (Barndorff-Nielsen and Shephard, 2002). The results show that CPU_t has a negative and significant effect, suggesting its ability to reduce the relative volatility of green energy stocks relative to brown energy stocks.⁵ This finding is in line with the above analysis and is justified with the following rationale. As investors move away from brown energy stocks into less pollutant green energy firms, brown stock returns tend to decrease more than green energy stock returns and thereby, their volatility tends to increase asymmetrically due to the asymmetric volatility effect (Bekaert and Wu, 2000). This volatility effect can explain the negative association between CPU and the relative volatility. Further, this backs evidence from recent literature showing the safe-haven property of green energy stocks against brown energy stocks (Saeed et al., 2020). Additionally, a recent study by Naeem et al. (2021) has highlighted the possibility to use green bonds to hedge the extreme risk of the energy markets. Our results further underline the observation that the volatility of green stocks decreases relative to the volatility of brown stocks during periods of uncertainty.

³ Results, which are unreported here due to brevity, show that the effect is robust and remains positive and qualitatively unchanged after controlling for financial and macroeconomic risk factors.

⁴ We use a quantile regression to estimate Eq. (1) and (2), and unreported results show a significant positive effect at middle and high quantiles of the ratio for both proxies of green energy stocks. The effect gets stronger and pseudo R^2 increases (reaching almost 25%) as we move to higher quantiles, reflecting the informational value of concerns about climate policy when the relative performance of green energy stocks to brown energy stocks is high.

⁵ Detailed results are available from the authors upon request.

Table 1
The relationship between CPU and the ratio of green to brown stocks.

Ratio G/B	Intercept α	CPU β_1	CPU at the 90th percentile β_2	R^2_{adj}
PBD/XLE	−3.2912*** (−12.1314)	0.3422*** (5.5241)		0.1621
PBD/XLE	−1.8454*** (−4.7923)	0.2368*** (2.7789)	0.0539** (1.9419)	0.1734
PBD/IXC	−2.5955*** (−10.1725)	0.3321*** (5.7210)		0.1897
PBD/IXC	−2.3557*** (−7.5388)	0.2754*** (3.5901)	0.0279 (0.6879)	0.1975
PBD/IYE	−2.8240*** (−10.2338)	0.3655*** (5.8060)		0.1856
PBD/IYE	−1.3384*** (−3.5158)	0.2498*** (2.9664)	0.0573** (2.1362)	0.1973
PBW/XLE	−2.2980*** (−7.0709)	0.3426*** (4.5826)		0.1526
PBW/XLE	−3.1098*** (−9.1632)	0.2981*** (3.4581)	0.0216 (0.4848)	0.1658
PBW/IXC	−1.6022*** (−5.1945)	0.3325*** (4.6844)		0.1756
PBW/IXC	−1.0955*** (−3.2125)	0.2131*** (2.8241)	0.0589** (2.4541)	0.2074
PBW/IYE	−1.8308*** (−5.5336)	0.3659*** (4.8098)		0.1728
PBW/IYE	−2.5979*** (−7.0577)	0.3112*** (3.8303)	0.0261 (0.4848)	0.1912

Ratio G/B refers to the ratio of prices of green to brown equity. CPU refers to the Climate Policy Uncertainty index of [Gavriilidis \(2021\)](#). We report the estimated coefficients for Eq. (1) and with interaction term for Eq. (2). The following ETFs are used for this ratio: Invesco Global Clean Energy ETF (PBD), Invesco WilderHill Clean Energy ETF (PBW), Energy Select Sector SPDR fund (XLE), iShares Global Energy ETF (IXC), and iShares US Energy (IYE). Robust *t*-statistics are given in parentheses.

***Refer to the 1% levels of significance.

**Refer to the 5% levels of significance.

Table 2
The effect of crises on the relationship between CPU and the ratio of green to brown stocks.

Ratio G/B	Intercept α	CPU β_1	GFC β_3	COVID-19 β_4	R^2_{adj}
PBD/XLE	−2.3015*** (−12.7954)	0.0889** (2.1933)	0.0078*** (7.5932)	0.0035*** (7.4687)	0.6141
PBD/IXC	−1.6568*** (−10.5382)	0.0940*** (2.7040)	0.0065*** (7.1734)	0.0034*** (7.4213)	0.6331
PBD/IYE	−1.8094*** (−10.1805)	0.1073*** (2.6830)	0.0074*** (7.3420)	0.0037*** (7.7075)	0.6240

Ratio G/B refers to the ratio of prices of green to brown equity. CPU refers to the Climate Policy Uncertainty index of [Gavriilidis \(2021\)](#). We report the estimated coefficients for Eq. (3). The following ETFs are used for this ratio: Invesco Global Clean Energy ETF (PBD), Energy Select Sector SPDR fund (XLE), iShares Global Energy ETF (IXC), and iShares US Energy (IYE). The GFC period is March 2008 to September 2009, and the COVID-19 period is February 2020 to March 2021. Robust *t*-statistics are given in parentheses.

***Refer to the 1% level of significance.

**Refer to the 5% level of significance.

Table 2 presents the estimates for the regression with crises interaction terms. These estimates show that the effect of CPU on the ratio of green to brown stocks is positive and significant for all cases after controlling for crisis periods. The 2008 global crisis and COVID-19 pandemic periods have a homogeneous positive effect on how CPU relates to the ratio of green to brown stocks, as indicated by the statistically significant and positive estimates for β_3 and β_4 . In general, both crises are reflected in an identical sign and similar magnitude of estimates, implying a higher reallocation of funds from brown energy stocks and into green energy stocks during crisis periods. This result corresponds with the perception that brown assets have higher climate betas than green assets (e.g. [Choi et al., 2020](#); [Engle et al., 2020](#)), which makes brown stocks underperform relative to green stocks during these crisis periods.⁶

4. Concluding remarks

We show that the recently developed climate policy uncertainty measure of [Gavriilidis \(2021\)](#) is a significant driver of the relative performance of green energy stocks to brown energy stocks. The positive effect is homogeneous across the various ETF data and the nature of the crises. The findings underline the importance of climate policy uncertainty on the preferences of investors, especially during crisis periods. It is shown that differing uncertainty levels are affecting a reallocation of assets. Therefore, holding a portfolio of green and brown energy stocks would be subject to climate policy uncertainty and differing awareness of climate change during crisis periods. As such, climate policy uncertainty should be considered in designing a style rotation strategy between green and brown energy stocks and in asset allocation decisions. There are implications for policymakers with regard to the ecological footprint of investments and ways to reduce them through promoting green energy investments to the detriment of brown energy investments. Lastly, this paper also underlines that reallocation between these equity categories significantly and asymmetrically affects their price volatility, and as such, becomes relevant to the analysis and management of risk associated with these investments.

⁶ [Bollen \(2007\)](#) points to the non-financial utility of investments driven by sustainability values.

CRedit authorship contribution statement

Elie Bouri: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **Najaf Iqbal:** Investigation, Writing – original draft, Writing – review & editing. **Tony Klein:** Visualization, Writing – original draft, Writing – review & editing.

Acknowledgment

Najaf Iqbal gratefully acknowledges the support from Academic Financial Aid Project for Top Talents in Universities of Anhui via grant number gxbjZD14.

References

- Alqahtani, A., Klein, T., 2021. Oil price changes, uncertainty, and geopolitical risks: On the resilience of GCC countries to global tensions. *Energy* 236, 121541. <http://dx.doi.org/10.1016/j.energy.2021.121541>.
- Barndorff-Nielsen, O.E., Shephard, N., 2002. Econometric analysis of realized volatility and its use in estimating stochastic volatility models. *J. R. Stat. Soc. Ser. B Stat. Methodol.* 64 (2), 253–280. <http://dx.doi.org/10.1111/1467-9868.00336>.
- Bekaert, G., Wu, G., 2000. Asymmetric volatility and risk in equity markets. *Rev. Financ. Stud.* 13 (1), 1–42. <http://dx.doi.org/10.1093/rfs/13.1.1>.
- Bloom, N., 2009. The impact of uncertainty shocks. *Econometrica* 77 (3), 623–685. <http://dx.doi.org/10.3982/ECTA6248>.
- Bollen, N.P.B., 2007. Mutual fund attributes and investor behavior. *J. Financ. Quant. Anal.* 42 (3), 683–708. <http://dx.doi.org/10.1017/S0022109000004142>.
- Bolton, P., Kacperczyk, M., 2021. Do investors care about carbon risk? *J. Financ. Econ.* 142 (2), 517–549. <http://dx.doi.org/10.1016/j.jfineco.2021.05.008>.
- Choi, D., Gao, Z., Jiang, W., 2020. Attention to global warming. In: Karolyi, A. (Ed.), *Rev. Financ. Stud.* 33 (3), 1112–1145. <http://dx.doi.org/10.1093/rfs/hhz086>.
- Demirer, M., Diebold, F.X., Liu, L., Yilmaz, K., 2018. Estimating global bank network connectedness. *J. Appl. Econometrics* 33 (1), 1–15. <http://dx.doi.org/10.1002/jae.2585>.
- Engle, R.F., Giglio, S., Kelly, B., Lee, H., Stroebel, J., 2020. Hedging climate change news. In: Karolyi, A. (Ed.), *Rev. Financ. Stud.* 33 (3), 1184–1216. <http://dx.doi.org/10.1093/rfs/hhz072>.
- Gavrilidis, K., 2021. Measuring climate policy uncertainty. *SSRN Electron. J.* <http://dx.doi.org/10.2139/ssrn.3847388>, URL: <https://www.ssrn.com/abstract=3847388>.
- Hsu, P.-H., Li, K., Tsou, C.-Y., 2020. The pollution premium. *SSRN Electron. J.* <http://dx.doi.org/10.2139/ssrn.3578215>, URL: <https://www.ssrn.com/abstract=3578215>.
- Huang, D.Z.X., 2021. Environmental, social and governance (ESG) activity and firm performance: a review and consolidation. *Account. Finance* 61 (1), 335–360. <http://dx.doi.org/10.1111/acfi.12569>.
- Huang, D., Kilic, M., 2019. Gold, platinum, and expected stock returns. *J. Financ. Econ.* 132 (3), 50–75. <http://dx.doi.org/10.1016/j.jfineco.2018.11.004>.
- Ko, J.-H., Lee, C.-M., 2015. International economic policy uncertainty and stock prices: Wavelet approach. *Econom. Lett.* 134, 118–122. <http://dx.doi.org/10.1016/j.econlet.2015.07.012>.
- Naeem, M.A., Bouri, E., Costa, M.D., Naifar, N., Shahzad, S.J.H., 2021. Energy markets and green bonds: A tail dependence analysis with time-varying optimal copulas and portfolio implications. *Resour. Policy* 74, 102418. <http://dx.doi.org/10.1016/j.resourpol.2021.102418>.
- Pástor, L., Stambaugh, R.F., Taylor, L.A., 2021. Sustainable investing in equilibrium. *J. Financ. Econ.* 142 (2), 550–571. <http://dx.doi.org/10.1016/j.jfineco.2020.12.011>.
- Rodriguez Lopez, J.M., Sakhel, A., Busch, T., 2017. Corporate investments and environmental regulation: The role of regulatory uncertainty, regulation-induced uncertainty, and investment history. *Eur. Manag. J.* 35 (1), 91–101. <http://dx.doi.org/10.1016/j.emj.2016.06.004>.
- Saeed, T., Bouri, E., Tran, D.K., 2020. Hedging strategies of green assets against dirty energy assets. *Energies* 13 (12), 3141. <http://dx.doi.org/10.3390/en13123141>.