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The Road to Net-zero: A Fund Flow Investigation

Louisa Chen and Koji Takahashi

Abstract

We analyze how U.S. green and brown energy equity mutual funds and ETFs respond to public attention on climate change from 2006 to 2022. Our findings indicate that green fund inflows consistently increased, peaking in 2020 in reaction to climate news, while brown fund inflows steadily declined. This shift toward green investments may discourage brown investments and help mitigate the negative impacts of climate news on stock market and industry production growth. The pace of transition from brown to green funds aligns with changes in U.S. climate policy, with a faster transition associated with positive stock market performance and industry production growth.

Keywords: Green and brown fund flows. climate change news. evolving transition. pace of transition.

JEL codes: G11, G23, Q43, Q54.

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1. Introduction

Climate change is a long-term shift in global or regional climate patterns, often refers to a rise in global temperatures due to unsustainable greenhouse gas emissions from fossil fuel consumption (Bolton et al. 2020). To limit global warming to 1.5°C, greenhouse gas emissions must be reduced by 45 percent by 2030 and reach net zero by 2050, as outlined in the Paris Agreement. In this study, we empirically examine several challenging issues in tackling climate change: what is the evolving transition pattern towards green investments from a financial trading perspective, and how does the speed of transition affect financial markets and economic output?

Climate change poses systemic risks to the economy and financial system, impacting economic activities (e.g., Litterman, 2020). Since the pioneering seminal works by Nordhaus (1977, 1992), much research has focused on the economic implications of climate change. However, the finance aspect, such as pricing, hedging, and investor attitudes towards climate risks, has only recently gained attention (see Giglio et al., 2021 for reviews). Among them, the main attention focusses on pricing and hedging of climate risk, with less on investment decisions and consequent trading activities.

Financial markets are a primary vehicle for mitigating climate risk by directing capital towards sustainable green investments and away from carbon-intensive industries. Green transition is more urgent than ever, as climate change is an accelerative process in the sense that exceeding certain climate tipping points could lead to catastrophic and irreversible impacts (Dangendorf et al., 2019; Bolton et al., 2020). However, given the limitations of technological innovations and the dependence of existing business models on fossil fuels, a rapid energy transition may lead to a substantial increase in energy system costs, halting GDP growth and employment (Hafner et al., 2021; Victor, 2019).

As predicted by the equilibrium model developed by Pástor et al. (2021) (PST model, hereafter), there is a shift in real investment from brown firms to green firms. This shift is attributed to changes in firms' cost of capital, which increases for brown firms and decreases for green firms. Green firms have a lower cost of capital compared to brown firms for three main reasons: investors have “green taste”; greener assets can hedge against climate risks leading to lower climate beta; and if the climate worsens unexpectedly, brown assets lose value relative to green assets due to, for instance, new regulations that penalizes brown firms.

Our analysis focuses on the net inflows of energy equity mutual funds and ETFs domiciled in the US from 2006 to 2022.[1] We conduct the analysis in three steps. Initially, we examine how green and brown energy fund flows respond to news about climate change over time, considering the signs, magnitude, non-linearity, and speed of the responses. Following the literature, we use climate change news index as a measure of economic agents' climate risk attention and concern. We simulate the potential impact of green energy investments on deterring brown energy investments and mitigating the adverse effects of climate news on the stock market and economy. Lastly, we explore the relevance of a rapid transition from brown to green investments on the performance of the stock market and the economy.

We use a vector autoregressive model in which the structural climate news is integrated directly as an exogenous variable (VARX, see Paul, 2020)[2]. The estimation consists of two forms: a constant parameter VARX initially, for some intuition, followed by a time-varying parameter VARX to detect any nonlinear patterns in the responses. Green and brown fund flows, along with the S&P 500 index return, VIX, and US industrial production growth, are the endogenous variables in the VAR system.

We identify green and brown energy equity funds by their names and portfolio holdings in the Lipper database. The aggregate fund flow is the percentage of net inflow over the total fund value of the month for green and brown funds, respectively. We apply the MeCCO USA climate change news index. This index monitors news about climate change published in highly circulated newspapers in the US, reflecting public attention to a broad range of physical and transitional climate risks.

The result of the constant parameter VARX demonstrates that green fund flows respond positively, yet brown fund flows respond negatively to climate news. This is in conjunction with

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[1] We use green and brown energy mutual funds and ETFs as a proxy for green and brown investments in the context of a low-carbon transition. Energy plays a crucial role in economic growth, with the majority of energy production still reliant on fossil fuels, making up around 82% of the global primary energy supply in the last four decades (IEA, 2016, in https://www.iea.org/energy-system/fossil-fuels#programmes). To move the global economy towards a low-carbon path, a crucial step is to reform the energy sector by shifting fossil fuels to renewable sources (UNFCCC, see https://unfccc.int/cop28).

[2] We adopt the VARX model developed by Paul (2020) and adjust the codes that is published at http://www.pascalpaul.de/replication-codes-varx/

a decrease in returns and an increase in volatility of the stock market, as well as declined industrial production growth. When we allow the parameters of the VARX to vary over time, the responses of the endogenous variables generally maintain the same signs, and their magnitudes fluctuate over the response horizon during the examination period of 2015 – 2022.[3]

Specifically, we find that in response to a climate news shock, investors steadily increase their green fund investments over a 9-month response horizon during the examination period, noticeable from 2017 to the late 2020. However, the rate of increase in green fund investments slows down since then. On the contrary, investments in brown funds decrease. The adverse response of stock market performance and industrial production growth become more severe towards the end of the examination period. This suggests that public's growing attention on climate change might boost the transition from brown to green investments in recent years, accompanied by increasing exposure of the stock market and economy to climate risk. Overall, our findings support the prediction of the PST model and show the ongoing shift from brown to green investments in the financial markets.

We further constrain the estimated coefficients of green fund flows in the time-varying VARX model and recalculate the impulse responses. We find that, in the absence of green fund investment support, the reaction of brown fund flows to the climate news becomes more negative over the 9-month response horizon and throughout the examination period. Similarly, heightened adverse effects are evident in the return and volatility of the stock market, as well as in industrial production growth. This suggests that green investments play a crucial role in real investment and risk hedging to address climate change.

By using the estimated time-varying cumulative impulse response (CIR) of the green and brown fund flows, we align with the principles outlined in the literature (Ball, 1994), and define the speed change of fund flows as the difference of the p^{th} period CIR between the two consecutive calendar months. We find that the speed change of green and brown fund flows progresses in contrasting directions, and the increase/decrease in net inflows into green and brown funds aligns with the upheaval in the U.S. changing climate policy regarding the

[3] The training sample data from 2006 to 2014 is used to calibrate the prior distributions of parameters for the time-varying VARX.

Paris Agreement, i.e., the shifting momentum of energy transition could potentially be influenced by government climate policies.

To examine whether a rapid transition from brown to green investments affects capital markets and the economy, we conduct a regression analysis. We look at the estimated CIRs of stock market return and industrial production growth in relation to the speed change in fund flows. Our findings indicate that in response to climate news, a rapid net inflow into green funds is strongly and positively correlated with stock market returns and industry production (IP) growth. Conversely, investments in brown funds have the opposite effect, especially on IP growth.

We perform various robustness tests on the time-varying VARX estimation, which includes an alternative method of identifying green funds by considering the E-rating of the fund's ESG rating, controlling for the influence of oil price, inflation, and extreme events in the sample. The results of these robustness tests have qualitative consistency with the main findings.

Our study contributes to literature in two ways. Firstly, we provide evidence to the theoretical literature regarding the transition from brown to green investments in the context of climate change. We focus on trading activity, which serves as a direct indicator of where the capital is being directed. Secondly, we contribute to the empirical literature by examining the hedging capabilities of green investments and the speed at which the transition from green to brown investments is occurring in relation to capital markets and the economy.

Our study is related to recent developments in theoretical climate finance literature. This literature suggests that the presence of climate risk can increase the market value of green firms while decreasing that of brown firms, resulting in a shift in real investments from brown to green firms (Ambec & Lanoie, 2008; Freeman, 1984; and Pástor et al., 2021). Our study is also related to the broader literature that explores the negative impacts of climate change on economic outcomes (e.g., Dell et al., 2014; Nordhaus, 2019; and Batten et al., 2020). A detailed literature review will be presented in the following section.

The remaining part of the paper is organized as follows: Section 2 reviews the related literature. Section 3 describes the sample data, and the methodology used. Sections 4 and 5 present the results of the VARX analysis and the speed of transition analysis. Section 6 presents the results of the robustness tests, and finally, Section 7 briefly concludes our findings and discusses policy implications.

2. Literature review

The increasing concern about the impact of traditional energy production and use on global warming could stimulate investments in clean and renewable energy (Climent and Soriano, 2011). According to the stakeholder theory, firms should create value for all stakeholders (Freeman, 1984), and green energy firms could achieve better financial performance compared to brown energy firms, as they may have lower costs and higher profits (see a review in Ambec and Lanoie, 2008). Pástor et al. (2021) demonstrate through an equilibrium model that expected returns depend on climate betas, in addition to market betas and investors preferences. Greener firms have lower climate betas than brown firms, thus have lower cost of capital and higher market values, attracting investment away from brown firms. Empirical studies also suggest that brown assets have higher climate betas than green assets (e.g., Choi et al., 2020; and Engle et al., 2020).

Recent empirical research has linked climate change to financial markets. While the majority focuses on the impact of climate risk on asset prices,[4] some studies shed light on investment flows. For example, Reboredo and Otero (2021) find that investment in green energy ETFs increased relative to traditional energy ETFs from 2009 to 2019, especially after the Paris Agreement. Other studies suggest that mutual fund investors tend to choose funds with lower climate-related transition risk or higher sustainable ratings (Ammann et al., 2019; Hartzmark and Sussman, 2019; Reboredo and Otero, 2021; Ceccarelli et al., 2023). A related strand of literature has explored how hedging climate risk by using low carbon footprint assets or portfolios, may or may not sacrifice financial returns (e.g., Andersson et al., 2016; de Jong and Nguyen, 2016; Trinks et al., 2018; Boermans and Galema, 2019; Monasterolo and de Angelis, 2020).

A large literature models and estimates the effects of climate change on economic outcomes. These studies usually start with some assumptions on future emissions, the extent and pattern of

[4] See, for example, Alekseev et al. (2024); Ardia et al. (2022); Bernstein et al. (2022); Bolton and Kacperczyk (2021); Flammer (2021); Ho (2022); Hong et al. (2019); Painter (2020); Pástor et al. (2022); Schlenker and Taylor (2021); Giglio et al. (2021); Hong et al. (2020); and Pástor et al. (2021).

global warming, and other possible aspects of climate change. Then, a range of methodologies are used to transform climate change to economic consequences. Climate change is believed to impact agricultural and industrial output, energy demand, economic growth, labor productivity and political stability, and potentially lead to significant financial losses, reduced wealth and lower GDP (see Dell et al., 2014; Bansal et al., 2016; Batten et al., 2020; Nordhaus, 2019 for reviews). Empirical studies indicate that abnormal temperature and other climate-related phenomenon increase economic risk, affecting firms' earnings and equity valuations, with a growing negative impact on equity prices over time (Bansal et al., 2016 a, b; and Hugon and Law, 2019).

3. Data and methodology

3.1 Data

3.1.1 Fund flows

Our data source for mutual funds and ETFs is Lipper. We create a dataset of equity energy mutual funds and ETFs through the following procedure. First, we gather a sample of mutual funds and ETFs that are within the industries of energy and utilities; domiciled in the U.S., denominated in USD, and primarily invest in equities worldwide. Following recent literature (see, for example, Martí-Ballester, 2019; and Lantushenko et al., 2020), we further identify green energy funds (REs) and brown energy funds (BEs) within this sample. Green energy funds are those whose names include at least one of the following keywords: *clean, climate, fossil, renewable, carbon, green energy, sustainable.* Within this initial sample, to avoid the greenwashing effect, we further exclude funds that invest more than 50% of their assets in firms categorized in the oil and gas production sector or in the oil equipment services and distribution sector. Brown energy funds are identified as those investing more than 50% of their assets in firms categorized in the oil and gas production sector or in the oil equipment services and distribution sector.

At the end of this process, we identify a total of 417 green funds and 371 brown funds (at the share class level),[5] with the number of green funds ranging from 70 to 358 and the number of brown funds ranging from 82 to 195 over the sample period. The average monthly number of green funds is 143, with an average of 0.18 billion USD in assets under management (AUM) per fund.

[5] The remaining funds, totaling 27,142, are considered non-green and non-brown funds.

In comparison, brown funds average 112 per month, each managing 0.39 billion USD on average. The average size of non-green and non-brown funds is 0.69 billion USD. Green funds consist of relatively small funds, compared to brown and non-green and non-brown funds. The average monthly return of green and brown funds is 0.53% and 0.3%, respectively, while non-green and non-brown funds have an average return of 0.56%.

We aggregate the monthly market value and net inflows[6] of the green energy funds, and express green energy fund flows (green fund flows, hereafter) as a percentage of the aggregate net fund inflow over the aggregate fund value within the month.[7] The same definition is applied for brown energy fund flows (brown fund flows, hereafter). Figure 1(a) displays the trend of green and brown fund flows across the sample period. It is apparent that green fund flows frequently surpassed brown fund flows after 2017. This trend suggests that the Paris Agreement, an internationally recognized treaty on climate change that came into effect on November 4, 2016, may have influenced investments in green energy.

3.1.2 Climate change news index and economic variables

Climate change is a complex phenomenon that presents various dimensions of risk. One is physical risk, such as extreme temperatures and rising sea levels, that cause damage to businesses and households. The other is the risk transit to a low-carbon economy - potential threats to certain business models from regulations aimed at reducing emissions (Engle et al., 2020; and (Jung et al., 2023).

Recent studies consider climate change news indices as measures of climate risk or climate change attention. They are typically created by using textual analysis to measure the intensity of climate change news coverage in newspapers, websites, or other media sources over time. Since these news reflect information (e.g., climate disasters and climate policies) that investors use in their climate-risk-based investment decisions, this metric can be used as an indicator of investor attention to both physical and transitional climate risks (see, for example,

[6] Fund flows in Lipper are calculated by subtracting fund performance.

[7] In this paper, "fund flow" refers to net inflow of the fund unless specified otherwise.

Engle et al., 2020; Choi et al., 2020; Faccini et al., 2021; Ardia et al., 2022; Kölbel et al., 2024; Li et al., 2024)

In this study, we use the Media and Climate Change Observatory (MeCCO) climate change news index. We do it for two considerations. One is a desire to measure news that is pertinent to wider economic agents who are concerned about climate risks. The MeCCO climate change news index monitors highly circulated newspapers in the US (MeCCO USA) and North America (MeCCO NA), compiling data from archives accessed through the Nexis Uni, Proquest and Factiva databases via the University of Colorado libraries. The index identifies relevant articles containing the terms ‘climate change’ or ‘global warming’, then calculates the total number of articles each month in each region divided by the number of newspapers searched that month.[8] The second benefit is that the MeCCO index covers our entire sample period. We transform the MeCCO indices into logarithmic value for further analysis.

Figure 1 (b) displays the trend of the climate change news indices - MeCCO USA and MeCCO NA from December 2006 to November 2022. Both exhibit an upward trend, particularly after 2010. For instance, MeCCO USA starts at a value of 5.4 in December 2006 and rises to 6.6 by November 2022. This corresponds with the growing apprehension regarding climate change seen globally.

The daily data of the S&P 500 index and VIX as well as monthly data of the US consumer price index are from WRDS. The monthly data of U.S. industry production and APSP crude oil index are from the website of the Federal Reserve Bank of St. Louis. We use the last day of the month S&P 500 index logarithm return (SP500 return, in percentage) and VIX (index level) as the monthly inputs. Industry production growth (IP growth) and oil return are the monthly percentage change of the initial time series. Inflation is the monthly percentage change of the US consumer price index. Table 1 presents the summary statistics and correlation matrix of the variables. All the time series are stationary according to the Augmented Dickey–Fuller unit-root test.

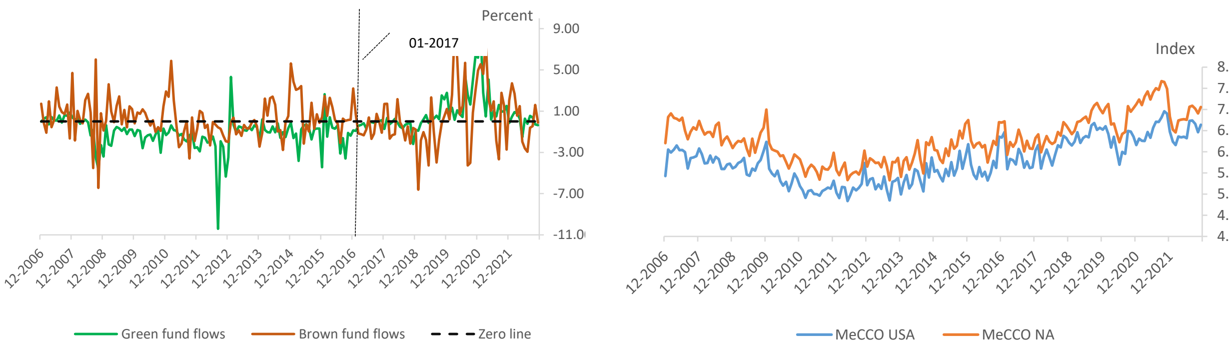
[8] For more details on index construction, please refer to the MeCCO website.

Figure 1. Green fund flows, brown fund flows and the MeCCO climate change news indices

This figure plots the monthly green fund flows, brown fund flows, and the MeCCO climate change news indices from 2006M12 to 2022M11. All variables are defined in Section 3.

(a) Green and brown fund flows

(b) MeCCO climate change news indices



Panel A of Table 1 indicates that the average green fund flows are negative throughout the sample period, whereas it is positive for brown fund flows. The limited investment in green energy prior to 2017 appears to heavily reduce the sample average. Panel B of Table 1 reveals that there is a strong and positive correlation between green fund flows and the two MeCCO climate change new indices, while this relationship is much weaker for brown fund flows.[9] This preliminary analysis suggests that investors are conscious of climate change and are leaning towards adjusting their investment portfolios towards green options. A summary definition of the variables is presented in Appendix A.

[9] Due to the similarity between MeCCO USA and MeCCO NA, we only report the results of the former in the remainder of the analysis.

Table 1. Summary statistics

All variables are defined in Section 3.1.

***Panel A**. Summary statistics*

	Obs	Mean	Median	Std. dev.	Min	Max
Green fund flows (%)	192	-0.44	-0.50	1.88	-10.40	8.58
Brown fund flows (%)	192	0.31	0.06	2.30	-6.62	8.96
SP500 rerturn (%)	192	0.14	0.26	1.43	-8.90	4.60
VIX (Index)	192	20.43	17.82	9.18	9.00	69.00
IP growth (%)	192	0.03	0.12	1.36	-13.20	6.28
MeCCO USA (Index)	192	5.78	5.73	0.50	4.84	6.96
MeCCO NA (Index)	192	6.30	6.25	0.53	5.32	7.67
Oil return (%)	192	0.27	1.68	9.72	-50.68	29.28
Inflation (%)	192	0.20	0.19	0.40	-1.92	1.37

***Panel B**. Correlation matrix*

	Green fund flows (%)	Brown fund flows (%)	SP500 rerturn (%)	VIX (Index)	IP growth (%)	MeCCO USA (Index)	MeCCO NA (Index)	Oil return (%)
Brown fund flows	0.25							
SP500 rerturn	0.10	0.15						
VIX	-0.03	0.12	-0.39					
IP growth	0.10	-0.17	0.17	-0.32				
MeCCO USA	0.48	0.05	0.01	0.05	-0.06			
MeCCO NA	0.53	0.13	0.05	0.06	-0.04	0.95		
Oil return	0.19	0.03	0.15	-0.17	0.38	-0.02	0.00	
Inflation	0.24	0.12	0.23	-0.24	0.23	0.13	0.16	0.61

3.2 Methodology

In this study, we investigate how trading activities on green and brown energy funds respond to climate change news, including the pace and magnitude of the response. We adopt Paul (2020) time-varying vector autoregressive model, where climate change news is considered an exogenous variable to fund flows and the economy. We chose this model because scientific studies have documented an acceleration in climate change over the past three decades. For example, both empirical studies and climate model projections indicate that global mean sea level has been rising faster since 1993 (see Nerem et al., 2018; and Dangendorf et al., 2019), and the risk premium associated with carbon dioxide emissions on equity prices is variable over time (Alessi et al., 2021). Reports from the IPCC and private scholars also suggest that the impacts of climate change are likely to be nonlinear and cumulative (IPCC, 2014[10], 2018[11]; and Nordhaus, 2019). Therefore, it is reasonable to assume that the response of green and brown investments to climate change news will also be nonlinear.

Additionally, while it is widely accepted that human activities such as carbon emissions contribute to current climate change, climate change and its associated risks are considered external factors to economic outcomes – at least in the short term (Bansal and Ochoa, 2011; and Carleton and Hsiang, 2016), The VARX is given below. For more detailed information about the model and its validity, please refer to the original paper by Paul (2020).

Assuming the general structural form of $\boldsymbol{y}_t$ evolves as follows:

$$Hy_t = C_0 + C_1 y_{t-1} + \cdots + C_k y_{t-k} + \epsilon_t, \quad (1)$$

where H and C_k are conformable coefficient matrices, ϵ_t is an $n \times 1$ vector of structural shocks. y_t is an $n \times 1$ vector of endogenous variables at month t, defined as follows:

$$\boldsymbol{y}_t \equiv [\text{GE}, \text{BE}, \text{SP500 return}, \text{VIX}, \text{IP growth}]', \quad (2)$$

where GE and BE represent the monthly aggregate net inflows of green and brown energy funds respectively, SP500 return is the logarithm return of the S&P 500, VIX is the S&P500 implied volatility index, and IP growth is the US industry production growth. All variables are defined in the previous section. Multiplying each side of the equation (1) by H^{-1}, we obtain the following equation:

$$y_t = B_0 + B_1 y_{t-1} + \cdots + B_k y_{t-k} + \mu_t, \quad (3)$$

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[10] See https://unfccc.int/topics/science/workstreams/cooperation-with-the-ipcc/the-fifth-assessment-report-of-the-ipcc

[11] See https://www.ipcc.ch/sr15/download/

where $\mu_t = H^{-1}\epsilon_t$ collects the impulse vectors of the shocks.

Assume that the interest lies in the identification of impulse responses to one of the structural shocks, denoted by $\epsilon_{1,t}$, the residual in the above model can be rewritten as:

$$\mu_t = s\epsilon_{1,t} + S\epsilon_{2,t}, \tag{4}$$

where s is the impulse vector associated with $\epsilon_{1,t}$ and the $(n-1) \times 1$ vector $\epsilon_{2,t}$ collects all other structural shocks. The contemporaneous *relative* impulse response of some other variable i in y_t with $i \neq j$ is defined as:

$$r_{ij} = \frac{s_i}{s_j}, \tag{5}$$

where s_i indicates the i^{th} element of vector s.

Now we consider an exogeneous instrument variable z_t and assume that z_t is correlated with the structural shock of our interest, $\epsilon_{1,t}$, and uncorrelated with the remaining structural shocks. Instead of using z_t as an instrument of $\epsilon_{1,t}$, we directly introduce it in the VAR model as an exogenous variable as follows:

$$y_t = \tilde{B}_0 + \tilde{B}_1 y_{t-1} + \cdots + \tilde{B}_k y_{t-k} + \tilde{A} z_t + \tilde{u}_t, \tag{6}$$

where $\tilde{A}$ is an impact vector for z_t, tildes are used to distinguish variables and coefficients from the notations. In this context, z_t is the climate news index and $\epsilon_{1,t}$ is a climate news shock about physical and transitional climate risks.

Then, the contemporaneous *relative* impulse response to shock $\epsilon_{1,t}$ is given by:

$$\widetilde{r_{ij}} = \frac{\widetilde{A_i}}{\widetilde{A_j}}, \tag{7}$$

where the estimated $\widetilde{A_i}$ and $\widetilde{A_j}$ with $i \neq j$ are two elements in $\tilde{A}$.

In the subsequent section, we first estimate the constant parameter VARX specified in equation (3) for initial intuition, then proceed to estimate the time-varying parameter VARX given by:

$$y_t = B_{0,t} + B_{1,t}y_{t-1} + \cdots + B_{k,t}y_{t-k} + A_t z_t + u_t, \quad (8)$$

t=1, …, T.

where $B_{0,t}$ is an $n \times 1$ vector of time-varying intercepts and $B_{j,t}$ for $j \in \{1, \dots, k\}$ are the $n \times n$ time-varying coefficient matrices with respect to the lagged endogenous variables. A_t is the $n \times 1$ vector of time-varying coefficients of the exogenous variable z_t. z_t is linked to the structural shock $\epsilon_{1,t}$ as follows:

$$z_t = \gamma\epsilon_{1,t} + \eta_t,$$

$E(\eta_t y_t) = 0$ and $\eta_t \sim N(0, \sigma_\eta)$.

Additionally, we define B_t as a vector that stacks all coefficients in the VAR model including one on exogeneous variable and assume that B_t follows a driftless random walk as follows:

$$B_t = B_{t-1} + \nu_t$$

Assume that the innovation terms follow a jointly normal distribution with mean zero, and the variance-covariance matrix is a block diagonal as follows:

$$\nu = Var\begin{bmatrix} u_t \\ \nu_t \end{bmatrix} = \begin{bmatrix} \Omega & 0 \\ 0 & \varrho \end{bmatrix},$$

where Ω and ϱ are positive definite matrices.

The contemporaneous *relative* impulse response is given by:

$$\widetilde{r_{t,\iota J}} = \frac{\widetilde{A_{t,\iota}}}{\widetilde{A_{t,J}}}\,. \tag{9}$$

4. Response of fund flows and the economy to climate news

In this section, we present the results obtained by using the climate new index - MeCCO Newspaper USA (MeCCO USA).

4.1 Constant parameter VARX

We start with a constant parameter VARX as defined in equation (3) to gain insight into the response of fund flows and the US economy to climate news. The estimation in equation (3) consists of the following specifications. Firstly, the lag length $k = 3$ is based on AIC. Secondly, the series of climate change news index (MeCCO USA) is projected on the 3 lags of $\boldsymbol{y}_t$, and residual from this projection is used as the exogenous variable z_t, ensuring that z_t is not correlated with $\boldsymbol{y}_t$ and is not serially correlated, as required by Paul (2020). Thirdly, the size of the shock is normalized to match the initial fall in the industry production growth to a 1SD climate news shock – z_t, as calculated in the previous step. Lastly, the confidence intervals are computed using a residual-based moving block bootstrap. [12]

Figure 2 presents the cumulative impulse response of green and brown fund flows, SP return and IP growth as well as the *impulse response* of VIX[13] to a climate news shock. The median response is shown, along with 68% and 90% confidence intervals. The sample period ranges from December 2006 to November 2022.

[12] All the time series involved in the constant VAR and time-varying VAR are stationary and no serial correlation.

[13] The remainder of the paper will present the *impulse response* for VIX (level) rather than cumulative impulse response.

As depicted in Figure 2, green fund flows experience an immediate increase of 1.01% following the climate news shock. The cumulative impulse response (CIR) continues to rise, reaching 3.72% after 9 months. In contrast, brown fund flows see a decrease of -0.89% immediately after the shock, eventually reaching 0.37% after 9 months. The significant difference in the response of green and brown fund flows to the climate news shock is consistent with the prediction of the PST model.

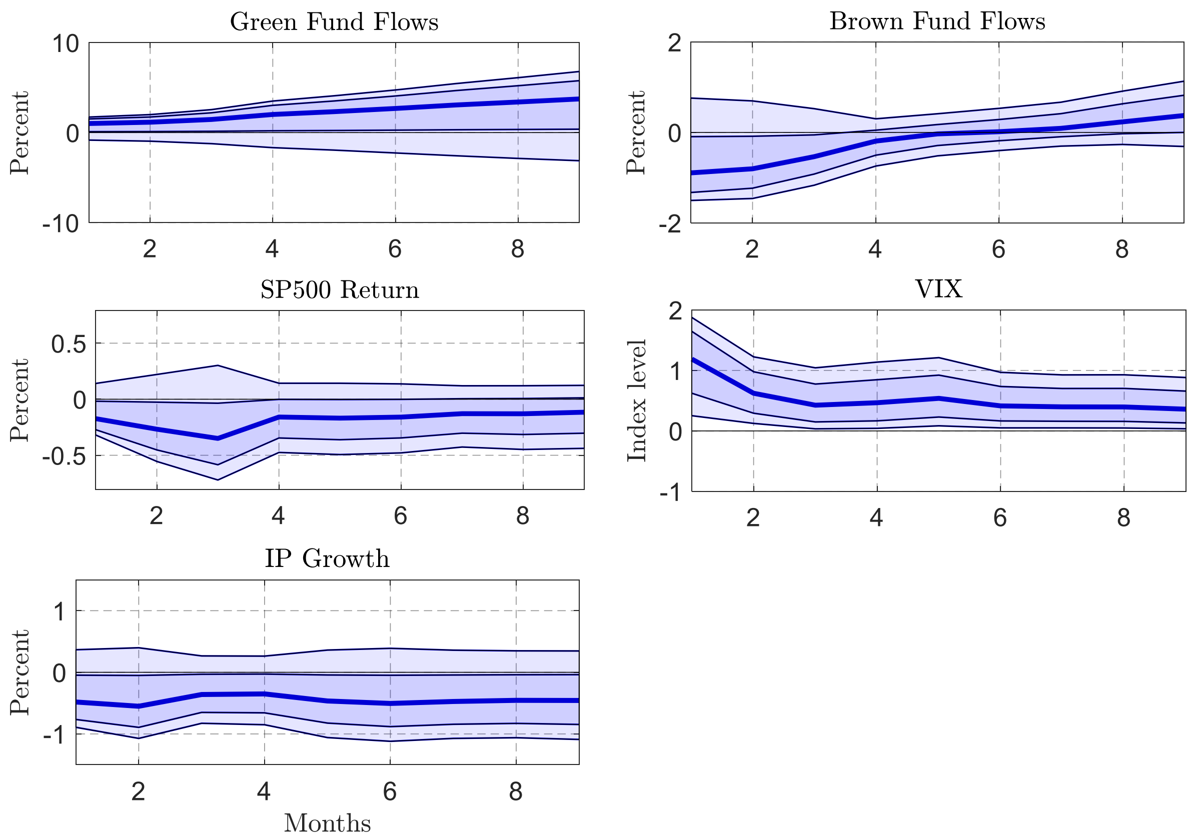
Turning to the economy, the climate news shock has a negative impact on the stock market and industrial production with decreasing returns and increasing volatility in the stock market, as well as a slowdown in the growth of industrial production. More specifically, the cumulative impulse response (CIR) of SP500 return declines by -0.17% immediately after the climate news shock and stabilizes at around -0.11% over a period of 9 months. The *impulse response* (*IR*) of VIX increases by 1.1 index point immediately after the shock, and then stabilizes at around 0.4 index point over the same 9-month period. The CIR of industrial production growth remains at around -0.48% during this time frame. These findings align with the theoretical prediction made by Nordhaus (2019).

The results of the constant parameter VARX provide an understanding of how fund flows and the economy respond to climate risk as seen in the news. Green investment is considered a hedging strategy against climate risk by both researchers and practitioners. In financial markets, climate risk raises the prices of green energy and reduces their volatility levels (Dutta et al., 2023). Investing in decarbonized indices enables long-term passive investors to hedge against climate risk without compromising financial returns (Andersson et al., 2016). From a macro perspective, green investments serve as a secure haven against climate uncertainty, and enhance financial stability (Cepni et al., 2022; and Yousaf et al., 2022).

The concept of green growth theory has been widely embraced by national and international organizations (e.g., OECD, United Nations Environment Program, and World Bank) since the 2012 Rio+ 20 Conference on Sustainable Development. Policymakers are now focusing on shifting the energy structure from brown energy sources (such as coal, oil, and gas) to green energy sources (such as wind, solar, and biofuel). Although the green growth theory suggests that technological advancements and substitutions can disconnect GDP growth from resource use and carbon emissions, there is limited empirical evidence supporting this claim (Hickel & Kallis, 2020).

Figure 2. Impulse response to a climate news shock with a constant parameter VARX

This figure shows the cumulative impulse responses to a climate news shock using a constant parameter 3-lagged VARX model according to equation (3), except for VIX which is plotted as an *impulse response*. The responses are normalized to match the initial decline in IP growth from a 1 SD climate news shock. The median response is displayed, along with 68% and 90% confidence intervals. Climate news index used is the MeCCO Newspaper USA (MeCCO USA). The sample period spans from December 2006 to November 2022. All variables are defined in Section 3.



4.2 Time-varying parameter VARX

As discussed in Section 3.2, financial investments, stock market, and the economy may respond to climate change in a non-linear manner. To address this issue, we estimate the VARX model with time-varying parameters as defined in equation (8). Following the methods of Primiceri (2005) and Paul (2020), we calibrate the prior distributions using a training sample of eight years (2006M12–2014 M12). Based on the OLS estimates of a constant parameter VARX model for the training sample, the mean and variance of B_0, scale matrix and degrees of freedom for the inverse-

Wishart prior of Ω and ϱ are set to be:

$$B_0 \sim N\left(\hat{B}_{OLS}, 6 \times V\left(\hat{B}_{OLS}\right)\right),$$
$$\Omega \sim \mathrm{IW}(I_n, n+1),$$
$$\varrho \sim IW\left(k_\varrho^2 \times \tau \times V\left(\hat{B}_{OLS}\right), \tau\right), \tag{10}$$

where $\hat{B}_{OLS}$ is the OLS point estimates for the training sample with a variance of $V\left(\hat{B}_{OLS}\right)$, $\tau = 97$ is the size of the training sample, k_ϱ is the prior belief about the amount of time variation in B_t. For the main analysis, we set $k_\varrho = 0.02$.[14] The simulation of the model is based on 5000 iterations of the Gibbs sampler, and the first 4000 are discarded for convergence.

To ensure the reaction to the same-size shocks $\epsilon_{1,t}$ over time, we normalize the response of IP growth on impact to -20 basis points at the beginning of the examination period (2015M4), giving a particular value of $\bar{z}$ the instrument to achieve this response. That said, $\bar{z} = (-0.2)/\bar{A}_{2015M4}$, where $\bar{A}_{2015M4}$ is the estimated posterior mean for IP growth at time 2015M4. The same variation $\bar{z}$ is then used to obtain contemporaneous impulse responses for other variables in 2015M4 or any subsequent period. Figure 3 presents the impulse responses of the time-varying VARX with a 9-month response horizon from 2015M4 to 2022M11.[15]

Overall, the impulse responses of the time-varying parameter VARX (Figure 3) are consistent with those of the constant parameter VARX (Figure 2) in terms of the signs of the responses, except that the CIR of brown fund flows remains negative in the 9-month response horizon from 2015 to 2022.[16] Most importantly, Figure 3 displays the changing impulse responses over time. Specifically, green fund flows respond positively to a climate news shock (i.e., net fund inflows increase). Its cumulative impulse response (CIR) rises steadily over the

[14] Primiceri (2005) indicates the sensitivity of results to certain parameters. As a result, we experiment with different prior values for $k_Q = \{0.01,\ 0.03\}$, finding that the outcomes remain consistent. Setting a lower value of k_Q decreases the time variation in the coefficients B_t, resulting in less time variation of the impulse response. Setting a higher value of k_Q works the opposite way.

[15] Appendix B presents the credibility intervals for a selected period - 2020M1, as an example.

[16] Note that the magnitude of the CIRs differs between Figures 2 and 3 because of the time-varying assumptions of $\bar{z}$ in the estimation.

9-month horizon in the examination period from 2015 to 2022, with a peak in the late 2020. On the other hand, the contemporaneous response of brown fund flows is negative. Its CIR keeps decreasing over both the 9-month response horizon as well as the entire examination period.

The CIR for SP500 return remains negative, showing an inverse U-shaped pattern in the 9-month response horizon over the examination period. Meanwhile, the impulse response (IR) of the stock market volatility (VIX) increases by 1.3 immediately after the climate news shock, then falls and stabilizes at a lower and positive level in the next 8 months. The overall IR of VIX becomes greater over both the 9-month response horizon and the examination period. These patterns suggest that growing investor attention to climate risk has had an increasing adverse impact on stock market performance in recent years. The CIR for IP growth exhibits a similar pattern and implications as that of SP500 return.

Figure 4 illustrates the time-varying CIRs of green and brown fund flows at selected impulse response horizons over the examination period.[17] At the 3-, 6- and 9-month horizons after the climate news shock, the CIRs of green fund flows are positive with an upward trend over the years. The increase in CIRs is more noticeable from 2017 to 2020, but has since slowed down.

This coincides with the changing climate policy of the US, which joined the Paris Agreement in November 2016 and withdrew in November 2020. Additionally, higher CIRs are also observed at longer horizons. The CIRs of brown fund flows show an opposite pattern, suggesting a shift from brown to green investments. A growing attention to climate change among investors appears to have boosted green investments while hindering brown investment in the last decade.

Our findings show a growing preference for shifting investments from brown to green energy over the past decade. Government climate policies may possibly influence investors' choices between green and brown assets. Achieving a net-zero emission global economy will be a challenging journey, and the transition to low-carbon energy is still incomplete.

[17] See Appendix G for the credibility interval of CIRs.

Figure 3. Time-varying impulse responses to a climate news shock

This figure shows the time-varying cumulative impulse response of green fund flows, brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX to an exogenous climate news shock (MeCCO USA) using equations (8) and (9) for the sample of 2015M1 – 2022M11. Prior $k_Q = 0.02$. All variables are defined in Section 3. *y*-axis: percentage or index level. *x*-axis (left): months. *x*-axis (right): years.

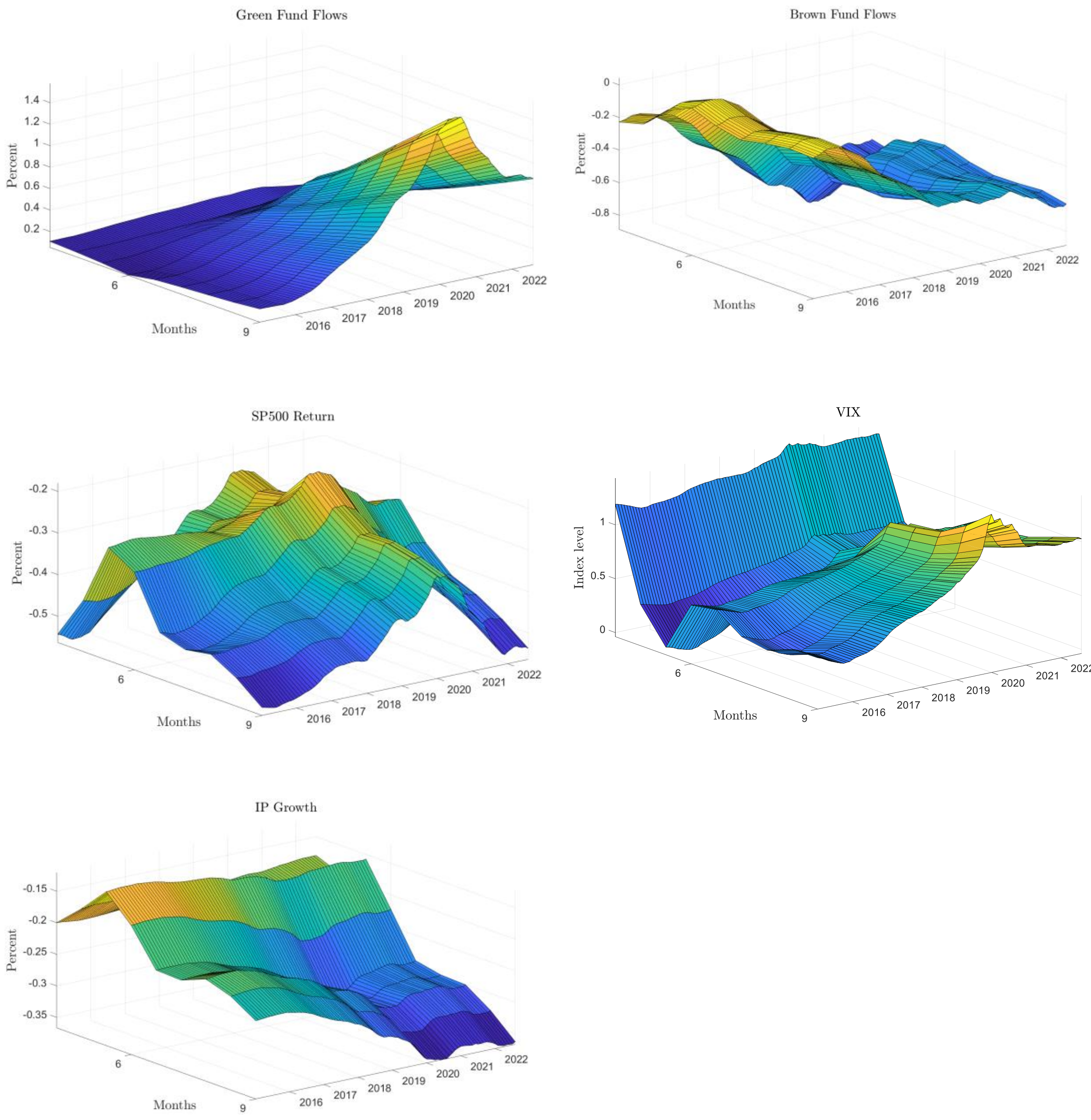
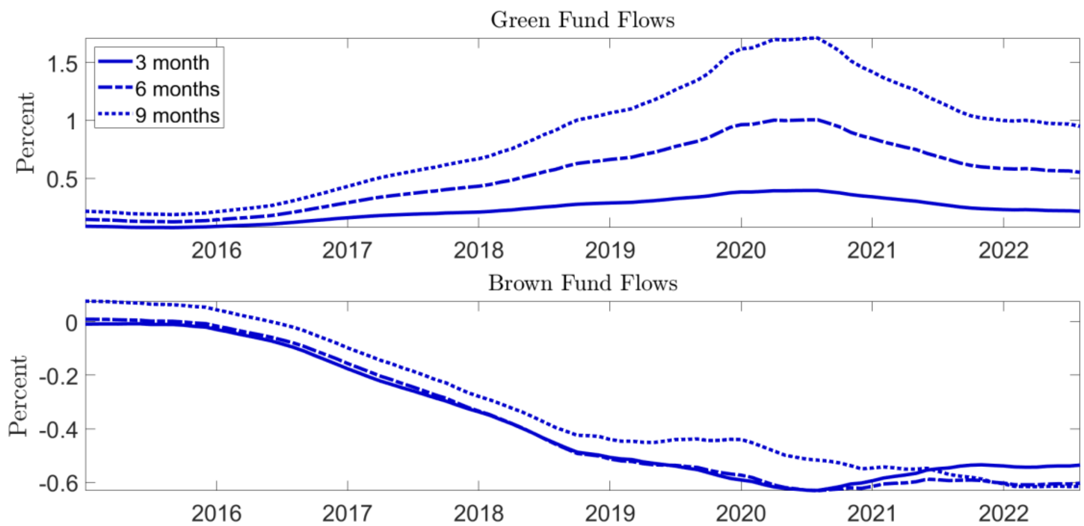


Figure 4 Time-varying impulse response of fund flows to a climate news shock at different horizons

This figure shows the time-varying cumulative impulse response of green and brown fund flows to an exogenous climate news shock (i.e., MeCCO USA) at the 3-, 6- and 9-month impulse response horizons using equations (8) and (9). The definition of the variables and the estimation approach are described in Figure 3.



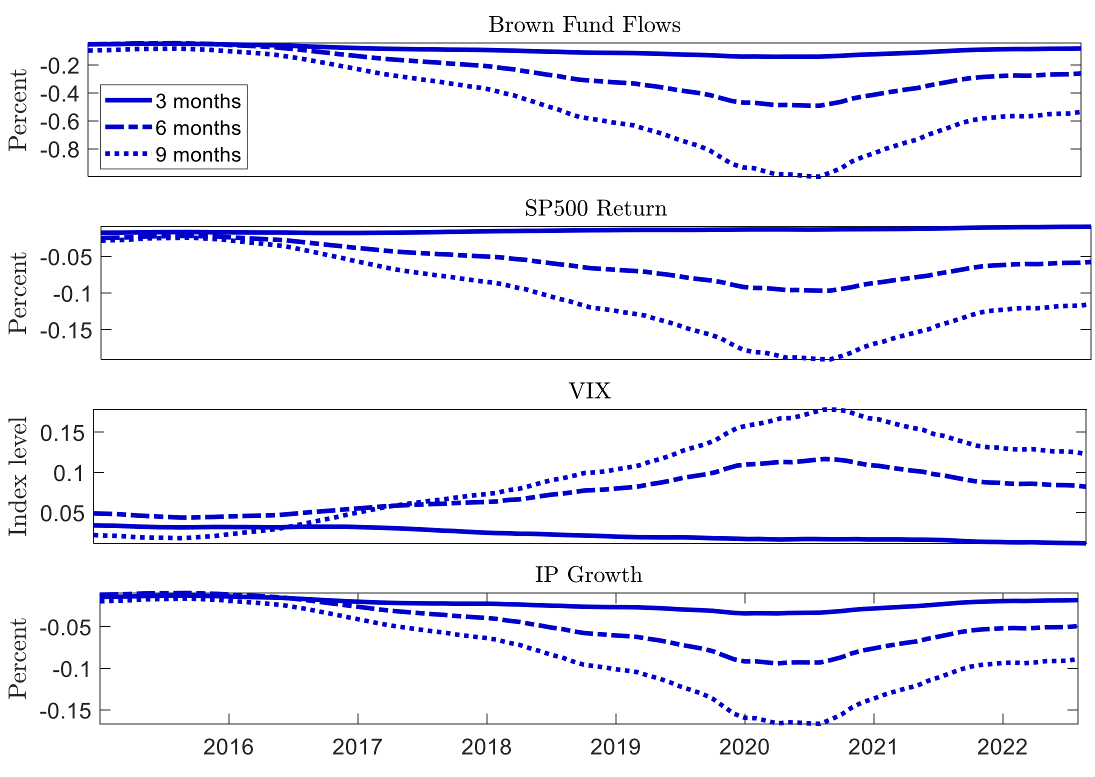
4.3 Time-varying parameter VARX with green fund flows restriction

Given the hypothesis and theory presented in the green investment literature, particularly the gap in empirical studies, we investigate how brown fund flows, the stock market, and the economy respond to climate news while assuming that the response of green fund flows is muted (i.e., there is no reaction of green fund flows to climate news). Consequently, we recalculate the cumulative impulse responses by constraining equation (8) with the estimated time-varying parameters $B_{t,1,GE} = \cdots = B_{t,k,GE} = 0$ and $A_{t,GE} = 0$. For a clear comparison, we present Figure 5 that illustrates the differences in CIRs between the models with unrestricted and restricted time-varying parameters.

Since green fund flows do not impact the other variables in the VARX system because they are muted, the CIRs of brown fund flows and the IRs of VIX in response to climate news becomes more positive, while the CIRs of S&P 500 returns and industrial production (IP) growth become more negative. This suggests that, in the absence of green fund investments, brown fund investments could increase, and both the stock market and industrial production would be more adversely affected by climate news. To put it another way, the decrease in IP growth and stock returns in the absence of green fund investments suggests that green fund flows play a crucial role in stimulating real investments and climate risk hedging via the capital market.

Figure 5. Time-varying impulse response to a climate news shock with restricted green fund flows over different response horizons

This figure shows the difference in the cumulative impulse responses of brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX over differernt response horizons between the restricted and non-restricted time-varying VARX models. In the restricted VARX model, the estimated time-varying coefficients B_1, B_2, B_3 and A_t of green fund flows in the VARX system are set to zero, while the non-restricted VARX model is described in Figure 3.



5. The speed of fund flows and climate change news

5.1 The speed of fund flows and its benefits

Transitioning to a green economy is not only an urgent call, but also a complex challenge. It requires large-scale transformations and investments in energy sectors, also business production and household consumption that are founded on the use of traditional energy. Some recent research argues that very rapid energy transitions can lead to a substantial increase in energy system costs, halting GDP growth and employment (even when considering great energy efficiency gains). Instead, a moderate energy transition can lead to lower power system costs while achieving the net-zero target (Hafner et al., 2021; Victor, 2019). In this regard, if investors withdraw too fast from brown funds towards investing in green funds, this may jeopardize the economy. Therefore, it is worth testing the sensitivity of the speed change (acceleration or deceleration) of fund flows to the stock market and output in response to climate news over time.

In the spirit of Ball (1994), we define the speed of fund flow as the level that the fund flow can research over a specific time after the climate news shock:

$$Speed_t^p = CIR\ Fund\ Flow_t^p,\ p \in [1,12] \tag{11}$$

where t is the p^{th} calendar month of the sample years 2015M4 – 2022M11, p is the p^{th} impulse response period, CIR Fund Flow is the cumulative impulse response of green and brown fund flows to climate news as estimated in the time-varying parameter VARX in Section 4.2. We interest in how a rapid transition from brown to green investments impact both capital markets and output. Therefore, we compute the change in the speed of fund flow as the difference of the speed of fund flow between two consecutive months:

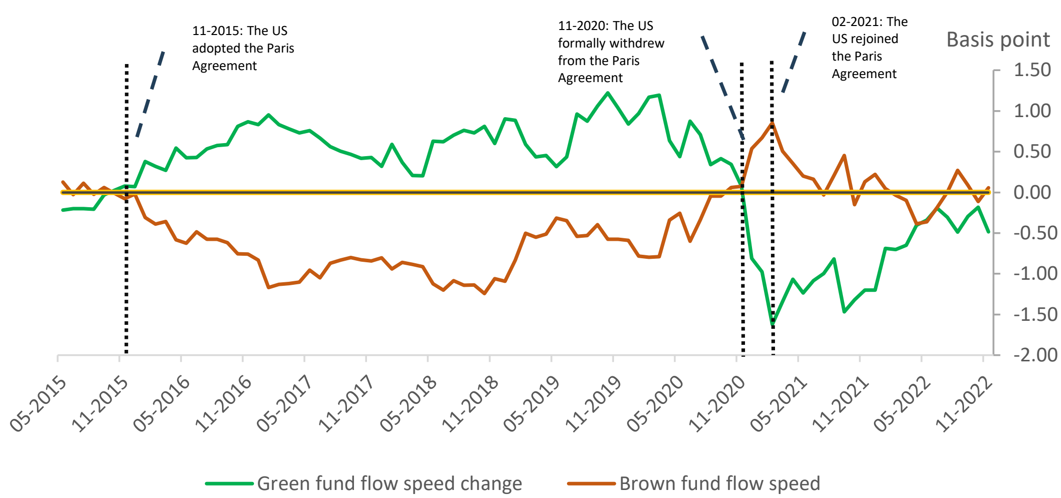
$$Fund\ flow\ speed\ change_t^p = Speed_t^p - Speed_{t-1}^p \tag{12}$$

This change reflects the evolving investors' perception towards climate change and asset allocation over time.

Figure 6 shows the estimated changes in the speed of fund flows for green and brown funds in the third month after the climate news shocks. The speed of green fund flows increased, meaning they accelerated, while the speed of brown fund flows decreased, meaning they decelerated. Starting at the end of 2015 when the US joined the Paris Agreement, green fund flows were faster than brown fund flows until November 2020 when the Trump Administration formally withdrew from the Paris Agreement. After that, brown fund flows accelerated and were faster than green fund flows until February 2021 when the Biden Administration took the office and rejoined the Paris Agreement. Since then, the speed of green fund flows has increased again, while the speed of brown fund flows has decreased. The changes in fund flow speed seem to be related to the changing climate policies of the U.S..

Figure 6. Changes in the speed of fund flows as responses to climate news shocks

This figure depicts the changes in the speed of green and brown fund flows in the third month after the climate news shocks, as calculated by equation (12).



It is important to understand how the changing pace of transition from brown to green fund investments is related to stock market performance and output. We therefore regress the CIRs of SP500 return and IP growth on the speed change of fund flows in the 3- and 6-month impulse response horizons. By using the estimated CIRs in our regression analysis, we can isolate the endogenous variables from the influences of other economic variables rather than the climate news. We focus on long response horizons, as investment transition may take time to impact the economy. The results of our analysis are presented in Table 2.

Panel A of Table 2 shows that in response to a climate news shock, a rapid increase in investments in green funds is strongly and positively linked with CIRs of SP500 return and IP growth for both the 3- and 6-month horizons. In contrast, a rapid increase in brown funds is negatively and significantly linked with IP growth, and has less linkage with SP500 return. While the results only show correlation and not causation, they suggest that, in the current climate-focused environment, investors are quickly transitioning to green investments, and the economy has been able to accommodate this rapid shift in recent years.

Using the estimated CIRs in the regression analysis comes with a caveat – it is subject to estimation errors. To provide a simple robustness check, we conduct the analysis using the actual fund flow speed, SP500 return and IP growth. We calculate actual speed change of fund flows as the first difference of the actual green and brown fund flows, then regress the actual SP500 return and IP growth on the 3- and 6-lagged speed change of green and brown fund flows, respectively. It is important to note that in this setting, we cannot separate climate news from the dynamics of the system.

Panel B of Table 2 indicates that the actual speed change of brown fund flows reduces SP500 return 3 and 6 months in advance at a 1% significance level, while the actual speed change of green fund flows only increases SP500 return 3 months in advance at a 10% significance level. Neither the actual speed change of green nor brown funds have a significant association with IP growth. These findings provide some support for the regression analysis conducted using the estimated data as in Panel A of Table 2.

6. Robustness

6.1 Alternative identification of green funds

We use a different set of criteria to identify green energy funds while keeping the identification of brown energy funds unchanged. The alternative procedure for identifying green energy funds is as follows. Firstly, we select green energy funds based on their names as the initial identification. Then, we retain funds whose average E score (i.e., the environmental component of the ESG) is above the 75th percentile of all funds to mitigate the issue of "green washing"[18]. This forms the final set of green energy funds. The average E score of fund *i* is calculated as following:

[18] See United Nations' definition of 'green washing' at https://www.un.org/en/climatechange/science/climate-issues/greenwashing.

$$\bar{E}_{it} = \sum_{j \in F_{it}} \frac{Inv_{ijt} \times E_{jt}}{InvE_{it}} \quad (13)$$

Table 2. The relationship between the changes in the speed of fund flows, and SP500 return and IP growth

Panel A of this table presents the results of the regression analysis where the CIRs of SP500 returns and IP growth in the 3 and 6 months after a climate news shock are examined in relation to the changes in green and brown fund flows speed. The speed change in fund flows is defined by equation (12). The CIR SP500 return and CIR IP growth are the cumulative impulse response of SP500 return and IP growth to a climate news shock as estimated in Section 4.2. Panel B of this table presents the regression results of the *actual* speed change in green and brown fund flows on SP500 return and IP growth. The *actual* speed change is the first difference of the fund flows between two consecutive months. *t* is the calendar month. *p*-values are in parenthesis. ***, ** and * indicates significance levels of 1%, 5% and 10%, respectively.

***Panel A**. The relationship between the speed change in green and brown fund flows to the CIR SP500 return and CIR IP growth based on the estimated cumulative impulse responses (CIRs)*

	CIR SP500 return^3_t		CIR IP growth^3_t		CIR SP500 return^6_t		CIR IP growth^6_t	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Green fund flow speed change^3_t (b_1)	0.80		0.57					
	(0.00)***		(0.00)***					
Brown fund flow speed change^3_t (b_2)		-0.42		-0.60				
		(0.09)*		(0.00)***				
Green fund flow speed change^6_t (b_1)					1.31		0.20	
					(0.00)***		(0.00)***	
Brown fund flow speed change^6_t (b_2)						1.57		-0.40
						(0.17)		(0.04)**
t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.02)**	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Constant	-0.29	-0.28	-0.15	-0.15	-0.44	-0.41	-0.24	-0.24
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Adj-R^2	0.38	0.23	0.27	0.17	0.31	0.10	0.80	0.77
Sample size	91	91	91	91	91	91	91	91

***Panel B**. The relationship between the speed change in green and brown fund flows to SP500 return and IP growth based on the actual fund flows, SP500 return and IP growth.*

	SP500 return$_t$	IP growth$_t$	SP500 return$_t$	IP growth$_t$
	(1)	(2)	(3)	(4)
Green fund flow speed change$_{t-3}$	0.10	0.04		
	(0.10)*	(0.48)		
Brown fund flow speed change$_{t-3}$	-0.13	0.02		
	(0.00)***	(0.57)		
Green fund flow speed change$_{t-6}$			-0.01	-0.02
			(0.87)	(0.68)
Brown fund flow speed change$_{t-6}$			-0.10	0.01
			(0.01)***	(0.79)
Constant	0.14	0.03	0.14	0.02
	(0.17)	(0.80)	(0.20)	(0.84)
Adj-R^2	0.06	0.01	0.03	0.01
Sample size	188	188	185	185

where Inv_{ijt} is the amount of investment in firm *j* within fund *i* at month *t*, $\mathrm{E_{jt}}$ is the score of the climate component of firm j's ESG, $InvE_{it}$ is the total amount of investment in all firms invested within fund *i* for which E score data are also available, the set of these firms is denoted as F_{it}.

By employing this different definition of green energy funds, we re-estimate the time-varying parameter VARX with the climate change news index. The result is presented in Appendix C, showing qualitative consistency with those in Section 4 in general. The only discrepancy is seen in brown fund flows, which exhibit a slightly altered trend – initially responding negatively to the climate news shock in the first two months, then shifting to a positive trend, albeit at a magnitude three times lower than that of green fund flows in general.

6.2 Control for oil price

Oil price movements are strongly linked to investor sentiment, industries related to oil, and industries that are highly sensitive to oil (see, for example, Hammoudeh et al., 2004; Qadan & Nama, 2018). Our data also indicates a relatively high correlation (at 0.39) of the APSP crude oil index return and brown fund flows. To eliminate the impact of oil prices on brown energy investment, the series of brown fund flows is projected on the return of the APSP crude oil index return, and the residual from this projection is used as the endogenous variable - brown fund flows. The result of the time-varying VARX analysis with the 'oil-free' brown fund flows is presented in Appendix D, showing qualitative consistency with those in Section 4.

6.3 Control for inflation

Since early 2021, the US and many other major economies have experienced high inflation, which has affected investment and economic growth. To account for the impact of inflation in our analysis, we include it as one of the endogenous variables and remove the VIX from the VARX to maintain degree of freedom in the estimation. The result is presented in Appendix E, showing qualitative consistency with those in Section 4.

6.4 Control for extreme events

Extreme events occur during the sample period from 2006 to 2022, such as the 2008 global finance crisis and the 2020 pandemic. To ensure that our results are not driven by these extreme events, we winsorize the endogenous variables at the 5^{th} and 95^{th} percentiles, and re-estimate the time-varying VARX. The result is presented in Appendix F, showing qualitatively consistency with those in Section 4.

7. Conclusion and policy implications

Climate change is an evolving and accelerating process. In recent years, the global community has placed greater importance on establishing a specific target date to achieve net-zero emissions, typically aligned with the temperature goals laid out in the Paris Agreement. Therefore, it is essential to comprehend how financial investments transit towards a low-carbon economy over an extended period, the speed of transition, and its effects on capital markets and the economy.

In this study, we investigate the flow of funds into green and brown energy equity mutual funds and ETFs in the context of climate news in the U.S. over the last two decades. Our results suggest that news about climate change encourages investments in green funds and discourages investments in brown funds, casting adverse effect on stock market and industrial production growth. The transition from brown to green energy investments is time-dependent and coincides with the changing U.S. climate policy from 2015 to 2022, as well as other significant market events like the “bull” stock market under expansionary monetary policy during this period.

An increase in green fund investment may deter brown fund investment and mitigate the adverse impacts of climate new shocks on stock market and industrial production growth. Considering the pace of energy transition in the context of climate news shocks, quick flows into green funds are associated with better stock market performance and industrial production growth, whereas the opposite is true for brown fund flows.

Our research results offer valuable insights for those interested in the net-zero transition policy. On the one hand, investors' awareness and attitude towards climate change have manifested in financial markets where trading has shifted towards green investments. However, the road towards a net-zero emission economy is not without obstacles. The rapid transition from brown to green fund investments was hindered during the period from November 2020 to February 2021, when the US temporarily withdrew from the Paris Agreement. The fluctuating speed of change in energy transition appears to be influenced by government climate policies.

On the other hand, establishing a specific target date for achieving net-zero emissions necessitates us to carefully consider the optimal speed of transition. This will allow us to maximize the speed of energy transition while considering feasible economic adjustments and technological innovations. Further research on identifying the optimal speed of transition will be a complex, challenging, but ultimately rewarding endeavor. Another important question that warrants further exploration is to disentangle physical and transition climate risks, and to assess their time-varying impacts on economic activities.

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Appendices

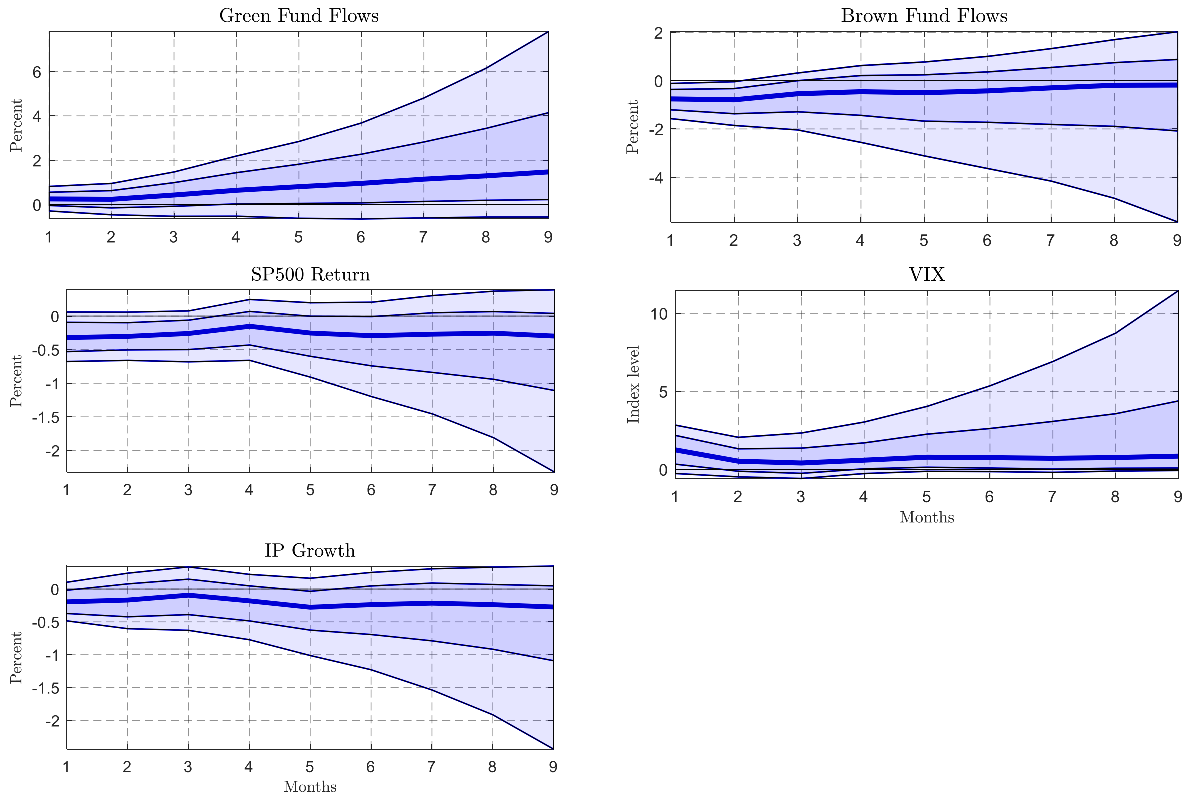
Appendix A. Variable definitions

Green fund flows (%)	The percentage of the aggregate net fund inflow over the aggregate fund value within the month for green funds. Green funds are identified as mutual funds and ETFs that are within the industries of energy and utilities; domicile in the US, denominated in USD, and primarily invest in equities worldwide; the name of the fund include at least one of the following keywords: *clean, climate, fossil, renewable, carbon, green energy, sustainable*; the fund holds less than 50% of their assets in firms categorized in the oil and gas production sector or in the oil equipment services and distribution sector.
Brown fund flows (%)	The percentage of the aggregate net fund inflow over the aggregate fund value within the month for brown funds. Brown funds are identified as mutual funds and ETFs that are within the industries of energy and utilities; domicile in the US, denominated in USD, and primarily invest in equities worldwide; the fund holds more than 50% of their assets in firms categorized in the oil and gas production sector or in the oil equipment services and distribution sector.
SP500 rerturn (%)	The last day of the month S&P 500 logarithm return in percentage.
VIX (Index)	The closing price of the CBOE S&P500 Volatility Index.
IP growth (%)	The monthly percentage change of the US industry production.
MeCCO USA (Index)	The total number of articles containing the terms '*climate change*' or '*global warming*' published in highly circulated newspapers each month in the US divided by the number of newspapers searched that month.
MeCCO NA (Index)	The total number of articles containing the terms '*climate change*' or '*global warming*' published in highly circulated newspapers each month in North America divided by the number of newspapers searched that month.
Oil return (%)	The monthly percentage change of APSP crude oil index.
Inflation (%)	The monthly percentage change of the US consumer price index.

Appendix B.

Figure B. Impulse Responses with time-varying parameter VARX for a selected period

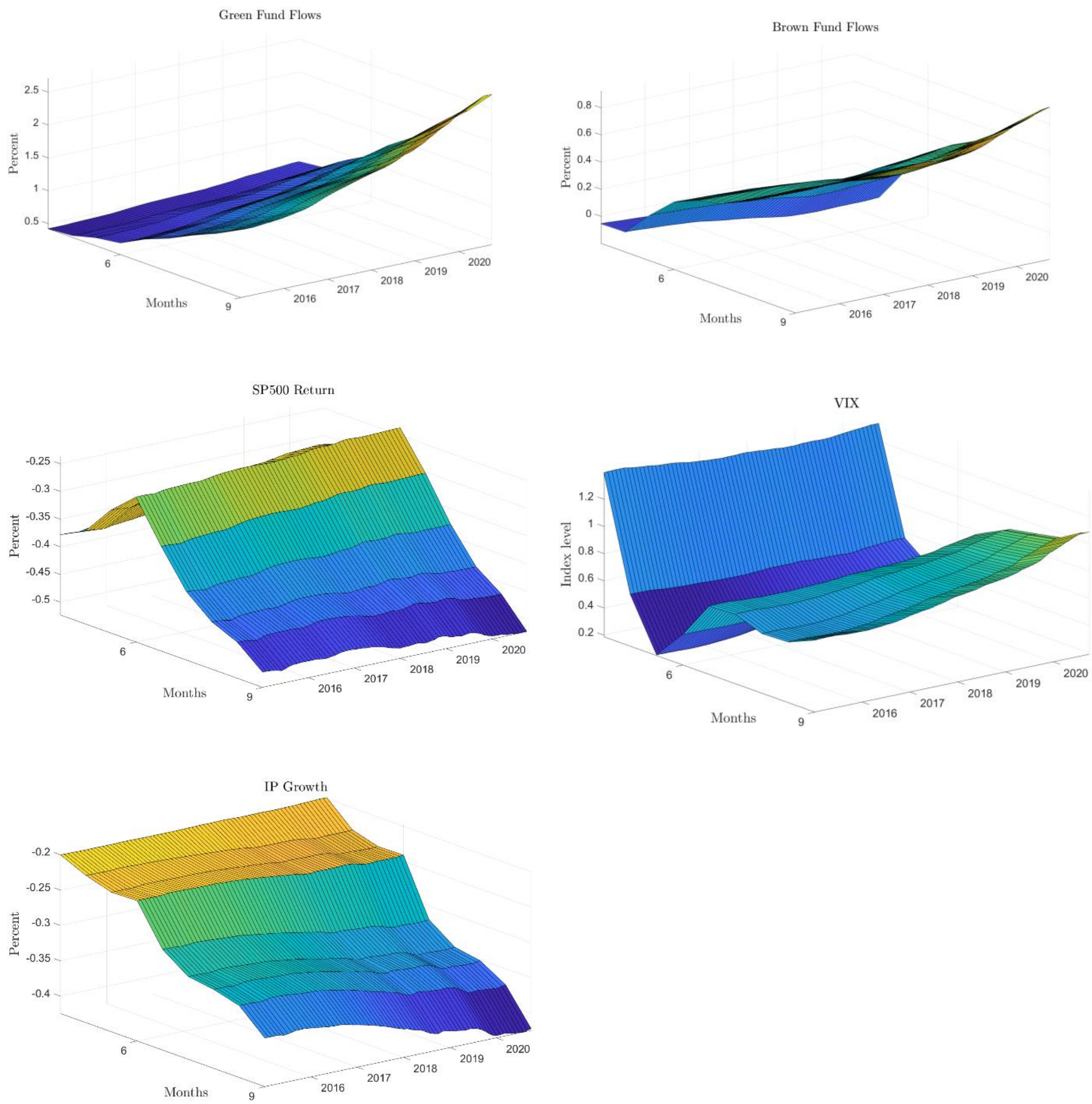
This figure plots the cumulative impulse responses of green fund flows, brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX to a climate news shock (i.e., MeCCO USA) for 2020 M1, along with 68 percent and 90 percent posterior credibility intervals based on iterations of the Gibbs sampler. All variables are defined in Figure 3. *y*-axis: percentage or index level. *x*-axis: months.



Appendix C. Alternative identification of green funds

Figure C. Time-varying impulse response to a climate news shock with an alternative identification of green funds

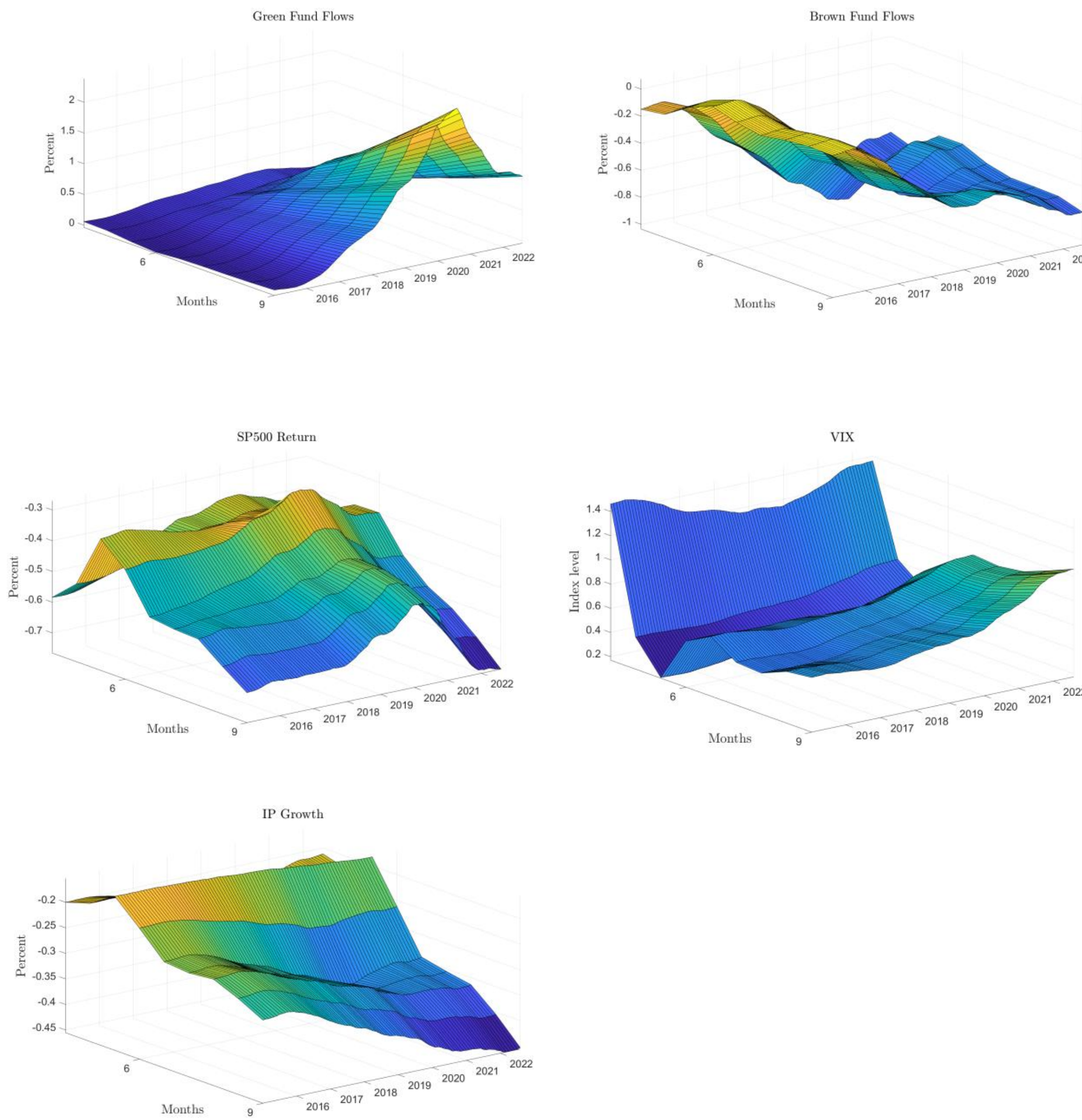
This figure displays the time-varying cumulative impulse response of green fund flows, brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX to an exogenous climate news shock (i.e., MeCCO USA) using equations (8) and (9) for the sample of 2015M1 – 2022M11. Prior $k_Q = 0.02$. Green funds are redefined in Section 6.1. Other variables are defined in Section 3. *y*-axis: percentage or index level. *x*-axis (left): months. *x*-axis (right): years.



Appendix D. Robustness test by controlling oil price

Figure D. Time-varying impulse responses to a climate news shock by controlling oil price

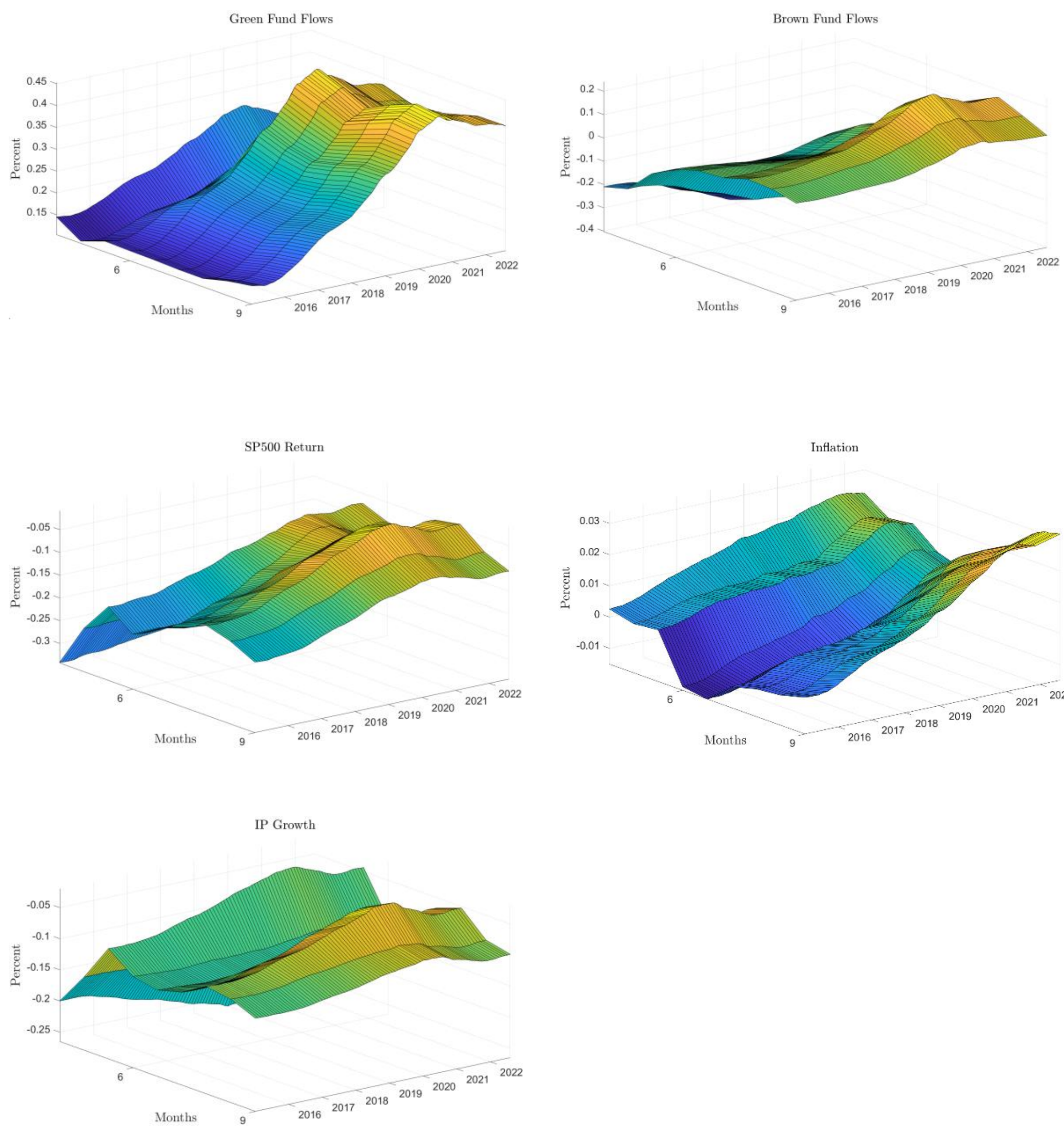
This figure displays the time-varying cumulative impulse response of green fund flows, brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX to an exogenous climate news shock (i.e., MeCCO USA) using equations (8) and (9) for the sample of 2015M1 – 2022M11. Prior $k_Q = 0.02$. Brown fund flows is the residual from the projection of brown fund flows on crude oil return. Other variables are defined in Section 3. *y*-axis: percentage or index level. *x*-axis (left): months. *x*-axis (right): years.



Appendix E. Robustness test by controlling inflation

Figure E. Time-varying impulse responses to a climate news shock by controlling inflation

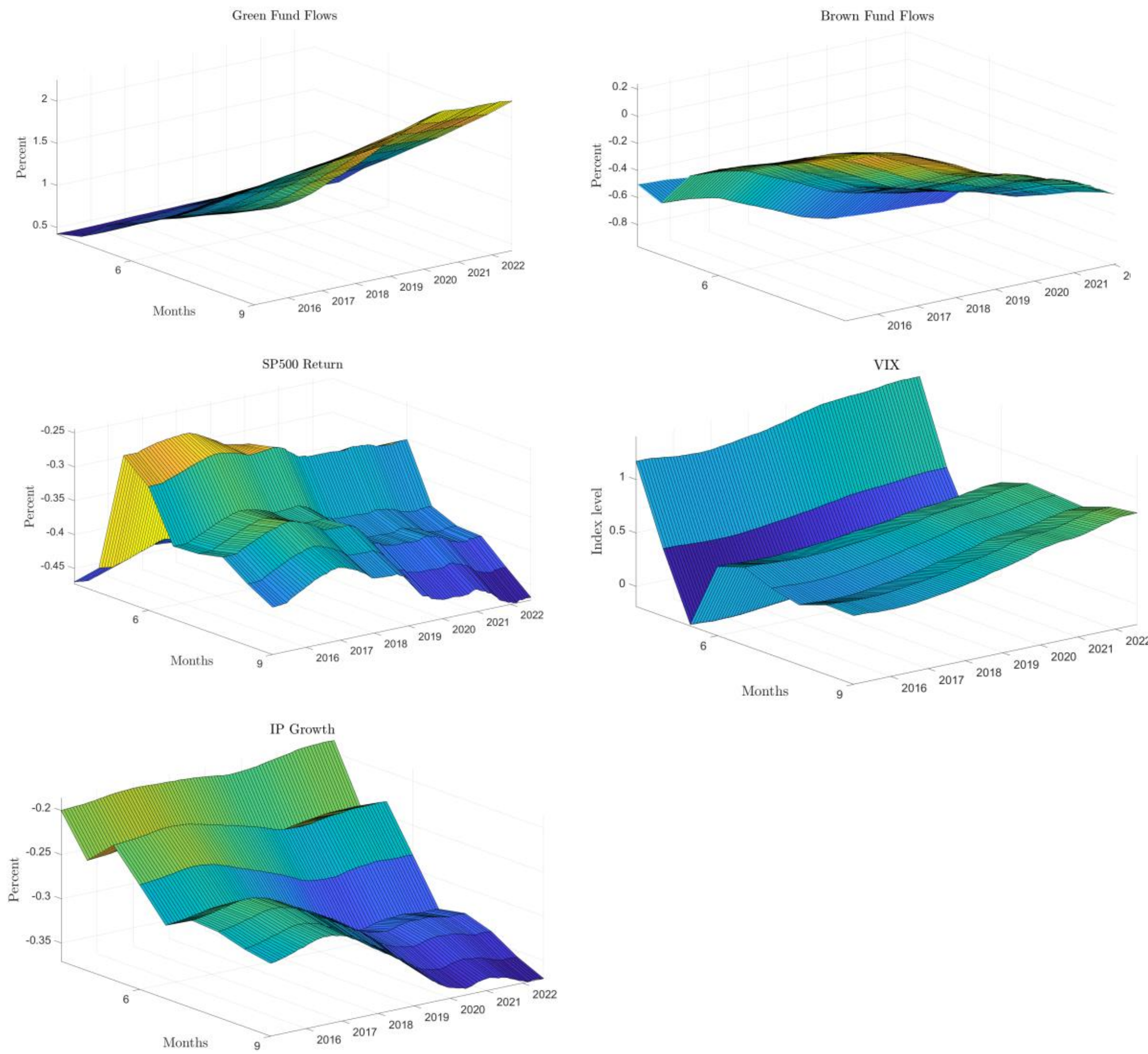
This figure displays the time-varying cumulative impulse response of green fund flows, brown fund flows, SP500 return, inflation and IP growth to an exogenous climate news shock (i.e., MeCCO USA) using equations (8) and (9) for the sample of 2015M1 – 2022M11. Prior $k_Q = 0.02$. All variables are defined in Section 3. *y*-axis: percentage or index level. *x*-axis (left): months. *x*-axis (right): years.



Appendix F. Robustness test by controlling extreme events

Figure F. Time-varying impulse responses to a climate news shock by controlling extreme events

This figure displays the time-varying cumulative impulse response of green fund flows, brown fund flows, SP500 return and IP growth, as well as the *impulse response* of VIX to an exogenous climate news shock (i.e., MeCCO USA) using equations (8) and (9) for the sample of 2015M1 – 2022M11. Prior $k_Q = 0.02$. All variables are defined in Section 3. The endogenous variables are winsorized at the 5th and 95th percentiles. *y*-axis: percentage or index level. *x*-axis (left): months. *x*-axis (right): years.



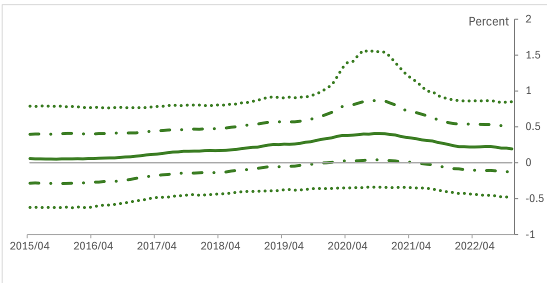
Appendix G. Credibility intervals of the CIRs for the baseline model

Figure G. Credibility intervals of the CIRs for the baseline model

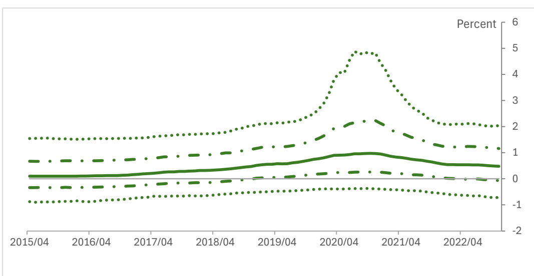
This figure presents the cumulative impulse responses (solid line) at the 3-, 6- and 9-month horizons to a climate news shock (i.e., MeCCO USA) for green (Panel A) and brown (Panel B) fund flows, along with 68 percent and 90 percent posterior credibility intervals based on iterations of the Gibbs sampler.

Panel A. *Green fund flows*

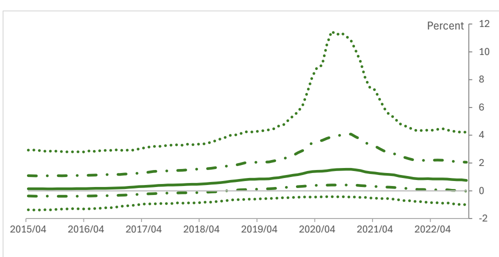
3-month



6-month

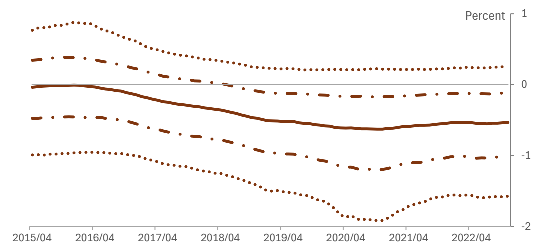


9-month

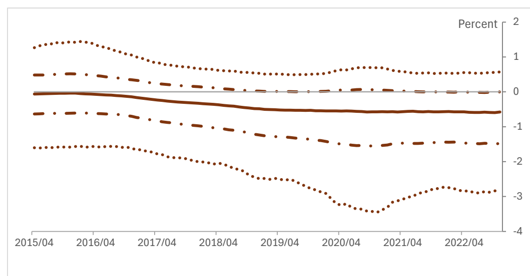


Panel B. *Brown fund flows*

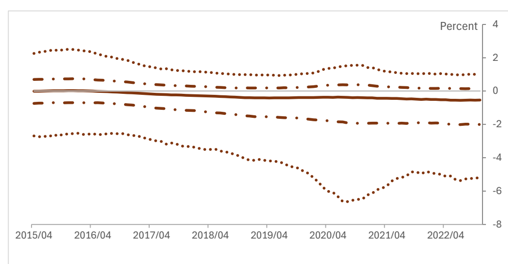
3-month



6-month



9-month



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