NORGES BANK
INVESTMENT MANAGEMENT

01 | 2021

THE ASSET PRICING EFFECTS OF ESG INVESTING

DISCUSSION NOTE

In this note, we discuss the asset pricing implications of the increasing consideration of Environmental, Social and Governance (ESG) issues in investing.

Date 02/07/2021
ISSN 1893-966X

The Discussion Note series provides analysis which may form relevant background for Norges Bank Investment Management's investment strategy and advice to the asset owner. Any views expressed in the Discussion Notes are not necessarily held by our organisation. The series is written by employees, and is informed by our investment research and our experience as a large, long-term asset manager.

dn@nbim.no
www.nbim.no

SUMMARY

THE ASSET PRICING EFFECTS OF ESG INVESTING

- Environmental, Social and Governance (ESG) issues have played a greater role in investing in recent years. In this note, we use two ESG modelling frameworks to explore how the increased focus on ESG issues can affect asset prices.

- We show that when investors incorporate ESG into their portfolios as a non-financial consideration, this leads to lower expected returns on higher ESG-scoring 'Green' assets, and higher expected returns on 'Brown' assets. As the presence of ESG-motivated investors in the market grows, however, increased flows into Green assets can lead to them outperforming Brown assets.

- We consider how asset prices are affected when ESG measures reflect risks to assets' expected cash flows. Focusing our discussion on climate change risks, we show that the pricing of assets reflects how their payoffs relate to the state of the economy in different climate scenarios. Brown assets have lower cash flows in adverse climate scenarios, implying lower prices and higher risk premiums, while Green have higher prices and lower risk premiums. The nature of cash flow risks can change depending on the investment horizon, for example if the economy is able to adapt following climate shocks.

- We discuss the difficulty in empirically identifying the effects of ESG investing on asset prices, in part due to non-financial and risk-based ESG investing both reducing expected returns on Green assets and increasing expected returns on Brown assets. Despite higher expected returns on Brown assets, we might also see outperformance of Green assets while ESG investing grows in popularity or during the transition to widespread use of green technologies.

1. Introduction

In recent years, there has been an increasing focus on Environmental, Social and Governance (ESG) issues in investing. The ESG label covers many diverse issues, ranging from concerns about preserving biodiversity to concerns about data privacy or the composition of company boards, though there is often a focus on issues related to climate change.

There are various ways in which investors incorporate ESG considerations into their investment processes. Recently, there has been a proliferation of ESG metrics, strategies and products that investors use to incorporate ESG concerns into their portfolios. This has complemented the traditionally more common practice of investors excluding companies from their portfolios, or engaging with the company management to address ESG concerns. As the ESG industry has grown, there has been an increase in capital allocated to 'Green' assets that score well on ESG metrics, relative to 'Brown' assets that score less well.

In this note, we discuss the implications of the growing popularity of ESG investing for asset prices. We use two theoretical frameworks that illustrate the mechanisms through which ESG considerations may impact asset prices, and consider the relative pricing of Green and Brown assets. To organise our analysis of the impact of ESG investing, we consider two broad reasons why investors may integrate ESG considerations into their portfolios. First, we consider 'Non-Financial' ESG investing, where investors are motivated by non-financial or ethical considerations. Second, we consider 'Risk-based' ESG investing, where investors are concerned with the risks to an asset's cash flows reflected in ESG scores. In our analysis, we do not refer to a specific scoring methodology in defining Green and Brown assets, and rather refer conceptually to high or low ESG scores for issues investors are concerned with.

In Section 2, we outline a simple model of non-financial ESG investors and financial investors, where ESG investors tend to allocate more capital to Green assets. We show that, in equilibrium, this leads to lower expected returns on Green assets and higher expected returns on Brown assets. In this framework, the prices of assets adjust to reflect preferences for Green assets, where the investor with average ESG preferences holds the market portfolio. The improvement in the ESG score of the ESG investor's portfolio compensates for a deterioration in their portfolio's expected return-risk profile. While in these circumstances Green assets will be expected to underperform Brown assets, there can be a transition period during which Green assets outperform, as the proportion of ESG investors in the market grows.

In Section 3, we then outline a model where ESG metrics reflect risks to asset payoffs, with a focus on climate change risks and the links to economic growth. We illustrate how the pricing of assets reflects how payoffs relate to the state of the economy under different climate outcomes. Brown assets have lower cash flows in adverse climate scenarios, which also tend to be associated with lower economic growth, implying lower prices and higher risk premiums. Green assets, on the other hand, have higher cash flows in adverse climate scenarios, implying higher prices and lower risk premiums. The nature of cash flow risks can also change depending on the investment horizon. For example, if the economy is able to adapt following climate shocks, an asset can be risky in the short term but less risky as the investment horizon extends.

Finally, we discuss the difficulty in distinguishing between the effects of non-financial and risk-based ESG investing and identifying their magnitudes. Both approaches tend to reduce expected returns on Green assets and increase expected returns on Brown assets in equilibrium. In addition, there can be reasons to expect higher returns on Green relative to Brown assets. We would expect to see outperformance of Green assets as the presence of ESG investors grows, for example through increases in the capital tied to ESG investing, or through stronger preferences for ESG and greater ESG cash flow risks. We might also justify high valuations of Green technology stocks based on potentially high but uncertain cash flows that could result from large-scale technological changes towards sustainable production in the global economy. It is also difficult to determine precisely the magnitudes of these effects on asset prices. This requires estimates of ESG preferences and capital across investors, and modelling of risks to broad asset classes over long horizons. As the green transition progresses, more data will become available, and it is also reasonable to expect that more resources will be devoted to empirical research on these issues.

2. Non-Financial ESG Investing

In this section, we outline a simple framework that considers the asset pricing effects of investors that have non-financial ESG 'preferences'. We model different investors that are motivated to varying degrees by financial and ESG concerns, similar to models such as Fama and French (2007), who add investor 'tastes' into a standard portfolio choice problem. A key feature of the framework is that some investors directly value ESG considerations, separate to the value they place on financial returns. This allows us to consider ESG investment motives that are entirely non-financial, for example due to ethical concerns. In addition to the conceptual distinction between financial and non-financial motives, there is evidence that investors do in fact incorporate ESG into their portfolios based on non-pecuniary motives, for example as documented in Hong and Kacperczyk (2009), Hartzmark and Sussman (2019) and Barber, Morse, and Yasuda (2021). Our framework describes the effects of ESG investing on stock prices, though the intuitions can be similarly applied to other types of assets.

Non-Financial ESG Preferences

To model ESG preferences, we use an extended version of the standard mean-variance portfolio problem that closely follows Pastor, Stambaugh, and Taylor (2021), and has many features in common with Baker, Bergstresser, Serafeim, and Wurgler (2018) and Pedersen, Fitzgibbons, and Pomorski

(2020). We assume that investors allocate their wealth for one period between a risk-free asset, r_f, and shares in companies. There are N companies, each with an observable ESG score, s_n, where $s_n > 0$ implies that company n is 'Green' and generates a positive societal impact through its operations. Each investor allocates a proportion of their wealth to shares in these firms, denoted by the vector of portfolio weights X_i. Excess returns, r, are determined by $r = \mu + \epsilon$ where μ is the vector of equilibrium expected returns and ϵ is a noise term. We assume ϵ is normally distributed with zero mean and covariance matrix Σ.

For the preferences of investor i, we assume the following exponential utility function:

$$u_i = -exp(-(a_i W_i + d_i s' X_i)), \quad (1)$$

where a_i is the investor's coefficient of absolute risk aversion and W_i is their end-of-period wealth. Separate to their wealth, the investor also places value on the ESG score of companies they invest in, captured through $d_i s' X_i$ in the utility function. Here, $s' X_i$ is the weighted-average ESG score of the investor's portfolio, and d_i measures the strength of the investor's preference for Green companies. This additional term in the utility function implies that investors can incorporate ESG considerations into their portfolio choice.

ESG Portfolios and Market Equilibrium

Next, we describe the optimal portfolio for an investor that is concerned about ESG, based on the utility function in equation (1). Pastor, Stambaugh, and Taylor (2021) show that the optimal portfolio weights for an investor are:

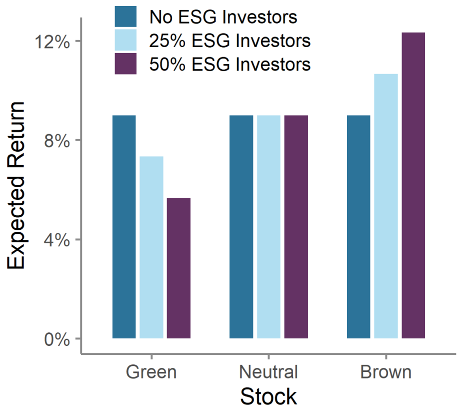
$$X_i = \frac{1}{a_i} \Sigma^{-1} (\mu + \frac{1}{a_i} d_i s). \quad (2)$$

The effect of including ESG scores in the investor's preferences can be understood by first setting $d_i = 0$. In this case, we would obtain the standard mean-variance optimal portfolio choice where investors balance the expected return and risk of their portfolio. In the case where $d_i > 0$, we introduce an additional source of demand for ESG stocks that does not only reflect expected returns and risk.

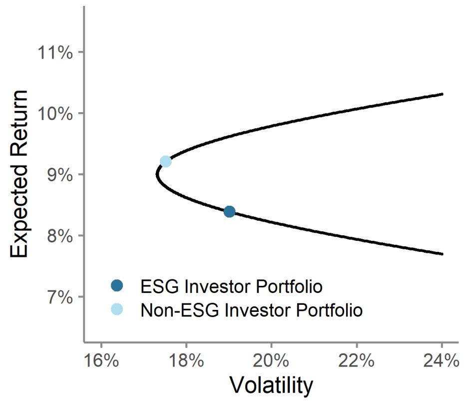
To illustrate the equilibrium implications of the addition of ESG concerns into portfolios, we use a simple numerical example. We simulate a large number of investors that vary in terms of their ESG preference parameter, d_i, and assume there are three stocks that investors allocate their capital to: a 'Green' stock ($s_1 = 1$), a 'Neutral' stock ($s_2 = 0$) and a 'Brown' stock ($s_3 = -1$).[1] Aside from their different ESG scores, the three stocks are identical in that they have the same return volatility (30% p.a.) and are uncorrelated with one another. This stylised representation of the investor's portfolio problem allows us to illustrate the impact of ESG considerations on equilibrium expected returns. However, we emphasise the direction of the effects rather than their magnitudes, given the simplistic setup.

[1] We assume that $a_i = 3$ for all investors.

Figure 1: Illustration of Equilibrium Impact of ESG Preferences and Portfolio Choice



(a) Equilibrium Expected Returns by Asset Type



(b) Risk-return Properties of Alternative Portfolios

Figure 1 (a) shows the equilibrium expected returns of the three stocks for alternative assumptions regarding the composition of the set of investors. The benchmark case assumes that the market is composed entirely of non-ESG investors ($d_i = 0$). We also show expected returns when the proportion of investors preferring higher company ESG scores is set at 25% and 50%.[2] Compared to the case with no ESG investors, the presence of ESG-motivated investors leads to lower expected returns on the Green stock in equilibrium. Naturally, we also observe a higher expected return on the Brown stock. In other words, investors with ESG preferences are willing to pay higher prices, and accept lower expected returns, for stocks that score well on ESG metrics.

In our example, the portfolio choice of ESG-motivated investors implies that they accept a deterioration in the risk-return properties of their portfolio. This is illustrated in Figure 1 (b), which compares the expected return and risk of the portfolios for the two types of investors.[3] The non-ESG portfolio lies on the upper section of the efficient frontier, meaning that they achieve the highest expected return possible given the volatility of their portfolio. Naturally, the ESG portfolio achieves lower expected returns, given the higher allocation to the Green asset. The ESG investor therefore accepts a lower Sharpe ratio through their preference for the Green asset.

To further understand the effects of ESG preferences, Pastor, Stambaugh, and Taylor (2021) show that equilibrium expected returns can be expressed as:

$$\mu = \mu_m \beta_m - \frac{\bar{d}}{a} s, \tag{3}$$

where μ_m is the market risk premium and β_m is the vector of market betas of the stocks. In the case with no ESG investors, expected returns would be determined by market betas and the market risk premium, the standard result of the Capital Asset Pricing Model (CAPM). With ESG-motivated investors, the changes in expected returns relative to the CAPM case are proportional to the average investor preference for ESG, $\bar{d}$, and the ESG scores of the stocks, s.

[2] We assume that these ESG investors have a d_i coefficient equal to 0.20.
[3] The frontier is constructed assuming 25% of investors incorporate ESG into their preferences.

It is worth emphasising that in equilibrium the pricing of assets will reflect the *average* ESG preference of investors. This implies that an investor with ESG preferences in line with this average holds the market portfolio, with no additional allocation to Green assets. It is therefore possible that some investors, while motivated by ESG considerations but less motivated than the average investor, would optimally choose to hold more Brown assets than the average investor. Investors considering allocations to Green assets would ideally evaluate their non-financial motives relative to other investors. To do this in practice, we would need to observe the distribution of capital amongst ESG-motivated investors and the strength of their preferences for ESG, which would determine the average preference in the market.[4]

Relative Performance of Green and Brown Assets

In line with the prediction from the model, there is a range of studies that document higher average returns of assets that likely score lower on different ESG metrics. A well-known example is Hong and Kacperczyk (2009), who document that 'sin' stocks of companies involved in industries such as tobacco, alcohol and gambling earn higher returns than comparable stocks in other industries. They suggest that sin stocks are avoided by institutions that are particularly exposed to public opinion, such as endowments and pension funds, and present evidence that these investor types are underrepresented as holders of these stocks. In addition, Barber, Morse, and Yasuda (2021) suggest that investors sacrifice returns for non-financial rewards when investing in venture capital funds.

While investors may expect to earn lower returns on Green assets in equilibrium, there would also be a transition period during which their expected returns fall and prices increase relative to Brown assets. We would expect to observe an increase in the prices of Green assets as the proportion of ESG investors increases, as in the example where the proportion of ESG-motivated investors increases from 25% to 50%. The pricing of higher expected returns for Brown assets would also imply lower prices, leading to the outperformance of Green assets relative to Brown assets. This presents a challenge when attempting to interpret the empirical evidence on the performance of ESG assets over the short term, given the growing prominence of ESG investing in recent years.

The transition and equilibrium effects are difficult to identify precisely, and this means that it can be challenging to interpret returns on different ESG strategies and investment products. These issues are further exacerbated by relatively short histories of available data, and different methodologies and standards associated with ESG metrics. Furthermore, there are likely other motivations underlying ESG investing, for example that ESG scores are related to asset payoffs, which will influence expected returns and which we discuss in Section 3.

[4] While not directly observable, we may be able to use survey evidence, such as in Amel-Zadeh and Serafeim (2018) and Krueger, Sautner, and Starks (2020), and portfolio holdings data to gauge the ESG demands of investors.

Social Impact of ESG Preferences

Given the focus on sustainability inherent in ESG preferences, it is natural to ask how ESG investing might influence the behaviour of companies. Within our framework, we would expect ESG investing to have a positive social impact due to the lower expected returns associated with Green firms. This follows naturally to the extent that these lower expected returns are reflected in a lower cost of capital for green firms. Studies such as Heinkel, Kraus, and Zechner (2001) and Pastor, Stambaugh, and Taylor (2021) provide extensions to the framework presented above to consider this issue. They show that a manager of a firm who chooses whether to undertake capital investment will discount the project cash flows at a lower rate and hence invest more. The opposing effect also occurs for Brown firms, which face a higher cost of capital and invest less. These effects can also incentivise companies to become greener to increase their market value. This implies that ESG considerations can have effects on firms through pricing as well as through more traditional approaches such as company engagement. There may also be additional incentives faced by firms, however, to portray themselves as Green companies, known as 'Greenwashing'. In practice, investors need to evaluate which companies are Green and Brown, and these characteristics of firms are not observed directly. Indeed, in general it can be difficult to assess a company's ESG characteristics using currently available ESG metrics, as discussed in Berg, Koelbel, and Rigobon (2020) and similar studies. To the extent that there is an asymmetry between firms and investors, it may be possible for firms to achieve higher market values if they are able to convince investors they are 'Green'.

3. Risk-based ESG Investing

In this section, we consider the effects of risk-based ESG investing on asset prices. So far, our discussion has precluded the possibility that ESG metrics contain information about asset payoffs or company profitability. In contrast to the previous section, we next consider the possibility that investors utilise ESG metrics due to the information they contain regarding the cash flow risks of assets. For many ESG issues, it is intuitive to think that ESG metrics contain information about an asset's payoff profile. For example, Gompers, Ishii, and Metrick (2003) find that firms with good corporate governance outperform others historically. In a similar spirit, Edmans (2011) shows that high employee satisfaction predicts high stock returns and earnings growth.[5] The outperformance associated with higher ESG scores can erode over time, however, as investors learn about and price in the positive association between ESG and company performance. For example, Bebchuk, Cohen, and Wang (2013) find that the outperformance of firms with good governance has disappeared in a more recent sample period.

Perhaps the most prominent ESG issue related to financial risks is climate change, and we focus our discussion in this section on this aspect of ESG

[5] More recently, Edmans, Li, and Zhang (2020) show that employee satisfaction is associated with higher long-run returns in countries with more flexible labour markets, such as the US and UK.

investing. We outline a stylised dynamic model that describes the financial risk associated with climate change, with a focus on the equity market. Our focus on climate change is driven by the fact that risks related to climate change have the potential to significantly impact and redistribute economic growth, and thus equity cash flows, at long horizons.

Our modelling framework closely follows Giglio, Maggiori, Rao, Stroebel, and Weber (2021). We model risk associated with climate change as a form of disaster risk: a low-probability catastrophic event with a potentially large impact on economic activity (Weitzman, 2014). The likelihood of a "climate disaster" varies over time and depends on economic activity.[6] We initially focus on physical climate change risk and discuss asset pricing implications of transition risk at the end of the section.

Climate Risk and Economic Activity

In order to consider the impact of climate change risk on asset prices, we first need to describe the links between climate risk and economic activity. We assume that aggregate real output growth, denoted as Δg_t, has the following dynamics:

$$\Delta g_{t+1} = \mu + x_t - J_{t+1} \tag{4}$$

$$x_{t+1} = \mu_x + \rho x_t + \phi J_{t+1}, \tag{5}$$

where x_t is a process that represents the expected deviation of the growth rate of the economy from the trend growth rate μ, and J_t is a jump process that represents a climate disaster. It takes a value between zero and one with probability λ_t in each period and value of zero with probability $(1 - \lambda_t)$. In the absence of a climate disaster, x_t is the sole driver of the variation in output growth. Once the disaster strikes, it lowers output growth, and at the same time increases the expected growth relative to the trend growth. The persistence of the above-trend growth depends on ρ. The adaptability of an economy to climate change risk is determined by the magnitude and persistence of the above-trend growth in the post-disaster period. The climate disaster probability λ_t evolves as follows:

$$\lambda_{t+1} = \mu_\lambda + \alpha \lambda_t + \nu x_t + \chi J_{t+1}. \tag{6}$$

The specification in equation (6) captures two important aspects of climate risk. First, the probability of adverse climate events increases when the economy grows at a faster rate, that is when ν is greater than zero. This positive link represents the negative externalities of economic activity on climate. Second, the occurrence of a disaster increases the probability of a subsequent climate disaster, that is when χ is positive. Such a feedback loop can be motivated by the interactions of multiple tipping points as discussed in Lemoine and Traeger (2016).

[6] Modelling climate change risk as a form of disaster risk whose likelihood depends on economic activity can be motivated by the literature on tipping points (Overpeck and Cole, 2006; Lemoine and Traeger, 2014). A tipping point can be defined as an irreversible change in the climate system. The likelihood of crossing climate tipping points is usually related to rising temperature.

Climate Risk and Equity Cash Flows

Next, we consider how the pricing of climate risks impacts the cash flow and discount rate components of asset prices. The performance of the stock market over the long run is linked to economic growth. Hence, to the extent that climate risk is related to economic growth, it will be reflected in equity cash flows. The pricing of cash flows will also depend on the exposure of assets' payoffs to climate risk through their discount rates. For example, cash flows that materialise in a climate disaster scenario are desirable and hence relatively less risky.

Equity cash flows reflect a subset of aggregate economic activity, Δg_t. We represent equity cash flows through a process that is similar to the process driving aggregate growth but has a separate set of parameters. The dividend growth rate, Δd_t, follows:

$$\Delta d_{t+1} = \mu_d + q y_t - \eta J_{t+1} \tag{7}$$

$$y_{t+1} = \mu_y + \omega y_t + \psi J_{t+1}, \tag{8}$$

where y_t represents the expected deviation of dividend growth from the trend growth.[7] Focusing on the overall equity market, the price of a single dividend paid out in n years, denoted as $P_t^{(n)}$, is given by:

$$P_t^{(n)} = \frac{D_t E_t \left[\exp\left(\Delta d_{t+1} + \Delta d_{t+2} + \ldots + \Delta d_{t+n}\right)\right]}{(1+\bar{r}_t^n)^{(n)}}, \tag{9}$$

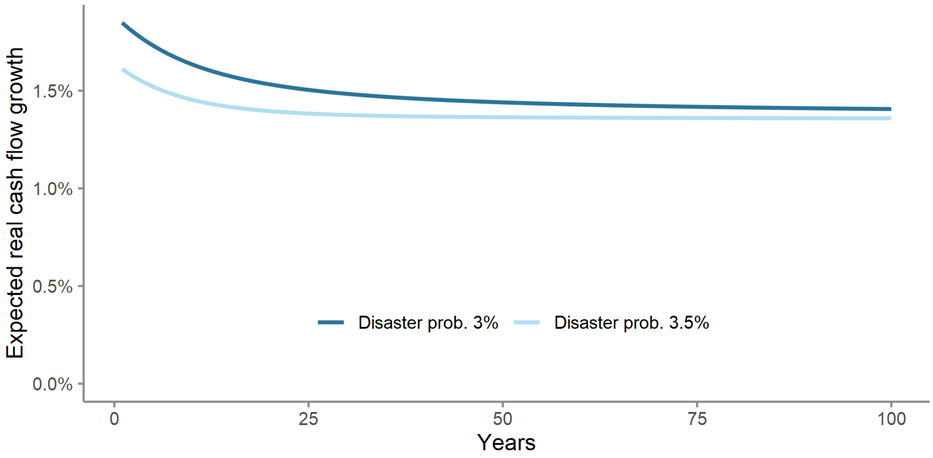
where D_t represents the current dividend and $\bar{r}_t^n$ is the discount rate of maturity n. The discount rate comprises two components, a risk-free rate and a risk premium that compensates investors for dividend risk. The value of the stock market is equal to the discounted value of all future dividends. By considering dividend payouts at different maturities we are able to explore the short- and long-term impact of climate change risk on equities. Equations (7) and (9) show that when forming their expectations about dividend growth, investors need to assess the likelihood λ_t of a climate disaster J at all relevant horizons.

Climate change risk materialises when J takes a value other than zero. Even in the absence of a climate disaster, however, the risk of disaster will be incorporated in asset prices as investors evaluate the likelihood of the disaster λ_t. The changing likelihood of climate change disaster can be interpreted as "climate change news", as discussed in e.g. Engle, Giglio, Kelly, Lee, and Stroebel (2020). Assets that perform well in periods marked by an increased likelihood of a climate disaster hedge climate change news. The pricing of equities will reflect their exposure to climate risks, where the overall market and Brown assets have a positive risk exposure through positive values of η and q, while Green assets have a negative exposure and hedge climate risks.

Another important consideration for investors is the degree of adaptability of

[7] We allow for a differentiated exposure of equity cash flows to climate risk through q^i and η^i, where i can refer to the overall equity market or to Green and Brown assets. Through these parameters, we are able to consider assets that co-move differently with economic growth.

Figure 2: Impact of climate change risk on equity cash flows



Note: The baseline calibration of the model works with the unconditional disaster probability of 3%. The chart shows per-period growth rates of expected real dividends.

the economy to climate change. Recent research such as Cruz and Rossi-Hansberg (2021) suggests that the economic impact of climate change is unevenly distributed across regions, and points to migration and innovation as key adaptation mechanisms. In the model, the riskiness of equity cash flows is determined by the degree of mean reversion in the growth rate of dividends after a climate disaster strikes. If ψ is positive, the dividend growth rate increases above trend growth after a disaster, and the increase is persistent if ω is greater than zero. A higher degree of mean reversion in dividend growth implies that the economy is more adaptable to climate change, i.e. output growth has the tendency to be significantly higher post-disaster, which makes long-horizon dividends relatively less exposed to climate change risk.[8]

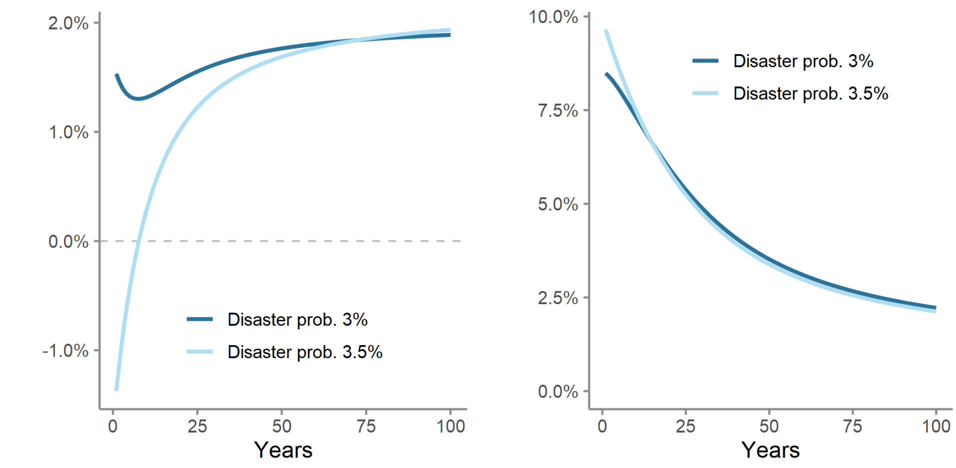
Pricing of Climate Risk

To illustrate the impact of climate change risk on asset prices, we initially focus on the implications for the overall market using the baseline calibration of the model outlined in Giglio, Maggiori, Rao, Stroebel, and Weber (2021).[9] The set of model parameters is provided in Appendix A. Figure 2 illustrates the impact of negative climate change news, that is a small increase in the likelihood of climate change disaster, on expected cash flows. Intuitively, an increased likelihood of a climate disaster lowers expected cash flow growth, where the decline is larger at shorter horizons. This short-term impact is driven by the assumption that the economy tends to grow faster following the disaster, thus making longer-horizon cash flows relatively less risky.

[8] Empirical evidence from an international panel indicates that large declines in consumption tend to be followed by periods of disproportionately high growth (Nakamura, Steinsson, Barro, and Ursua, 2013).

[9] The model presented in Giglio, Maggiori, Rao, Stroebel, and Weber (2021) is calibrated to match selected moments of observed asset prices such as residential real estate, government bonds and equities. Although the model-implied magnitudes are plausible, we use them for illustrative purposes rather than focussing on quantitative conclusions.

Figure 3: Impact of climate change risk on expected returns



Note: Both panels show the impact of an increase in the probability of a climate disaster from 3% to 3.5%. The baseline calibration of the model works with the unconditional disaster probability of 3%.

Next, we consider how expected returns - the rates at which cash flows are discounted - are impacted by climate change news. In contrast to Section 2, we assume that investors are motivated solely by financial concerns. Hence, the impact of climate change risk on discount rates is driven exclusively by investors' risk considerations. Changes in the likelihood of a climate change disaster have an impact on both components of discount rates, the risk-free rate and the risk premium. Panel (a) of Figure 3 shows that an increase in the likelihood of a disaster lowers the risk-free rate. This is because higher overall risk in the economy makes risk-free assets more desirable and investors are willing to accept a lower expected return to hold them.

An increase in the likelihood of a climate change disaster also leads to higher risk premiums, to compensate investors for higher dividend risk. As shown in Panel (b) of Figure 3, the increase in risk premiums primarily occurs at shorter maturities, which is where the increase in dividend risk is concentrated. Due to partially offsetting effects of increased climate risk on the risk-free and the risk premium components, the overall effect on discount rates can be relatively small.[10]

The slope of the term structure of risk premiums is driven by the relative riskiness of short- and long-maturity dividends. The model calibration implies a significant degree of mean reversion in the dividend growth rate post-disaster, which makes long-horizon cash flows relatively less risky (as indicated in Figure 2). The lower riskiness of long-horizon dividends is reflected in the downward-sloping term structure of discount rates, where near-term cash flows require higher risk premiums than long-horizon cash flows. In an economy that is less adaptable to climate change risk, the term

[10] The distinction between the two components is still important, however, as it alters return-risk properties of both equity and fixed income assets.

structure of risk premiums would be *flatter*, but at a *higher level*.

To further illustrate the effect of exposure to climate risk on discount rates, we compare the pricing of Green and Brown assets, shown in Figure 4.[11] In this example, the cash flows of Green assets are discounted at very low rates due to their hedging properties, implying a low cost of capital and low expected returns for these investments. Depending on the magnitude of the climate hedging effect, investors might discount Green investments with rates below the risk-free rate.

There are some studies documenting that exposure to climate change risk is reflected in asset prices, and that the pricing of climate risk aligns with the effects presented in Figure 4. For example, in equity markets, Bolton and Kacperczyk (2021) find that firms with higher total carbon dioxide emissions earn higher returns, or equivalently have higher discount rates, even after controlling for size and other effects. To isolate the effect of climate change on asset prices, a number of studies turn to different asset classes, such as real estate (Bernstein, Gustafson, and Lewis, 2019) or municipal bonds (Painter, 2020). These studies also find that assets with higher exposure to climate change risks, for example as measured by exposure to rising sea levels, are associated with lower prices. Much of the current literature focuses on the immediate effects of climate change on assets with little scope for adaptation. We have less evidence available to assess the long-term impact of climate change, and the effects on broader equity market or global asset classes. To the extent that there is some evidence suggesting that market pricing incorporates information about climate risks, an investor is in effect paying a premium for climate change protection when investing in Green assets.

Transition Risk and Other Considerations

Our discussion so far has focused on the asset pricing implications of *physical* climate risk. The increased awareness of physical climate risk naturally intensifies efforts to transition to a green economy. Indeed, recent years have seen a range of policy initiatives aimed at mitigating the impact of economic activity on climate.[12,13] The transition to a green economy requires the mass adoption of new technologies across a range of sectors. The combined effect of policy initiatives and new green technologies on asset prices is usually referred to as the *transition* risk of climate change. In contrast to physical climate risk, which is largely undiversifiable, transition risk appears more diversifiable by transacting in financial markets.[14]

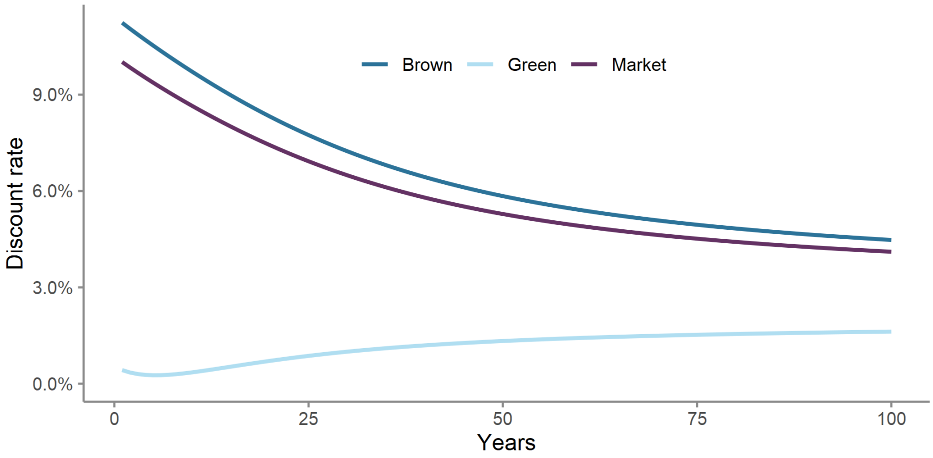
[11] For the overall market, we use the baseline calibration where $q^m = 1$ and $\eta^m = 3$. The exposure of Green assets is the mirror image of the market, with $q^g = -q^m$ and $\eta^g = -\eta^m$, reflecting their climate hedging properties. The cash flows of Brown assets are more exposed to climate risk than the market, with parameters $q^b = 1.2 \times q^m$ and $\eta^b = 1.2 \times \eta^m$. μ_d^i is set so that all three asset types have an identical long-run growth rate.

[12] Well-known examples include the Paris Agreement of 2016, the Next Generation EU plan of 2020 and a number of other plans at a national level.

[13] The idea behind the transition to a green economy is to break the positive link between economic growth and the likelihood of climate disasters, implying $\nu = 0$ in the framework outlined above.

[14] A successful transition to a green economy will inevitably produce winners and losers among firms. Hence, investors may be able to diversify transition risk by holding a broadly diversified portfolio. In contrast, a climate shock is likely to have a market-wide impact.

Figure 4: Pricing effects of different exposures to climate change risk



Note: The baseline calibration of the model works with the unconditional disaster probability of 3%.

Large structural changes in the economy such as the green transition can also be accompanied by elevated valuations attached to assets related to the "new economy", in this case the green economy. In line with historical evidence on asset pricing effects of such structural changes, some green technology firms seem to enjoy high valuations relative to the market. Even though high asset valuations and high return volatility might appear as irrationally high ex-post, they can be rational ex-ante, for example as shown in Pastor and Veronesi (2009). This is due to the highly uncertain and positively skewed payoffs of green assets, with high payoffs if their productivity turns out to be high and if there is a mass adoption of the technologies that they produce.[15] In other words, high valuations of green technology firms are likely driven by high cash flow expectations, in addition to low discount rates.

So far, we have assumed that climate change risk can be accurately represented by models such as the one presented in this section. There is, however, a considerable degree of uncertainty around several aspects of climate change and modelling its impact on humankind and economic activity (Lemoine, 2021; Pindyck, 2021). While a quantitatively accurate representation of climate change risk is extremely challenging to achieve, it does not necessarily imply that climate change risk is not reflected in prices in financial markets. This kind of model uncertainty or ambiguity has been the subject of a long line of research. Studies that focus on decision-making in situations characterised by a high degree of unquantifiable uncertainty indicate that it is optimal to assign extra weight to the worst outcomes (Epstein and Schneider, 2008; Hansen and Brock, 2018; Barnett, Brock, and Hansen, 2020). This would suggest that asset prices may reflect not only quantifiable climate change risk but also uncertainty related to the economic effects of climate change.

[15] The split between Green and Brown assets is not always clear-cut. One reason for this is that Brown firms have incentives to become Green. In fact, recent research suggests that oil & gas firms are key innovators in green technologies (Cohen, Gurun, and Nguyen, 2020).

4. Conclusion

In this note, we have outlined different ways in which ESG investing may impact asset prices, distinguishing between the equilibrium effects of non-financial and risk-based motives. While separating these motives is useful for understanding how asset pricing effects arise, the effects are likely to interact and therefore be difficult to identify. Whether Green asset demands are derived from non-financial preferences for ESG, or based on the ability of a Green asset to hedge against adverse climate outcomes, our frameworks anticipate lower expected returns on Green relative to Brown assets in equilibrium.

While equilibrium outcomes suggest that expected returns on Green assets will be lower, there can still be reasons why Green assets can outperform Brown assets. For example, as the presence of ESG-motivated investors grows, we would observe a transition period to a new equilibrium, during which we would expect green assets to outperform other assets. In addition, ESG investing may be associated with Green technology stocks that have potentially high but uncertain payoffs that could result from a transition to a greener economy.

Determining the magnitudes of these effects either in equilibrium or during the green transition is challenging. Amongst other things, it requires estimates of the distribution of ESG preferences across investors as well as the size of capital they allocate to ESG investing. While there is suggestive evidence that the amount of capital allocated to ESG investing has been growing rapidly, precise estimates of both inputs are hard to obtain. Recent developments in incorporating data on portfolio holdings into asset pricing models present a promising avenue of research for understanding the role of ESG in investing. We also have less evidence available to assess the long-term impact of climate change, and the effects on broader equity market or global asset classes. As the green transition progresses, more data will become available, and it is also reasonable to expect that more resources will be devoted to empirical research on these issues.

References

Amel-Zadeh, A. and G. Serafeim (2018). Why and How Investors use ESG Information: Evidence from a Global Survey. *Financial Analysts Journal 74*(3), 87–103.

Baker, M., D. Bergstresser, G. Serafeim, and J. Wurgler (2018). Financing the response to climate change: The pricing and ownership of US green bonds. NBER working paper.

Barber, B. M., A. Morse, and A. Yasuda (2021). Impact investing. *Journal of Financial Economics 139*(1), 162–185.

Barnett, M., W. Brock, and L. P. Hansen (2020). Pricing uncertainty induced by climate change. *The Review of Financial Studies 33*(3), 1024–1066.

Bebchuk, L. A., A. Cohen, and C. C. Wang (2013). Learning and the disappearing association between governance and returns. *Journal of Financial Economics 108*(2), 323–348.

Berg, F., J. F. Koelbel, and R. Rigobon (2020). Aggregate confusion: The divergence of ESG ratings. Working paper.

Bernstein, A., M. Gustafson, and R. Lewis (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics 134*, 253–272.

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

Cohen, L., U. G. Gurun, and Q. H. Nguyen (2020). The ESG-Innovation Disconnect: Evidence from Green Patenting. NBER working paper.

Cruz, J.-L. and E. Rossi-Hansberg (2021). The Economic Geography of Global Warming. NBER working paper.

Edmans, A. (2011). Does the stock market fully value intangibles? employee satisfaction and equity prices. *Journal of Financial economics 101*(3), 621–640.

Edmans, A., L. Li, and C. Zhang (2020). Employee Satisfaction, Labor Market Flexibility, and Stock Returns Around the World. Working paper.

Engle, R. F., S. Giglio, B. Kelly, H. Lee, and J. Stroebel (2020). Hedging climate change news. *The Review of Financial Studies 33*(3), 1184–1216.

Epstein, L. and M. Schneider (2008). Ambiguity, Information Quality, and Asset Pricing. *Journal of Finance 63*(1), 197–228.

Fama, E. F. and K. R. French (2007). Disagreement, tastes, and asset prices. *Journal of Financial Economics 83*(3), 667–689.

Giglio, S., M. Maggiori, K. Rao, J. Stroebel, and A. Weber (2021). Climate Change and Long-Run Discount Rates: Evidence from Real Estate. *Review of Financial Studies forthcoming*, 1–45.

Gompers, P., J. Ishii, and A. Metrick (2003). Corporate governance and equity prices. *The Quarterly Journal of Economics 118*(1), 107–156.

Hansen, L. P. and W. Brock (2018). Wrestling with Uncertainty in Climate Economic Models. Working paper.

Hartzmark, S. M. and A. B. Sussman (2019). Do investors value sustainability? A natural experiment examining ranking and fund flows. *The Journal of Finance 74*(6), 2789–2837.

Heinkel, R., A. Kraus, and J. Zechner (2001). The effect of green investment on corporate behavior. *Journal of Financial and Quantitative Analysis 36*(4), 431–449.

Hong, H. and M. Kacperczyk (2009). The price of sin: The effects of social norms on markets. *Journal of Financial Economics 93*(1), 15–36.

Krueger, P., Z. Sautner, and L. T. Starks (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies 33*(3), 1067–1111.

Lemoine, D. (2021). The Climate Risk Premium: How Uncertainty Affects the Social Cost of Carbon. *Journal of the Association of Environmental and Resource Economists 8*(1).

Lemoine, D. and C. Traeger (2014). Watch Your Step: Optimal Policy in a Tipping Climate. *American Economic Journal: Economic Policy 6*(1), 137–166.

Lemoine, D. and C. Traeger (2016). Economics of tipping the climate dominoes. *Nature Climate Change 6*(5).

Nakamura, E., J. Steinsson, R. Barro, and J. Ursua (2013). Crises and Recoveries in an Empirical Model of Consumption Disasters. *American Economic Journal: Macroeconomics 5*(3), 35–74.

Overpeck, J. and J. Cole (2006). Abrupt Change in Earth's Climate System. *Annual Review of Environment and Resources 31*, 1–31.

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics 135*(2), 468–482.

Pastor, L., R. Stambaugh, and L. Taylor (2021). Sustainable Investing in Equilibrium. *Journal of Financial Economics forthcoming*.

Pastor, L. and P. Veronesi (2009). Technological revolutions and stock prices. *American Economic Review 99*(4), 1451–83.

Pedersen, L. H., S. Fitzgibbons, and L. Pomorski (2020). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics forthcoming*.

Pindyck, R. (2021). What We Know and Don't Know about Climate Change, and Implications for Policy. *Environmental and Energy Policy and the Economy 2*, 4–43.

Weitzman, M. (2014). Fat Tails and the Social Cost of Carbon. *American Economic Review: Papers and Proceedings 104*(5), 544–546.

Appendix A: Parameters of the calibrated model

Parameter		Value
δ	Time discounting	0.99
γ	Degree of risk aversion	10
μ	Average output growth	0.02
ρ	Output growth persistence	0.85
ϕ	Output growth after disaster	0.025
η	Exposure of earnings to disaster	3
ω	Persistence of earnings growth	0.915
ψ	Earnings growth after disaster	0.24
$\bar{\lambda}$	Unconditional mean disaster prob.	0.03
α	Persistence of disaster prob.	0.75
ν	Relation between disaster prob. and output growth	0.1
χ	Exposure of disaster probability to disaster	0.05
ξ	Drop in growth after disaster	21%

Note: The calibrated values of variables align with those presented in Giglio, Maggiori, Rao, Stroebel, and Weber (2021). Variables for time discount rate δ and risk aversion γ calibrate the preferences of the representative investor. Variables μ, ρ, and ϕ define the dynamics of output growth, and η, ω, ψ the corresponding dynamics for equity cash flows. Remaining parameters concern the probability and severity of climate disasters. Parameters λ_{μ}, μ_x, μ_y, and μ_d are functions of the parameters reported in the table.