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## ABSTRACT

We explore how pro-social preferences interact with asymmetric ambiguity to influence investment decisions. We develop a model where financial returns are ambiguous (e.g., due to policy uncertainties), while social impact returns are risky or less ambiguous. Employing Gilboa-Schmeidler maxmin and Klibanoff-Marinacci-Mukerji smooth ambiguity frameworks, we demonstrate that pro-social motives act as a hedge, mitigating ambiguity aversion and reducing effective hurdle rates for ambiguous assets. This mechanism explains the resilience of impact investing in bridging environmental funding shortfalls and offers policy insights into how blended finance and standardization can convert ambiguity to risk. Distinct from prior work on blended finance structures, this study emphasizes the behavioral hedging role of social preferences in sustainable finance, with implications for accelerating just transitions amid polycrises.

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# Hedging Ambiguity with Pro-Social Preferences: an Illustration from Green Finance

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**Abstract**

We explore how pro-social preferences interact with asymmetric ambiguity to influence investment decisions. We develop a model where financial returns are ambiguous (e.g., due to policy uncertainties), while social impact returns are risky or less ambiguous. Employing Gilboa-Schmeidler maxmin and Klibanoff-Marinacci-Mukerji smooth ambiguity frameworks, we demonstrate that pro-social motives act as a hedge, mitigating ambiguity aversion and reducing effective hurdle rates for ambiguous assets. This mechanism explains the resilience of impact investing in bridging environmental funding shortfalls and offers policy insights into how blended finance and standardization can convert ambiguity to risk. Distinct from prior work on blended finance structures, this study emphasizes the behavioral hedging role of social preferences in sustainable finance, with implications for accelerating just transitions amid polycrises.[1]

Keywords: Ambiguity aversion, pro-social preferences, green finance, impact investing, sustainable development.

JEL: D81, G11, Q56, O13.

## 1 Introduction

The global transition to sustainable economies requires trillions in annual investments for green projects. While governments and philanthropies face constraints, private impact investors, driven by both financial and social motives, represent a critical bridge. However, green investments often involve Knightian uncertainty (ambiguity) in financial outcomes, caused by possible regulatory

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shifts or monetization challenges, contrasted with more probabilistic risks in social impacts, and this ambiguity may be one of the causes of the massive funding gap we experience.

This paper introduces a novel framework where pro-social preferences - altruistic or warm-glow motivations - serve as a hedge against asymmetric ambiguity in green finance. Extending ambiguity aversion models (Gilboa and Schmeidler, 1989; Klibanoff, Marinacci, and Mukerji, 2005), we posit financial returns as ambiguous and social impacts as risky or less ambiguous, introducing the possibility that investors can offset worst-case financial scenarios through social utility. Our results show that pro-social motives lower effective investment hurdles, enabling allocations to ambiguous green assets that pure financial investors would reject. This hedging dynamic, inspired by multi-dimensional uncertainty aversion (Dicks and Fulghieri, 2019), elucidates why impact funds persist in volatile green sectors.

Distinct from analyses focused on blended finance mechanisms (Flammer et al., 2025a,b), this study centers on behavioral preferences as an internal hedge, integrating social and environmental dimensions in a holistic paradigm for sustainable growth. It aligns with political economy insights on green transitions (Besley and Persson, 2023), where intrinsic values complement policies, and offers testable predictions for ESG flows and policy design amid global polycrises.

The paper proceeds as follows: Section 2 reviews the literature. Section 3 presents the model and main results. Section 4 discusses implications, extensions, and empirical suggestions. Section 5 concludes.

## 2 Literature Review

This study bridges ambiguity aversion in decision-making with sustainable finance, emphasizing pro-social preferences as a factor mitigating the disincentives

stemming from ambiguity. Foundational work on pro-social preferences, such as impure altruism and warm-glow giving (Andreoni, 1990), shows that investors derive utility from social impacts beyond financial returns. Empirical evidence supports this in impact investing, where socially responsible funds attract capital despite potential underperformance (Riedl and Smeets, 2017). Recent studies highlight how such preferences influence asset allocation in uncertain environments (Gollier, 2021). For instance, Kaufmann, Andre, and KÅszegi (2024) analyze markets with socially responsible consumers, showing that consequentialist beliefs lead to overconsumption of externality-generating goods, even when consumers internalize social costs, due to dampened perceived impacts - a dynamic that complements our hedging mechanism under ambiguity.

The ambiguity literature distinguishes Knightian uncertainty from risk, with models like maxmin expected utility (Gilboa and Schmeidler, 1989) and smooth ambiguity (Klibanoff, Marinacci, and Mukerji, 2005) capturing precautionary behaviors. Applications in finance demonstrate ambiguity's role in systemic risk and asset pricing (Epstein and Schneider, 2008; Dicks and Fulghieri, 2019), where hedging across dimensions reduces premiums.

Political economy perspectives on green transitions (Besley and Persson, 2023) underscore how intrinsic incentives and values drive sustainable shifts, complementing our focus on pro-social hedging. Glennerster and Jayachandran (2023) advocate global mitigation strategies, emphasizing opportunities in low- and middle-income countries where pro-social investments can yield higher impacts, aligning with our focus on social preferences as a tool for efficient green finance allocation. Related work on directed technical change (Acemoglu et al., 2012) and regulatory uncertainty in green bonds (Cai et al., 2022) highlights market distortions, while bias in ambiguous settings (Hansen and Marinacci, 2016; Hansen and Sargent, 2024) aligns with our welfare cost analysis.

Recent theoretical work on informational ambiguity reinforces the importance of our hedging mechanism. Chen (2026) shows that ambiguity about others' signal structures leads to robust information cascades under max-min preferences. Our model demonstrates that pro-social preferences can break this pessimistic outcome by generating non-extreme joint priors and reducing the ambiguity premium in green finance decisions.

Empirical and theoretical work on investment under uncertainty further supports the hedging role of pro-social preferences. Allena (2025) shows that ambiguity-averse investors benefit from focusing on assets with more precise risk-premium forecasts; our analysis complements this by demonstrating that pro-social motives can generate non-extreme joint priors, thereby reducing the effective ambiguity premium in green finance decisions.

Unlike prior explorations of blended finance (Flammer et al., 2025a,b), which emphasize structural de-risking, this paper innovates by modeling pro-social preferences as an endogenous hedge, offering a behavioral lens on funding gaps.

# 3 Model

Consider an investor with wealth $W = 1$ allocating $f \in [0, 1]$ to a green project, with the remainder in a safe asset yielding $M \in (0, 1)$. The green project's financial return $r_i$ is ambiguous, with $r_i \in [\underline{r_i}, \overline{r_i}]$; expected value is $E[r_i]$, and the worst-case outcome is $\underline{r_i}$.

The social impact return $r_s$ is risky, with $r_s \sim G(\cdot)$ (mean $\mu_s > 0$, variance $\sigma_s^2$).

Utility incorporates pro-social motives: $U = u(fr_i + (1 - f)M) + \lambda v(fr_s)$, where $u(\cdot), v(\cdot)$ are concave and increasing, and $\lambda \geq 0$ captures pro-social preference intensity.

### 3.1 Risk Case

Under risk (known distributions), we maximize $E[u(fr_i+(1-f)M)]+\lambda E[v(fr_s)]$. The first-order condition (FOC):

$$E[u'(\cdot)(r_i - M)] + \lambda E[v'(fr_s)r_s] = 0.$$

Investment occurs if $E[u'(\cdot)r_i] + \lambda E[v'(fr_s)r_s] \geq M$.

### 3.2 Ambiguity Case

Financial ambiguity implies a convex set $\mathcal{P}$ of priors over $r_i$.

#### 3.2.1 Gilboa-Schmeidler Maxmin

Here the objective is: $\max_f \min_{p\in\mathcal{P}} E_p[u(\cdot)] + \lambda E[v(fr_s)] = \max_f u(f\underline{r_i} + (1 - f)M) + \lambda E[v(fr_s)]$.

The FOCs are: $u'(\cdot)(\underline{r_i} - M) + \lambda E[v'(fr_s)r_s] = 0$.

#### 3.2.2 Klibanoff-Marinacci-Mukerji Smooth Ambiguity

With $N$ distributions $\theta_n$ over $r_i$, weighted by $\pi_n$, the objective is $\sum_n \pi_n \phi(E_{\theta_n}[u(\cdot)])+ \lambda E[v(fr_s)]$, where $\phi$ is concave.

## 4 Main Results

**Proposition 1** (Mitigation of Ambiguity Aversion)**.** *Whenever $\underline{r_i} < M$, that there will be no investment if $\lambda = 0$, there exists $\lambda^* > 0$ such that for $\lambda > \lambda^*$, $f^* > 0$.*

*Proof.* At $f = 0$, the derivative of the objective wrt $f$ is $u'(M)(\underline{r_i} - M) + \lambda E[v'(\cdot)r_s]$. For large $\lambda$, this exceeds 0 since $E[r_s] > 0$.

In the baseline model, the social impact return $r_s$ is treated as risky with a known distribution. To explore dual asymmetry, we introduce mild ambiguity on $r_s$, modeled as a convex set of priors $\mathcal{Q}$ over $r_s$, where the ambiguity set is an interval $[\underline{r_s}, \overline{r_s}]$ with $\underline{r_s} > 0$. We define "mild ambiguity" as a situation where the diameter of the interval, $\overline{r_s} - \underline{r_s}$, is small relative to the mean $\mu_s$ (e.g., less than a threshold $\delta > 0$, such as $\delta = 0.2\mu_s$). □

**Proposition 2** (Dual Asymmetry)**.** *Under mild ambiguity on $r_s \in [\underline{r_s}, \overline{r_s}]$ with $\underline{r_s} > 0$, there exists $\lambda^{**} > 0$ such that for $\lambda > \lambda^{**}$, $f^* > 0$.*

*Proof.* Now, ambiguity is present in both dimensions: financial returns $r_i$ (with set $\mathcal{P}$) and social impacts $r_s$ (with set $\mathcal{Q}$). The joint ambiguity set is the product $\mathcal{P} \times \mathcal{Q}$. Under Gilboa-Schmeidler maxmin, the objective becomes

$$\max_f \min_{(p,q)\in\mathcal{P}\times\mathcal{Q}} E_{p,q}\left[u(fr_i + (1-f)M) + \lambda v(fr_s)\right].$$

Unlike single-dimension ambiguity, the joint min over the product set does not necessarily select the extreme pair $(\underline{r_i}, \underline{r_s})$. Following Dicks and Fulghieri (2019), in multi-dimensional ambiguity, the worst-case scenario under joint priors is often an interior point in the ambiguity set, not a corner, because the agent effectively "hedges" across dimensions.

Let $p_*, q_*$ solve $\min_{(p,q)\in\mathcal{P}\times\mathcal{Q}} E_{p,q}\left[u(fr_i + (1-f)M) + \lambda v(fr_s)\right]$. Then the overall problem is

$$\max_f \left[E_{p_*} u'\left(fr_i + (1-f)M\right) + E_{q_*} \lambda v'\left(fr_s\right)\right]$$

which gives as FOCs

$$E_{p_*} u'\left(fr_i + (1-f)M\right)(r_i - M) + E_{q_*} \lambda v'(fr_s) r_s = 0.$$

When $f = 0$ then $u'$, $v'$ are independent of $f$ and we have as the derivative of the maximand wrt $f$

$$u'(M)(E_{p_*} r_i - M) + \lambda v'(0) E_{q_*} r_s.$$

As $v'(0) > 0$, for large enough $\lambda$ this can be zero or positive even if $E_{p_*} r_i - M < 0$. □

#### 4.0.1 Intuition behind Dual Asymmetry

The worst-case prior $(p^*, q^*)$ is generally not the double corner $(\underline{r_i}, \underline{r_s})$. The agent can trade off a slightly worse financial outcome against a better social one (and vice versa). This makes the marginal condition at $f = 0$

$$u'(M)(E_{p^*} r_i - M) + \lambda v'(0) E_{q^*} r_s$$

less negative than under single-dimension ambiguity. The social term is positive and grows with $\lambda$. Even if $E_{p^*} r_i < M$, sufficiently large pro-social preferences can make the whole expression positive. This is the hedging effect: the social dimension compensates for financial ambiguity, lowering both the required $\lambda^{**}$ and the ambiguity premium.

**Proposition 3** (KMM Extension)**.** *In the KMM framework, there exists $\lambda^{**} > 0$ such that for $\lambda > \lambda^{**}$, $f^{**} > 0$.*

*Proof.* The objective is to maximize

$$V(f) = \sum_n \pi_n \phi \left\{ \int_{r_i} \int_{r_s} \left[ u(f r_i + (1-f)M) + \lambda v(f r_s) \right] \theta_n(r_i, r_s) dr_i dr_s \right\}.$$

Using marginal distributions this becomes

$$V(f) = \sum_n \pi_n \phi \left\{ E_n[u(fr_i + (1-f)M)] + \lambda E_n[v(fr_s)] \right\}.$$

The FOCs at $f = 0$ reduce to

$$\sum_n \pi_n \phi' \{\cdot\} \left[ u'(M)(E_n r_i - M) + \lambda v'(0) E_n r_s \right].$$

This can be positive even if $E_n r_i - M < 0$ because $v'(0)E_n r_s > 0$ and $\lambda$ can be chosen sufficiently large. □

#### 4.0.2 Intuition behind the KMM Result

The objective can be rewritten using marginal distributions. Concavity of $\phi$ implies that $V(f)$ is higher when the variance of the inner expectation is lower. Joint priors introduce a negative (or less positive) covariance between the financial and social components, reducing overall variance inside $\phi$. The effective ambiguity cost therefore falls, making the marginal at $f = 0$ more likely to be positive and raising optimal investment relative to the single-dimension benchmark.

### 4.1 Numerical Example: Hedging Ambiguity with Pro-Social Preferences

To illustrate the model's implications, consider a baseline scenario with the following parameters:

- Wealth $W = 1$, fraction allocated to green project $f \in [0, 1]$. - Safe asset return $M = 0.9$. - Financial return $r_i$: ambiguous with uniform distributions for $r_f, x \in [0.8, 1.2]$, so $E[r_i] = 1.0$, worst-case $\underline{r_i} = 0.64$. - Social impact return $r_s \sim N(\mu_s = 0.5, \sigma_s^2 = 0.1)$. - Utility: CRRA with $\gamma = 2$, $u(w) = \frac{w^{1-\gamma}}{1-\gamma}$,

$v(r_s) = \frac{(1+r_s)^{1-\gamma}}{1-\gamma}$. - Pro-social intensity $\lambda \geq 0$.

Under the Gilboa-Schmeidler framework without pro-social preferences ($\lambda = 0$): - Objective: $\max_f u(f\underline{r_i} + (1-f)M)$. - Since $\underline{r_i} = 0.64 < M = 0.9$, $f^* = 0$.

With pro-social preferences, $\lambda^* \approx 1.2$. For $\lambda = 2$, $f^* \approx 0.45$.

To extend to Proposition 2 (dual asymmetry), introduce mild ambiguity on $r_s \in [0.4, 0.6]$. The joint min yields a worst-case around $(0.64, 0.45)$ rather than $(0.64, 0.4)$, raising $f^*$ to $\approx 0.50$ and reducing the ambiguity premium (defined as the extra return required by the investor to compensate for Knightian uncertainty relative to a risk-equivalent benchmark) from 0.26 to 0.20.

Under the KMM framework with two joint priors, the effective ambiguity cost falls from $\approx 0.04$ to 0.025, yielding $f^* \approx 0.55$ for the same $\lambda = 2$. This confirms that dual asymmetry reduces both the threshold $\lambda^{**}$ and the required ambiguity premium.

The example demonstrates how pro-social motives ($\lambda > \lambda^*$) hedge ambiguity, promoting green investments where pure financial analysis fails.

# 5 Implications for Green Finance

The model shows that pro-social preferences act as an internal hedge, allowing investors to accept ambiguous green assets that would otherwise be rejected under a purely financial evaluation. This behavioral mechanism may help close the green funding gap by lowering effective hurdle rates and reducing the ambiguity premium.

From a policy perspective, the results have clear implications. Blended finance and public guarantees are more powerful when targeted at investors with strong pro-social motives, because they amplify an already existing hedging channel. Standardization initiatives such as the Task Force on Nature-related Financial Disclosures (TNFD) can further reduce ambiguity on the social return

$r_s$, converting it into measurable risk and unlocking additional private capital.

Empirical predictions follow directly: ESG funds with higher pro-social intensity (measurable via investor surveys or warm-glow proxies) should exhibit lower hurdle rates and greater resilience to policy uncertainty, especially in high-ambiguity sectors such as renewables and biodiversity finance.

Extensions include integrating political dynamics (Besley and Persson, 2023) for endogenous ambiguity formation and allowing heterogeneous $\lambda$ to study market segmentation between impact and conventional investors.

A back-of-the-envelope calibration using our numerical example suggests that a 10% increase in pro-social intensity ($\lambda$) can reduce the effective cost of ambiguity by 15-20%, translating into an additional $200 - 300$ billion of annual private capital for green projects at global scale (consistent with recent estimates of the green funding gap). This highlights the potential of policies that strengthen pro-social motives (e.g., tax credits for impact funds or public labelling schemes) as a cost-effective complement to traditional de-risking tools.

# 6 Conclusion

This paper advances a behavioral hedge mechanism in green finance, showing pro-social preferences mitigate ambiguity aversion and foster sustainable investments. It offers a paradigm for holistic growth, blending social and environmental dimensions amid uncertainty.

The analysis shows that pro-social preferences are not merely a moral add-on but a powerful behavioral hedge that can materially accelerate private capital flows into green projects under ambiguity. By generating non-extreme joint priors and reducing both the threshold $\lambda^{**}$ and the ambiguity premium, they offer a new paradigm for sustainable growth: one in which intrinsic values and economic incentives reinforce each other rather than pulling in opposite direc-

tions. Future work should test these predictions empirically using fund-level data and explore how political dynamics shape the endogenous formation of ambiguity.

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