



Green Bond Pricing, Greenwashing, and Carbon Taxation under Asymmetric Information

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Background



Green firm

Enterprise that has minimal negative impact or potentially a positive effect on the global or local environment ... for simplicity, zero GHG emission. (brown firm: positive GHG emissions).



Green bond

A fixed-income instrument to finance green business.

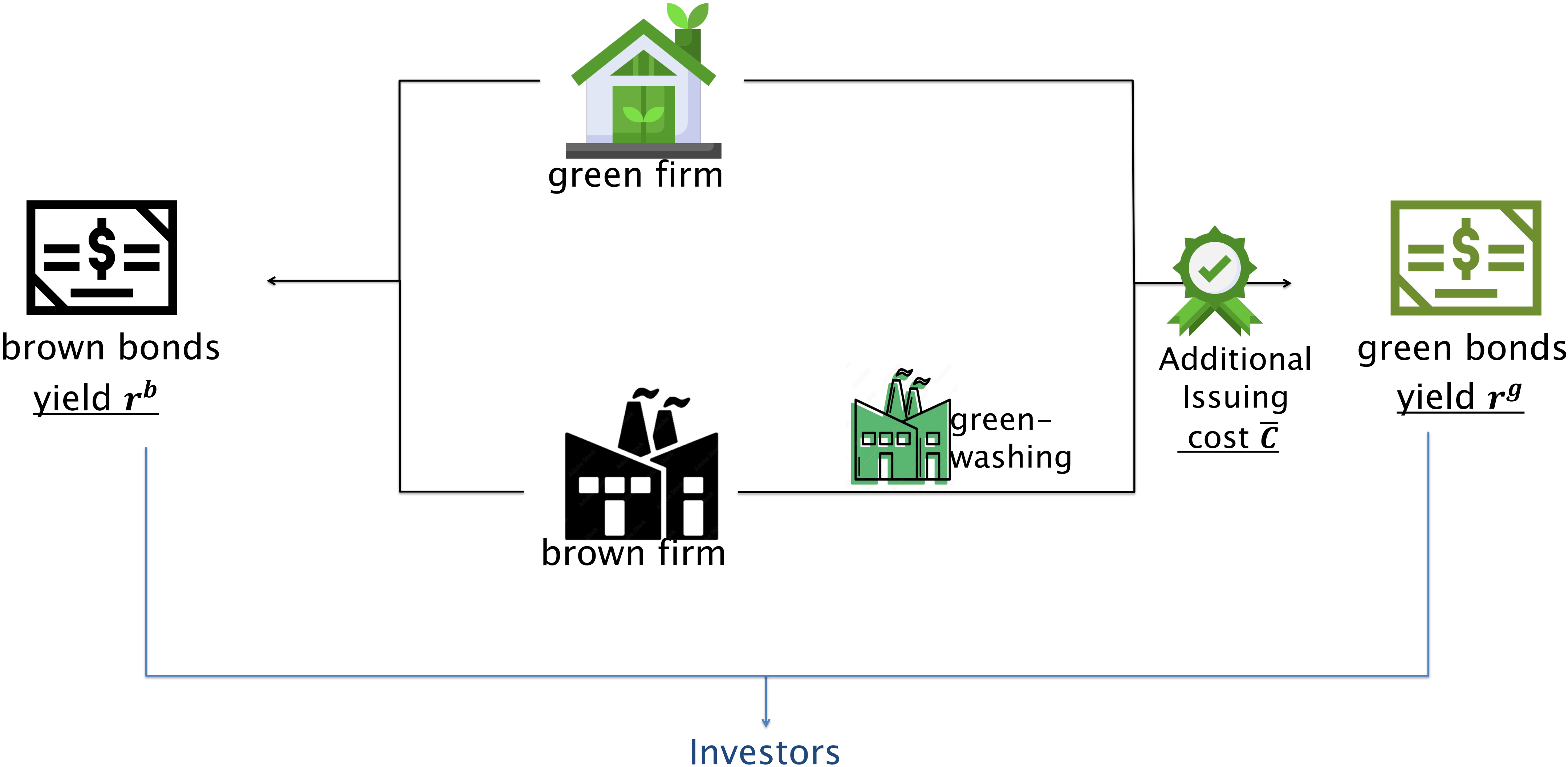
- Issuance requirements: information disclosure; external review, etc.
- Benefits: environment, reputation, diversification, etc.



Greenwashing

Green PR and green marketing are deceptively used to decorate a brown firm as a green firm.

Bond issuance



Investors can only recognize green and brown bonds, cannot identify green and brown firms.

Research questions & Conclusions

Research Questions

1. How to price green bonds?
2. How to evaluate the level of greenwashing?
3. How does carbon taxation affect the pricing of green bonds and the level of greenwashing?

Conclusions

1. Greenium exists when there are asymmetric information, transition risk and greenwashing cost.
2. The level of greenwashing depends on greenium, green bond's additional issuing cost, and greenwashing cost.
3. When the carbon tax is low, the level of greenwashing is low, and the greenium is low. When the carbon tax is high, the levels of greenwashing and greenium are uncertain.

Literatures

Theoretical literatures

Green asset pricing

Pastor et al. (2021); Pedersen et al. (2021); Barber et al. (2021); Jondeau et al. (2021).
Green assets should provide a lower expected return because of green preferences and physical risks.

We show that greenium can exist without green preference.

Climate policy

Carattini et al. (2021); Diluiso et al. (2020).
[E-DSGE] A big and sudden move of carbon tax policy could generate a substantial threat to financial stability.

We prove that a small and swift carbon taxation decreases greenwashing.

Adverse selection and signaling

Gao and Ueda (2021); Figueroa and Leukhina (2015)
Literature on adverse selection and costly signals for debt contracts.

Empirical literatures

No premium on green bonds

Flammer, C. (2021); Larcker et al. (2020)
Papers empirically showed that green bonds are not priced at a premium compared to brown bonds.

Green bond premium

Baker et al. (2018); Zerbib et al. (2019)
Papers empirically found that green bonds tend to be priced at a premium (investors environmental concerns).

We can theoretically support both cases and discuss the conditions of the existence of greenium.

Contributions

- There are little theoretical research on green bond pricing. This paper addresses the information asymmetry in the green bond market.
- The model does not have an exogeneous green (ESG) preference to explain the green bond premium.
- Current theoretical literatures mostly include physical risk (e.g., climate catastrophes). Empirical literatures are difficult to distinguish which risks they report (most likely physical risks). This paper tries to analyze the effect of transitional risk.
- The model can explain two different empirical findings: (1) with greenium; (2) without greenium.
- The model quantifies greenwashing and discuss its effect on green bond pricing.

Settings (1)

Bond issuers (firms)

- Risk neutral. Borrow to produce. Limited liability.
- 2 Types: green & brown firms. Private information.
- Production: (AK model)

$$y^j = A_d k^j, j \in \{green, brown\}$$

- Emissions:
 - Green firms: zero emission
 - Brown firms: emission intensity
 - $e_i \sim U(0,1]$ uniform distribution.
- Financing method: issuing bonds
 - Green bonds
 - Brown bonds
- After production, firms choose to repay or default.

Bond buyers (investors)

- Risk neutral.
- Invest in green or brown bonds.
- Only observes bonds' types, not firms' types.
- No-arbitrage condition: expected return of green bonds and brown bonds should be the same.

Settings (2)

Bonds

Brown bonds

- Coupon rate r^b (exogenous)

Green bonds

- Coupon rate r^g (endogenous)
- Green bonds additional issuing cost \bar{C}
 - External review fee, reporting cost, etc.
- Greenwashing cost $f(e_i)$
 - Extra cost for brown firms issuing green bonds.
 - Increasing, continuous, convex function.
 - $f(e_i = 0) = 0, \lim_{e_i \rightarrow 1} f(e_i) \rightarrow \infty$
 - Define $f(e_i) = -\sigma \ln(1 - e_i)$

Transition risks

- Stems from uncertainty around carbon taxation.
- Government implements carbon tax after bond issuance.
 - Carbon tax rate τ with probability p ;
 - No carbon tax with probability $(1 - p)$.
- Note: Carbon tax rate is exogenous in the model.

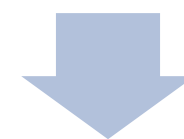
Timeline

One-period model: 4 stages

Green and brown firms issue green and brown bonds.



Investors buy green and brown bonds.



Transition risk (carbon taxation) is realized.



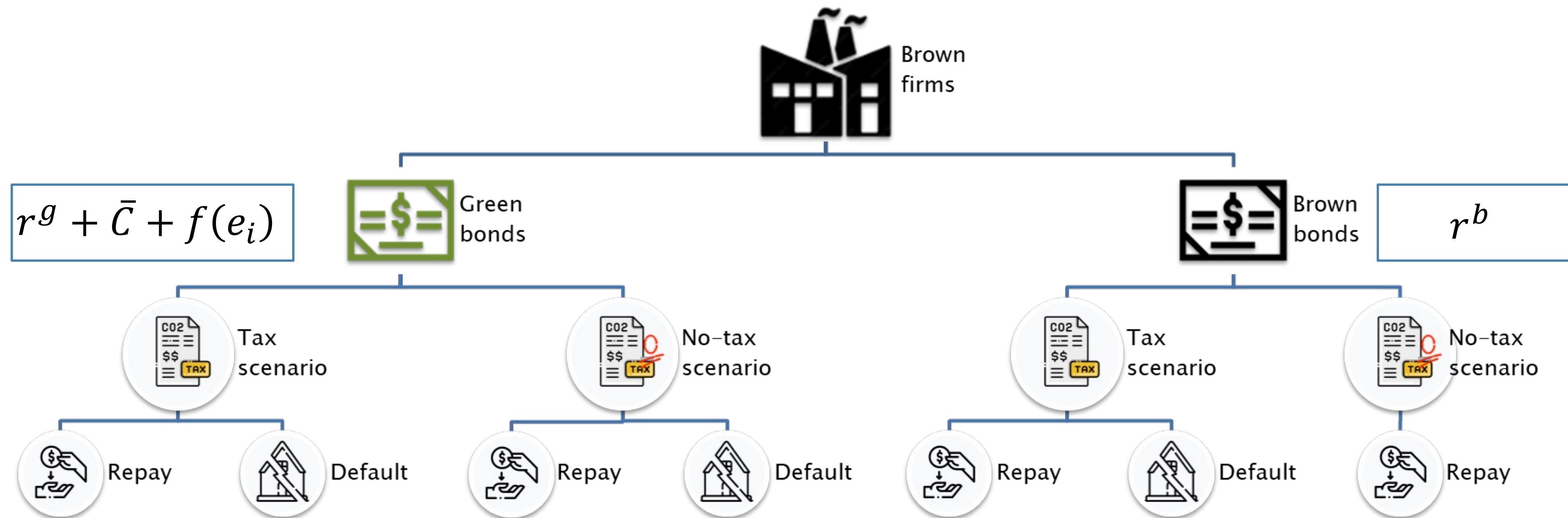
Repay or default: depending on firms' emissions and carbon tax.

Model: Green firms

	Green bonds	Brown bonds
Issuing cost	$r^g + \bar{C}$	r^b
Green firms choose to issue green bonds when	$r^g + \bar{C} < r^b$	

- For green firms, the carbon tax is irrelevant.
- We only discuss the case that green firms choose green bonds.
 - Otherwise, if green firms do not choose green bonds, there will not exist green bonds market.

Model: Brown firms



- Brown firms have positive emissions intensity. → Carbon tax is implemented on brown firms.
- Brown firms choose green or brown bonds based on carbon tax rate and carbon emissions.

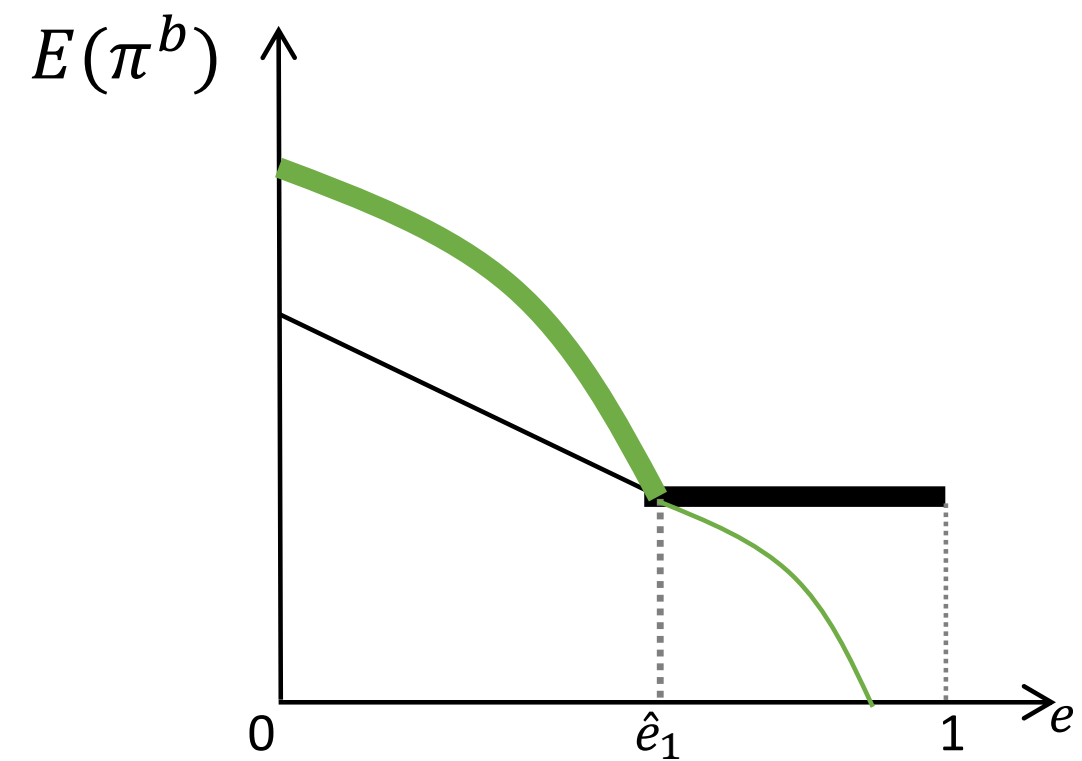
Intuitively,

1. Brown firms with low emission intensities → issue green bonds (greenwashing cost is small).
2. With higher emission intensities/ a higher carbon tax rate, brown firms are more likely to default.

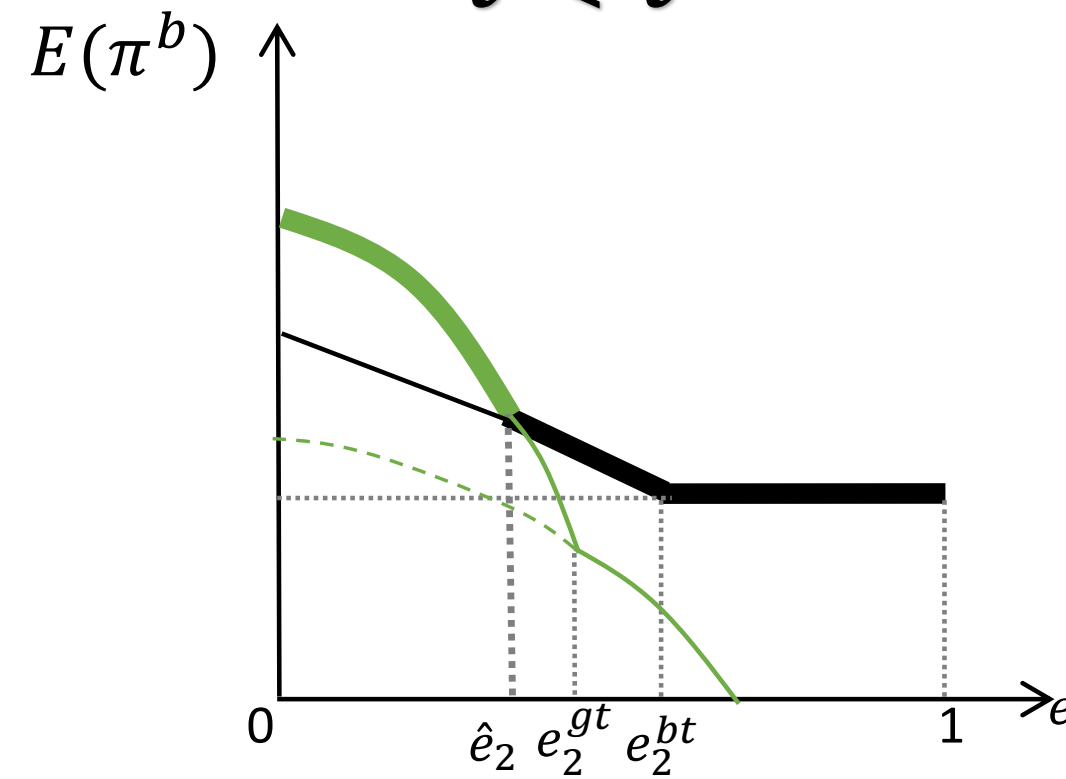
Model: Brown firms (Cont.)

Brown firms choose green or brown bonds based on carbon tax rate and carbon emissions...

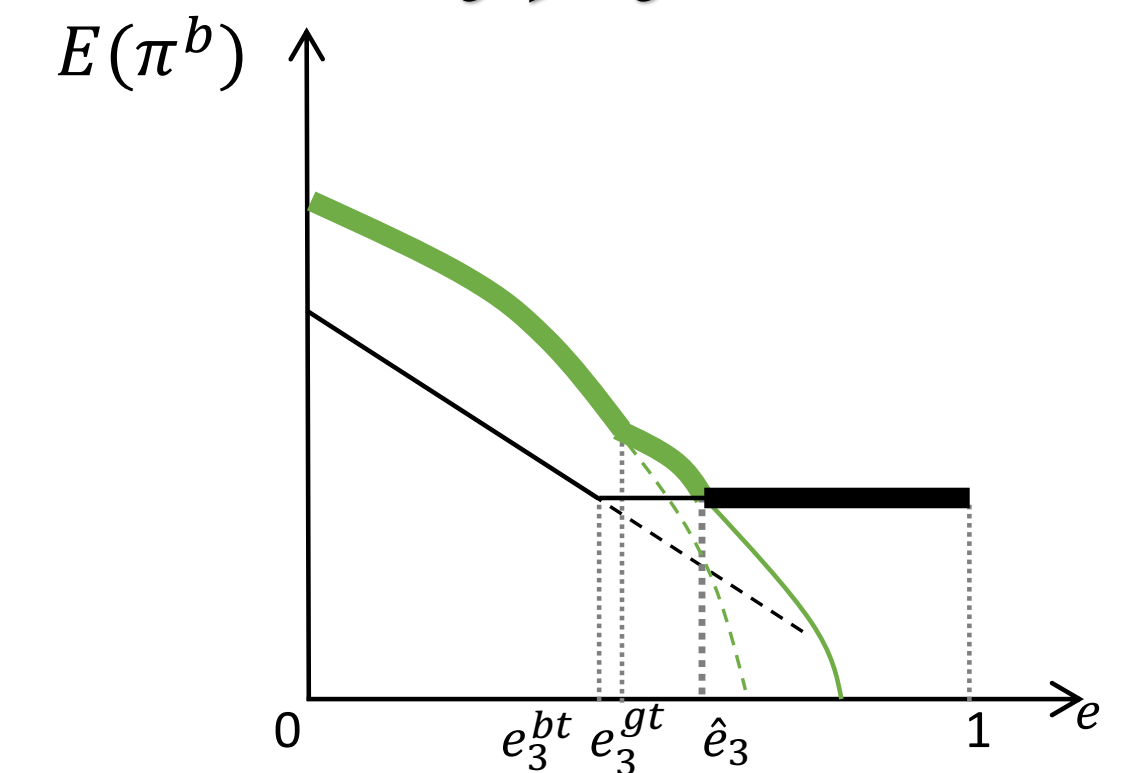
Case 1: Baseline $\hat{\tau}$



Case 2: Low tax
 $\tau < \hat{\tau}$



Case 3: High tax
 $\tau > \hat{\tau}$



e_i	Bonds	Default under tax
$(0, \hat{e}_1)$	Green	Repay
$[\hat{e}_1, 1)$	Brown	Default

e_i	Bonds	Default under tax
$(0, \hat{e}_2)$	Green	Repay
$[\hat{e}_2, e_2^{bt})$	Brown	Repay
$[e_2^{bt}, 1]$	Brown	Default

e_i	Bonds	Default under tax
$(0, e_3^{gt})$	Green	Repay
$[e_3^{gt}, \hat{e}_3)$	Green	Default
$[\hat{e}_3, 1]$	Brown	Default

Note: Horizontal axis: emission intensity. Vertical axis: brown firms' expected profits. Green curve: brown firms use green bonds. Black line: brown firms use brown bonds. Turning points: thresholds of default under tax. Bold line: brown firms' strategies.

Model: Bond markets

Case 1: Baseline $\hat{\tau}$

Green bond market

- Green firms: αN .
- Brown firms (greenwashing): $(1 - \alpha)N\hat{e}_1$.
- No default. $E(R_1^g) = r_1^g$.

Brown bond market

- Brown firms: $(1 - \alpha)N(1 - \hat{e}_1)$.
- No tax: no default.
- W/ tax: all default.
- $E(R_1^b) < r^b$.

Case 2: Low tax

Green bond market

- Green firms: αN .
- Brown firms (greenwashing): $(1 - \alpha)N\hat{e}_2$.
- No default. $E(R_2^g) = r_2^g$.

Brown bond market

- Brown firms: $(1 - \alpha)N(1 - \hat{e}_2)$.
- No tax: no default.
- W/ tax: partial default.
- $E(R_2^b) < r^b$.

Case 3: High tax

Green bond market

- Green firms: αN .
- Brown firms (greenwashing): $(1 - \alpha)N\hat{e}_3$.
- No tax: no default.
- W/ tax: partial default.
- $E(R_3^g) < r_3^g$.

Brown bond market

- Brown firms: $(1 - \alpha)N(1 - \hat{e}_3)$.
- No tax: no default.
- W/ tax: all default.
- $E(R_3^b) < r^b$.

No-arbitrage condition

$$E(R_n^g) = E(R_n^b),$$

$$n \in \{1, 2, 3\}$$

Model: Results

Based on carbon tax rate, brown firms' strategies and no-arbitrage constraint between green and brown bonds $E(R_n^g) = E(R_n^b)$, we can solve green bond coupon rate, $r_n^g, n \in \{1, 2, 3\}$.

Case 1: Baseline $\hat{\tau}$

$$F_1(r_1^{g*}) = r_1^{g*} - r^b$$

Case 2: Low tax $\tau < \hat{\tau}$

$$F_2(r_2^{g*}) = r_2^{g*} - r^b$$

Case 3: High tax $\tau > \hat{\tau}$

$$F_3(r_3^{g*}) = r_3^{g*} - r^b$$

Greenium.

$$+ \frac{1}{2} p \left(\frac{y^b}{k^b} - r^b \right) \left(\frac{1}{\hat{e}_1^*} - 1 \right) = 0$$

$$+ \frac{1}{2} p \left(\frac{y^b}{k^b} - r^b \right) \frac{(1 - e_2^{bt})^2}{e^{bt}(1 - \hat{e}_2)} = 0$$

$$+ p \left(\frac{y^b}{k^b} - r^b \right) \left(\frac{1}{2} \frac{\hat{e}_3 + 1}{e_3^{bt}} - 1 \right)$$

$$+ \frac{1}{2} p \left[\frac{y^b}{k^b} - r_3^{g*} - \bar{C} - f(e_3^{gt}) \right] \frac{-(\hat{e}_3 - e_3^{gt})^2}{e_3^{gt} \hat{e}_3}$$

$$+ p [f(e_3^{gt}) - E(f(e))] \frac{\hat{e}_3 - e_3^{gt}}{\hat{e}_3} = 0$$

(Default) risk premium.

Application #1: Greenium

Greenium

- Bond spread: $r^b - r^g > 0$.
- Greenium exists under three requirements:
 1. information asymmetry between firms and investors.
 2. greenwashing cost
 3. transition risk

Greenium

- Default risk premium
 - Transition risk: carbon tax policy
 - Expected default loss: brown firms > green firms

Adverse selection: (lemon market)

- Brown bond issuers are brown firms with high emission intensities. (too costly to issue green bonds, by greenwashing cost).
- Brown firms with high emission intensities are likely to default under carbon tax.

Greenium

- Green bonds spread: $r^b - r^g = 0$.
- 3 cases:
 - No information asymmetry (perfect information)
 - Investors will directly invest in green firms.
 - No transition risk: $p = 0$ or 1.
 - Brown and green firms have same (zero) default risk.
 - No greenwashing cost: $f(\cdot) = 0$
 - Green bonds have no value as signals.

Real world implications:

- Currently, transition risks are not fully considered in bonds market.
- Greenwashing cost is potentially small because of incomplete regulations in green bonds market.

Application #2: Greenwashing

Brown firms	Green bonds	Brown bonds
Issuing cost	$r^g + \bar{C} + f(e_i)$	r^b
Greenwashing threshold	\hat{e} satisfies $f(\hat{e}) = (r^b - r^g) - \bar{C}$	

- Recall: Greenwashing is defined as brown firms issuing green bonds.
- The threshold depends on greenium $(r^b - r^g)$, green bond additional issuing cost \bar{C} , and greenwashing cost $f(\cdot)$.

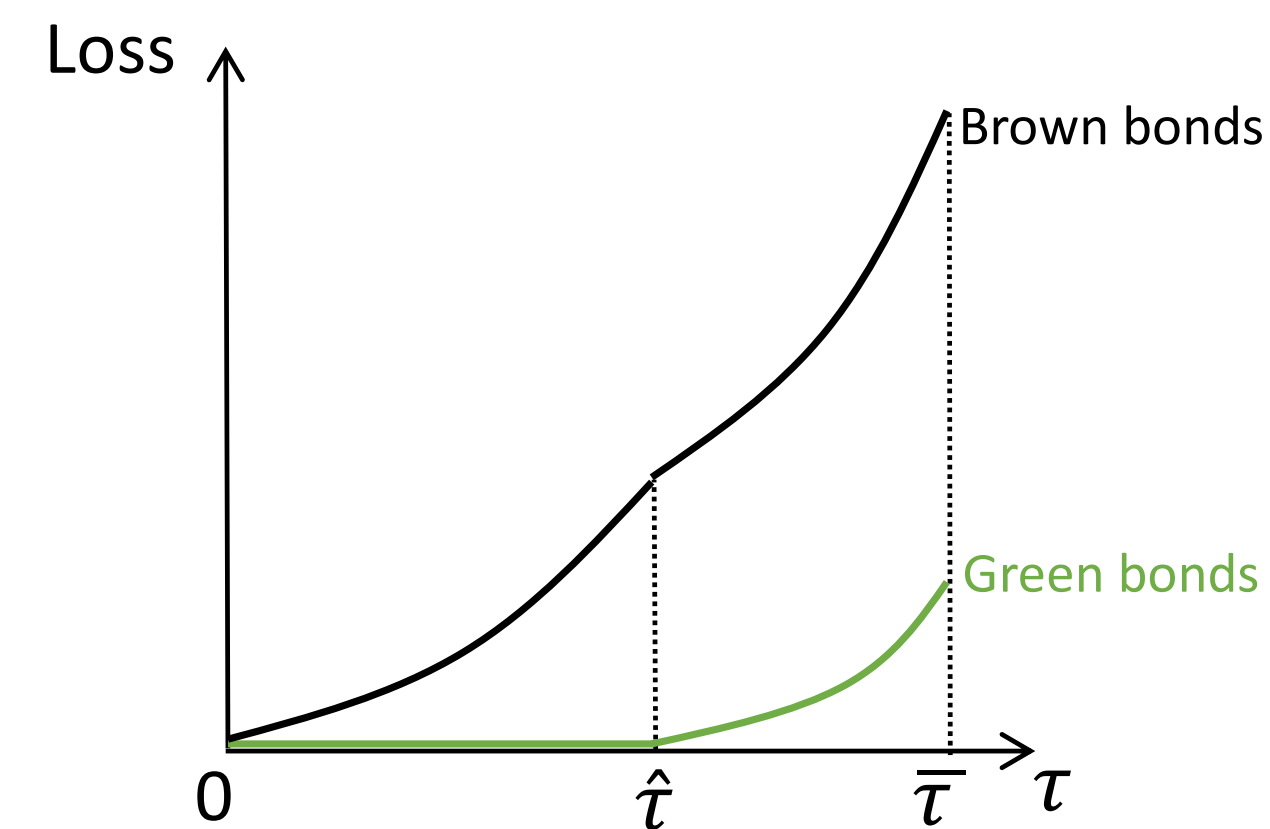
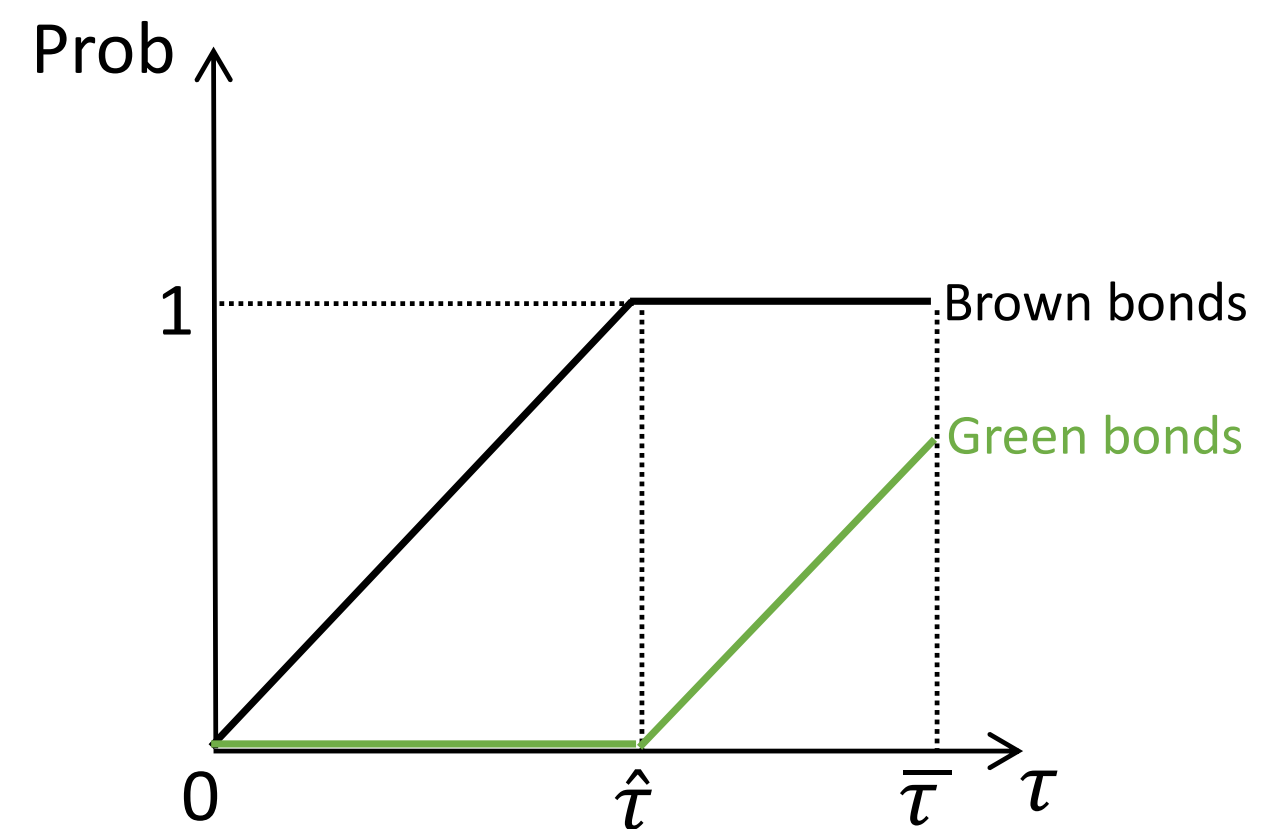
A policy implication:

steeper greenwashing cost function $f(\cdot) \rightarrow$ greenwashing decreases.

- E.g., detailed guidance on information disclosure, a catalog of green business, constant monitoring of green business after bond issuance, etc.

Application #3: Carbon tax and Greenium

- Greenium ($r^b - r^g$) is the default risk premium.
- Default risk premium = Δ average default probability \times Δ average loss when a default happens



- Baseline case: $\hat{\tau}$.
- When carbon tax rate is low, $\tau < \hat{\tau}$, (case 2)
 - Δ default probability lower than baseline, Δ expected loss lower than baseline.
 - So greenium is lower than baseline.
- When carbon tax rate is high, $\tau > \hat{\tau}$, (case 3)
 - Δ default probability lower than baseline, Δ expected loss higher than baseline.
 - So greenium is uncertain, comparing baseline.

Conclusions

1. Greenium exists when there are asymmetric information, transition risk and greenwashing cost.
2. The level of greenwashing depends on greenium, green bond additional issuing cost, and greenwashing cost.
3. When the carbon tax is low, the level of greenwashing is low, and the greenium is low. When the carbon tax is high, the levels of greenwashing and greenium are uncertain.

Policy implications:

1. Government plays a crucial role in the existence of green bond market: transition risk, unified taxonomy, compulsory information disclosure, etc.
2. Government should use constrained green subsidies, to reduce green bond issuing cost while increasing greenwashing cost.



The end.
Thank you for your attention!