Green Finance and Climate Policy

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Most prominent green debt instrument: Green bonds

- Bond whose proceeds are committed to climate-friendly purposes
- Eg, Apple’s large $1.5B green bond in 2016
  - "Reducing its impact on climate change by using renewable energy sources and driving energy efficiency in its facilities, products and supply chain"
  - CO2 emissions reduced by \( \approx 439,000 \)t

[Image of Annual Green Bond Impact Report 2017 Update]
The "green bond boom" (Morgan Stanley 2017)

- 2013-2017: Volume of green bonds \( \simeq \times 2 \) every year

![Amount of green bonds issued by year and type](image)

- Supply: Different issuer types
  - Mostly corporations: utilities, energy, transportation

Source: Bloomberg green bond data

- Trend likely to continue (Morgan Stanley 2017)
The urgent climate problem

Traditional prescription of economists: **Tax carbon!**

1. But evident **political resistance**
   - Effective carbon tax still extremely low in OECD&G20 (OECD 2018)

2. Alternative to publicly support climate-friendly investments?
   - Financing needed $200bn-$1000bn a year (Reichelt 2010)

3. But other governments’ constraints: **indebtedness and expertise**

   ⇒ Green finance increasingly appealing work-around to investors and financial institutions
   - UNEP 2017
   - Eg ECB, Bank of England, of France, of Sweden

"Green Bonds may be our best hope for tackling climate change"
(HBS 2019)

- Is it effective?
Stylized facts

Recent empirical literature on corporate green bonds

1. Firms issuing green bonds significantly improve the environment
   - Flammer 2019: CO2 and overall rating

2. Green bonds cost almost the same as conventional bonds
   - Tang & Zhang 2018: Corporate green bond spread $\simeq -7bps$ (0.07%)

3. But firms’ green bonds increase their stock price
   - Tang & Zhang 2018: Abnormal stock returns 1.4% around $[-10, +10]$, decreasing at firm level
   - Baulkaran 2019: 1.5% around same window
   - Flammer 2019: 0.67% around $[-1, 0]$, persistent, and enhanced operating performance

4. Certification is critical
   - Flammer 2019: Significant effects only if certification
Lessons

What do these findings suggest?

1. Standards’ effectiveness
   - CBI and IMCA standards credible to investors
   - Even though adherence is voluntary

2. Role of stock market
   - Stock market’s manifest reaction to decisions on green bond market

3. Imperfect information
   - Abnormal returns show imperfect anticipation
   - Firms’ commitments to certified green projects reveal information
   - Probably related to operating performance

4. Green bond boom explained by managers’ sensitivity to stock market reaction
   - Managers’ compensation emphasizes short-term stock performance (eg, Bolton)
   - Eg, Bolton, Scheinkman & Xiong 2006, Georgen & Renneboog 2011

⇒ Abnormal returns + short-termism = Incentives to undertake green projects
What we do

Despite increasing prevalence of green finance in practice, very little is known about its economic mechanisms and possible contribution to climate policy

1. **Theoretical model consistent with stylized facts**
   - *(Today)* Most basic version: One-project firms in bond and stock markets choose whether their projects’ technology will be green or conventional
   - Extension 1: Green bond spread
   - Extension 2: Extensive margins (firms’ choice to abandon projects)

2. **Implications for optimal policy:**

   *Can green finance help governments address the climate problem?*

3. **(Too preliminary) Empirical validation of theoretical predictions**
More related literature

- **Burgeoning literature on green finance**
  - Tang & Zhang 2018; Flammer 2019: Green bonds
  - Kotchen & Costello 2018: Project selection
  - Brière, Pouget & Ureche 2018; Gollier & Pouget 2019: Shareholders’ activism
  - Krüger 2015: Investors’ concern
  - We connect the bond and stock markets and show investors’ reaction even if not altruistic

- **Vast literature on carbon pricing**
  - We examine green finance as an instrument

- **Labeling and voluntary agreements**
  - Bonroy & Constantatos 2014: Consumer labels
  - Lyon & Maxwell 2003: Voluntary actions and extensive margins
  - Labels for investors

⇒ First formal analysis of green finance as a climate policy instrument
Model

Firms

Mass-1 continuum of projects/firms and dates \( t = 0, 1 \)

\[
1 \text{ unit of capital at date } t = 0 \quad \mapsto \quad \text{Revenue } Y \text{ at date } t = 1
\]

- Date 0 choice between green and conventional technologies \( k = G, B \)

\[
\text{CO2 emissions at date } t = 1 : \quad x_B > x_G \geq 0
\]

- CO2 taxed at unit rate \( \tau \), penalizing green firms less heavily

- Firms only differ by CO2 abatement cost: Firm \( i \in [0, 1] \) has cost

\[
c_k(i) = \begin{cases} 
c_B \\
c_G(i), \text{ increasing in } i \in [0, 1], \\
& \text{if } k = B; \\
c_G(i), \text{ increasing in } i
& \text{if } k = G,
\end{cases}
\]

and, therefore abatement cost \( \Delta c(i) \equiv c_G(i) - c_B \), increasing in \( i \)
Model

Firms with green finance

- Projects financed by bonds that repay $R \equiv 1 + r$, exogenous
- Green projects ($k = G$) are financed by certified green bonds
- At $t = 1$, profit of firm $i \in [0, 1]$ with technology $k = G, B$ is
  \[
  \pi = \pi_k(i) = Y - R - c_k(i) - \tau x_k
  \]
- At $t = 0$, managers observe $i$ and choose $k = G, B$:
  \[
  \max_k \mathcal{U}_k(i) = \alpha \frac{\pi_k(i)}{1 + \rho} + (1 - \alpha) S_k,
  \]
  where
  - Profit $\pi_k(i)$ at $t = 1$ is perfectly anticipated by manager but not by market
  - Stock price $S_k$ at $t = 0$ is function of $k$
  - $\alpha \in (0, 1)$ measures captures short- and long-term objectives
Model
Stock investors with green finance

Stock investors require exogenous return $\rho$

- They observe firms’ technology choice $k = G, B$ but not projects’ type $i$
- Stock price at date $t = 0^+$ is

$$S_k = \frac{\mathbb{E}[\pi_k(i) | k]}{1 + \rho}$$

- We will show that stock investors react positively to green bond issuance:

$$\Delta S \equiv S_G - S_B \geq 0$$
Model
Firms’ issuance of green bonds

Assumption 1 (All projects will be undertaken)

\[ \pi(B, 1) \geq 0 \]

Managers choose \( k = G \) iff \( \mathcal{U}_G(i) \geq \mathcal{U}_B(i) \):

Proposition 1 (Green bonds)
Number of green firms \( i^e \) (volume of green bonds issued) is solution to

\[
\frac{\Delta c(i^e)}{\text{marginal cost}} - \frac{\tau \Delta x}{\text{tax}} - \frac{1 - \alpha}{\alpha} (1 + \rho) \Delta S^e = 0, \quad (1)
\]

increasing with \( \Delta S^e \) (to be determined), \( \tau \), and \( (1 - \alpha) \)
Model

Stock returns at green bond issuance

$\Delta S^e$?

- Stock investors form rational expectation: $k = G \iff i \leq i^e$

Proposition 2 (Stock market reaction)

In equilibrium,

$$\Delta S(i^e) = \frac{\alpha}{1 + \rho} \left( c_G(i^e) - \bar{c}_G(i^e) \right) > 0$$

(2)

- Abnormal returns at issuance follow:

$$A_G(i^e) = (1 - i^e) \frac{\Delta S(i^e)}{S^0(i^e)} > 0,$$

(3)

where ex ante stock price is $S^0(i^e) = i^e S_G(i^e) + (1 - i^e) S_B$
Model
Equilibrium with green finance

Proposition 3 (Equilibrium with green finance)

1. A unique equilibrium exists
2. It is interior if and only if projects are sufficiently heterogenous

Difference with and without green finance?

Without green finance,
- $k = G, B$ not certified
- Stock investors cannot use $k$
- $\Delta S = 0$
- Equilibrium $i^0 < i^e$
Analysis
Effect of green finance: Compare equilibrium with and without

Proposition 4 (Effect of green finance)

1. Green finance induces **more green projects** $i^e > i^0$, due to
   - Stock price difference $\Delta S^e > 0$
   - Short-termism $(1 - \alpha)$

2. If $c_G(i)$ is convex, **carbon tax effect is amplified**:

   \[
   \frac{di^e}{d\tau} > \frac{di^0}{d\tau}
   \]

   due to increasing $\Delta S(i^e)$
Welfare and social optimum

- Let $\delta > 0$ be the constant marginal social cost of carbon
- Total emissions $X = x_B - i\Delta x$
- Social welfare
  
  $$W = Y - R - \int_0^i c_G(i)di - (1 - i)c_B - \delta(x_B - i\delta x), \quad (4)$$

- Optimal number of green firms $i^*$

\[
\frac{\Delta c(i^*)}{\text{marginal cost}} = \frac{\delta \Delta x}{\text{marginal benefit}}
\]
Policy
Welfare analysis of green finance

Proposition 5 (Welfare impact of green finance)
When $\tau < \delta - (1 - \alpha) \left[ \frac{c_G(i^*) - \bar{c}_G(i^*)}{\Delta x} \right]$, then green finance improves welfare.
Policy
Optimal policy with green finance

Remark (Carbon tax with green finance)
If carbon tax was an option, with green finance, welfare maximizing tax would be

$$\tau^* = \delta - (1 - \alpha) \frac{[c_G(i^*) - \bar{c}_G(i^*)]}{\Delta x} < \delta$$

Optimal subsidy $\eta$ to green projects?
- Equilibrium becomes: $\Delta c(i^e) - \tau \Delta x - (1 - \alpha) [c_G(i^e) - \bar{c}_G(i^e)] - \eta = 0$

Proposition 6 (Optimal green subsidy with green finance)
With green finance, optimal green subsidy is:

$$\eta^* = (\delta - \tau) \Delta x - \frac{1 - \alpha}{\alpha} (1 + \rho) \frac{\Delta S(i^*)}{\text{Carbon pricing gap}} \frac{\Delta S(i^*)}{\text{Green finance effect}}$$
Extension 1: Green bond spread

Green bond spread and concerned bond investors

Recent empirical literature on corporate green bonds

1. Green bond premium: Firms issuing green bonds slightly pay less
   - Tang & Zhang 2018: Corporate green bond spread $\approx -7 \text{bps}$ (0.07%)
   - Kapraun & Scheins 2019: All kinds of bond spread $\approx -24 \text{bps}$
   - Example ICE/BALM indices

2. Green bonds attract "concerned" bond investors
   - Baker et al 2018, Flammer 2019
Extension 1: Green bond spread

Supply and demand for green bonds

- We allow green and conventional bonds to have different yields

\[ s \equiv r_G - r \]

spread

- Profits become

\[ \pi(k, i) = Y - R_k - c_k(i) - \tau x_k, \ k = G, B \]

where \( R_k \equiv 1 + r_k \) is gross repayment

- **Supply of green bonds:**

\[ s = \Delta c(i) - \tau \Delta x - \frac{1 - \alpha}{\alpha}(1 + \rho)\Delta S^e \]

- We assume a continuum of bond investors indexed by \( l \in [0, 1] \) and arranged in decreasing order of their concern for the climate:

\[ r = r_G + \theta(l)X \]

- **Demand for green bonds:**

\[ s = \theta(l)X(l) \]
Extension 1: Green bond spread

Analysis with demand for green bonds

\[ \theta(i)X(i) \]

\[ \Delta c(i) \]

\[ \Delta c(i) - \tau \Delta x \]

\[ \Delta c(i) - \tau \Delta x - (1 - \alpha) [c_G(i) - \bar{c}_G(i)] \]

\[ s^e \]

\[ i^0 \]

\[ i^e \]

\[ s \]

\[ i \]

\[ 1 \]

⇒ Analysis unchanged but effect of green finance augmented by spread \( s^e \geq 0 \)
Extension 2: Extensive and intensive margins

Critical dimension of climate policy which should induce firms to

1. (Intensive margin) Undertake green rather than conventional projects
2. (Extensive margin) Abandon least efficient projects

Previous model focuses on the former and is not meant to examine the latter: All conventional projects generate the same profit

- We assume that firms’ differ in two dimensions:
  - $i \in [0, 1]$, efficiency at green technology
  - $j \in [0, 1]$, efficiency at ordinary technology

\[
c_k(i, j) = \begin{cases} 
  c_B(j), \text{ increasing in } j, & \text{if } k = B \\
  c_G(i), \text{ increasing in } i, & \text{if } k = G
\end{cases}
\]

- We do away with Assumption 1, allowing abandoned projects
- Three options
  \[ k = G, B, \emptyset \]
Extension 2: Extensive and intensive margins

Equilibrium without green finance

Analysis is more complex:

1. Managers are sensitive to stock market reactions
2. Investors observe $j$ and whether firms are operating and seek to infer $i$
Extension 2: Extensive and intensive margins

Effects of green finance
Green finance induces firms to

1. Undertake more green rather than ordinary projects
2. Abandon their least efficient ordinary projects (no effect on green projects)

Intuition: With green finance

1. Low $j$ and choice $B$ reveals high $i$
2. High $j$ and choice $G$ reveals nothing

Implications:

- Direction of climate policy
- Unlike standard voluntary actions
Conclusion

The paper develops the first formal analysis of green finance as a climate policy instrument

- Our model examines firms that undertake green and ordinary projects, and finance the former by issuing green bonds
  1. Green bonds signal to stock investors otherwise unobservable efficiency at controlling CO2 emissions
  2. They may provide less expensive capital due to the presence of concerned investors

- The model’s predictions account for recently established stylized facts
- The model has implications for the second-best structure of climate policy
  1. If carbon tax is low, green finance may improve welfare
  2. Green finance may further amplify the effect of increased carbon tax
  3. Green finance induces firms to abandon ordinary projects, like optimal climate policy