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Clean Energy Investment and Credit Rationing

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MOTIVATION

- Potential capital market failures typically not considered in environmental economics.
  - Although: risk of socially not optimal allocation (Akerlof, 1970; Jaffee and Stiglitz, 1993; Stiglitz, 1993; Stiglitz and Weiss, 1981)

However:

- Clean energy investments rely highly on services provided by capital markets:
  - Capital costs dominate cost structure (Evans et al., 2009; Wiser et al., 1997).
  - Project finance structure (Pollio, 1998).
- Information asymmetry between lenders and borrowers (clean sector):
  - Borrowers use new clean technologies (Carpenter & Petersen, 2002).
  - Young and small firms with no or reduced prior relationship with a bank (Berger & Udell, 2002; Bharath et al., 2011; Bräuning & Fecht, 2012; Jiménez & Saurina, 2004; Petersen & Rajan, 1995).

» Capital market failures highly relevant for clean energy projects.

» Approach: Theoretical model with financial market imperfection, i.e. information asymmetry between principal/ bank and agent/borrower (Arping et al., 2010; Gale, 1990; Janda, 2011; Philippon & Skreta, 2012)

MODEL 1/2: SETUP

Production:

- Dirty sector: 2 types, $d \in \{\underline{d}, \overline{d}\}$, output, $y_{\underline{d}} = y_{\overline{d}} = y_D$, emissions, $e_{\overline{d}} < e_{\underline{d}}$.
- Clean sector: 2 types, $c \in \{\underline{c}, \overline{c}\}$, output, $y_{\underline{c}} = y_{\overline{c}} = y_C$, success probabilities, $0 < \delta_{\underline{c}} < \delta_{\overline{c}} < 1$, requiring a loan from lender/bank.

➢ 4 types of producers in the economy (with their shares in brackets):

$\underline{cd}\ [\theta_c\theta_d]$, $\underline{c}\overline{d}\ [\theta_c(1-\theta_d)]$, $\overline{c}\underline{d}\ [(1-\theta_c)\theta_d]$, $\overline{cd}\ [(1-\theta_c)(1-\theta_d)]$.

Loan Market:

- Information asymmetry between borrowers (clean producers) and lender.
- Loan contracts comprise the probability to receive the loan, π_k, and the loan repayment, R_k, with $k \in \{\underline{cd}, \underline{c}\overline{d}, \overline{c}\underline{d}, \overline{cd}\}$.
- Expected profit of cd-type borrower applying for a contract designed for k-type:

$$P_{cd,k} = \pi_k[\delta_c(y_C - R_k) - y_D].$$

- Lender's expected profit for a loan to a borrower of type k:

$$B_k = \pi_k[\delta_c R_k - \rho].$$

➢ Bank maximises profits from lending subject to the (potential) borrowers' participation constraint ($P_{cd,k} > 0$) and incentive compatibility constraints (each borrower chooses the contract designed for him, i.e. $cd = k$).

MODEL 2/2: LAISSEZ-FAIRE ALLOCATION

Assumption: $y_D > y_D - c_e e_{\overline{d}} > \delta_c y_C - \rho > y_D - c_e > y_D - c_e e_{\underline{d}} \geq 0$, $c \in \{\underline{c}, \overline{c}\}$

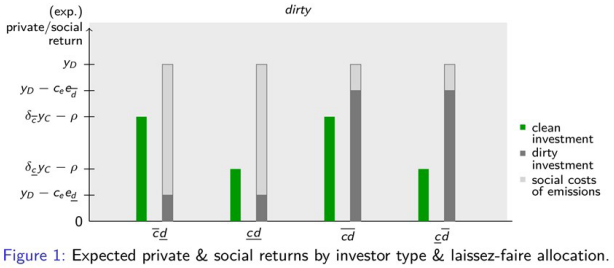

Figure 1: Expected private & social returns by investor type & laissez-faire allocation.

- Dirty investments: producers do not consider social costs of emissions ($c_e e_{\underline{d}}$).
- Under laissez-faire: all producers choose dirty sector.

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RESULTS 1/2: ECONOMY WITH EMISSION TAX ONLY

Introducing emission tax $\tau = c_e$ ⟶ private = social returns in dirty sector:

- Relative return to clean investments ↑
- Type-$c\underline{d}$ producers attempt to switch to the clean sector.
- Only type-$\overline{c}\underline{d}$ borrowers receive loan, type-$\underline{cd}$ don't (credit rationing!).

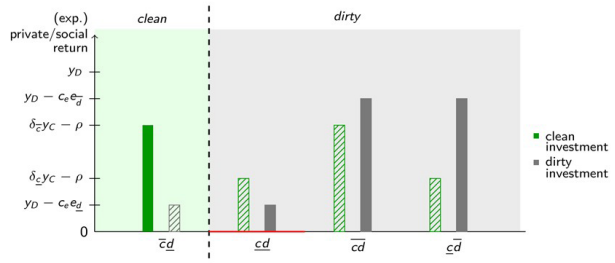

Figure 2: Expected private/social returns by investor type & allocation.

RESULTS 2/2: EMISSION TAX & CREDIT MARKET INTERVENTION

We consider two alternative instruments:

- Interest subsidy, s ⟶ $P_{cd,k} = \pi_k[\delta_c(y_C - (R_k - s)) - (y_D - \tau e_d)]$.
- Loan guarantee, g ⟶ $B_k = \pi_k[\delta_c R_k + (1 - \delta_c)g - \rho]$.

- No credit rationing! Government expenditures lower for g than s, $G_g < G_s$.
- Optimal policy mix: combining τ with g.

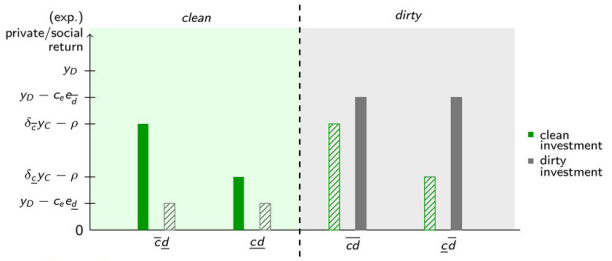

Figure 3: Expected private/social returns by investor type & allocation.

DISCUSSION: SOME DYNAMICS

- Innovation spillovers ⟶ type-$\underline{c}d$ catches up to type-$\overline{c}d$ (in finite time):

$$\dot{\delta}_{\underline{c},t} \equiv \delta_{\underline{c},t} - \delta_{\underline{c},t-1} = \theta_d \left(\pi_{\underline{c},t-1}\theta_c + \pi_{\underline{c},t-1}(1-\theta_c)\right)\left(\delta_{\overline{c},t-1} - \delta_{\underline{c},t-1}\right) \forall\, t > 0.$$

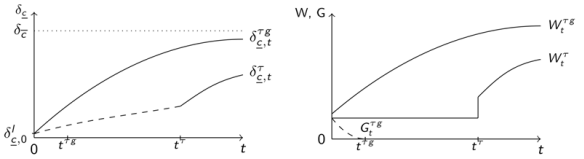

Figure 4: Left: Evolution of the probability of success of type-$\underline{c}d$ with loan guarantee ($\delta^{\tau g}_{\underline{c}}$) and without ($\delta^{\tau}_{\underline{c}}$). Right: Total welfare with loan guarantee ($W^{\tau g}_t$) and without (W^{τ}_t), and government expenditures ($G^{\tau g}_t$).

- Credit rationing vanishes at $t^{\tau g}$ with and at t^{τ} without government intervention.
- Without g (or s): credit rationing reduces spillovers ⟶ $\delta^{\tau}_{\underline{c},t} < \delta^{\tau g}_{\underline{c},t}\ \forall\, t > 0$.
- Forgone welfare resulting from no or delayed intervention on loan market.

CONCLUSIONS

Main analysis

- Tax internalises the emission externality, but there is credit rationing due to information asymmetries on loan market.
- Additional government intervention on credit market (interest rate subsidy or loan guarantee) can resolve issue of credit rationing (first-best outcome).
- Alternative assumption (not presented above): emission tax is (politically) not feasible:
  - Government can use intervention on credit market to incentivise clean investment.
  - However, policy mix with emission tax yields superior results with respect to total welfare due to induced self-selection in dirty sector.

Some Dynamics

- Necessity of government intervention on credit market is finite (credit rationing vanishes at some point).
- Risk of substantial welfare costs resulting from no or delayed intervention on credit markets.