How unconventional is green monetary policy?

Melina Papoutsi   Monika Piazzesi   Martin Schneider
ECB   Stanford & NBER   Stanford & NBER

NBER Summer Institute 2021

Unconventional monetary policy

- Low interest rate environment
  - ▸ main tool for (unconventional) monetary policy: asset purchases
  - ▸ government bonds, MBS,.... most recently corporate bonds
  - ▸ goal: lower firms' cost of capital, stimulate investment
  - → Which corporate bonds should central banks buy?

- Conventional view:
  - ▸ monetary policy should aim for "market neutrality"
  - ▸ no mandate to favor particular firms, e.g. green investment
  - ▸ in practice: bond purchases proportional to bonds outstanding

- This paper:
  - ▸ What are "market neutral" asset purchases? Is the current ECB portfolio neutral?
  - ▸ What are optimal purchases with financial frictions & climate externalities?

Empirics: how green is the ECB bond portfolio?

- Measure ECB holdings, outstanding securities, emissions by sector

- Benchmark: market portfolio of firm values = equity + debt
  - corresponds to sectoral capital shares

- ECB bond portfolio $\approx$ sector shares of emissions $\neq$ market portfolio
  - ECB overweighs dirty industries relative to market portfolio

- Portfolio composition reflects implementation of market neutrality
  - ECB purchases are proportional to bonds outstanding
  - dirty sectors issue relatively more bonds

- Are dirty asset purchases market neutral? are they optimal? should purchases be greener?

Theory relates asset purchases to relative price distortions

- Growth model with heterogeneous firms, climate externalities & fin frictions
  - firms differ by riskiness and emission intensity
  - asset purchases work through liquidity and risk premia, effects differ across firms:
    - direct effect: lowers liquidity premia on firms' bonds, benefits bond-levered firms more
    - indirect effect: purchase program creates more safe government debt, lowers risk exposure of private intermediaries, lowers risk premia on many assets, benefits risky firms more (GE)

- Market neutral policy = firms' *relative* costs of capital unchanged
  - only macro effects, does not distort market portfolio
  - exists only if direct and indirect effects cancel (divine coincidence)
  - current ECB portfolio not neutral: favors dirty firms, both bond-levered and risky

- Optimal policy: designs carbon tax & asset purchase program
  - optimal purchases address financial frictions, favor risky firms

- Monetary policy if no carbon tax : beneficial to favor green firms

Measuring ECB portfolio and market portfolio

- ECB portfolio by sector
  - ▶ start from ECB Securities Holdings Statistics (SHS) on purchases of indiv bonds
  - ▶ merge to ECB Centralized Securities Database (CSDB) on bonds outstanding
  - ▶ important: special purpose entities
    - raw data: bonds by firms in finance sector are 56% of the ECB holdings, ineligible
    - example: ECB buys bonds from Royal Dutch Shell (oil manufac), bonds are issued by Shell International Finance BV (finance sector)
    - we research SPEs, attribute bonds to right sector, reduce bonds from finance sector to 11%
    - show results for nonfinancial sectors only

- Three measures of market portfolio by sector
  1. capital income from Eurostat
  2. book assets from Orbis
  3. market value for public companies from Orbis

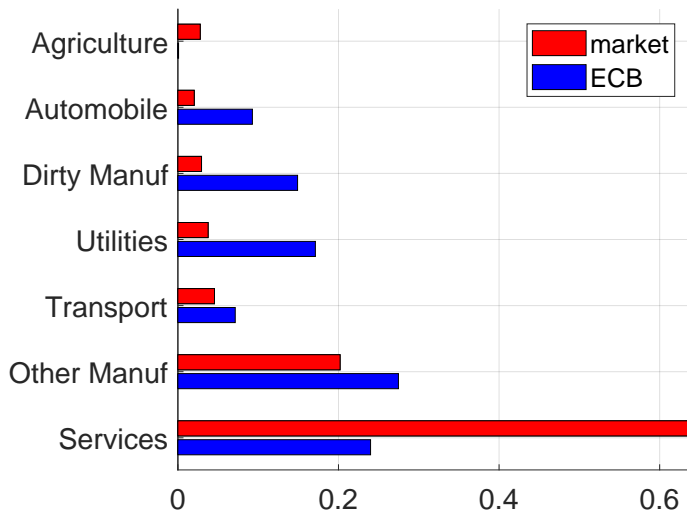 same main result, in talk only show 1.

Market shares by sector

Dirty Manuf = oil & coke, chemicals, basic metals, nonmetallic minerals
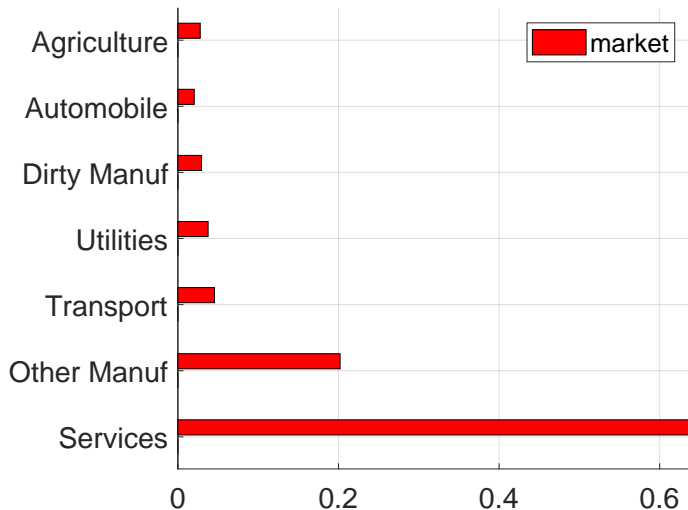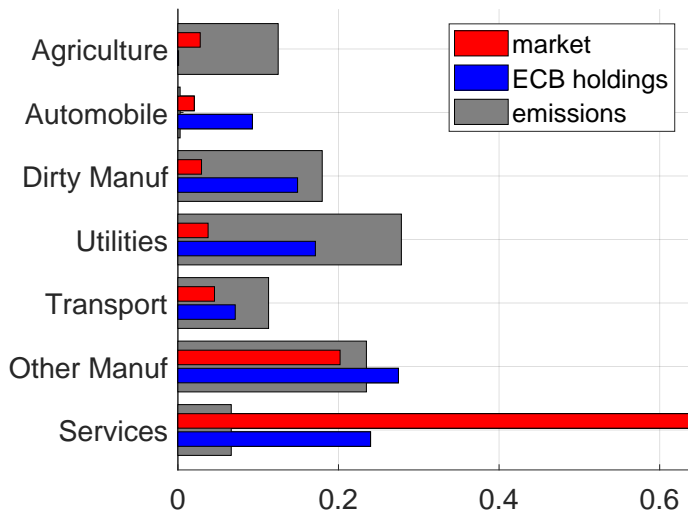
Market portfolio vs ECB portfolio

Dirty Manuf = oil & coke, chemicals, basic metals, nonmetallic minerals

ECB portfolio looks more like emission shares

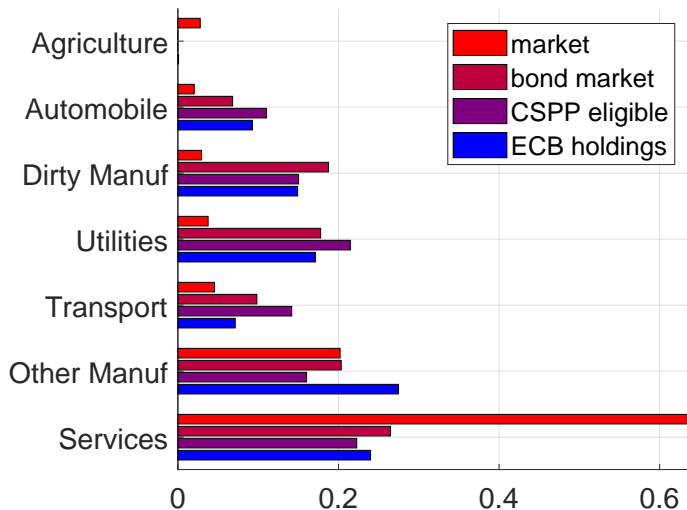Dirty Manuf = oil & coke, chemicals, basic metals, nonmetallic minerals

Empirical findings

- ECB portfolio $\approx$ sector shares of emissions $\neq$ market portfolio

- Why? ECB buys proportionally to bonds outstanding

- Eligibility criteria do not change the basic finding

ECB portfolio vs bonds outstanding, eligible bonds

Growth model with climate externalities & fin frictions

- Rep agent with preferences over final consumption good

$$\sum_{t=0}^{\infty} \beta^t u(C_t)$$

inelastically supplies one unit of labor

- Final good is made of N intermediate goods

$$Y_t = \prod_{n=1}^{N} y_{t,n}^{\gamma_n}$$

- Firm-specific climate externalities in production

  TFP declines with temperature η_t, temperature raised by emissions

$$y_{t,n} = z_{t,n}(\eta_t)\ k_{t-1,n}^{\alpha_n}\ l_{t,n}^{1-\alpha_n}, \quad \eta_{t+1} = \eta_t + \sum_{n=1}^{N} \varepsilon_{t,n}\ y_{t,n}$$

Financial frictions

- 2 technologies for households to hold firms' capital = bonds + stocks

- asset holdings through central bank or private intermediary technology

- both technologies come with balance sheet costs

  - cost functions $\tilde{h}(\tilde{b}_t; \phi_t)$, $h(a_t; \phi_t, \tilde{b}_t)$: resource costs in terms of final good
    - increasing in asset holdings, quasiconvex, homogenous of degree one in all holdings
    - private asset holdings a_t contain firms' bonds & stocks and central bank debt
    - increasing in firm leverage ϕ_t = bonds / capital, decreasing in central bank holdings $\tilde{b}_t$

  - interpretation: risk taking & liquidity
    - risky investments are costly, some don't pan out, resources are gone
    - holding claims to more or more levered capital is riskier
    - holding safe government debt reduces risk for private intermediaries
    - central bank participation can make bond markets more liquid

Private Intermediaries

- portfolio of private bonds, stocks, central bank debt $a = (b, s, d)$; vector of returns R^a

- competitive, owned by households, maximize shareholder value

$$\max_{a_t} M_{t+1} \sum_i R^a_{t+1,i}\, a_{t,i} - h(a_t; \phi_t, \tilde{b}_t) - \sum_i a_{t,i}$$

with household pricing kernel $M_{t+1} = \beta u'(C_{t+1})/u'(C_t)$

- FOCs for bonds of firm n

$$M_{t+1} R^b_{t+1,n} = 1 + \frac{\partial h}{\partial b_n}(a_t; \phi_t, \tilde{b}_t) \quad \text{return premium over safe rate}, \quad M_{t+1} R^f_{t+1} = 1$$

Firms

- Intermediate goods firms
  - choose lev $\phi_{t-1,n}$ to minimize cost of capital $R_t^n := \phi_{t-1,n} R_{t,n}^b + (1-\phi_{t-1,n}) R_{t,n}^s$
  - hire labor at wage w_t, sell goods at price $p_{t,n}$ in competitive markets
  - pay carbon tax τ_t per unit of emissions
  - maximize profits

$$(p_{t,n} - \tau_t \varepsilon_{t,n}) \, y_{t,n} - w_t l_{t,n} - R_t^n k_{t-1,n}$$

- Firms' FOCs for capital

$$(p_{t,n} - \tau_t \varepsilon_{t,n}) \, \alpha_n \frac{y_{t,n}}{k_{t-1,n}} = R_t^n \qquad \text{contains return premia on bonds \& stocks}$$

- Final good firms
  - buy intermediate goods at price $p_{t,n}$, sell final good at price one

Equilibrium

- Government policy
  - central bank bond holdings $\tilde{b}_t$ financed with debt $D_t = \sum_{n=1}^{N} \tilde{b}_t$, also carbon tax τ_t
  - consolidated budget constraint with lump sum transfers T_t

$$\sum_{n=1}^{N} R_{t,n}^b \tilde{b}_{t-1,n} + D_t + \tau_t \sum_{n=1}^{N} \varepsilon_{t,n} y_{t,n} = R_t^D D_{t-1} + \sum_{n=1}^{N} \tilde{b}_{t,n} + \tilde{h}\left(\tilde{b}_t; \phi_t\right) + T_t$$

- Agents optimize and markets clear

- Firms' capital shares $\kappa_t = k_t / K_t$ held by
  - central bank as bond portfolio $\tilde{\kappa}_t = \tilde{b}_t / D_t$ with debt share $\delta_t = D_t / K_t$
  - private intermediaries as bond & stock portfolio $\kappa_t - \delta_t \tilde{\kappa}_t$

- Equilibrium cost of capital of firm n

$$M_{t+1} R_{t+1}^n = 1 + \phi_{t,n} \frac{\partial h}{\partial b_n} + (1 - \phi_{t,n}) \frac{\partial h}{\partial s_n} =: 1 + MC_n(\kappa_t - \delta_t \tilde{\kappa}_t; \phi_{t,n}, \delta_t \tilde{\kappa}_t)$$

Frictionless benchmark

- Capital allocation across firms: market portfolio κ solves

$$\underbrace{\frac{\alpha_n \gamma_n}{\kappa_n} \frac{Y}{K}}_{\substack{\text{marginal product} \\ \text{of capital}}} = \underbrace{R^n(\phi_n)}_{\substack{\text{cost of} \\ \text{capital}}} = \underbrace{R^f}_{\text{safe rate}}$$

  - ► market portfolio equates marginal products
  - ► market shares $\kappa_n = \alpha_n \gamma_n$ reflect technology & preferences only

- Modigliani-Miller & Ricardian equivalence hold

  - ► ϕ indeterminate, asset purchases irrelevant for investment & climate
  - ► government buys assets, private sector undoes policy, same κ

- Some commentators: financial frictions do not matter + important that purchases are designed to be market neutral

  - ► in a frictionless world, private sector undoes policy

Equilibrium without a carbon tax

- Capital allocation across firms with financial frictions

$$\underbrace{\frac{\alpha_n \gamma_n}{\kappa_n} \frac{Y}{K}}_{\substack{\text{marginal product} \\ \text{of capital}}} = \underbrace{R^n(\phi_n)}_{\substack{\text{cost of} \\ \text{capital}}} = \underbrace{R^f}_{\text{safe rate}} (1 + \underbrace{MC_n(\kappa - \delta\tilde{\kappa}; \phi_n, \delta\tilde{\kappa})}_{\substack{\text{marginal} \\ \text{holding cost}}})$$

  ▸ market portfolio equates marginal products net of marginal holding costs
    - evaluated at optimal leverage that minimizes cost of capital

  ▸ firms with higher cost of capital: lower investment

  ▸ three channels for central bank purchases $\delta\tilde{\kappa}$
    1. take firm n risk off private intermediaries' balance sheets
    2. replace private risky securities with safe government debt
    3. lower private holding costs by making bond market more liquid

Discussion of assumptions

- Role of central bank
  - real model, focus on risk premia & investment, not price stability
  - with flexible prices, get similar effects in nominal model (PS 2020)
  - medium run perspective: decade of large CB balance sheets

- Balance sheet costs of private intermediaries vs central bank
  - capture familiar theme from literature: QE stimulates economy when government is better able to commit to repay than private sector
  - new element here: heterogeneous firms with severity of frictions described by h, reflected in firm level risk premia
  - h can be identified from effects of purchase programs on firms' costs of capital

- Interaction: climate externality & financial frictions
  - expect parameters of h to vary with emission intensities ε_n in x-section
  - evidence that brown firms pay higher premia

Linear-quadratic holding cost

- Modeling risk with small number of risk factors
  - vector $\beta_n(\phi_n)$ = risk exposures of total firm value
  - bonds, stocks: portfolios of risky firm value & riskfree asset, risky weights $\rho_n^b(\phi_n)$, $\rho_n^s(\phi_n)$
  - $\beta_n, \rho_n^b, \rho_n^s$ increase in leverage ϕ_n, less so if firm has more tangible assets

- Intermediary risk exposures
  - asset holdings $a = (b, s, d)$ with total assets $A = \sum_n b_n + s_n + d$
  $$\omega(a; \phi) := \sum_n \beta_n(\phi_n) \left(\rho_n^s(\phi_n) s_n + \rho_n^b(\phi_n) b_n \right) / A$$
  - holding more levered firms increases exposure, less so if firms have more tangible assets
  - holding safe central bank debt d *reduces* exposure per unit of assets

- Holding cost for private intermediary
  $$h(a; \phi, \tilde{b}) = s'l^s + b'(l^b - \Delta) + dl^d + \tfrac{1}{2}\gamma\omega(a; \phi)'\Sigma\omega(a; \phi) \; A$$
  $$\underbrace{\qquad\qquad\qquad\qquad}_{\text{liquidity cost}} \quad \underbrace{\qquad\qquad\qquad\qquad}_{\text{cost of risk taking}}$$
  - $\Delta_n > 0$ iff $\tilde{b}_n > 0$: central bank participation makes market for firm n bonds more liquid

Asset pricing with linear-quadratic holding cost

- **Equilibrium risk exposure** of private intermediaries

$$\boldsymbol{\omega} = \sum_n \beta_n \left(\kappa_n - \rho_n^b \delta \tilde{\kappa}_n \right)$$

  - central bank reduces private holdings of risky capital

- Return premia on bonds

$$l_n^b - \Delta_n + \gamma \rho_n^b \beta_n' \Sigma \boldsymbol{\omega} - \tfrac{1}{2} \gamma \boldsymbol{\omega}' \Sigma \boldsymbol{\omega}$$

  - lower liquidity premia $-\Delta_n$ if central bank eligible, controlling for risk
    yield spreads, bid-ask spreads, repo turnover by eligibility: Todorov 2020, Mota-Papoutsi 2021
  - risk premia exhibit factor structure (similar equation for stocks)
    Fama-French 1993, Elton-Gruber-Blake 1995, Ang 2014, Bai-Bali-Wen 2019
  - central bank reduces exposure $\boldsymbol{\omega} \rightarrow$ reduces *all* premia, including on ineligible bonds,
    more so for riskier firms : Todorov 20, De Santis-Zaghini 21
  - convenience yield on safe debt can push intermediaries' safe rate below R^f
    short rate disconnect: Duffee 1997, Lenel-Piazzesi-Schneider 2019

Asset pricing with linear-quadratic holding cost

- **Equilibrium risk exposure** of private intermediaries

$$\boldsymbol{\omega} = \sum_n \beta_n \left(\kappa_n - \rho_n^b \delta \tilde{\kappa}_n \right)$$

  - central bank reduces private holdings of risky capital

- Return premia on bonds

$$l_n^b - \Delta_n + \gamma \rho_n^b \beta_n' \Sigma \omega - \tfrac{1}{2} \gamma \omega' \Sigma \omega$$

  - lower liquidity premia $-\Delta_n$ if central bank eligible, controlling for risk
    yield spreads, bid-ask spreads, repo turnover by eligibility: Todorov 2020, Mota-Papoutsi 2021
  - risk premia exhibit factor structure (similar equation for stocks)
    Fama-French 1993, Elton-Gruber-Blake 1995, Ang 2014, Bai-Bali-Wen 2019
  - central bank reduces exposure $\omega \rightarrow$ reduces *all* premia, including on ineligible bonds,
    more so for riskier firms : Todorov 20, De Santis-Zaghini 21
  - convenience yield on safe debt can push intermediaries' safe rate below R^f
    short rate disconnect: Duffee 1997, Lenel-Piazzesi-Schneider 2019

Asset pricing with linear-quadratic holding cost

- **Equilibrium risk exposure** of private intermediaries

$$\boldsymbol{\omega} = \sum_n \beta_n \left(\kappa_n - \rho_n^b \delta \tilde{\kappa}_n \right)$$

  - ▸ central bank reduces private holdings of risky capital

- Return premia on bonds

$$l_n^b - \Delta_n + \gamma \rho_n^b \beta_n' \Sigma \boldsymbol{\omega} - \tfrac{1}{2} \gamma \boldsymbol{\omega}' \Sigma \boldsymbol{\omega}$$

  - ▸ lower liquidity premia $-\Delta_n$ if central bank eligible, controlling for risk
    yield spreads, bid-ask spreads, repo turnover by eligibility: Todorov 2020, Mota-Papoutsi 2021
  - ▸ risk premia exhibit factor structure (similar equation for stocks)
    Fama-French 1993, Elton-Gruber-Blake 1995, Ang 2014, Bai-Bali-Wen 2019
  - ▸ central bank reduces exposure $\boldsymbol{\omega} \to$ reduces *all* premia, including on ineligible bonds,
    more so for riskier firms : Todorov 20, De Santis-Zaghini 21
  - ▸ convenience yield on safe debt can push intermediaries' safe rate below R^f
    short rate disconnect: Duffee 1997, Lenel-Piazzesi-Schneider 2019

Cost of capital & impact of central bank purchases

- Cost of capital = weighted average of bond & stock returns

$$\frac{\alpha_n \gamma_n}{\kappa_n} \frac{Y}{K} = R^n = R^f \left(1 + \phi^n (l_n^b - \Delta_n) + (1 - \phi^n) l_n^s + \gamma \beta_n' \Sigma \omega - \frac{1}{2} \gamma \omega' \Sigma \omega \right)$$

  - lower liquidity premium $-\Delta_n$ attracts capital to firm n, more so if more bond-levered
  - lower intermediary risk exposures ω shift capital to more risky firms

- Magnitudes: compare aggregate effects versus cross section
  - aggregate MPK depends on average risk premia weighted by market portfolio κ
  - fact: large dispersion of risk premia across firms $\to$ large differences in β_ns
  - $\to$ if lower ω has large aggregate effects, it strongly favors risky firms

- What is a dirty firm?
  - relatively more bond-levered: more tangible assets, cheaper to issue bonds
  - relatively risky: high β_n, especially for climate risk factor (Hsu-Li-Tsou 2020)
  - benefits more from both lower liquidity premia & lower intermediary risk exposure

Market neutrality

- Our definition: market neutral policy does not change relative costs of capital R^n/R^m
  - $\rightarrow$ market neutral policies do not change market portfolio κ
  - ► start from laissez-faire equilibrium with $\delta = 0$
  - ► comparative static to equilibrium with CB purchase program $\delta > 0$

- Is there a market neutral CB portfolio $\tilde{\kappa}$?
  - ► generally no: two key sources of non-neutrality
    1. CB purchases lower liquidity cost on bonds $\rightarrow$ favors more bond-levered firms
    2. CB provides safe debt, lowers private risk exposure in GE $\rightarrow$ favors more risky firms
  - ► when are these effects absent?
    1. segmented markets for private securities & central bank debt (cost h separable)
    2. all firms have same bond-leverage (or CB buys stocks)
  - $\rightarrow$ very special financial system, not in line with data

Market neutrality with linear-quadratic cost

- Suppose firm n issues bonds, firm m does not
  - $\rightarrow$ difference in cost of capital compares liquidity & risk premium
    $$\phi^n l_n^b + (1 - \phi^n) l_n^s - l_m^s + \gamma(\beta_n - \beta_m)' \Sigma \omega$$
  - $\blacktriangleright$ central bank can reduce l_b^n firm-by-firm and reduce ω for everyone
  - $\rightarrow$ existence of neutral portfolio requires "divine coincidence"

- Buying bonds in proportion to outstanding bonds not automatically neutral
  - $\blacktriangleright$ policy rule: $\tilde{\kappa}_n = \phi^n \kappa_n / \sum_n \phi^n \kappa_n$
    - reduces liquidity premium for all bond issuers, favors more bond-levered firms
    - reduces risk exposure and therefore risk premium, favors more risky firms
  - $\blacktriangleright$ Is the ECB's current portfolio market neutral?
    - qualitatively, could have offsetting effects if safer firms lever more
    - quantitative studies suggest risk > liquidity effects *for cost of capital*
    - with climate risk factor, dirty firms more risky *and* more levered

Optimal policy

- Social planner chooses carbon tax + asset purchase program
  - ▸ "principle of targeting": carbon tax fixes externality
  - ▸ purchase program addresses financial frictions, not climate externality

- Optimal government portfolio $\tilde{\kappa}$ with & without climate externalities

$$\underset{\substack{\text{marginal private}\\ \text{holding cost}\\ \text{of firm } n \text{ capital}}}{MC_n} = \underset{\substack{\text{marginal government}\\ \text{holding cost}\\ \text{of firm } n \text{ bonds}}}{\frac{\partial \tilde{h}}{\partial \tilde{b}}} + \underset{\substack{\text{marginal private}\\ \text{holding cost}\\ \text{of CB purchases}}}{\frac{\partial h}{\partial d} + \frac{\partial h}{\partial \tilde{b}}}$$

  carbon tax changes capital allocation, affects purchase program

- Optimal policy depends on government holding cost
  - ▸ linear-quadratic example with same holding costs for CB & private intermediaries
  - → CB lowers premia for risky firms more, optimal policy typically not neutral!
  - ▸ optimal size of CB trades off risk reduction & holding cost of its debt

Endogenous leverage

- Tradeoff theory of capital structure
  - bonds cheaper to hold than equity + loans for given risk: $l^b < l^s$
  - bonds increase cost of risk taking: function β_n increasing in ϕ
  - optimal leverage balances the two effects
- Effect of central bank purchases
  - risk reduction encourages additional leverage
  - shift from stocks + loans to bonds, but also increase in stocks + loans
  - same results on neutrality (change in cost of capital through leverage is 2nd order)
- Optimal policy
  - planner chooses optimal leverage together with purchase program
  - encouraging *some* leverage is optimal!

Conclusion

- ECB portfolio $\approx$ sector shares of emissions $\neq$ market portfolio
  - ECB overweighs dirty sectors firms relative to market portfolio

- Market neutrality
  - should be defined as same relative costs of capital,
    otherwise purchase program distorts market portfolio
  - holding bonds in proportion to outstandings not a simple recipe for neutrality,
    instead ECB currently favors relatively risky and bond-levered firms

- With carbon tax, optimal purchases address financial frictions
  $\rightarrow$ policy should favor risky firms

- Without carbon tax, greener investment beneficial