# Welfare consequences of sustainable finance

Hong et al. (2023)

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Env.Climate

# Introduction

- This paper studies the welfare consequences of investment mandates in sustainable finance
  - Mandate raises the cost of capital for unsustainable, incentivizing them to reform
  - Mitigation investment reduces the risk of climate change, benefiting production and households
  - Mitigation investment reduces consumption, which is costly to households
  - We do not know whether mandate helps or hurts welfare
- This paper theoretically studies the welfare effects of sustainable finance

# Model

- Climate state: $\mathcal{S} \in \{\mathcal{G}, \mathcal{B}\}$ with transition $Pr(\mathcal{B}|\mathcal{G}) = \zeta_t$ and $Pr(\mathcal{B}|\mathcal{B}) = 1$
  - $\zeta_t = \zeta(n_t; \mathcal{G})$ decreasing and convex in $n_t$

Firm side:

- Firm has two types of capital: productive $K_t$ and decarbonization $N_t$
  - Path of $K_t$: $\frac{dK_t}{K_{t-}} = \phi(\frac{I_{t-}}{K_{t-}})dt + \sigma d\mathcal{W}_t - (1-Z)d\mathcal{J}_t$
  - Path of $N_t$: $\frac{dN_t}{N_{t-}} = \omega(\frac{X_{t-}}{N_{t-}})dt + \sigma d\mathcal{W}_t - (1-Z)d\mathcal{J}_t$
  - Disaster rates $\lambda_t^{\mathcal{G}} = \lambda(n_t; \mathcal{G})$ and $\lambda_t^{\mathcal{B}} = \lambda(n_t; \mathcal{B})$ decreasing and convex in $n_t$
- Firm's production function: $Y_t = AK_t$
- Firm generates and removes carbon emissions by $K_t$ and $N_t$
  - emission generation: $E_t = eK_t$
  - emission removal: $R_t = \varrho N_t$
- Decarbonization-productive capital ratio: $n_t = \frac{N_t}{K_t}$
  - $n_t$ evolves as $\frac{dn_t}{n_{t-}} = [\omega(\frac{X_{t-}}{N_{t-}}) - \phi(\frac{I_{t-}}{K_{t-}})]dt$
- Sustainable firm: $X_t \geq m_t K_t$

# Model

Household side:

- Investment mandate: $Q_t^S \geq \alpha Q_t = \alpha(Q_t^S + Q_t^U)$
- Epstein-Zin utility: $V_t = \mathbb{E}_t \left[\int_t^\infty f(C_s, V_s) ds\right]$

**Market clearing conditions**

- Household demand for S portfolio equals the total supply by firms choosing to be sustainable
- Household demand for U portfolio equals the total supply by firms choosing to be unsustainable
- Net supply of risk-free asset is zero
- $Y_t = I_t + X_t + C_t$

# Model Solution

Market equilibrium without mandate

- Under-provision of decarbonization capital.
  - Firm $i$ pays for the investment cost of $X_t$
  - All firms enjoy the benefits of climate risk reduction
  - Externality makes $X_t$ under-provided

# Model Solution

Market equilibrium with mandate, given $m(n;\mathcal{S})$ and $\alpha$:

- All firms have the same Tobin's Q

$$q^S(n;\mathcal{S}) = q^U(n;\mathcal{S})$$

- All firms have the same investment-capital ratio

$$i^S(n;\mathcal{S}) = i^U(n;\mathcal{S})$$

- The investment-q equation holds for all firms:

$$q(n;\mathcal{S}) = \frac{1}{\phi'(i(n;\mathcal{S}))}$$

- Cash flow wedge equals mitigation spending

$$cf^S(n;\mathcal{S}) - cf^U(n;\mathcal{S}) = m(n;\mathcal{S})$$

where $cf^U(n;\mathcal{S}) = A - i(n;\mathcal{S})$

# Model Solution

Market equilibrium with mandate, given $m(n;\mathcal{S})$ and $\alpha$:

- The required rate of return for sustainable firms lowers down

$$r^U(n;\mathcal{S}) - r^S(n;\mathcal{S}) = \frac{m(n;\mathcal{S})}{q(n;\mathcal{S})}$$

- Aggregate consumption equals aggregate dividends

$$c(n;\mathcal{S}) = cf(n;\mathcal{S}) = A - i(n;\mathcal{S}) - x(n;\mathcal{S})$$

$m(n;\mathcal{S})$ can be endogenized. Steady state can be achieved for given $\alpha$.

# Model Solution

Market equilibrium with mandate when $m(n;\mathcal{S})$ is endogenized, given $\alpha$.

The FOCs for $i(n;\mathcal{S})$ and $x(n;\mathcal{S})$ are

$$\rho\left(\frac{A-\mathbf{i}(\mathbf{n};\mathcal{S})-\mathbf{x}(\mathbf{n};\mathcal{S})}{b(\mathbf{n};\mathcal{S})}\right)^{-\psi^{-1}} = \phi'(\mathbf{i}(\mathbf{n};\mathcal{S}))b(\mathbf{n};\mathcal{S}) \quad (1)$$

$$\rho\left(\frac{A-\mathbf{i}(\mathbf{n};\mathcal{S})-\mathbf{x}(\mathbf{n};\mathcal{S})}{b(\mathbf{n};\mathcal{S})}\right)^{-\psi^{-1}} = \omega'(\mathbf{x}(\mathbf{n};\mathcal{S})/\mathbf{n})b'(\mathbf{n};\mathcal{S}) \quad (2)$$

where $b(n;\mathcal{S}) = u(n;\mathcal{S}) \times q(n;\mathcal{S})$ is the welfare measure.

# Fist-Best Solution

When the planner can choose $(\boldsymbol{C}, \boldsymbol{I}, \boldsymbol{X})$ to maximize agents' welfare, the FOCs for $i(n;\mathcal{S})$ and $x(n;\mathcal{S})$ are

$$\rho\left(\frac{A-\mathbf{i}(\mathbf{n};\mathcal{S})-\mathbf{x}(\mathbf{n};\mathcal{S})}{b(\mathbf{n};\mathcal{S})}\right)^{-\psi^{-1}} + \phi'(\mathbf{i}(\mathbf{n};\mathcal{S}))\mathbf{n}b'(\mathbf{n};\mathcal{S}) = \phi'(\mathbf{i}(\mathbf{n};\mathcal{S}))b(\mathbf{n};\mathcal{S}) \tag{3}$$

$$\rho\left(\frac{A-\mathbf{i}(\mathbf{n};\mathcal{S})-\mathbf{x}(\mathbf{n};\mathcal{S})}{b(\mathbf{n};\mathcal{S})}\right)^{-\psi^{-1}} = \omega'(\mathbf{x}(\mathbf{n};\mathcal{S})/\mathbf{n})b'(\mathbf{n};\mathcal{S}) \tag{4}$$

where $b(n;\mathcal{S}) = u(n;\mathcal{S}) \times q(n;\mathcal{S})$ is the welfare measure.

# Welfare-Maximizing Mandate vs. First-Best

Welfare-Maximizing Mandate does **NOT** attain the first-best.

Why over-investment of $i(n; \mathcal{S})$?

- Increasing $I$ has two effects in planner's problem
  1. direct effect of reducing consumption
  2. indirect effect of reducing long-term decarbonization capital ratio $n = N/K$
- Investment $I$ is costlier in the planner's problem due to the indirect effect

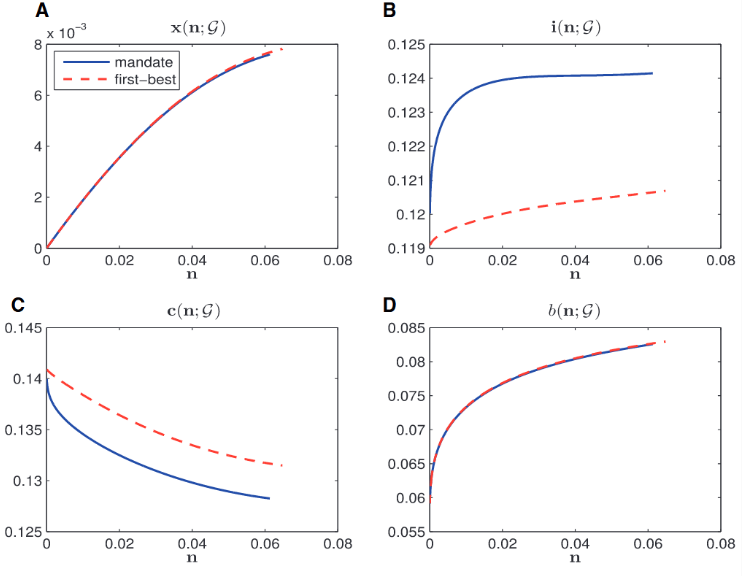
$\Rightarrow$ Over-investment in $I$ in the welfare-maximizing mandate.

To achieved the first-best, an additional tax on $I$ is needed.

# Calibration

| Parameters | Symbol | Value |
|---|---|---|
| Elasticity of intertemporal substitution | $\psi$ | 1.5 |
| Time rate of preference | $\rho$ | 4.2% |
| Coefficient of relative risk aversion | $\gamma$ | 8 |
| Productivity for $K$ | $A$ | 26% |
| Adjustment cost parameter for $K$ | $\eta_K$ | 5 |
| Adjustment cost parameter for $\mathbf{N}$ | $\eta_{\mathbf{N}}$ | 5 |
| Diffusion volatility for $\mathbf{N}$ and $K$ | $\sigma$ | 9% |
| Depreciation rates for $\mathbf{N}$ and $K$ | $\delta_K = \delta_{\mathbf{N}}$ | 6% |
| Jump arrival baseline parameter from state $\mathcal{G}$ to $\mathcal{B}$ | $\zeta_0$ | 0.02 |
| Jump arrival sensitivity parameter from state $\mathcal{G}$ to $\mathcal{B}$ | $\zeta_1$ | 0.1 |
| Power-law exponent | $\beta$ | 39 |
| Jump arrival baseline parameter with $\mathbf{n}=0$ in state $\mathcal{G}$ | $\lambda_0^{\mathcal{G}}$ | 0.05 |
| Jump arrival baseline parameter with $\mathbf{n}=0$ in state $\mathcal{B}$ | $\lambda_0^{\mathcal{B}}$ | 2 |
| Mitigation technology parameter | $\lambda_1$ | 0.3 |

# Laissez-faire vs. Welfare-Maximizing Mandate vs. First-Best



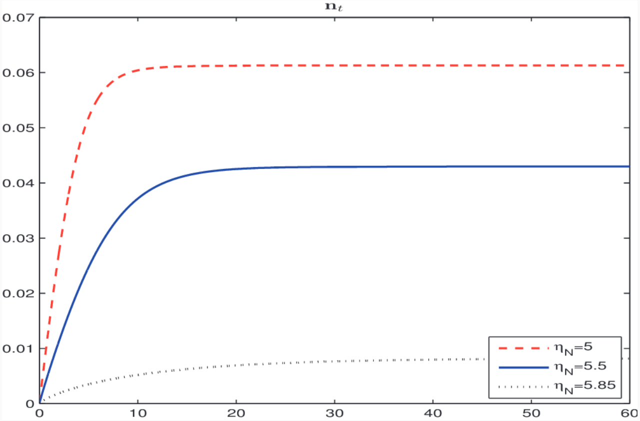
# Laissez-faire vs. Welfare-Maximizing Mandate vs. First-Best

| | | Laissez-faire | Mandate | First-best |
|---|---|---|---|---|
| Scaled mitigation spending | $\mathbf{x}^{ss}$ | 0 | 0.76% | 0.78% |
| Scaled decarbonization stock | $\mathbf{n}^{ss}$ | 0 | 6.13% | 6.48% |
| Scaled aggregate investment | $\mathbf{i}^{ss}$ | 11.83% | 12.41% | 12.07% |
| Average Tobin's q | $\mathbf{q}^{ss}$ | 2.45 | 2.64 | 2.52 |
| Scaled aggregate consumption | $\mathbf{c}^{ss}$ | 14.17% | 12.82% | 13.15% |
| Expected GDP growth rate | $\mathbf{g}^{ss}$ | 2.04% | 2.44% | 2.30% |
| (Real) risk-free rate | $r^{f,ss}$ | 1.10% | 0.73% | 0.91% |
| Stock market risk premium | $rp^{ss}$ | 6.73% | 6.58% | 6.60% |
| Aggregate welfare measure | $b^{ss}$ | 0.0542 | 0.0826 | 0.0830 |
| Time from $\mathbf{n}$=0 to 0.99$\mathbf{n}^{ss}$ in $\mathcal{G}$ | | 0 | 10.9 | 10.0 |

The steady-state value of $\mathbf{n}$ in state $\mathcal{G}$ is $\mathbf{n}^{ss}$=0.0613.

Welfare-maximizing mandate alone well approximates the first-best outcomes.

# Transition to Steady State




Optimal transition path is highly sensitive to the relative adjustment costs of decarbonization to productive capital.

# Conclusion

- The required return for sustainable firms is lower than that for unsustainable firms
- Welfare-maximizing mandate well approximates the first-best outcomes quantitatively
  - Mandate makes over-investment in productive capital and under-consumption
  - An investment tax makes first-best outcomes achievable
- Transition path is highly sensitive to the adjustment costs of decarbonization capital

# References

Hong, H., N. Wang, and J. Yang (2023). Welfare consequences of sustainable finance. *The Review of Financial Studies 36*(12), 4864–4918.