The Impact of Innovation Finance on Achieving Sustainable Growth Globally

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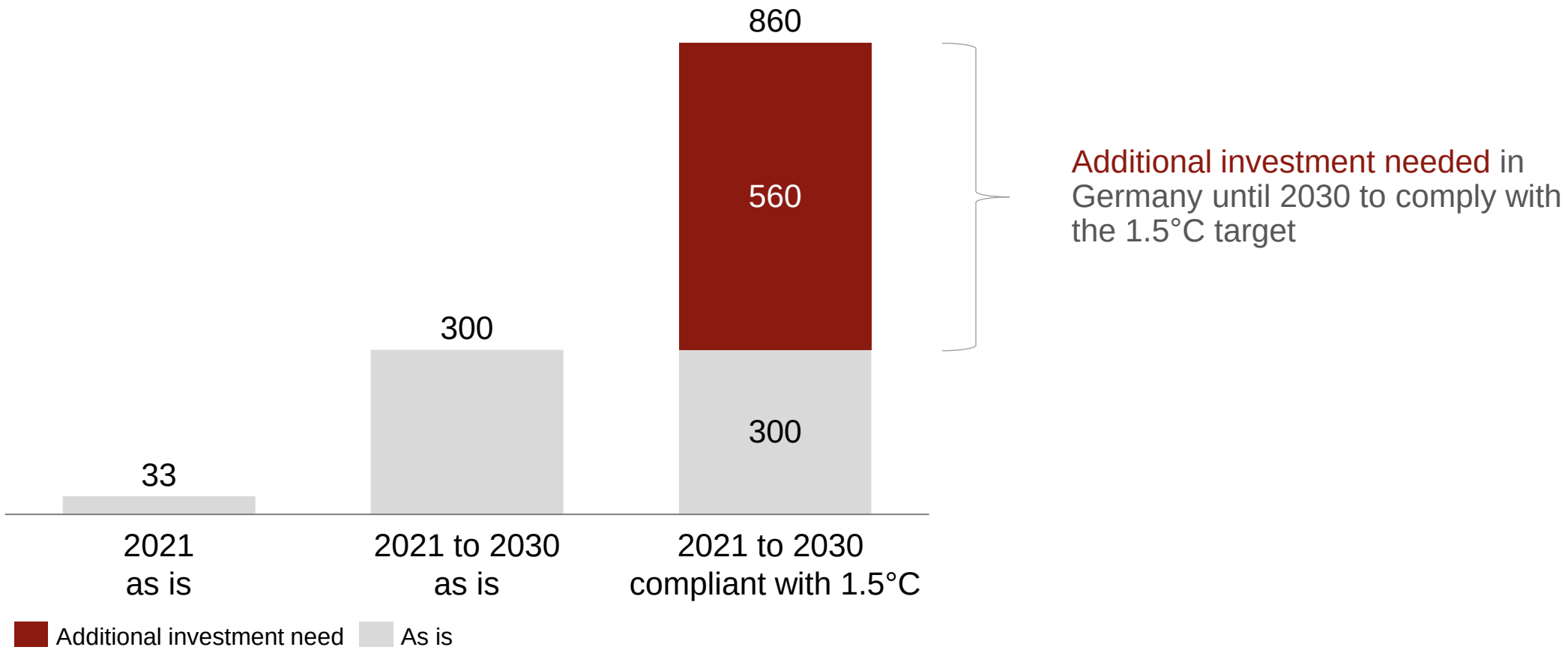
To Achieve Climate Targets, Considerable Increase in Investments Necessary

Investments and Investment Requirements to Achieve the 1.5°C Target in Germany
in bn €



Additional investment needed in Germany until 2030 to comply with the 1.5°C target

Source: BCG (2021)

Capital for Investments to be Provided by Companies and Financial Intermediaries

Four Types of Investors to Provide Capital

	Public	Private
Real economy	Public companies	Private companies
Financial economy	Public financial intermediaries	Private financial intermediaries

Investors' Decisions and Questions

i. Invest or provide capital yes or no?

ii. Invest or provide capital for 'green' or 'brown' investments?

iii. Which type of finance to provide?

iv. How do policy / regulatory instruments change this?

Our focus

Source: Own representation

Agenda

- Aim and Scope
- Related Literature and Our Contribution
- The Model Structure
- Model Results
- Discussion

Three Goals of our Research

Market failure

1. Show that different types of financing frictions have an impact on the achievement of sustainable growth globally

2. Demonstrate the effect of different policy and regulatory instruments

3. Account for the dynamics between developed and developing economies

Methodological Approach

- Continuous-time macroeconomic growth model of directed technical change
- Groups of follower and leader countries, representing the developed world ('global North') and developing world ('global South')
- Four types of different investors (public, private, real, financial)
- Debt or equity finance
- Endogenous decision for (a) amount of 'green' and 'brown' finance, (b) type of finance
- Financing frictions
- Policy and regulatory instruments

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Three Related Strands of Literature—our Contribution at the Sustainability-related Intersection of the Real and the Financial Economy

Related Literature	Literature Sub-strand	(I) Sustainability-unrelated	(II) Sustainability-related
A Real economy: endogenous growth and innovation	A.1 Growth, innovation & technological diffusion	Endogenous innovation and technology diffusion as explanation for growth (e.g., Romer, Barro and Sala-i-Martin)	Green growth models, incorp. environmental externalities (e.g., Nordhaus, Popp)
	A.2 Directed technical change	Directed technical change (e.g., Aghion, Acemoglu)	Models of directed technical change including 'clean' and 'dirty' sectors (e.g., Acemoglu)
	A.3 Climate policy and sector-specific models	N/A	Climate models to assess the impact of environmental policies or sector-specific models to assess, e.g., the energy transition
B Financial economy: innovation finance and optimal capital structure	B.1 Optimal capital structure decisions and private innovation financing	Capital structure decisions: choice between debt, equity, other financing options (e.g., Modigliani & Miller, Straebulaev & Whited)	Adequate financing of sustainable innovation, often in the context of the energy transition (e.g., Egli, Polzin)
	B.2 Public-private innovation finance	The role of the public sector in innovation and innovation finance	Financing innovation with non-profit goals: 'mission-oriented' R&D, PPP, innovative financing instruments
C Real and financial economy: impact of financing on real economy	C.1 Finance in innovation and technological diffusion & in the energy transition	The impact of dynamics in the financial sector on real economy outcomes, e.g., regarding innovation activity and direction	☆ ■ The impact of dynamics in the financial sector on green growth & the achievement of climate goals ■ Sector-specific models incorporating the financial economy, e.g., E3 models incorporating a financial sector

Note: PPP = public-private partnerships. ☆ Field of our contribution

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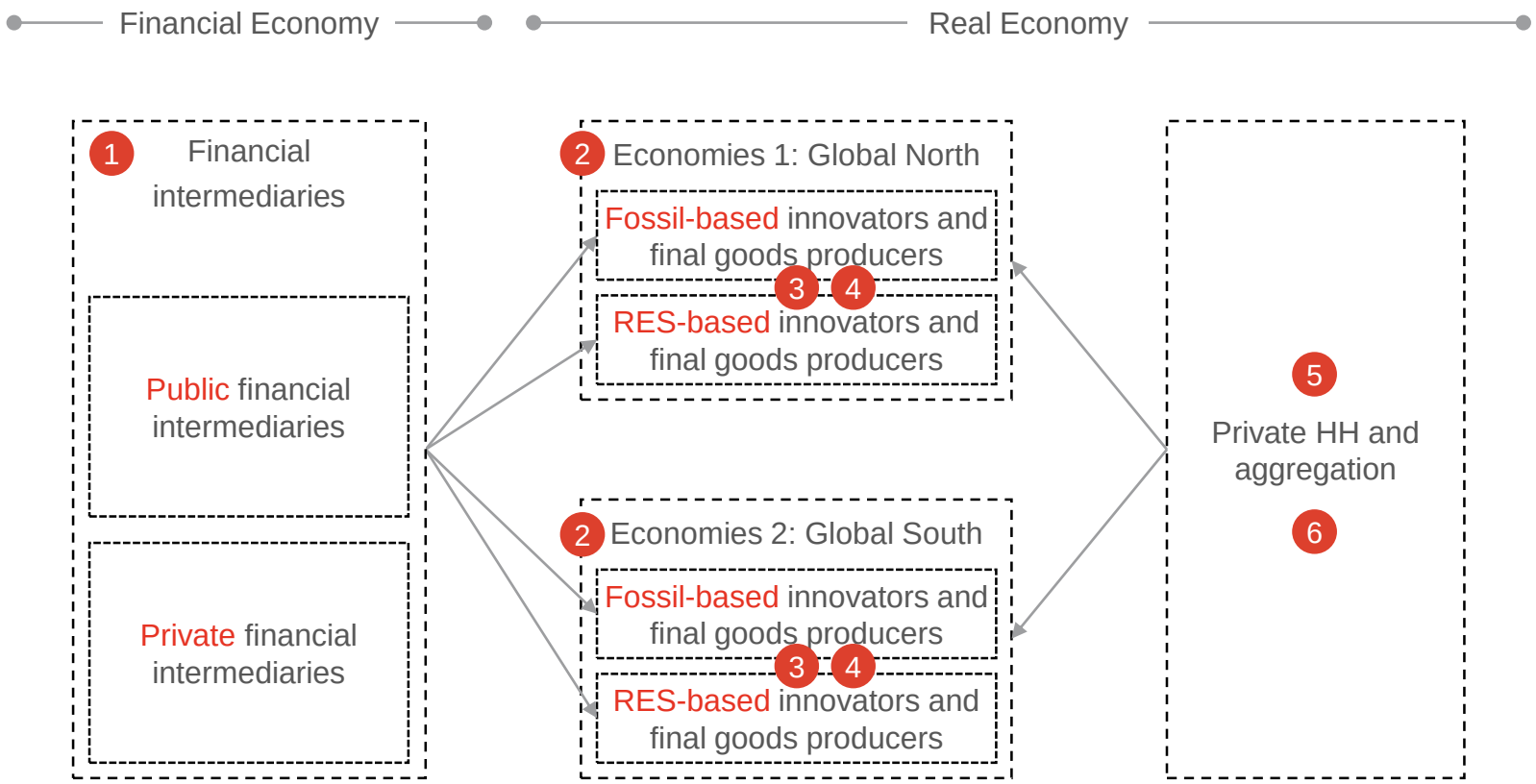
We Build a Model of Directed Technical Change with a Group of Leader and Follower Countries and an Endogenous Private and Public Financing Decision

The Model Structure



Comments

1. Financial intermediaries endogenously decide to which innovation to provide funding
2. Two groups of economies: leader countries ('global North') and follower countries ('global South')
3. In both economies: fossil-based and RES-based innovation possible (endogenous decision)
4. In both economies: innovation and imitation possible (endogenous decision)
5. Private HH of both economies make a consumption decision maximizing their utility
6. Overall budget constrained by the economies' total available resources

- Continuous time model
- Growth is based on variants

Note: HH = households. RES = renewable energy sources.

1 Deep Dive | Financing Decisions of Private and Public Financial Intermediaries Endogenously Determined at Each Point in Time

Private financial intermediaries

- Private financial intermediaries max. shareholder value
- Two types of securities: private debt and equity

Price of debt, depending, inter alia, on leverage

Price of debt, purely market based

Number of securities issued

$$\max_{a^d_{r,i},a^e_{r,i},a^d_{f,i},a^e_{f,i}} \left[R^d_{f,i}\left(a^d_{f,i},a^{pd}_{f,i}\right) - v^d_{f,i}\right] a^d_{f,i} + \left[R^e_{f,i}\left(a^d_{f,i},a^{pe}_{f,i},a^{pd}_{f,i}\right) - v^e_{f,i}\right] a^e_{f,i} + \left[R^d_{r,i}\left(a^d_{r,i},a^{pd}_{r,i}\right) - v^d_{r,i}\right] a^d_{r,i} + \left[R^e_{r,i}\left(a^d_{r,i},a^{pe}_{r,i},a^{pd}_{r,i}\right) - v^e_{r,i}\right] a^e_{r,i} - h_i\left(a^d_{f,i},a^e_{f,i},a^d_{r,i},a^e_{r,i}\right)$$

Holding costs

- Financiers' decision influences innovators' financing costs $\varphi^d_{k,i}$ and, thus, their demand for financing options

$$\varphi^d_{k,i} = a^d_{k,i} \frac{1}{\iota^d_{k,i}} \left(1 - \tau^d_{r,i}\right) \left[R^d_{f,i}\left(a^d_{f,i},a^{pd}_{f,i}\right) - v^d_{f,i}\right]$$

Exemplary for private debt

Public financial intermediaries

- Public financial intermediaries maximize stakeholder value
- Two types of securities: public debt and equity

Internal carbon price

$$\max_{a^{pd}_{r,i},a^{pe}_{r,i},a^{pd}_{f,i},a^{pe}_{f,i}} \left[R^{pd}_{f,i}\left(a^d_{f,i},a^{pd}_{f,i}\right) - v^{pd}_{f,i} - p^{CO2}_i\right] a^{pd}_{f,i} + \left[R^{pe}_{f,i}\left(a^d_{f,i},a^e_{f,i},a^{pd}_{f,i}\right) - v^{pe}_{f,i} - p^{CO2}_i\right] a^{pe}_{f,i} + \left[R^{pd}_{r,i}\left(a^d_{r,i},a^{pd}_{r,i}\right) - v^{pd}_{r,i}\right] a^{pd}_{r,i} + \left[R^{pe}_{r,i}\left(a^d_{r,i},a^e_{r,i},a^{pd}_{r,i}\right) - v^{pe}_{r,i}\right] a^{pe}_{r,i} - h^p_i\left(a^{pd}_{f,i},a^{pe}_{f,i},a^{pd}_{r,i},a^{pe}_{r,i}\right)$$

- Influence of innovators' financing costs analogous

Note: RES = renewable energy sources.

2 Deep Dive | Fossil- and RES-based Innovators Minimize Financing Costs and Maximize Revenues from Innovation and Imitation

Fossil- and RES-based innovators

- Innovators face financing costs as described

Exemplary for private debt

$$\varphi_{k,i}^{d} = a_{k,i}^{d} \frac{1}{\iota_{k,i}^{d}} \left(1 - \tau_{r,i}^{d}\right) \left[R_{f,i}^{d}\left(a_{f,i}^{d}, a_{f,i}^{pd}\right) - v_{f,i}^{d}\right]$$

- Aggregation: total financing costs

$$\varphi_{k,i}^{fin} = \varphi_{k,i}^{d} + \varphi_{k,i}^{e} + \varphi_{k,i}^{pd} + \varphi_{k,i}^{pe}$$

Costs for private equity

Costs for public debt

Costs for public equity

- Financing costs one influencing factor to innovation activity
- Innovators minimize financing costs

$$\min_{a_{k,ij}^{d}, a_{k,ij}^{e}, a_{k,ij}^{pd}, a_{k,ij}^{pe}} \varphi_{k,i}^{fin}$$

- s.t.

Innovation and imitation activity

$$\left[\left(\frac{N_{k,2}}{N_{k,1}}\right)^{-\sigma} - \left(\frac{N_{k,2}}{N_{k,1}}\right)^{\frac{b}{2}-\sigma} + \left(\frac{N_{k,2}}{N_{k,1}}\right)^{\frac{b}{2}}\right] \left(\eta_{k,i}^{R\&D} + \varphi_{k,ij}^{fin}\right) = Y_{k,i} p_{k,i} + \sum_{s \in S} a_{k,i}^{s} v_{k,i}^{s}$$

Internal financing

External financing

R&D costs

Aggregation

- Overall budget constraint

Total output

$$\left[\gamma Y_{r,i}^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma) Y_{f,i}^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} = C_i + x_{r,i} N_{r,i} + x_{f,i} N_{f,i} + e_{r,i} \dot{N}_{r,i} + e_{f,i} \dot{N}_{f,i}$$

Consumption

Production of intermediate goods

Innovation and imitation

Note: RES = renewable energy sources.

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We Investigate a Benchmarking Scenario plus Five Different Scenarios to Assess the Impact of Financial Frictions and of Regulation and Policy Instruments—Exemplary

Scenarios 0 to II—Impact of Financial Frictions

0 Benchmark

- No financing costs
- Scenario for basic functioning of the model

I Initial State

- Financing costs
- Negligible financial frictions

II Financial Frictions

- Tax shield on private debt
- Information asymmetries & moral hazard
- Flotation and holding costs

Scenarios III to V—Regulation and Policy Instruments

III Green Public Financiers

- Green public financial intermediaries
- Development aid

IV Green Financial Regulation

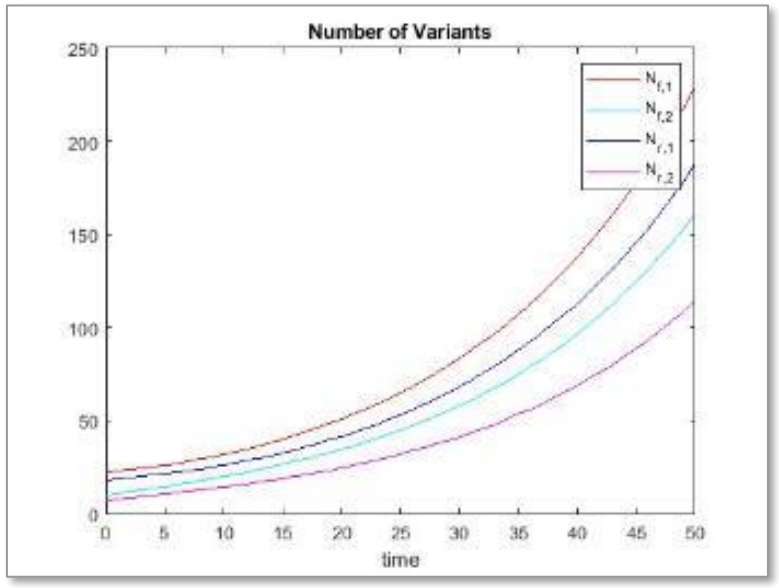
- Green regulation of private financial intermediaries
- Risk-shifting to governments

V Elevated Carbon Price

- Elevated carbon prices with different developments over time

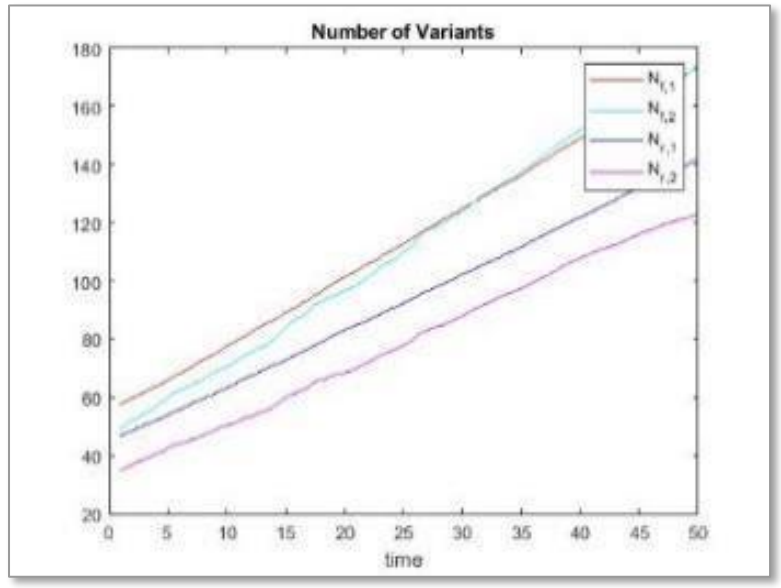
Benchmark vs. Initial State with Financing Costs—Financing Costs Curb the Number of Variants and, thus, Growth

0 Benchmark



- No financing costs (manually set to 0)
- No financial frictions, i.e., no inefficiencies in capital markets
- Both groups of economies with the same characteristics
- Scenario for comparison

I Initial State—Financing Costs



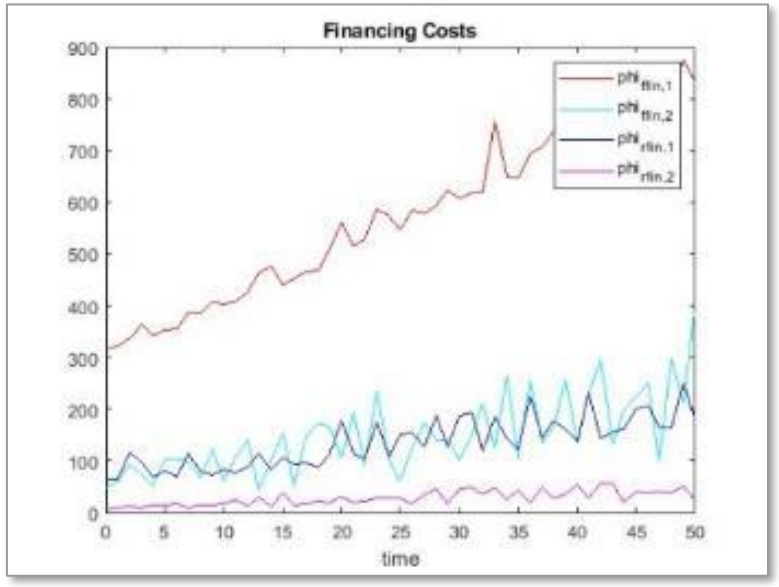
- Introduction of financing costs
- Negligible financial frictions, i.e., negligible inefficiencies in capital markets
- Moderating effect on the total number of variants and, hence, economic growth
- Comparable impact on fossil- and RES-based sectors

Deep dive on next page

Note: RES = renewable energy sources.

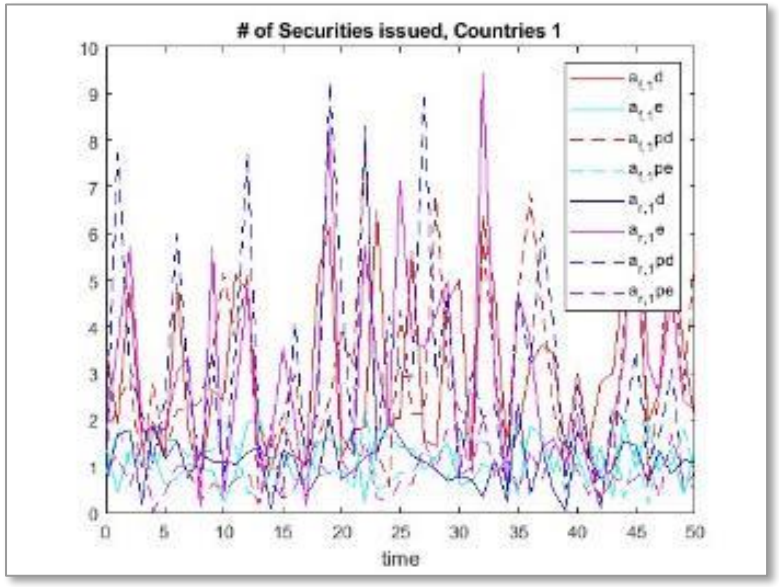
Deep Dive | Initial State—Financing Costs: Highest Number of Securities Issued for Fossil-based Innovation, Financing Structure Reflects Particularities of RES Financing

Cumulated Financing Costs



- Cumulated financing costs = Financing costs * number of securities issued
- Cumulated financing costs highest for fossil innovation and imitation in countries 1
  - Developments in line with variant growth: highest increase in fossil variants in economies 1

Number of Securities Issued

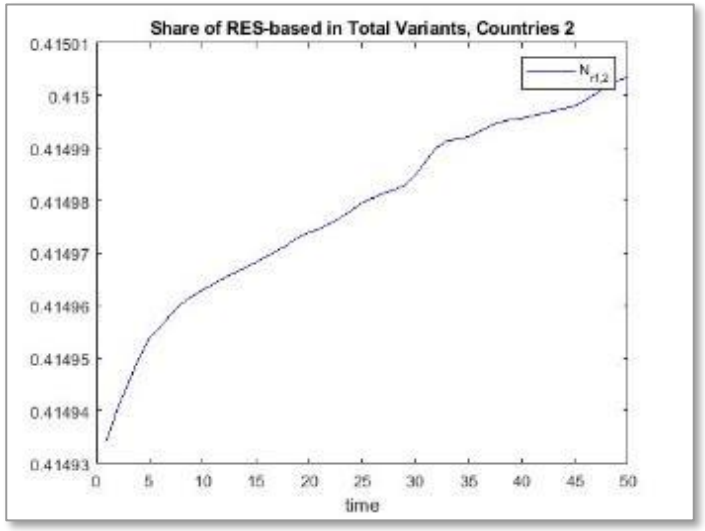


- Within the fossil sector, preference for private debt finance
  - This is in line with pecking order theory
- Within the RES-based sector, higher volumes of equity and public debt finance
  - This reflects limitations in the bankability of RES-related innovation due to, e.g., a lack of collateral

Note: RES = renewable energy sources.

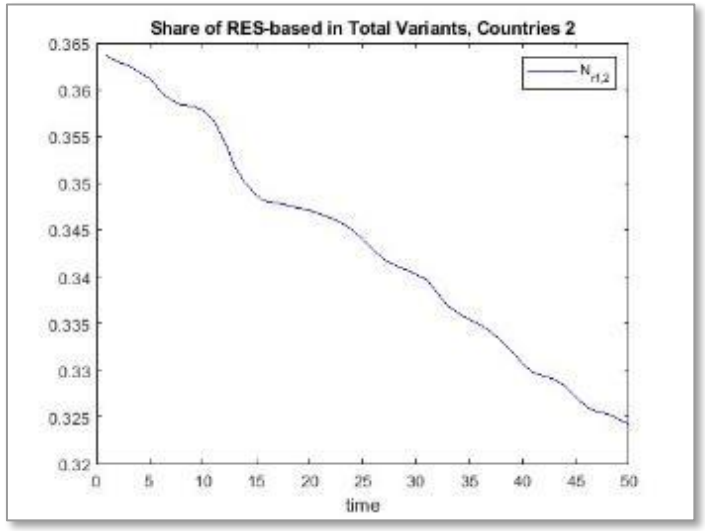
II Initial State with Financing Costs vs. Financial Frictions—Financial Frictions Lead the Economy to a Fossil-based Growth Path

I Initial State



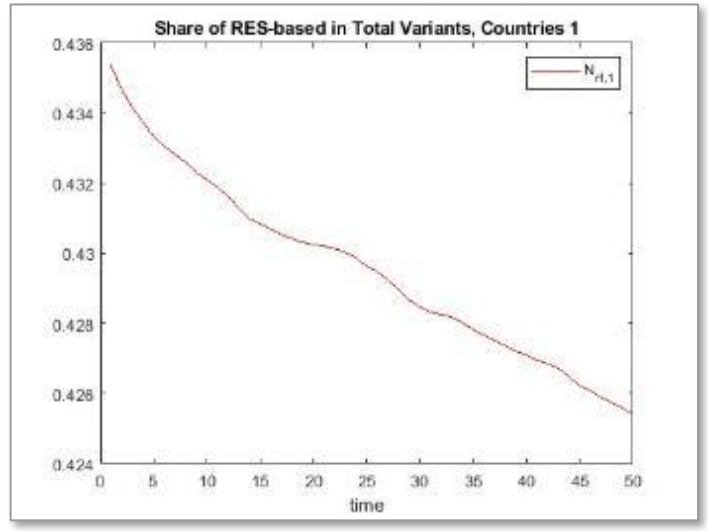
- Without financial frictions, share of RES-based variants increasing
- However, share of RES-based variants strives against a limit
- Hence, partially RES-based, partially fossil-based growth in the long run

II.1 Inefficient RES Investment, E2



- Frictions in the financing of RES-based innovation in economies
- Share of RES-based variants decreasing in economies 2
  - Hence, fossil-based growth in the long run in economies 2
  - Economies 1 still partially fossil-, partially RES-based growth)

II.2 Inefficient RES Investment

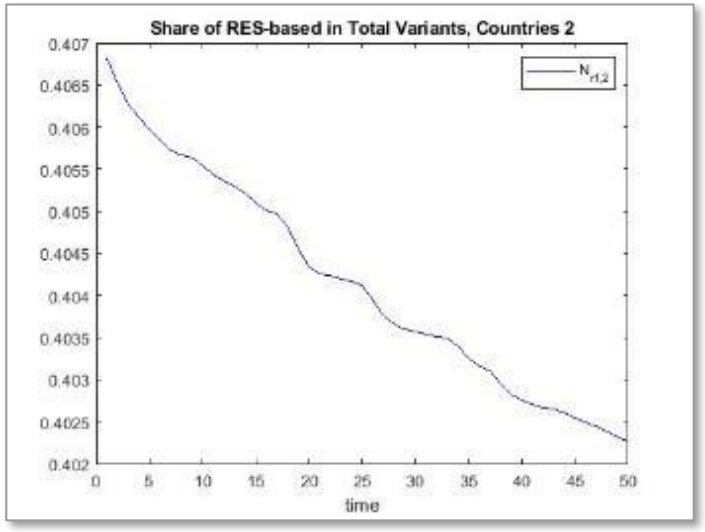


- Frictions in the financing of RES-based innovation in both economies
- Share of RES-based variants decreasing in both economies
  - Hence, fossil-based growth in the long run in both economies

Note: E1 = economies 1. E2 = economies 2. RES = renewable energy sources.

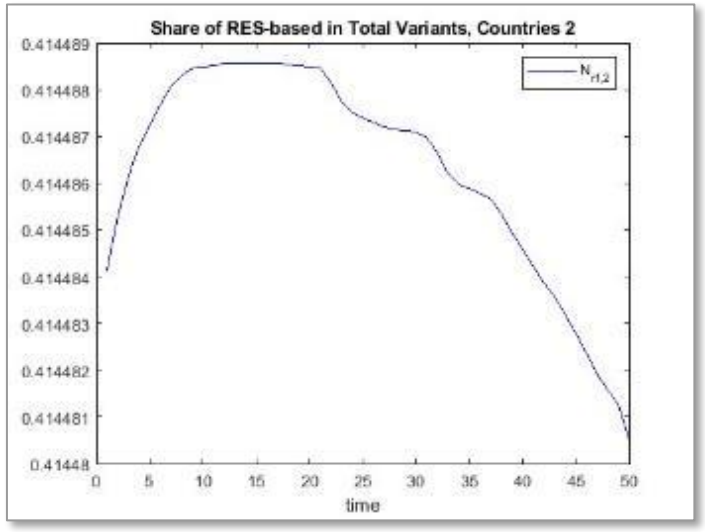
III Green Public Financiers—Green Public Financial Intermediaries Insufficient to Incentivize RES-based Growth in the Long Run

III.1 Internal Carbon Price



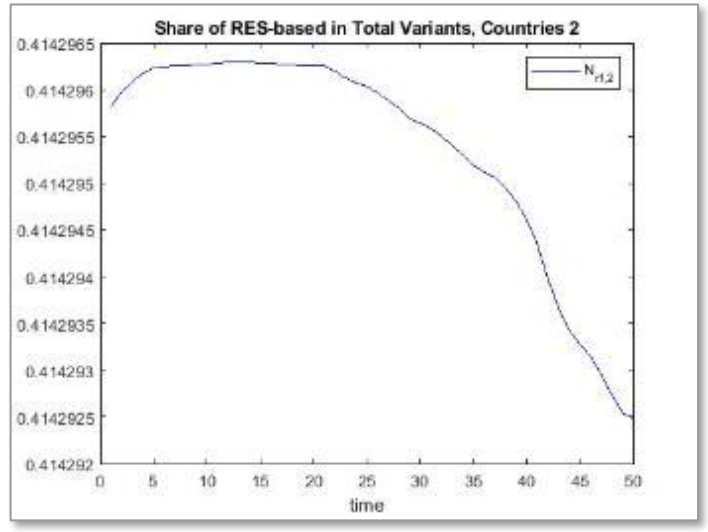
- Frictions in the financing of RES-based innovation in both economies
- Internal carbon price set by public financial intermediaries
- Even in the case of high internal carbon price, no incentivation of RES-based growth

III.2 Improved Financing Conditions



- Frictions in the financing of RES-based innovation in both economies
- Improved financing conditions of RES-based innovation provided by public financial intermediaries
- Initial growth of RES-based variants, however, no incentivation of RES-based growth in the long run

III.3 International Development

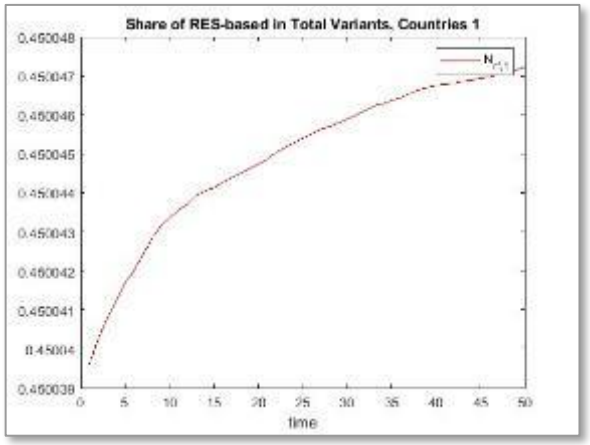


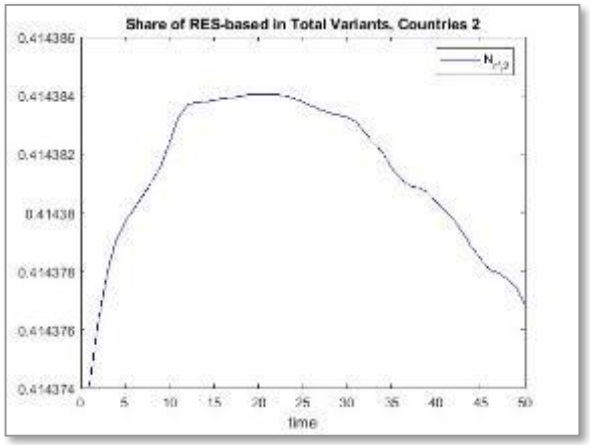
- Frictions in the financing of RES-based innovation in both economies
- International development leading to a reduction of inefficiencies in the capital markets (e.g., moral hazard)
- Initial growth of RES-based variants, however, no incentivization of RES-based growth in the long run

Note: RES = renewable energy sources.

IV Green Financial Regulation—Green Regulation of Private Financial Intermediaries can Incentivize RES-based Growth, However, not Stable

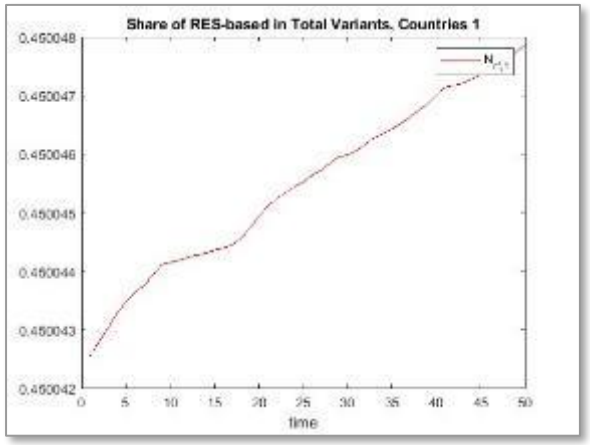
IV.1 Green Obligations

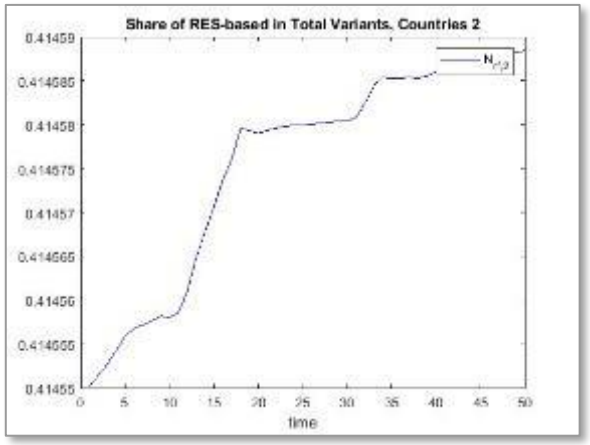




- Regulatory obligations lead to a partially RES-based growth path in the long run in the economies 1 ('global North')
- In the economies 2 ('global South'), green obligations not sufficient in the long run
  - This is due to an assumed lower institutional efficiency in the global South

IV.2 Risk Shifting to Public Sector



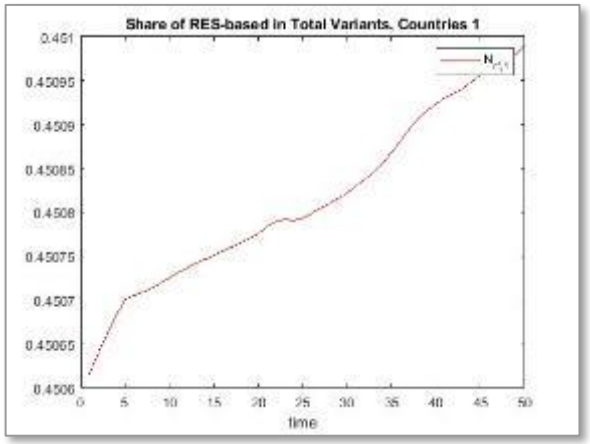


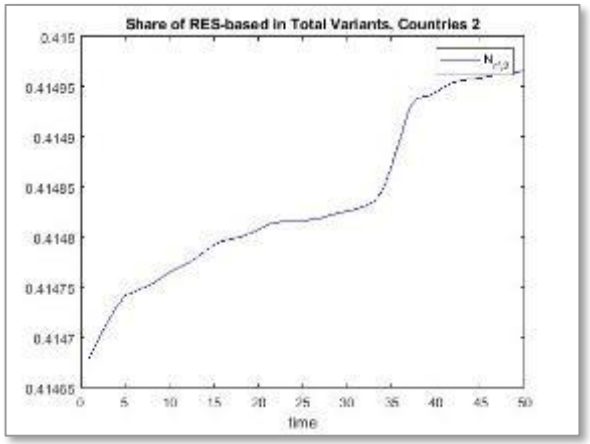
- Risk shifting from private financial intermediaries to the public sector can incentivize a RES-based growth path
- However, high costs induced for the public sector, especially in the economies 1 ('global North')

Note: RES = renewable energy sources.

V Carbon Price—A Sufficiently High Carbon Price with an Extensive Coverage Well-suited to Incentivize RES-based Growth

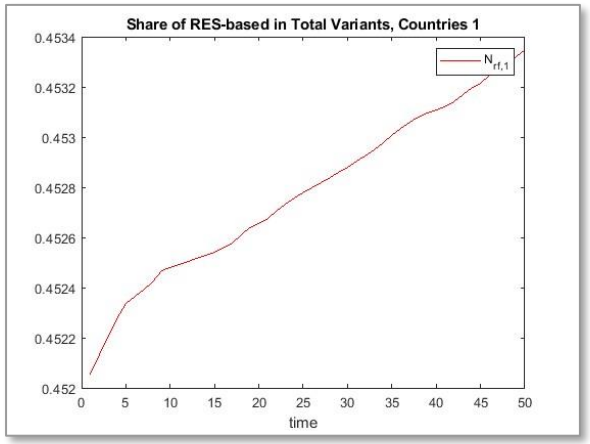
V.1 Degressively Increasing Carbon Price

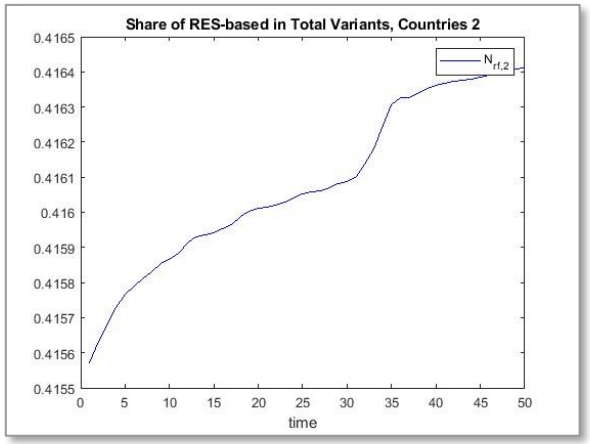




- A sufficiently high carbon tax can incentivize a RES-based growth in the long run
- Precondition is a wide coverage of emissions
- Here: degressively increasing carbon tax in both groups of economies

V.2 Decreasing Carbon Price





- A sufficiently high carbon tax can incentivize a RES-based growth in the long run
- Precondition is a wide coverage of emissions
- Here: decreasing carbon tax in both groups of economies

Note: RES = renewable energy sources.

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First Results Indicate Need to Address Frictions in the Financing of RES-based Innovation to achieve Sustainable Growth in the Long Run

Conclusions

- In the absence of financing frictions, a partially RES-based growth path is reached in the long run in a stylized economy reflecting current framework conditions
- Frictions in the financing of RES-based innovation can lead the global economy to a growth path relying on fossil-based innovation
- Therefore, it is essential to take into account financial frictions in growth models of directed technical change
- Different regulatory and policy instruments can be put in place to mitigate the effect of financial frictions

Policy Recommendations

- Increased valuation of the environment by public financial intermediaries is not sufficient to steer the global economy towards a fully RES-based growth path in the long run
- Regulation of private financiers only leads to RES-based growth if governments mitigate the risks of sustainable investments (and bear the high costs of it)
- A combination of an increased valuation of the environment by public financial intermediaries and a stricter regulation of private financiers can incentivize RES-based growth
- An immediate and sufficiently high carbon price can also steer the economy towards a RES-based growth path, however, extensive coverage required

Note: RES = Renewable Energy Sources.

Thanks for your kind attention.

Any questions?

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