Measuring the Sustainability of the Bioeconomy

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What is the Bioeconomy?

”The bioeconomy covers all **sectors and systems that rely on biological resources** (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles”

(Definition by the European Commission)

“[...] the **need to achieve sustainability** constitutes a strong incentive to modernise our industries and to reinforce Europe’s position in a highly competitive global economy, thus **ensuring the prosperity of its citizens**”

(European Commission, 2018, p. 4)

Measuring the Bioeconomy

- From “knowledge-based bioeconomy” to “Sustainable & Circular”
- Indicators to measure the bioeconomy
- Based on economic theory
- Measuring Sustainable Development

Measuring Sustainability

- The literature includes several suggestions for measuring sustainability:
    - The Ecological Footprint (EF) (Wackernagel and Rees, 1996)
    - The UN's Human Development Index (HDI) (Sagar and Najam, 1998)
    - Bhutan's Gross National Happiness Index (Mukherji and Sengupta, 2004)

Genuine Savings and Investment

- World Bank's measure of genuine savings and Arrow, Dasgupta and Mäler's approach on inclusive wealth and genuine investment

- The concept of **inclusive wealth** and **genuine investment** are similar:
  - A society's inclusive wealth is determined by measuring **the shadow value of the economy's stock of capital assets**
  - Genuine investment is defined as a measure of **changes in the economy's set of capital assets weighted at shadow prices**.

Research Objective

Measure the sustainability of the bioeconomy

- Develop an indicator for sustainable development of the bioeconomy
- Based on Arrow et al.'s proposal

Compare the sustainability in EU Member States

- EU-28
- *Between 2005 and 2015*

Data

- Value of investments into bioeconomy sectors from Cingiz et al. (2021)
- Bio-based share of value added for 28 EU MS and 36 sectors from 2005 to 2015 using Input-Output tables
- Risk-adjusted discount rate of 10.5%
- Riskless rate of return calculated by the ten-year average long-term interest rate from OECD

Methodology – Intergenerational well-being

- Arrow et al. (2012): **Intergenerational well-being** $V(t)$ is the discounted flow of current and future generations' utilities U.

$$V(t) = \int_t^{\infty} \left[U\left(\underline{C}(s)\right) e^{-\delta(s-t)} \right] ds, \delta \geq 0$$

- **Sustainability:** non-declining intergenerational well-being over time $\Delta V_t \geq 0$
- **Genuine investment:** Changes in well-being ΔV_t, i.e. as a measure of changes in the economy's set of capital assets weighted at shadow prices.

Methodology – Sustainable Investment

- Sustainability related investment projects characterized by the following features:

  - **Irreversibility**: The investments' immediate costs are partially or completely irreversible (i.e. sunk costs)

  - **Uncertainty**: The investment's expected future rewards are uncertain

  - **Flexibility**: The investment's timing is flexible (e.g. Arrow and Fisher, 1974; Dixit and Pindyck, 1994)

Methodology – Uncertainty

- Arrow et al. (2012) model requires a forecast of the economy's future after time t to well-define the intergenerational well-being

- Takes these time varying factors as exogenous

- We suppose genuine investments ($\hat{V}(t)$) follow a Geometric Brownian Motion

Methodology - Flexibility

- McDonald and Siegel (1986)'s the basic model of the value of waiting to invest under uncertainty, irreversibility, and flexibility

- Scatasta et al. (2006) are one amongst many researchers who suggest making use of the real option model, i.e. to compare the value of an immediate genuine investment decision to the option value of a postponed genuine investment decision

Genuine Investment under Uncertainty, Irreversibility, and Flexibility

- As a result of the model (skipping the Math) we end up with a threshold function $\hat{V}^*$:

$$\hat{V}^* = \underbrace{\frac{\beta_1}{\beta_1 - 1}}_{\text{Hurdle rate}} I$$

$$\beta_1 = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left[\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma^2}}$$

- Where *r is* the riskless rate of return, δ is the difference between the discount rate and the value added's temporal trend, σ is the value added's temporal variance

Preliminary results - Aggregate hurdle rates

- Lithuania's bioeconomy has the highest hurdle followed by Latvia and Ireland.

- The three countries with the lowest hurdle rates for their bioeconomies are The Netherlands, Portugal, and Belgium.

Country	Bioeconomy	Non bio-based
AUT	1.023	1.017
BEL	1.015	1.022
DEU	1.021	1.012
DNK	1.028	1.025
ESP	1.029	1.034
FIN	1.049	1.029
FRA	1.018	1.012
GBR	1.091	1.182
GRC	1.039	1.088
HUN	1.327	1.559
IRL	2.949	1.722
ITA	1.010	1.010
LTU	3.907	4.599
LVA	3.160	4.903
NLD	1.011	1.014
POL	1.760	2.516
PRT	1.012	1.024
SVK	1.932	3.698
SVN	1.049	1.126
SWE	1.081	1.109

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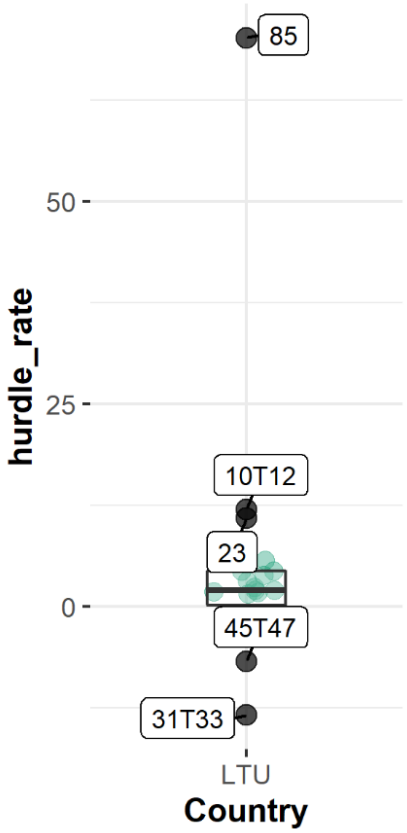
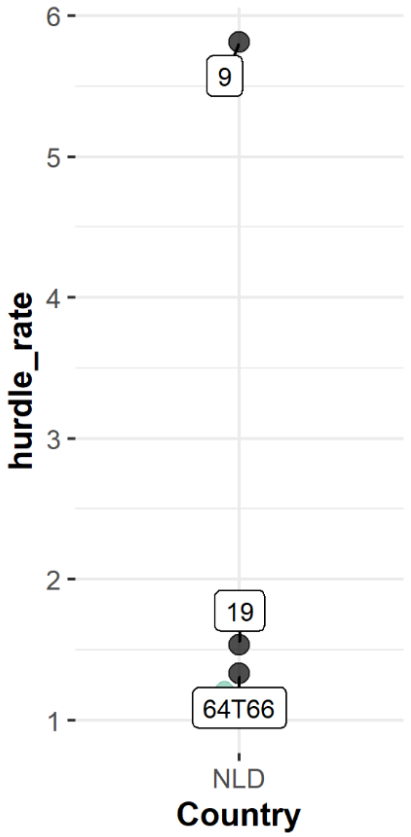
Sectorial hurdle rates - Lithuania

- Sectors with the lowest hurdle rates in Lithuania are Wholesale and retail trade; repair of motor vehicles (-13.423) and Other manufacturing; repair and installation of machinery and equipment (-6.796). Promoting the bio-based production in these sectors would increase the resilience of the bioeconomy.



Sectorial hurdle rates – The Netherlands

- Sectors with a high hurdle rate in The Netherlands are Mining support service activities (5.815), Coke and refined petroleum products (1.536) and Financial and insurance activities (1.332).



Limitations and Next Steps

- We do not explicitly measure the environmental and social dimension of sustainability
- Irreversible benefits of the bioeconomy
- Dashboard with all countries and sectors

Any questions or suggestions?

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