TWINRD
ECODIGITAL FUTURES

Annual Project Meeting

GEM-E3 Update

MACROECONOMIC MODELLING OF R&D FOR THE TWIN TRANSITION

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E3 Modelling - Ricardo

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GEM-E3 model

- A large scale applied economic model that captures the interdependencies between the economy, energy and the environment.

Economy

- 67 economic activities
- 46 regions
- 5 Labor occupations per country
- Consistent sectoral projections via:
  - Linking all economic activities and countries with bilateral trade
  - Inter-dependencies across the value chain
  - Detailed budget accounting for Firms, Households, Government

Energy

- 9 fuels
- 12 power generation technologies
- Physical and monetary representation of all energy flows
- Explicit representation of energy mix in the production process of firms
- Representation of major energy policies (RES deployment, energy efficiency directive etc.)

Environment

- Explicit representation of all GHG emissions (CO_2, CH_4, N_2O, HFC, PFC, SF_6)
- Bottom-up representation of key abatement options of GHG emissions
- Carbon pricing
- CO_2 budgets and association with temperature impacts
- Explicit representation of Climate Policies (NDCs, Carbon Neutrality policies, Carbon clubs, CO_2 standards)

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Clean technologies manufacturing

- GTAP v11 Database

- Disaggregate to represent the clean technologies manufacturing
  - Production structure
  - Demand
  - Trade (Bilateral Exports)

- Clean technologies manufacturing
  - PV equipment
  - Wind equipment
  - Batteries
  - Electric Vehicles Manufacturing

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Total factor productivity

- Total factor productivity in GEM-E3 is composed from two parts:
  - Exogenous total factor productivity
  - Endogenous total factor productivity

- The endogenous part is composed of:
  - the learning by doing
  - the learning by research
  - the knowledge spillovers
  - the human capital stock measure
  - the total factor productivity of the previous period

$$tfp_{pr,r,t} = tfp^{exo}_{pr,r,t} \cdot tfp^{endo}_{pr,r,t}$$

$$tfp^{endo}_{pr,r,t} = tfpLD_{pr,r,t} \cdot tfpLRHC_{pr,r,t} \cdot tfpSPILL_{pr,r,t} \cdot tfpLAG_{pr,r,t}$$

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Learning by research

- The total factor productivity from the learning by research is based on the cumulative R&D capacity by sector [pr], by region [r] and by time [t]

$$tfpLRHC_{pr,r,t} = \left(\frac{\sum_{pr} cumRD_{pr,r,t}}{\min_{c} \sum_{pr} cumRD_{pr,c,0}} \right)^{\beta_{LR}}$$

- and is linked with the human capital measure to include different absorption rates.

$$\beta_{LR} = \gamma_{LR} \cdot ln \left(\frac{HC_{r,t}}{\min_{c} HC_{c,0}} \right)$$

- The cumulative R&D expenditures are expressed by the following formula:

$$CUMRD_{pr,r,t} = (1 - \delta RD)^{\Delta t} \cdot CUMRD_{pr,r,t-1} + RD_{pr,r,t-1} \cdot \left[\frac{(1 - \delta RD)^{\Delta t+1} - 1}{(1 - \delta RD) - 1} - 1 \right]$$

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Spillovers

- Spillovers are proxied by applying a flow matrix to the R&D expenditures by country and sector. This measure is used to approximate the knowledge absorption from the innovations produced by foreign countries. It is assumed that the rate of absorption is analogous to bilateral trade shares / citations. The spillovers measure is expressed by the following formula:

$$cumSPILL_{pr,r,t} = \sum_{c} \frac{BTR_{pr,r,c,0}}{\sum_{cc} BTR_{pr,r,cc,0}} \cdot cumRD_{pr,c,t}$$

- and is linked with the human capital measure to include different absorption rates.

$$\beta_{SPILL} = \gamma_{SPILL} \cdot ln\left(\frac{HC_{r,t}}{\min_{c} HC_{c,0}}\right)$$

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R&D Expenditures

- R&D expenditures in Energy from IEA Database (Public R&D)
  - Energy Technology RD&D Budgets - Data product - IEA
  - Aggregate category: Renewables
- Total R&D expenditures (OECD, Dataset: Gross domestic expenditure on R&D by sector of performance and type of R&D)
  - Public R&D Expenditures
  - Private R&D Expenditures
- **IEA:** No explicit data by clean energy technology
- Energy efficiency, Fossil fuels, Renewables, Nuclear, Hydrogen and fuel cells, Other power and storage technologies, Other cross-cutting technologies/research, Unallocated, Total Budget.
- The split of Renewables category by clean technology manufacturing is based on their production level.

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Spillovers

- The matrix of technology transfers (spillovers) is based on the patent-citations approach.
- Patent data has been collected for the period 1995-2015. All citations have been grouped by IPC family codes for the purposes of sectoral spillovers and by geographic indicator for the purposes of regional spillovers.
- The patent pool (220359 patents) has been identified by a refined search of IPC classification codes, using the WIPO IPC Green Inventory classifications and Boolean operators for the inclusion or exclusion of certain key-words from the IPC categories.
- Forward citations are provided by the PatentInspiration services for the respective patent codes. PatentInspiration services have also provided data on the patent origin, which has been identified according to the location of the inventor.
- The analysis includes more than 1000 different IPC codes (4th level of classification, e.g. B32B3/00) and expert judgement was used in order to derive to the suitable mapping of IPC codes with GEM-E3 sectors. IPC v8 to NACE Rev.2 (Eurostat 2015) concordance tables have been used but as those include 4-digit IPC codes (3rd level) further assumptions were made where necessary. Further correspondence tables have been used, namely UNSTATS correspondence tables from NACE Rev.2 to ISIC Rev.4 and GTAP correspondence tables from ISIC to GSC (GTAP) sectors

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Matrix of technology transfers (spillovers)

	Wind	PV	Hydro	CCS	Nuclear	Biomass Feedstock	Biodiesel	Ethanol	Electric Vehicles
Agriculture	0%	0%	1%	1%	0%	2%	5%	9%	0%
Fossil fuels & Utilities	0%	0%	0%	6%	0%	25%	11%	8%	0%
Metals and minerals	6%	8%	1%	5%	18%	2%	0%	2%	11%
Chemical and paper products	2%	6%	1%	36%	10%	45%	57%	40%	1%
Electronic and equipment goods	66%	75%	50%	47%	67%	17%	15%	24%	86%
Consumer goods	0%	1%	1%	2%	0%	1%	2%	4%	0%
Transport	0%	0%	0%	0%	0%	0%	0%	0%	0%
Contruction	7%	8%	6%	0%	1%	0%	0%	0%	0%
Services	0%	0%	7%	4%	2%	7%	4%	4%	0%
Biomass Feedstock	0%	0%	0%	0%	0%	0%	0%	4%	0%
Ethanol	0%	0%	0%	0%	0%	1%	3%	0%	0%
Bio-diesel	0%	0%	0%	0%	0%	0%	0%	2%	0%
Equipment for wind power technology	0%	0%	32%	0%	0%	0%	0%	0%	1%
Equipment for PV panels	1%	0%	0%	0%	0%	0%	0%	0%	0%
Equipment for CCS power technology	0%	0%	0%	0%	1%	1%	1%	2%	0%
Electric Vehicles	2%	1%	0%	0%	0%	0%	0%	0%	0%
Hydro equipment	15%	0%	0%	0%	1%	0%	0%	0%	1%
Nuclear equipment	0%	0%	0%	0%	0%	0%	0%	0%	0%

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Key updates

- Update structure based on the use of the latest available data
  - Clean technologies manufacturing
  - R&D Expenditures

- New insights on technology transfers based on the work in WP4.

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Looking forward to a productive meeting!

THANK YOU!

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