GEM-E3-R&D

A COMPUTABLE GENERAL EQUILIBRIUM MODEL WITH ENDOGENOUS TECHNOLOGY PROGRESS DRIVEN BY R&D

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GEM-E3-R&D

- World model
- Multiple countries (above 50 of which the 28 EU MS individually)
- Multiple sectors of activity (36)
- Model horizon until 2050
- Detailed representation of energy supply and demand, the energy-related technologies and emissions
- MCP formulation – operating in GAMS
- Calibrated on GTAP, WIOD and EUROSTAT data
- Fully endogenous capital-labour-energy and materials production functions
- Fully endogenous households' consumption behaviour with distinction between durables and non-durables
- Endogenous bilateral trade flows
- Dynamic investment functions by sector
- Equilibrium unemployment
- Capital flows and financing closure
- Detailed representation of public policy instruments

ENDOGENOUS TECHNOLOGY PROGRESS

Productivity (by production factor and overall) by sector evolves partly endogenously as a result of:

- R&D expenditures based on private and public financing
- Spillovers effects through trade and interindustrial relationships
- Learning by doing (related to scale)

Knowledge production functions produce innovation exhibiting decreasing returns to scale

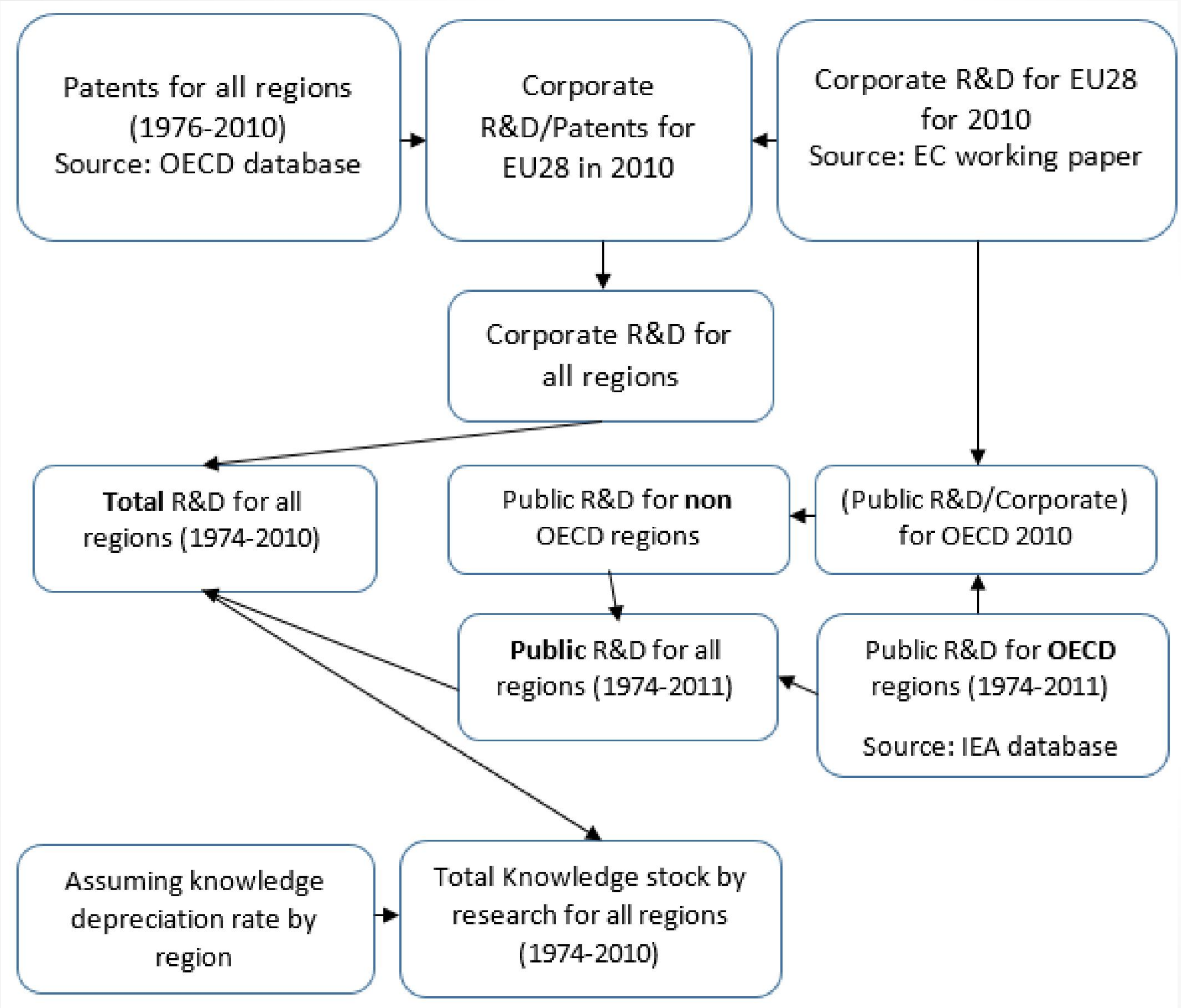
In a general equilibrium context, financing R&D implies crowding out effects but increases productivity, the latter inducing growth effects due to higher efficiency

- A discrete sector (R&D) produces innovation; firms decide how to spend in R&D together with the purchasing of production factors
- Productivity gains apply to new capital vintage
- The link between R&D and innovation depends on a **knowledge** variable and on **fishing out effect** which relates to the exhaustion of inventions.
- The cost structure of the R&D sector is calibrated to data extracted from the ANBERD database combined with Input-Output data

		Purchases	
		Firms (1..n)	**RD**
Sales	**Firms**	✓	✓
	RD	Sales of R&D	✓
Value added		✓	✓
Output			

Institutional sectors	
Firms	**Financing of R&D**
House-holds	
Govern-ment	

DATA ON R&D


Patents for all regions (1976-2010) Source: OECD database
Corporate R&D/Patents for EU28 in 2010
Corporate R&D for EU28 for 2010 Source: EC working paper
Corporate R&D for all regions
Total R&D for all regions (1974-2010)
Public R&D for non OECD regions
(Public R&D/Corporate) for OECD 2010
Public R&D for all regions (1974-2011)
Public R&D for OECD regions (1974-2011)
Source: IEA database
Assuming knowledge depreciation rate by region
Total Knowledge stock by research for all regions (1974-2010)

TWO FACTOR LEARNING CURVES

Clean Energy Technologies

- Photovoltaic
- Wind
- Hydro
- Biomass
- Turbines
- Carbon Capture and Storage
- Nuclear
- Electric Vehicles
- Fuel Cells
- Energy Efficiency Equipment

Historical data on

- Unit costs
- Cumulative instalments
- World trade

The generalised equation to represent the two factor learning curve (TFLC) concept for the clean energy technologies is:

$$C = C_0 * CSales^{-a} * RDSTOCK^{-b}$$

- C is the cost per unit of production,
- $CSales$ represents cumulative output or cumulative capacity
- $RDSTOCK$ is the stock of R&D
- C_0 is the cost of the first unit produced
- a is the elasticity for learning by doing mechanism and
- b is the elasticity for the learning through innovation mechanism.

SPILLOVERS

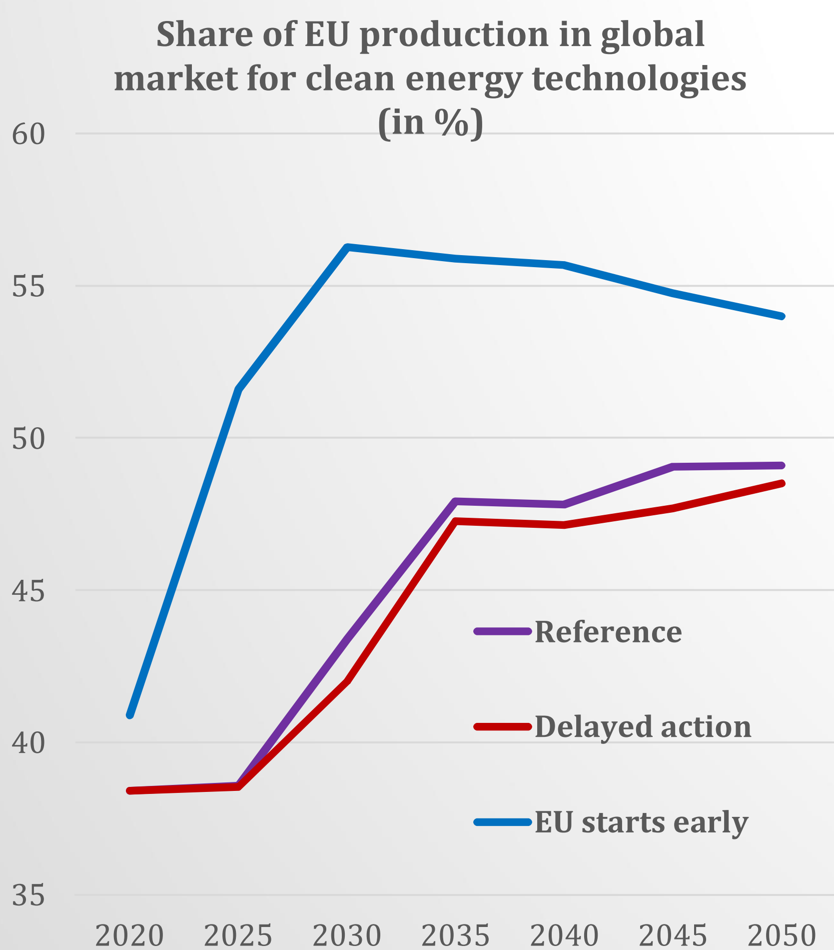
- The model includes:
  - International spillovers (based on international patent matrices) and
  - Inter sectoral spillovers
- Takes into account indirect productivity effects induced by the purchases of efficient intermediate goods.
- Spillovers are assumed free (i.e. there is no extra cost in absorbing the knowledge produced abroad)
- Imported R&D energy intensive goods compete with domestically produced goods.
- Spillovers concerning clean energy technologies relate mainly to the equipment goods industry

ILLUSTRATIVE APPLICATION

- Can the EU economy get First Mover Advantage from pioneering strong climate action?
  - First mover advantage is meant as the possible trade and growth benefits stemming from technological leadership in technologies required to implement transition to a low carbon emitting economy
  - Scenarios:
    - EU Alone (EU applies Energy and Climate Roadmap, alone)
    - Delayed Action (all world regions act after 2030)
    - Early EU Action (EU starts now and rest follow after 2030)
- Clean energy technologies have a large potential of cost reduction if developed at a large scale.

Results already published in peer reviewed publications and developed in research projects, including SIMPATIC and AMPERE

IF OTHER WORLD REGIONS START DECARBONIZING LATER, EUROPE WOULD GAIN A TECHNOLOGICAL FIRST MOVER ADVANTAGE



- **EU invests in R&D for clean energy technologies by 2030 and takes advantage of a fast growing EU market enabling learning by doing and economies of scale**
- **The learning achieved by the EU as the first mover provides cost advantages which allow leadership in global markets**
  - However, the diffusion of technology (spillover effects) worldwide reduces the advantages over time
- **The results depend on:**
  - In all cases the EU has to meet the same carbon budget (the same as EU Roadmap)
  - European internal market is sufficiently large to allow for achieving a large part of learning potential for clean technologies
  - Spillovers from trade are slow

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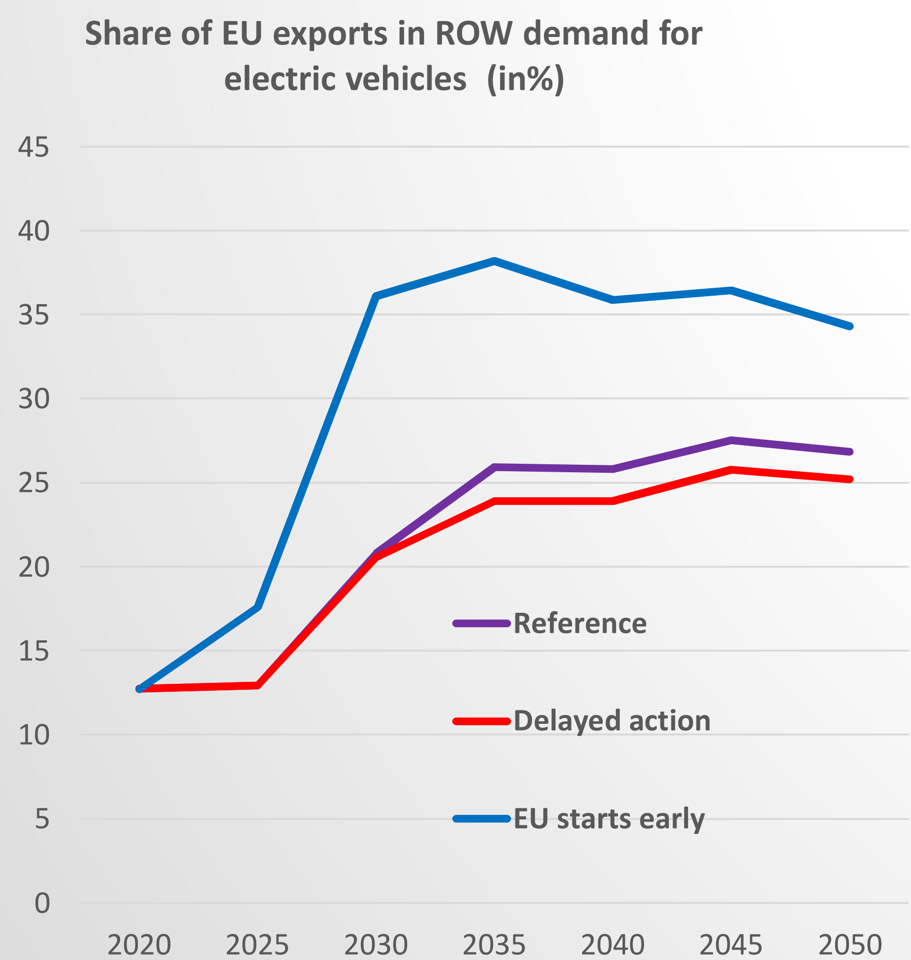

- **Electric vehicles is the main winner in European exports**
  - Very large potential world market (43% of global clean energy market by 2050)
  - EU already enjoys a comparative advantage in vehicle trade
- **CCS, turbine and efficiency technologies are also important**
- **High exposure to trade of PV and wind business; trade results uncertain**

CONCLUDING REMARKS

- The GEM-E3-R&D model is operational but data and calibration requirements are complex
- The applications are very encouraging so far
- Regarding the clean energy technologies application:
  - Estimation of two factor learning curves is fairly robust for certain clean energy technologies (i.e. PV) but indirect methods must be used for not yet deployed technologies (i.e. CCS and electric vehicles).
  - Spillovers are important but difficult to quantify
  - Conditions under which a first mover advantage can exist:
    - The European internal market is sufficiently large and unified to allow for achieving a large part of learning by doing potential for clean energy technologies
    - Ambitious GHG emission reduction targets are eventually adopted by other regions of the world thus developing a large market for such technologies
    - Spillovers are sufficiently small or at least delayed to enable the retention of competitive edge for a period of time