Formulating and implementing EU decarbonization pathways in a CGE model using detailed engineering data derived from a bottom-up model

The case of the transport sector

Francesco Clora (fc@ifro.ku.dk)
Wusheng Yu

19/06/2019

UNIVERSITY OF COPENHAGEN

EUCALC

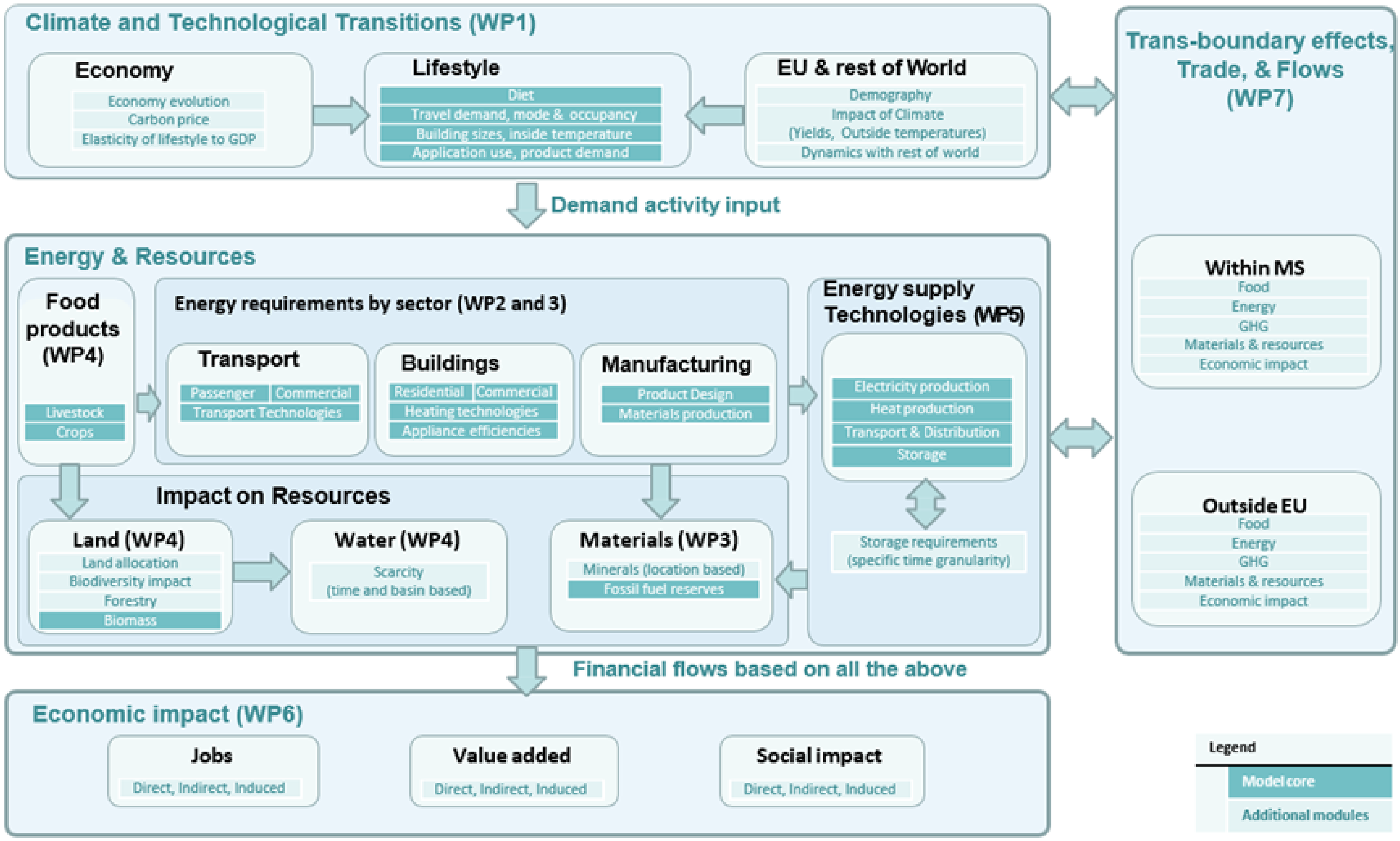
Outline

- European Calculator model
- Rationale and research question
- Improvements to GTAP-E model
- 2050 economic baseline
- GTAP-EUCalc interface
- Preliminary Results
- Conclusions

European Calculator (EUCalc)

- Delineating **decarbonization pathways** for the EU (+Switzerland), from 2015 to 2050
- Evaluation of trade-offs and synergies arising from **user-defined modifications to supply and demand in key emitting sectors**
- **A model with intermediate complexity**, filling the gap between IAM and the need to develop readily accessible tools for decision-makers and other stakeholders

EUCALC: a bottom-up lever-based approach



- Users can control **60 levers**, expressing their GHG abatement ambition regarding *behavior*, *technology* or *practice* patterns among the different sectors
  - Each lever has **4 level settings**, according to the GHG abatement ambitions

GTAP-E in EUCalc: rationale and research question

- Bottom-up models alone cannot simulate trade effects of decarbonization pathways

- A modified version of GTAP-E is used to model trade effects of user-defined pathways

- Three scenarios are evaluated against a counterfactual:
  - **Counterfactual**:
    - All EUCalc transport levers on 1, i.e. BAU development
    - GTAP-E 2050 BAU baseline, constructed using reference projections
  - **Scenarios** are based on the abatement ambition levels developed through a co-design process with key stakeholders
    - **Medium**: all levers on 2 (more ambition than lvl1, but not reaching full potential)
    - **High**: all levers on 3 (full potential of available solutions)
    - **Max**: all levers on 4 (transformational changes)

GTAP-E model improvements

- Two alternative demand systems
  - CDE to project the 2011 GTAP9 baseline to 2050
  - CD to simulate the decarbonization scenarios in 2050
- Twist parameters (simulating preference-driven demand changes) added to
  - CES production structure (allowing for changes in cost shares)
  - CD private demand structure (allowing for a within-budget shift)
- Isoelastic aggregate supply of land
  - Land price elasticities estimated by Philippidis et al. (2017)
- Equations to incorporate GTAP9 nonCO2 database emissions
  - A linear relationship between non-CO2 emissions and their drivers is assumed
- Sets of equations accounting for changes in
  - GHG emissions and sectoral GHG intensities
  - GHG emissions embedded in trade
  - Sectoral and regional carbon leakage
  - Trade of aggregate EU(+Switzerland) vs ROW

GTAP-E 2050 baseline

- A baseline dataset towards 2050 is constructed in 5y time steps, using reference projections for:
  - **GDP**: EU Reference Scenario 2016 and OECD-SSP2
  - **Population**: EUROSTAT, EU 2015 Ageing Report and SSP2 projections for IIASA
  - **Labor force**: EUROSTAT, EconMap2.4 and EU 2015 Ageing Report
  - **Differential sectoral productivity growth**: Bekkers et al. (2019)
  - **Fossil fuel price** trajectories: IEA (2017)

- The 2050 baseline dataset is aggregated to
  - 13 sectors
  - 32 countries/regions

Transport sector in EUCalc. Levers

Levers in the transport module [passenger][freight]
Demand [pkm/capita] [tkm]
Occupancy [passenger/vehicle] [ton/vehicle]
Utilization rates [pkm/vehicle/year] [tkm/vehicle/year]
Lifetime of vehicles [total km/vehicle]
Modal share [%/mode]
Energy efficiency of vehicles [MJ/pkm] [MJ/tkm]
Low emission technology development [% of new vehicles / technology]
Fuel mix [%/fuel type]

- Users can act on 16 transport levers:
  - *Avoid/reduce*
  - *Shift*
  - *Improve*

Transport sector in EUCalc. Technologies

Passenger Mode	LDV	2W	Bus	Rail	Metro-tram	Aviation
	ICE-diesel	ICE-diesel	ICE-gas			
	ICE-gas	ICE-gas	ICE-diesel	ICE		ICE
	ICE-gasoline	ICE-gasoline	ICE-gasoline			
Technologies in each mode	BEV	BEV	BEV			BEV
	FCEV	FCEV	FCEV	FCEV		
	PHEV-diesel	PHEV	PHEV			
	PHEV-gasoline					
				CEV		

Freight Mode	HDVH	HDVL	HDVM	Rail	IWW	Marine	Aviation
	ICE-diesel	ICE-diesel	ICE-diesel				
	ICE-gas	ICE-gas	ICE-gas	ICE	ICE	ICE	ICE
	ICE-gasoline	ICE-gasoline	ICE-gasoline				
Technologies in each mode	BEV	BEV	BEV		BEV	BEV	BEV
	FCEV	FCEV	FCEV		FCEV	FCEV	
	CEV	CEV	CEV	CEV			
	PHEV-diesel	PHEV-diesel	PHEV-diesel				
	PHEV-gasoline	PHEV-gasoline	PHEV-gasoline				

GTAP-EUCalc interface

- Levers cannot be directly implemented in GTAP-E
- Technologies need to be mapped onto the three GTAP transport sectors
- "Intermediate" EUCalc model outputs are needed to generate economically sensible exogenous shocks
  - For each technology, the EUCalc generates the following outputs:
    - Passenger kilometer [pkm]
    - Tonne kilometer [tkm]
    - Energy demand [MJ]
    - Vehicles [number]

GTAP-EUCalc interface. Tech aggregation

EUCalc mode	GTAP sector
IWW	Water transport
Marine	
Aviation	Air transport
Other	Rail&Road transport

- Within each GTAP transport sector:
  - Electric and hybrid techs are separated from fossil fuel vehicles
  - A measure "weighting" passenger and freight transportation is produced to generate the shocks (*pkm* and *tkm* are not directly comparable):

$$\overline{\alpha} = \frac{\overline{VPA}}{\overline{VPA} + \sum_k \overline{VFA_k}}$$

$k = GTAP\ sectors$

  - Assumptions:
    - No private household demand for freight transport
    - No intermediate demand for passenger transport

GTAP-EUCalc interface. Exogenous shocks

- Using intermediate EUCalc outputs, five measures are generated for each scenario for each GTAP sector

- The shocks to GTAP-E are then calculated as percentage changes with respect to the baseline

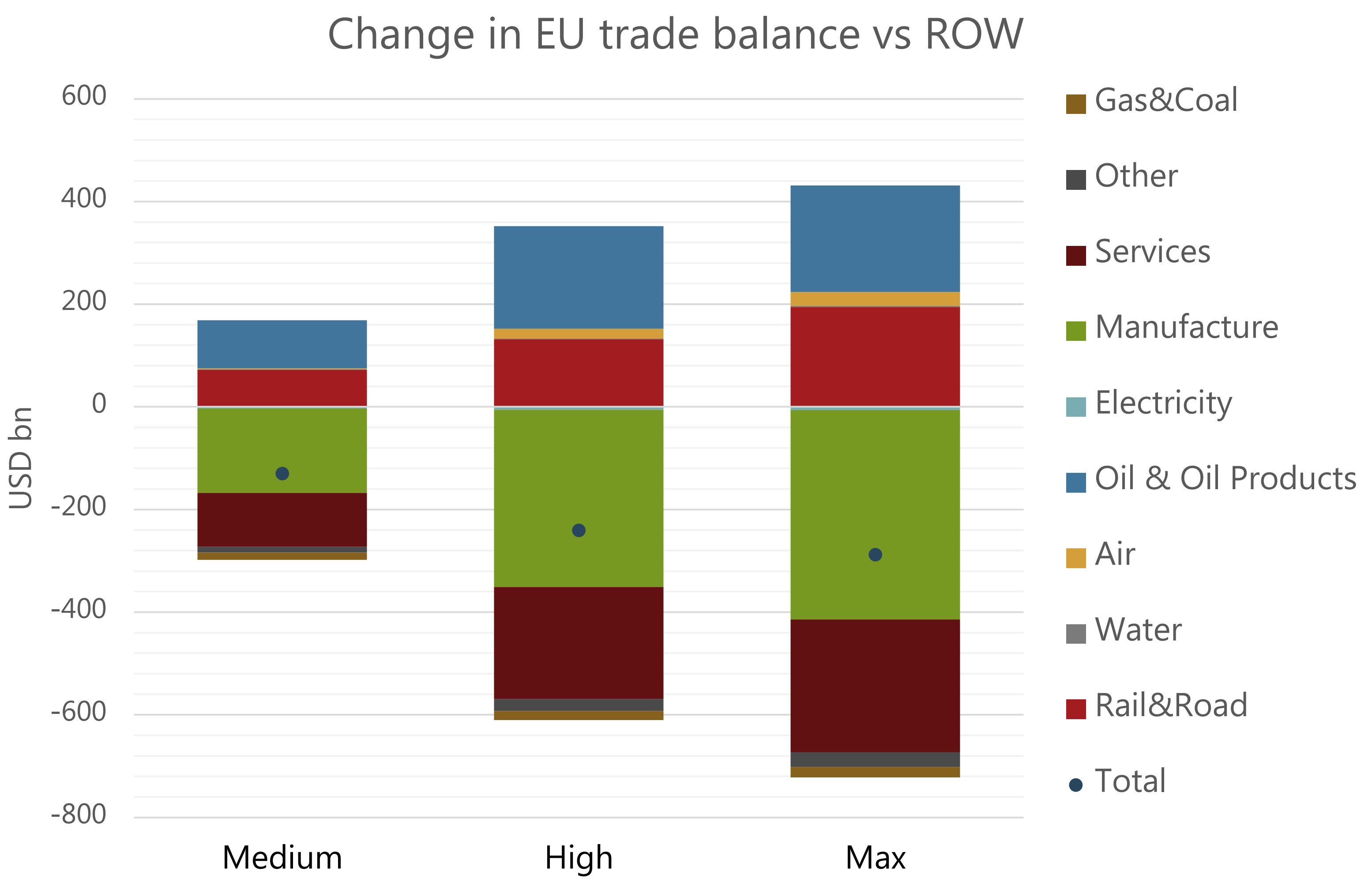
EUCalc-derived measures	GTAP-E exogenous shocks
Freight transport demand [tkm]	**Intermediate demand** for transport, via a twist parameter
Passenger transport demand [pkm]	**Private household demand** for transport, via a twist parameter
Fleet structure [MJ_{ely} vs MJ_{ff}]	**Intermediate demand for oil products and electricity**, by transport sectors, via twist parameters
Energy efficiency [pkm/MJ; tkm/MJ]	**Technological change** in the use of the **energy** composite, by transport sector
Vehicle efficiency [pkm/vehicle; tkm/vehicle]	**Technological change** in the use of **capital**, by transport sector

Shocks to BAU 2050 baseline

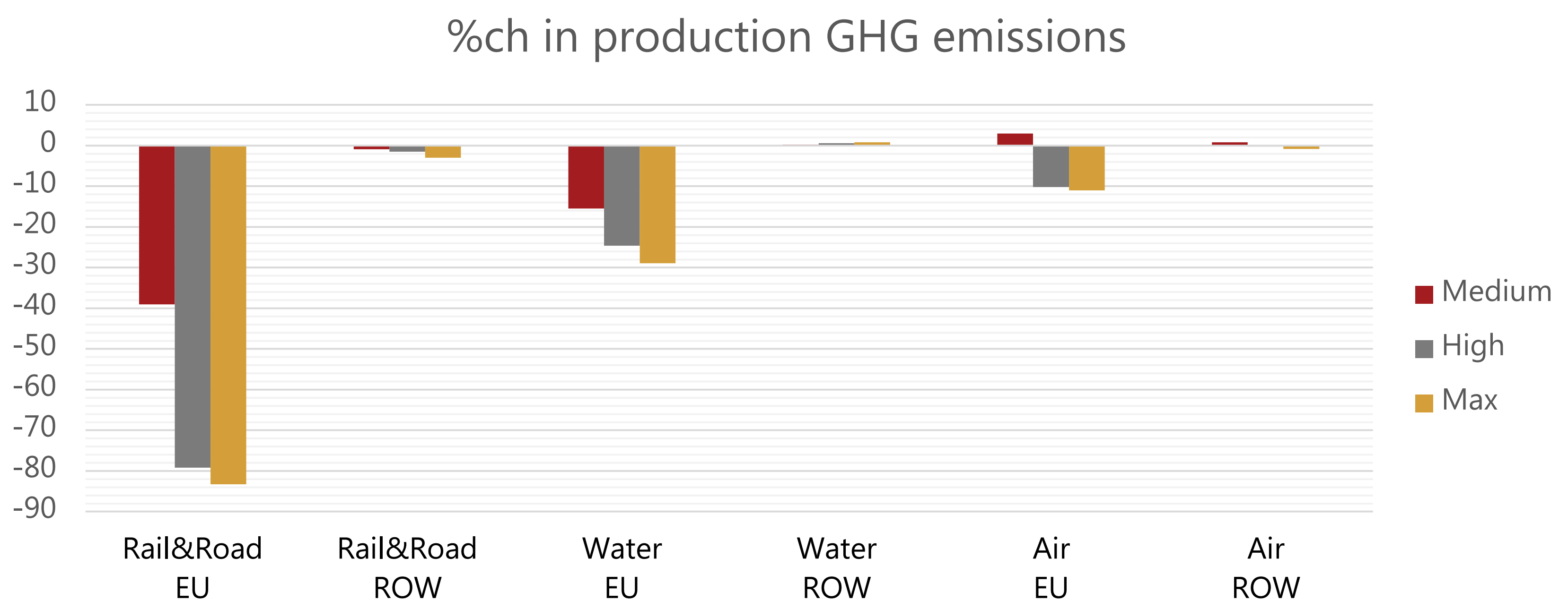
GTAP-E variable	Medium	High	Max
Intermediate demand for transport, by all sectors	↓	↓↓	↓↓↓
Private household demand for transport	↓	↓↓	↓↓↓
Intermediate demand for oil products, by transport sector	↓	↓↓	↓↓↓
Intermediate demand for electricity, by transport sector	↑	↑↑	↑↑↑
Energy efficiency, by transport sector	↑	↑↑	↑↑↑
Capital efficiency, by transport sector	↑	↑↑	↑↑↑

- **Abatement potential** in different transportation sectors reflected in shocks' magnitude
- **Abatement ambition** of different scenarios reflected in shocks' proportions

Results. Balance of trade



Results. GHG emissions



%ch in total GHG	Medium	High	Max
EU	-3.65	-11.56	-11.71
ROW	0.42	0.90	0.91
World	**0.16**	**0.09**	**0.09**

Conclusions

- Attaching the CGE model to the BU modules
  - Enables the EUCalc tool to generate economic results, including EU linkages to the rest of the world
  - Maximizes the potential of the CGE model by allowing it to evaluate a vast amount of BU-based scenarios derived from different lever combinations
- Efforts demonstrate the practical way of utilizing detailed engineering data in a TD model
  - Aggregation needed both at the "tech" and "variable" level
- Decarbonizing the EU transport sector has
  - Notable effects on the EU net trade position vs ROW
  - Minor effects in GHG emissions

Additional material

Capital and energy efficiency measures

- Capital efficiency measure, per each transport sector

$$K_{eff} = \overline{\alpha}\left(\frac{\sum_i pkm_i}{\sum_i veh_i}\right) + (1-\overline{\alpha})\left(\frac{\sum_j tkm_j}{\sum_j veh_j}\right)$$

  - i = technology, passenger, in EUCalc transport module
  - j = technology, freight, in EUCalc transport module

- Energy efficiency measure, per each transport sector:

$$eny_{eff} = \overline{\alpha}\left(\frac{\sum_i pkm_i}{\sum_i eny_i}\right) + (1-\overline{\alpha})\left(\frac{\sum_j tkm_j}{\sum_j eny_j}\right)$$

Emissions embedded in trade

- The emission intensity of sectoral output is calculated

$$GHGVOA(j,r) = \frac{GHGPROD(j,r)}{VOA(j,r)} \quad \left[\frac{ktonCO2e}{mUSD}\right]$$

- The emission intensity coefficient is attached to exports to calculate emissions embedded in exports and imports

$$GHGXS(i,r,s) = VXWD(i,r,s) * GHGVOA(i,r) \quad [ktonCO2e]$$
$$GHGXI(i,r,s) = VXWD(i,r,s) * GHGVOA(i,s) \quad [ktonCO2e]$$

Shocks to EU BAU 2050 baseline (% change)

Passenger demand	Medium	High	Max
Rail&Road	-5	-10	-21
Water	-5	-10	-21
Air	-5	-10	-21

Freight demand	Medium	High	Max
Rail&Road	-5	-11	-20
Water	-3	-8	-10
Air	-4	-10	-15

Demand for oil products	Medium	High	Max
Rail&Road	-41	-84	-88
Water	-15	-24	-29
Air	3	-10	-11

Demand for electricity	Medium	High	Max
Rail&Road	563	1127	1297
Water	81	162	186
Air	87	175	202

Energy efficiency	Medium	High	Max
Rail&Road	55	131	244
Water	3	11	12
Air	-3	5	5

Vehicle efficiency	Medium	High	Max
Rail&Road	30	99	181
Water	-3	-8	-10
Air	-0.3	-0.8	-1.2