



Long-term interdependencies of oil markets and climate policy: Coupled analysis with a game-theoretic oil market model and an energy system model

Uwe Remme, Tobias Rehl, Fabian Kesicki, Markus Blesl and Ulrich Fahl

**Institute of Energy Economics and the Rational Use of Energy (IER)
Energy Economics and System Analysis (ESA)**

International Energy Workshop 2008

June 30th, 2008 Paris

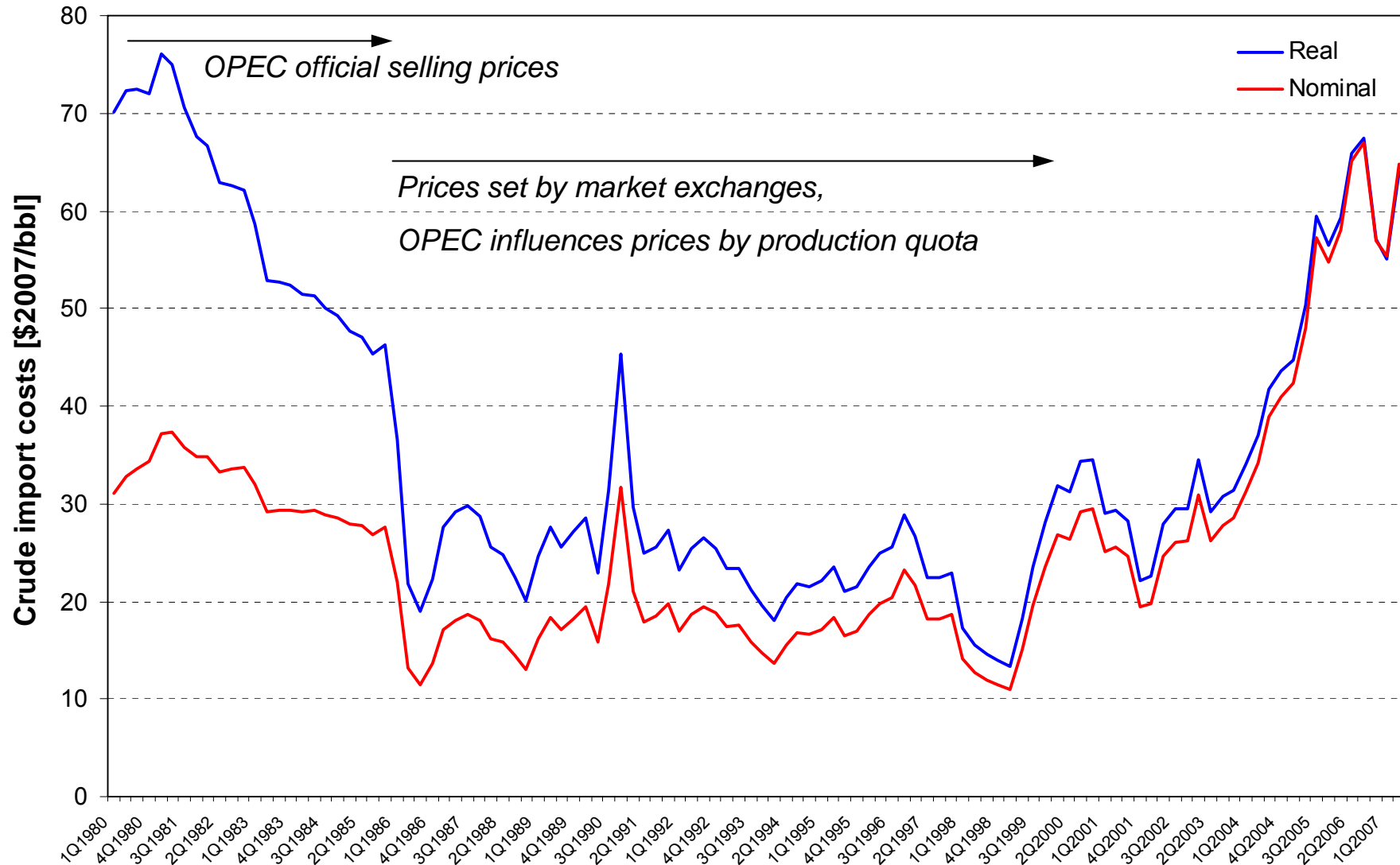


Overview

- Introduction
 - i. Factors influencing the oil price
- Scope of analysis
- Methodological approach
 - i. Linking an oil market and an energy system model
- Preliminary scenario results
- Conclusions



Development of global oil prices





Factors influencing the oil price

Supply

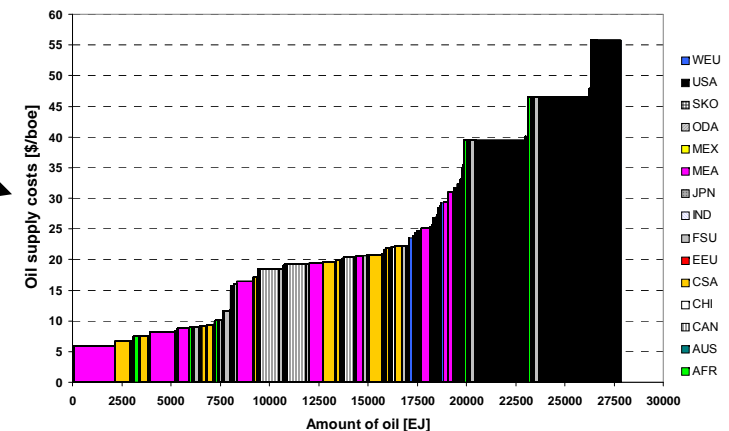
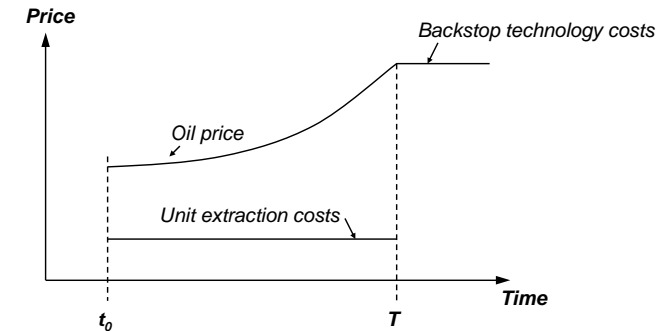
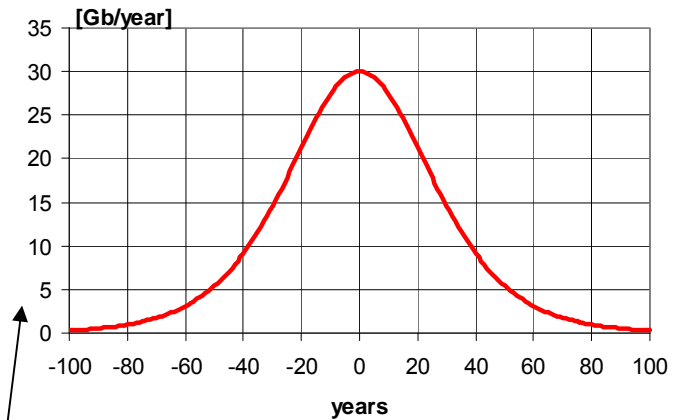
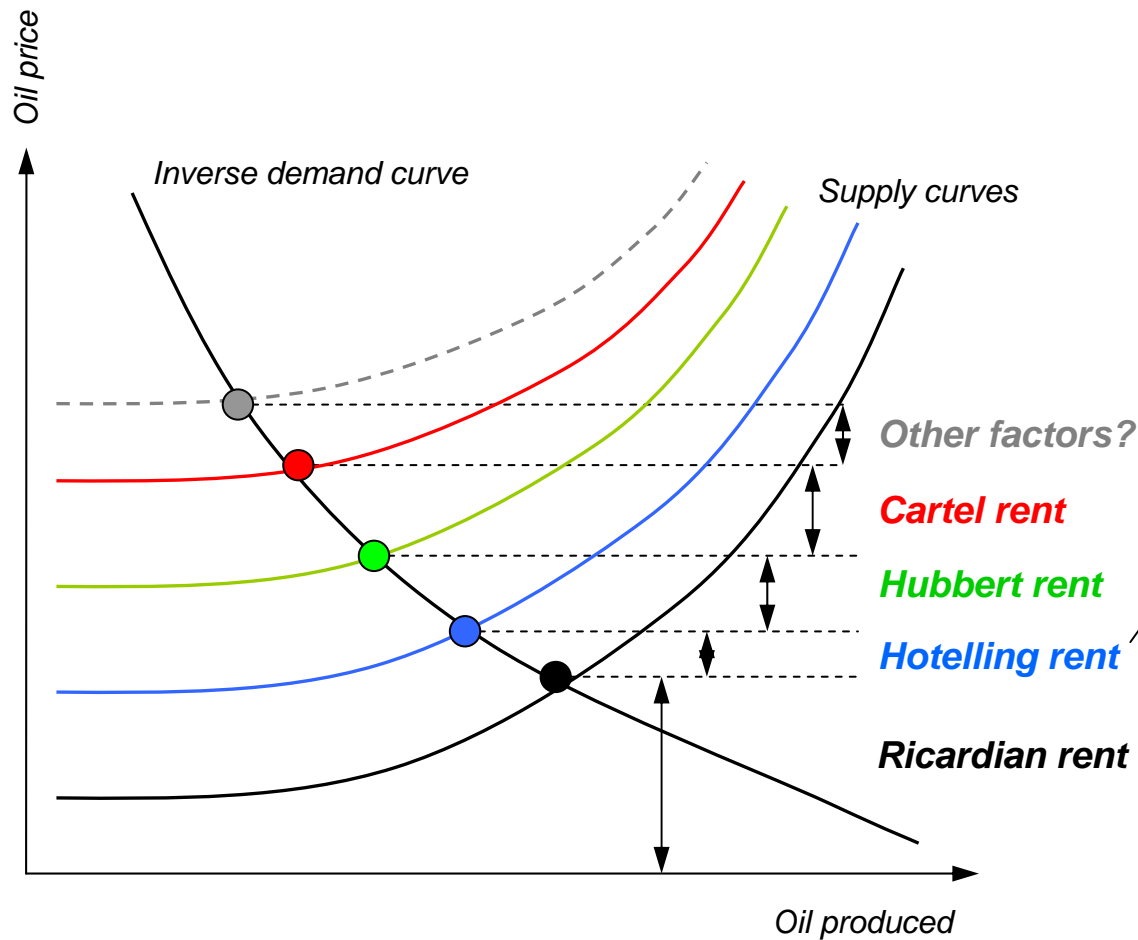
- Reserves and resources
- Exploration activities
- Geologic restrictions in production rates
- Production capacity
- Disruptions in production or transport
- Cartel behaviour
- Geopolitic aspects

Demand

- Stock levels
- Refining capacity
- Speculation in oil markets
- Financial investors
- Demand growth (esp. in Asia and the Middle East)



Components of long-term oil prices



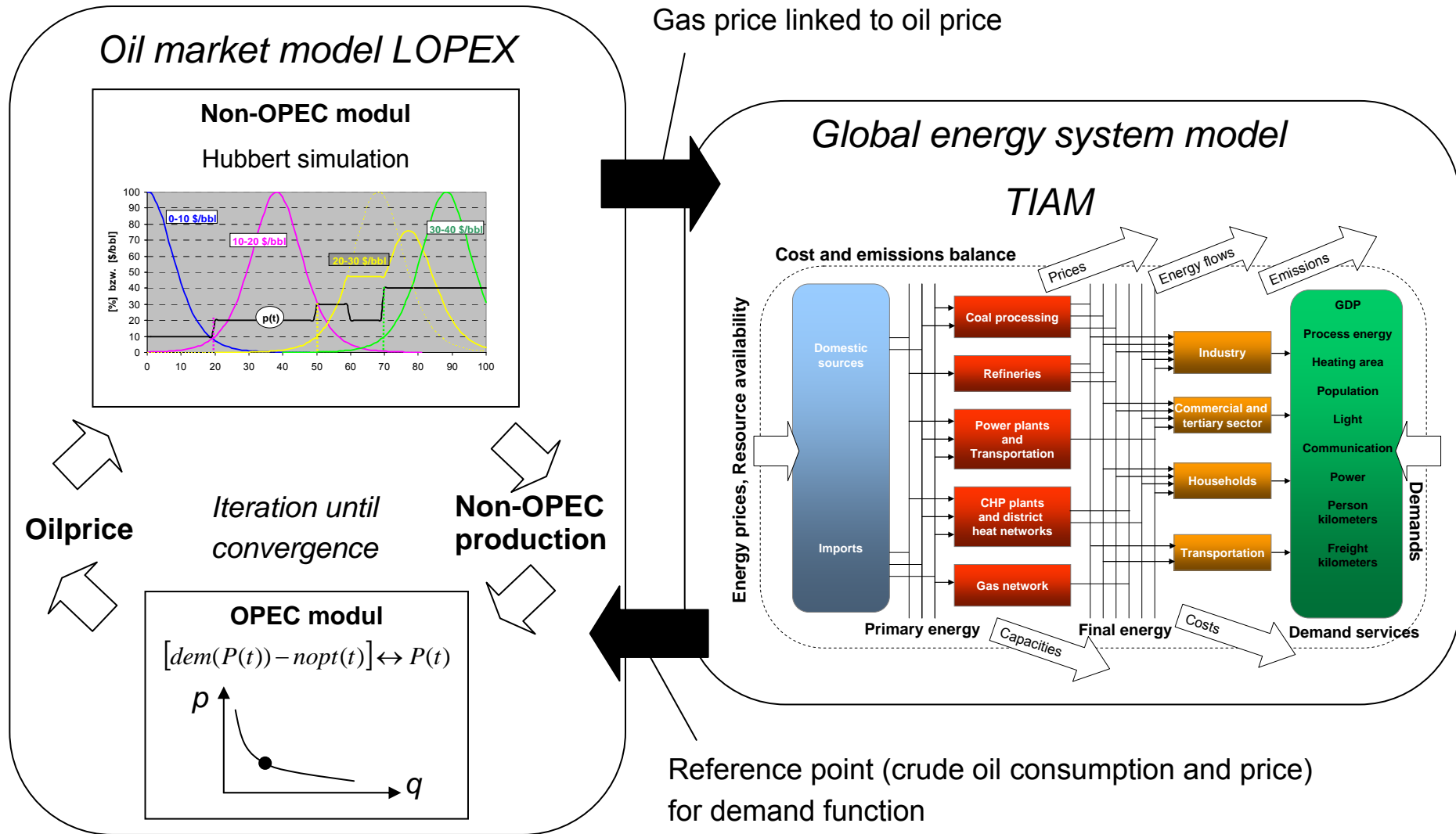


Scope of analysis

- Analysis questions:
 - i. Long-term equilibrium on oil market incl. OPEC's cartel behavior
 - ii. Sensitivity of oil market equilibrium on
 1. Available resources and their production costs
 2. Restrictions in production profiles (e.g. Hubbert)
 3. Technology progress on supply and demand side
 - iii. How does the structure of the energy system evolve?
 - iv. How can the oil prices be affected by policy instruments?
 - v. What are the interdependencies of policy measures (e.g. GHG mitigation) and oil prices?
- Approach:
 - i. Soft-linking the global oil market model LOPEX with the energy system model TIAM



Modelling approach





Oil market model: LOPEX

Periods: 10-year periods from 1980 to 2100 (1976-1985,...,2096-2105).

2 Regions: OPEC = perfect cartel, Non-OPEC = Wettbewerbsrand (Simulation).

Typ: Optimizing overall discounted OPEC-Revenue under perfect foresight

$$\text{Max}_{P(t), X_{OPEC}(t)} \sum_t d(t) \cdot (P(t) \cdot X_{OPEC}(t) - \text{SUPPLYCOST}(X_{OPEC}(t), R_{OPEC}(t)))$$

Format: Mixed Complementary Programming (MCP)

Constraints:

- limited resources:

$$\sum_t X_{OPEC}(t) \leq R_{OPEC}(t)$$

- OPEC covers demand determined by iso-elastic demand function minus Non-OPEC production:

$$X_{OPEC}(t) = d_{ref}(t) \cdot \left(\frac{P(t)}{p_{ref}(t)} \right)^{\varepsilon(t)} - nop(t)$$



Global energy system model: TIAM

- **TIMES Integrated Analysis Model**
- **Based on TIMES model generator:**
 - i. Developed by ETSAP
 - ii. Dynamic partial equilibrium model approach with inter-temporal objective function (perfect foresight) minimizing total discounted system costs
 - iii. Technologically detailed „bottom-up“ model for each region
 - iv. Covering energy flows from the useful energy demand over end-use sectors and conversion sector to the primary supply
- **Time horizon 2000 – 2100**
- **15 world regions with**
 - i. Bilateral trade in hard coal, pipeline gas, LNG, crude oil, petroleum products (distillates, gasoline, heavy fuel oil and naphtha) and bioethanol
 - ii. Global trade in emission permits possible
- **Emissions: CO₂, N₂O, CH₄**
 - i. Carbon capture and sequestration (power generation and alternative fuel production)
 - ii. Mitigation options for N₂O and CH₄
- **Climate module** (3-reservoir model for calculating atmospheric CO₂ concentrations)
- **Multi-stage stochastic programming** (uncertainties in emission targets, demands, bounds)



Scenario definitions

- Population [million]

	2005	2010	2020	2030	2040	2050	2100
World	6409	6757	7390	7942	8511	9015	10139

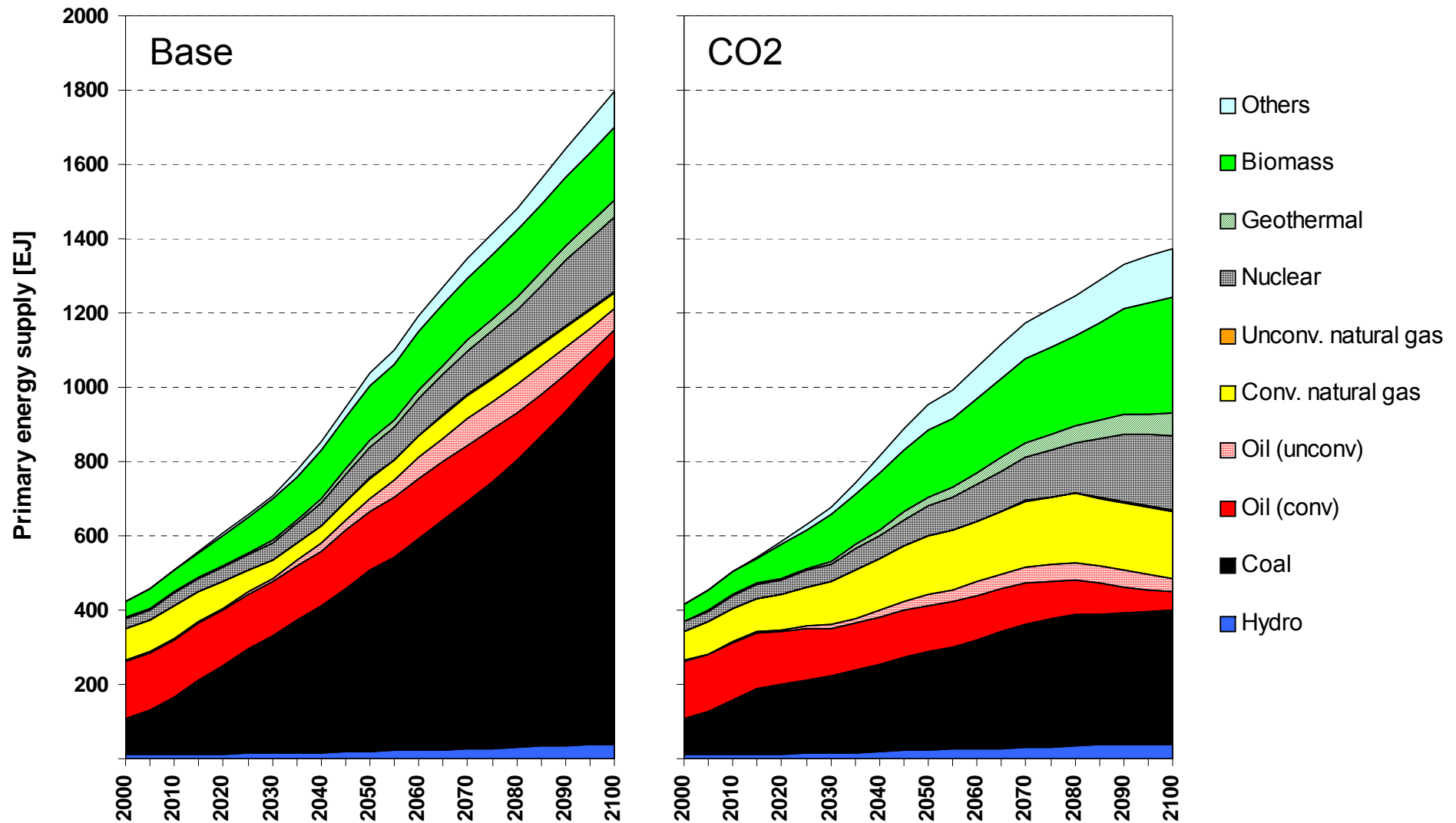
- GDP growth [%]

	2005-2010	2010-2020	2020-2030	2030-2040	2040-2050	2050-2100
World	3.1%	2.9%	2.8%	2.6%	2.5%	2.1%

- BASE scenario: no explicit CO₂ mitigation policies
- CO₂ scenario: CO₂ price increasing from 10\$/t CO₂ in 2015 to 100\$/t in 2050 and 400\$/t CO₂ in 2100

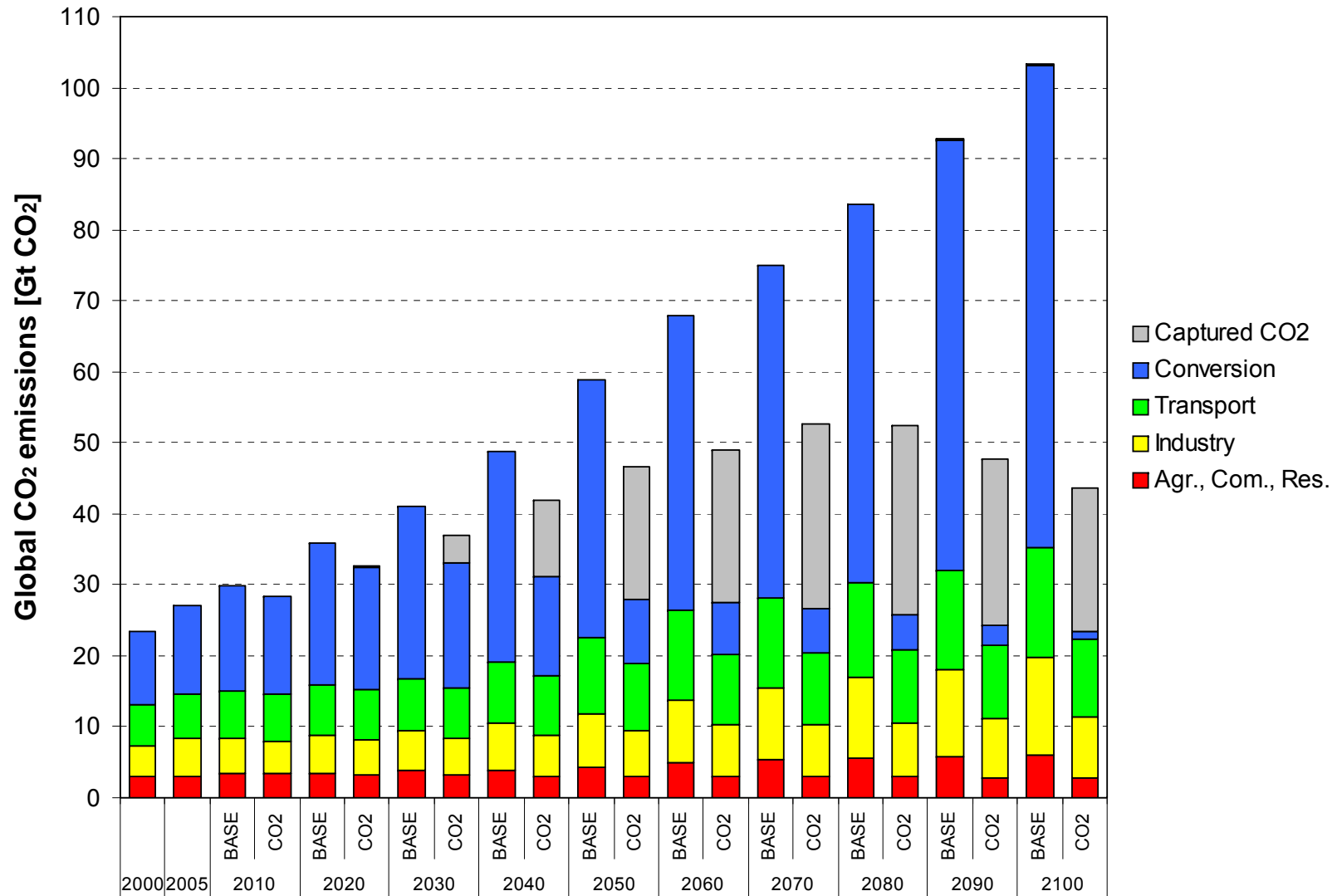


Total primary energy supply (world)



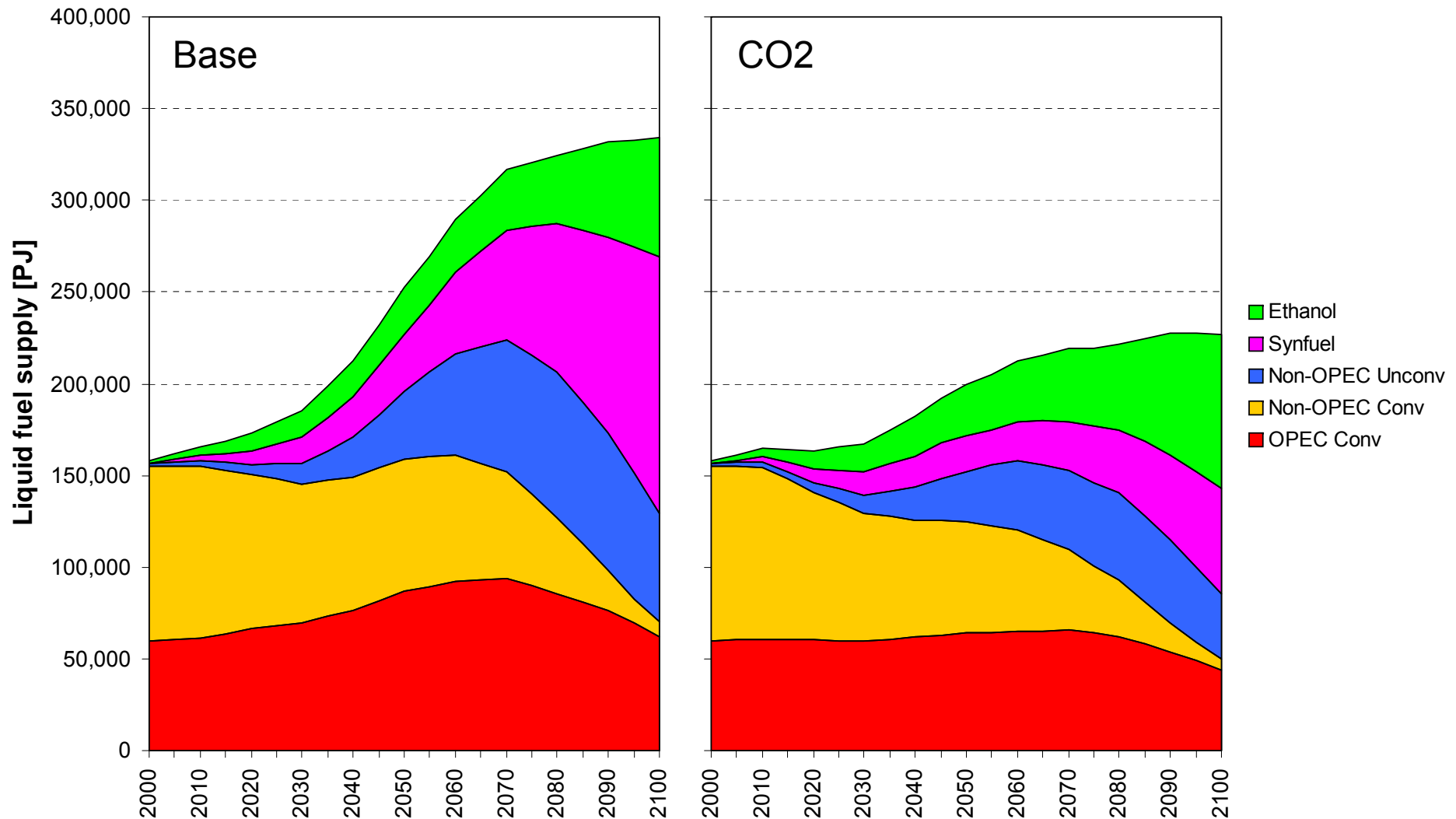


CO₂ emissions



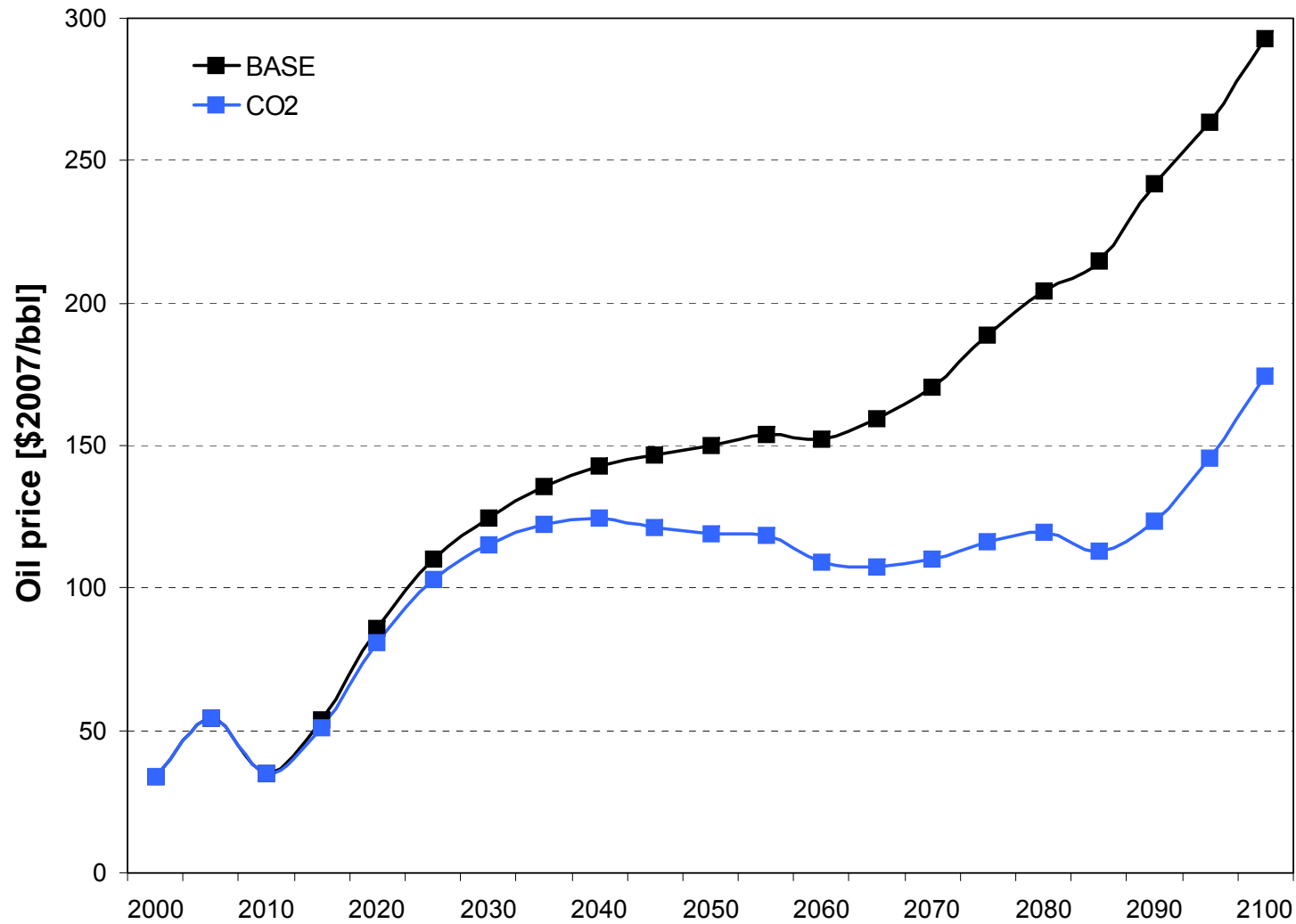


Global liquid fuel supply





Oil price





Conclusions

- OPEC cartel can maintain market power by withholding production.
- It benefits from the depletion of conventional resources in Non-OPEC regions.
- Cartel rent can be restricted by alternative fuels to oil. Results very sensitive to rate by which these fuels penetrate the market.
- CO₂ mitigation policies reduce OPEC's market power by nearly halving the oil price.
- Outlook
 - i. Refine price analysis.
 - ii. Analysis further scenarios
 - iii. Better integration of Hubbert curve type of behavior in TIAM.