Transportation Energy Demand and Emissions in China’s Provinces to 2030

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Outline

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  Research questions
  Methodology for regional & modal projection

Baseline projections

Policy analysis example
  Fuel + sectoral output taxes
  Broader economic impact
  Transport sector impacts

Extensions
Review
Review

Paltsev et al. (2004) — household transport within a computable general equilibrium framework (MIT EPPA model).

- Karplus et al. (2013) — detailed methodology for household *vehicle* transport (HVT), application to the U.S. with detail of advanced powertrain technologies.
- Kishimoto et al. (2012) — application to China (single region); Karplus et al. (2012) — global fuel economy standards.

Zhang et al. (2013) — China Regional Energy Model (*C-REM*).

- International Energy Workshop, 04 June 2014 — (general) recursive-dynamic projections to 2030.
Research questions

- How do transport activity and emissions evolve across China’s regions to 2030, within broader economic trends?
- What impacts do transport-focused policies have across sector sectors and provinces?
China Regional Energy Model overview

Features:
- 14 sectors
- Interprovincial migration impacts on labor market through 2020 (X. Luo)
- Pollutant representation (C. Waugh)
- Health effects module (K.-M. Nam)
- 30 provinces in China
- Rest of world aggregated to four regions

Data sources:
- GTAP Data base v8 (Narayanan G. et al., 2012) for international economic data; energy, emissions.
- Aggregation, balancing and adjustment for consistency of the Social Accounting Matrix (SAM) and energy flows.
Chinese provinces & regions

西 West — 中 Central — 东 East
### Transportation subsectors

<table>
<thead>
<tr>
<th>Code</th>
<th>TRN sub-sector</th>
<th>Physical unit&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>Non-road (&quot;other&quot;) freight</td>
<td>tonne·km</td>
</tr>
<tr>
<td>FR</td>
<td>Road freight</td>
<td>tonne·km</td>
</tr>
<tr>
<td>P0</td>
<td>Non-road commercial passenger</td>
<td>passenger·km</td>
</tr>
<tr>
<td>PR</td>
<td>Road commercial passenger</td>
<td>passenger·km</td>
</tr>
<tr>
<td>HVT</td>
<td>Household (private) vehicle transport</td>
<td>passenger·km</td>
</tr>
</tbody>
</table>

<sup>1</sup>Model outputs in economic value terms (constant 2007 RMB) are indexed to physical accounts.
F0, FR, P0, PR: sectoral production

Gross output $i$

$\sigma_{klem}$

$M_1 \quad \cdots \quad M_j \quad \cdots \quad M_J$

KLE

$\sigma_{eva}$

Energy

$\sigma_{enoe}$

Energy

$\sigma_{en}$

Non-ELE

Capital-Labor

$\sigma_{va}$

K

L

ELE

COL GAS CRU OIL GDT
HVT: own-supplied transport

Household consumption

$\sigma_{HT1} = 0.5$

Other consumption

Passenger transport (P)

$\sigma_{HT2} = 0.2$

Commercial passenger transport

Household vehicle transport (HVT)

New HVT

Fuel

Powertrain capital

Vehicle capital

Services

OIL MAN MAN SER

Vintage HVT
Recursive-dynamic projection

Methodology of MIT EPPA (Paltsev et al., 2005) and USREP (Rausch et al., 2011) models adopted

1. Solve the static model in the 2007 base year.
2. Update exogenous quantities using dynamic parameters:
   - Population & labour productivity.
   - Autonomous energy efficiency improvement (Schmalensee et al., 1998)
   - Resource depletion & exploration.
   - Capital accumulation & deprecation [& vintaging].

(Contrast with forward-looking models in which agents perform intertemporal utility/profit maximization over present and future period consumption, with all periods solved simultaneously; see Babiker et al., 2009)
Baseline projections
Gross regional product

Growth rates differ across regions over time; disparity in per-capita incomes persists.

Regional GDP

Growth (AAGR) [%]

Provincial GDP

[10^9 USD @ 2007]

[10^3 USD @ 2007/capita]
Gross regional product
GDP and emissions per capita, all provinces, 2007–2030

CO₂ emissions per capita vs. GDP per capita [10^3 USD@2007]
CO₂ emissions, all sectors

- Xī
- Zhōng
- Dōng

Time: '07, '10, '15, '20, '25, '30

CO₂ emissions [Gt/a]
Total & per capita activity, by mode

[Graph showing activity trends by mode and region, with axes labeled in Chinese and English.]

[Legend: FR, FO, PR, PO, HVT]
HVT stock and per-capita ownership

Total vehicles \([10^6]\) vs. Year

- Western China
- Central China
- Eastern China

Vehicles per capita vs. GDP \([10^3 \text{ USD @ 2007/capita}]\)

- 西 (West)
- 中 (Central)
- 东 (East)
Egy. demand & CO$_2$ emissions, by mode

Energy [100 Mtce/a]

CO$_2$ [100 Mt/a]

2010 '20 '30

HVT
PO
PR
FO
FR
Policy analysis example
Analysis of an example policy

Model a transport-sector specific policy\(^2\)—10% ad-valorem taxes on:

1. OIL input to HVT.
2. Output of road passenger (PR) sector.
3. Output of road freight (FR) mode.

- Lump-sum remittance to households.
- Policy begins in 2015 and continues through end of model forecast period (i.e. 2030).

\(^2\)In a GE framework, transport sectors will also respond to changes in demand & (energy) input prices caused by economy-wide policy, or by targeted policy in non-transport sectors.
Policy impact: aggregate consumption

Some differences across provinces, but small overall impact on this measure of welfare due to remittance.
Policy impact: transport activity change
Indexed to baseline projection — 1.0 = baseline value in given year
CO₂ emissions of transport sectors
Policy impact: some reduction in energy intensity; fuel switching
Policy impact: vehicle ownership

Thin trajectories = policy case

![Graph showing the relationship between GDP (10^3 USD @ 2007/capita) and vehicles per capita. The graph includes three trajectories, each representing a different region (West, Middle, East).]
Extensions
GDP & vehicles per capita — the data
Sichuan prefectures 1998–2011; prov. average (grey)
GDP & vehicles per capita — the data
Extensions & ongoing work

Regional framework → incorporation of data & studies on heterogeneous transport system

Characteristics & trends of province-level transport:

- Freight- or road-intensive; link to economic structure.
- Freight network and content transformation → increasing road shares.
- Income elasticity of vehicle ownership.³

Transport-specific policies that differ by province:

- Vehicle emissions & fuel quality standards → air pollution → health impacts. e.g. Beijing will reach China 5/V standard earlier than other regions.
- Fuel economy of vehicles.
- Ownership & driving restrictions.
- Infrastructure expansion.

Interaction with economic, energy & climate policy.

³May be national, or global—but do delay, technology, policy effects modify?
References I


References II


