ELECTRICITY MARKETS IN A CARBON-CONSTRAINED WORLD: REFORMING SCHEDULING PRACTICES IN CHINA AND INDIA

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Electricity markets: past, present and future

• Majority of OECD and over 70 non-OECD countries have reformed vertically-integrated utilities, incl some / all of:
  → Unbundled and competitive generation companies
  → Wholesale spot markets for real-time balancing
  → Unbundled and competitive retail companies
  → Cost-based / incentive regulation for grid monopolies
  → Independent regulator

• Spot markets essential to “standard” model:
  – Fine time and geographic granularity matches various needs
  – Well-designed spot markets create incentives for flexibility and naturally prioritize renewable energy

• Some adjustments to accommodate higher RE
  – E.g., flexibility products, dynamic reserves, capacity value..
  – (Assume well-functioning standard spot market)
  – In very-high RE system, marginal costs may need to be revisited

(Hunt, 2002; Joskow, 2008; Neuhoff, Wolter, & Schwenen, 2016; Conejo & Sioshansi, 2018)
Diverging from the “standard model”

• Country motivations for reform are varied:
  – Efficiency
  – Customer choice
  – Private finance
  – Reliability

• ...and implementation frequently diverges from model:
  – Legacy gov’t planning institutions distort markets
  – Non-standard market designs
  – Uneven implementation, political favoritism, non-independent regulator...

• Aggregate panel data show price and cost changes sensitive to degrees of institutional development

• Regional integration studies examine benefits of coupling (standard) markets

• Few studies have investigated effects of transitional, non-standard markets on scheduling and dispatch

(Williams & Ghanadan, 2006; Jamasb, Nepal, & Timilsina, 2017; Neuhoff, Wolter, & Schwenen, 2016)
CHINA
Data

• Provincial case studies
  – Diversity of systems & market experiments
• 66 interviews (2015-2016) plus several scoping visits
  – Government (central + local)
  – Grid (central + reg’l + local)
  – Research (academic + grid-affiliated)
• Archival materials (gov’t and grid reports, media accounts)
• See my dissertation (2018) for full results

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China’s rounds of power sector reforms

1949-1985: Vertically-integrated state-run utility
  – Centralized investment & planning → State finances limited

1985 (Round 1): Open investment in generation
  – Local gov’t, private & foreign investors “competed” with bundled ministry owned generation → Inefficient plan allocation

1997-2002 (Round 2): Corporatization and unbundling
  – Separate grid & generation → Lacks competition (“equal shares”)
    → Inefficient grid cost regulation (“difference tariffs”)
  – Generation market pilots failed → Local gov’ts prevent regionalism
  – Independent regulator (until 2014) → Lacks authority and independence

2015- (Round 3): Provincial market experimentation
  – Convert planned quotas to competitive contracts
  – “Relatively independent” exchanges
  – Regulated cost-of-service T&D services

(NEA; Andrews-Speed 2013; Zhang & Heller 2007; State Council, 2015)
Power market penetration, 2017H1

(CEC, 2018)
Commitments, hydro schedules

Distance

Regional / national spot market

Limited inter-prov balancing

Intra-prov gen adjustments

Limited inter-prov adjustments

Commitments, hydro schedules

Inter-regional plans for large gens

Inter-prov transmission negotiations

Intra-prov quota

China dispatch and scheduling

Hour Day-ahead Monthly Annual

Time
China (w/markets)

Regional / national spot market

Limited inter-prov balancing

“Peaking markets”

Intra-prov gen adjustments

Limited inter-prov adjustments

Commitments, hydro schedules, physical contracts

Inter-prov transmission negotiations

Intra-prov quota, physical contracts

Inter-regional plans for large gens

Distance

Hour Day-ahead Month Annual

Time
INDIA
Data

• Two state case studies
  – High RE and flexibility challenges
  – Range of perceived sophistication of operation, discom health
• 34 interviews (2017) plus 1 day of observation
  – Gov’t & regulators (central + state)
  – Grid operators (central + state)
  – RE companies
  – Research (academic + grid-affiliated)
India’s power market evolution

Pre-1991: vertically-integrated State Electricity Boards

1990s: Open investment to private and foreign IPPs
  – Guaranteed rates of return, expensive
  – Some state-level regulatory commissions

2003: Electricity Act to create all-India competitive market
  – Formally launched unbundling:
    SEBs → Gencos, Load dispatch centers, Distribution companies
  – But, only nominally unbundled in some states (e.g., subsidiaries of former SEB)
  – State regulatory commissions

2005-: National Electricity Policy and Tariff Policies
  – Formalize bidding process
  – Preference for long-term contracts (e.g., coal = 25 years)
  – Two-part tariffs (Availability Based Tariff)

2010: Power market regulations
  – National power exchanges

(Kumar and Chatterjee 2012; Tongia 2007; Government of India, 2005; CERC, 2017)
### Market size

<table>
<thead>
<tr>
<th>Transaction</th>
<th>Share of generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term PPAs</td>
<td>~90%</td>
</tr>
<tr>
<td>Short-term (&lt; 1 year) contracts</td>
<td>10%</td>
</tr>
<tr>
<td>...Bilateral: traders</td>
<td>3%</td>
</tr>
<tr>
<td>...Bilateral: discom-discom</td>
<td>2%</td>
</tr>
<tr>
<td>...Power exchange: day-ahead</td>
<td>3%</td>
</tr>
<tr>
<td>...Power exchange: intra-day</td>
<td>0.08%</td>
</tr>
<tr>
<td>...Deviation settlement / UI</td>
<td>2%</td>
</tr>
</tbody>
</table>

(CERC, 2017)
India dispatch and scheduling

- **Regional / national spot market**
  - URS: Regional pooling unused inter-state gens
  - Deviation settlement (UI)
  - Intra-state gen adjustments

- **Power exchanges**

- **Inter-regional PPAs (2-part)**

- **Inter-state gen PPAs (2-part)**

- **Intra-state gen PPAs (2-part)**
DISCUSSION
Partial liberalization effects on flexibility

• Both have medium- to long-term physical obligations that dominate total energy transactions

• Distortions of short-run dispatch
  – India: 2-part tariffs in merit order
  – China: inflexible quota/contract allocation

• Different operations, markets and regulations at state, regional and national levels
  – Longer distance less flexible at short time intervals

• Different treatment of conventional vs. RE
  – India: e.g., long-term contracts
  – China: e.g., monthly scheduling

• Potential for grid operator conflicts of interest
  – India: incomplete unbundling
  – China: revenue structure
Research on restructuring for decarbonization

• More qualitative work is needed
  – Evaluate *de facto* institutions of regulation (beyond binary indicators)
  – Disaggregate scheduling & dispatch practices

• Quantitative models moving beyond ideal assumptions
  – Analyze legacy institutions, non-standard markets... interactions w/RE characteristics

• New formulations and solution techniques
  – Formulating dispatch heuristics and complex contract structures
  – Sensitivities around uncertain / unobservable political parameters require computational efficiency
  – Long-term political constraints: coupling challenges across long time horizons (cf planning models w/operational detail)
Policy recommendations

For long-term structural reforms for efficient, low-carbon market operations:

1. Increase centralization of market design and oversight
2. Establish consistent policy for transition costs
3. Rely more strongly on financial vs. physical contracts
4. Establish/strengthen short-term markets

Medium-term policies:

1. Central planning and control over investments: e.g., reduce/eliminate new coal plant permitting in China
2. Adjust RE support policies: e.g., tariffs to incorporate integration costs
3. Expand sub-national market coupling
4. Establish reserve accounting and sharing mechanisms
THANK YOU.

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References


India dispatch (detailed)

Day-ahead:
• 1000: All generators declare available capacity for next day (15-min blocks) to State Load Dispatch Center (SLDC), Regional Load Dispatch Center (RLDC)
• 1000-1100: Gujarat: SLDC will help state-owned discoms (GUNL) with identifying exchange purchases
• 1100-1700: Exchange
• 1500: SLDC sends schedule to RLDC
• 1700: RLDC confirms schedule w/SLDC
• 1800: SLDC notifies generators day-ahead schedule (Tamil Nadu: up to 2400, can revise schedule)

Real-time principles:
• Seek to minimize Unscheduled Interchange (UI) according to frequency deviations
• Once day starts, will incur first-part fixed cost tariff
• Schedule generators acc “merit order” (variable costs in contract, or exchange)
• More commonly...“back down” plants according to reverse MO
• RE is supposed to be “must-run”, meaning it should not be considered in MO

Real-time timing:
• 2.5-1.5 hour ahead (ha): intra-day exchange (extremely small)
• 1.5 ha: normal changes to schedule
• 1-0.5 ha: Un-Requisitioned Surplus (URS): regional pooling of inter-state generators’ excess capacity, SLDC can view and purchase in MO
• 0.5 ha: SLDC notifies intra-state generators of backing down