New Thinking in Industrial Policy: Perspectives from Developed and Developing Countries

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Industrial Policies for Multi-Stage Production: The Battle for Battery-Powered Vehicles

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Industrial Policies with Multi-Stage Production, Increasing Returns to Scale, and Endogenous Facility Location Choice

How do industrial policies shape global supply chains?

- Industries targeted by industrial policies often share key features
- High fixed costs among competing locations
  $\rightarrow$ Most locations won't receive plants (substitutes)
  - There is a core input that drives costs of the downstream product (complements)
- Understanding the impact of those policies is challenging
  $\longrightarrow$ Indirect effects via impact on plant location choice

Main Takeaway:

- Changes in plant location choices drastically affect how we quantify the impact of industrial policies (and even affect the direction of change!)

Discrete (Facility Location) Choice vs "Smooth" Increasing Returns to Scale

Impact of industrial policies with fixed costs:

- Open/Close decisions (facility location choice) induce "jumps" in "delivered marginal cost"
- But the direction of those "jumps" is not determined by parameter values

For example:

- Industrial policy in one region can move delivered MC up or down in other regions
- Trade restrictions can move delivered MC up or down

$\longrightarrow$ Quantitative policy evaluation requires estimation of "when/where" jumps occur, their direction, and magnitude

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Solving Facility Location Choice: Substitutes or Complements?

- Within production stage: substitutes.
- Across production stages: complements
- $\longrightarrow$ This problem is neither sub-modular (locations are substitutes) nor super-modular (locations are complements)
- With a continuum of inputs, squeezing/pruning algorithms cannot be used. $\longrightarrow$ This problem is NP-hard: $2^{L.K}$ combinations (L locations, K stages)

Solving Facility Location Choice: New Computational Method

- In our application to the battery electric vehicle industry (BEV), inputs are discrete (battery cells), and stages of production (including final assembly) are observed
  - This reduces the problem to a choice of L^K paths across the K stages of production for a given BEV model sold in a given destination
    ... But paths are inter-dependent across models and destinations
  - Key difference: discrete set of inputs and single sourcing (not input substitutability)

Theoretically, this problem is still NP-hard, but in practice it can be quickly solved (global optimum) using advances in optimization techniques for linear programs with integer constraints (Mixed Integer LP)

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Solving Facility Location Choice w Integer Linear Programming

- Recasting the facility location choice problem as a (mixed) integer linear program has been studied extensively in the operations research (OR) literature – but has not received much attention in the economics literature
- It efficiently solves problems that involve:
  1. Multiple stages of production with no restrictions on complementarity or substitution between facilities (super vs sub modularity)
  2. Flexible specification of fixed costs across groups of products, locations, and stages of production
  3. Endogenous market entry to multiple markets
  4. Many different demand and production cost structures (including trees)

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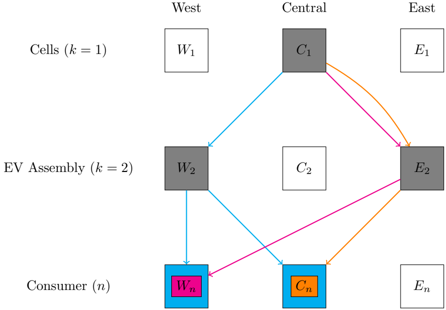
Optimization Over Paths



- Firm chooses which models *m* to sell to each market *n*
  - Subject to market entry/access cost
- Firms chooses which facilities to open at each production stage
  - Subject to facility fixed cost
- Firm chooses optimal path through open facilities

- Chosen path is associated with a delivered marginal cost
  - (as a function of parameters to be estimated)
- ... and variable profits per model *m* and destination market *n*
  - (depends on delivered marginal cost and an endogenous level of market demand to be estimated)

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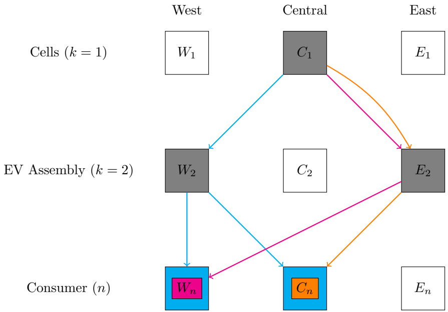

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Necessary Industry Characteristics for this Framework

- Constant marginal costs
- Inputs from different plants are perfect substitutes if all dimensions of the product are specified (need dis-aggregated sourcing data)
- Plants are "uncapacitated" : no long run constraints on output

$\longrightarrow$ Single sourcing

- No bargaining between buyer and supplier

$\longrightarrow$ Single decision maker

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High Up-Front Investments (Especially for Batteries)

Tesla Investing $3.6B For Battery And Semi Production In Nevada

$4.9B electric vehicle battery plant announced for Windsor, Ont.

GM Plans Biggest Manufacturing Investment Ever In Its Home State For EV, Battery Production

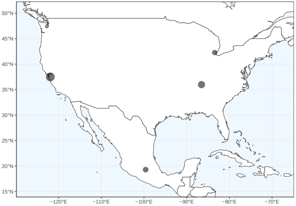
FORD TO LEAD AMERICA'S SHIFT TO ELECTRIC VEHICLES WITH NEW MEGA CAMPUS IN TENNESSEE AND TWIN BATTERY PLANTS IN KENTUCKY; $11.4B INVESTMENT TO CREATE 11,000 JOBS AND POWER NEW LINEUP OF ADVANCED EVS

Toyota's North Carolina Battery Plant Investment Nears $14B

VW breaks ground on new battery factory, will invest €20b into "PowerCo" spinoff

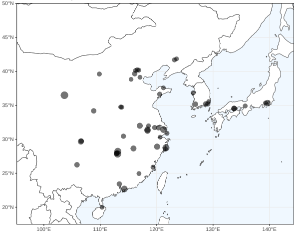
Assembly Location Expansion: 2015-2022

4 Assembly Plants in 2015, Total 75k BEVs

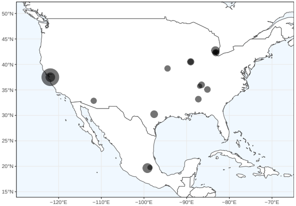


16 Assembly Plants in 2015, Total 80k BEVs

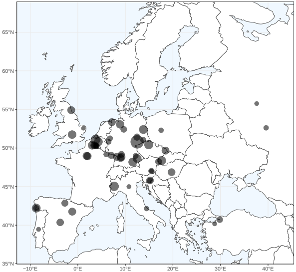
52 Assembly Plants in 2015, Total 175k BEVs



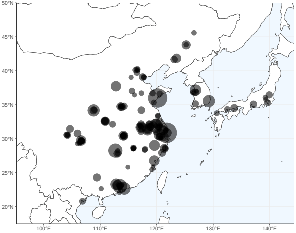
17 Assembly Plants in 2022, Total 812k BEVs



52 Assembly Plants in 2022, Total 1392k BEVs

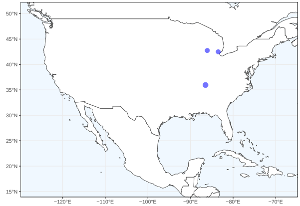


170 Assembly Plants in 2022, Total 5893k BEVs



Cell Production Expansion: 2015-2022

3 Cell Plants in 2015, Total 0.6GWh



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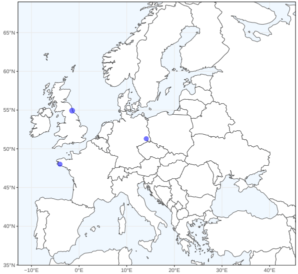
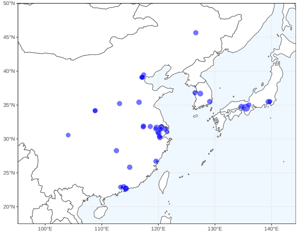
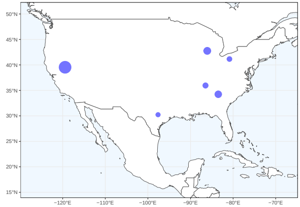


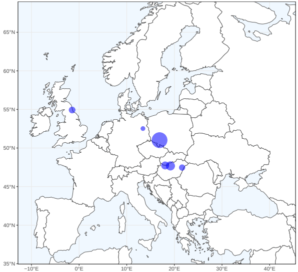
39 Cell Plants in 2015, Total 9.8GWh



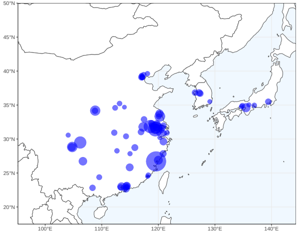
6 Cell Plants in 2022, Total 34.1GWh



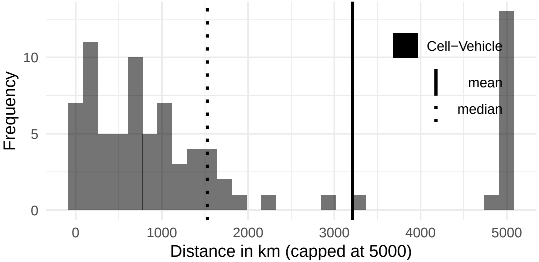
6 Cell Plants in 2022, Total 64.8GWh



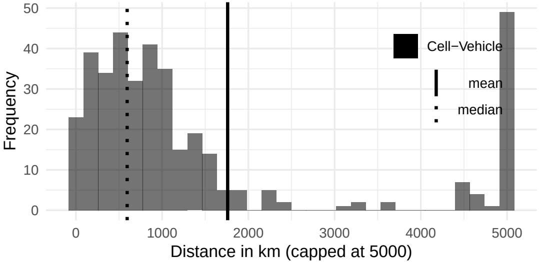
74 Cell Plants in 2022, Total 374.2GWh



Proximity Matters for Cells and Vehicles

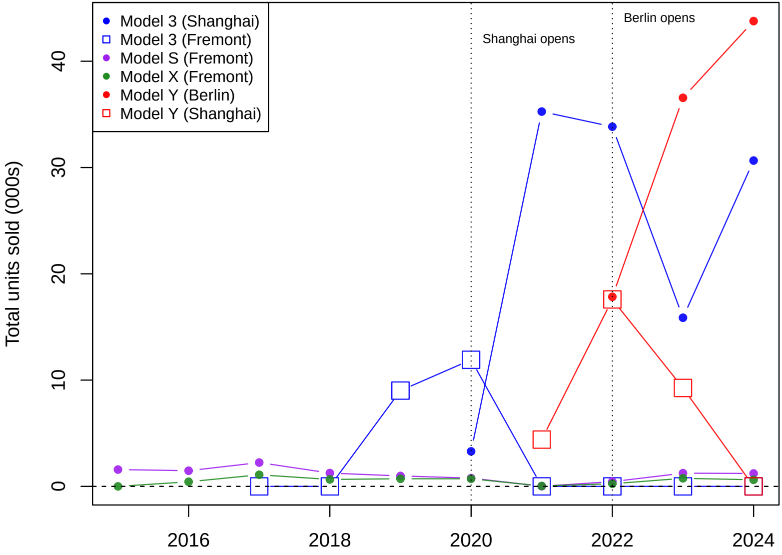


2015

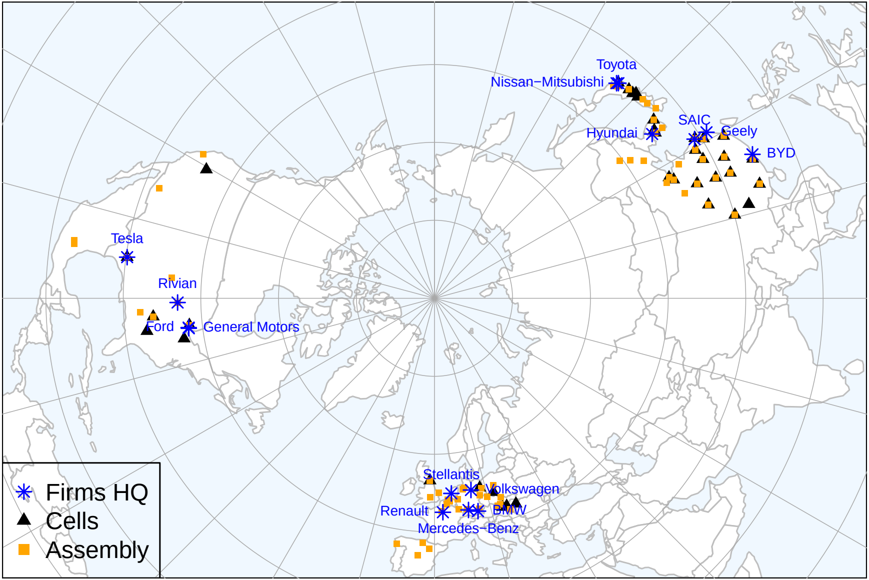


2022

Multi-Sourcing is Transitory or Across Models/Trims: German Tesla Multi-Sourcing



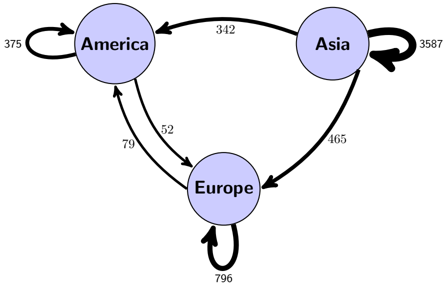
Top EV Firms and Their Location Alternatives



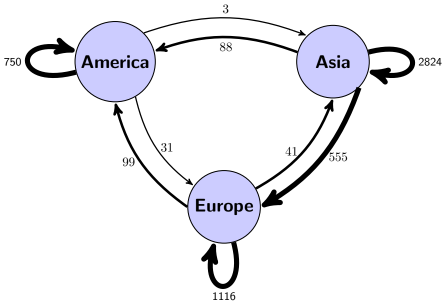
Total Configurations: $2^{24+60} \longrightarrow$ median locations/groups: 24 (cell) 60 (assembly)

Cross-Continental BEV Flows

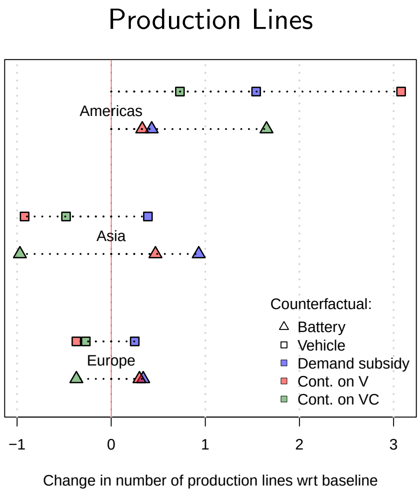
Cells (000s of vehicles)

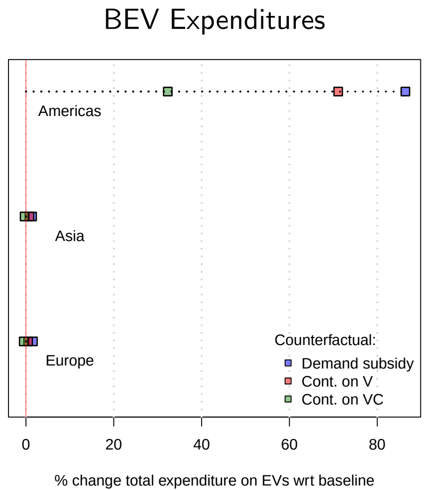


Vehicles (000s)

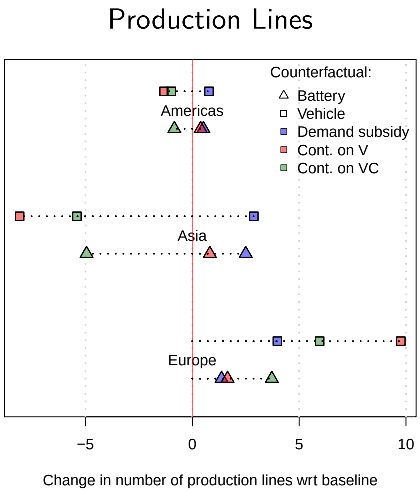


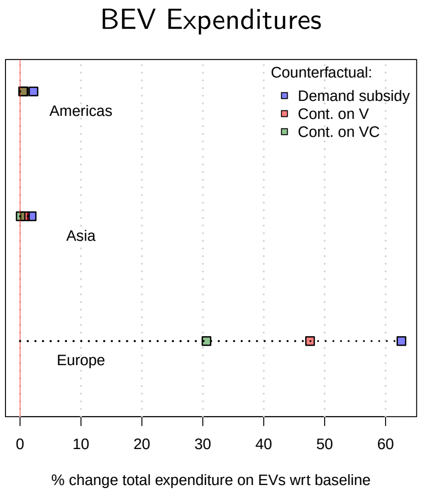
Predicted Impact of NA BEV Subsidies





Predicted Impact of EU BEV Subsidies





BEV Subsidies: EV Price Changes

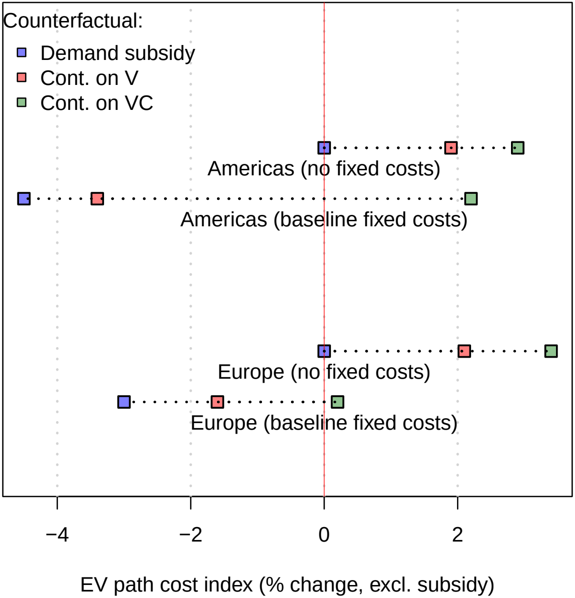
Americas

Policy	Elig. share		Cost index		Tot Exp
	# path	revenue	subs.	costs	
1: Unconditional	100.0	100.0	-20.0	-4.5	86.4
2: Continental V	43.4	90.5	-17.4	-3.4	71.1
3: Continental V+C	21.5	68.3	-14.7	2.2	32.3

Europe

Policy	Elig. share		Cost index		Tot Exp
	# path	revenue	subs.	costs	
1: Unconditional	100.0	100.0	-20.0	-3.0	62.6
2: Continental V	68.4	85.3	-15.8	-1.6	47.6
3: Continental V+C	47.3	66.8	-12.1	0.2	30.6

Impact of Plant Fixed Costs for Cost Reductions



Final Thoughts

- Current trade and industrial policies profoundly affect global production networks
- In order to assess the ultimate impact of those policies on various objectives (domestic production/employment, consumer prices, environmental, geopolitical)
- $\longrightarrow$ Must be able to evaluate how those policies will reshape global production networks
- $\longrightarrow$ Need models & tools that can handle the massive complexity associated with those network choices and deliver realistic predictions