Why do warehouses decentralize more in certain metropolitan areas?

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Conference on Urban Freight 2016
Overview

- Warehousing Decentralization
  - Why should we care?
  - Why do location patterns change?
  - What do we know about it?

- Research Framework
  - How do we measure?
  - What do we test?

- Results
  - How have they changed?
  - Which factors explain it?

- Discussion
  - What have we learned?
Warehousing Decentralization
Why should we care?

- Warehousing and distribution centers (W&Ds)
  - NAICS493 “Warehousing and Storages”
  - An intermediary that connects supply chain
  - Part of goods production and distribution system

- Warehousing decentralization?
  “...the phenomenon of relocation and concentration of logistics facilities toward suburban areas outside city centre boundaries”

Dablanc and Rakotonarivo (2010)
Why should we care?

- Growth of W&D and foreign trade since 2000
  - W&D jobs 33% ↑ vs. All U.S. jobs 4% ↑ ¹
  - Foreign trade 40% in $ ↑ vs. U.S. population 10% ↑ ²

- Key segments of domestic goods movement (US) ³
  - Within metro-level – 51% in tons
  - By truck – 77% in tons

Why should we care?

- **W&Ds as truck trip generators**
  - If W&Ds are located **farther from markets**
    - Truck travel would increase (VMT)
    - Impact would increase
  - E.g. Tokyo case (Sakai, et al. 2015)

- **Negative externalities**
  - Congestion, increased fuel consumption, air pollution
  - Noise, vibration, infrastructure damage
  - Environmental justice issues
Why do location patterns change?

- **Economic restructuring** (Hesse and Rodrigue, 2004)
  - Globalized, geographically dispersed supply chains
  - Advances in transport tech. – reduced transport costs
  - Advances in logistics tech. – instant response, short dwell time
  - Access to national and global markets
  - Proximity to highways, rail and intermodal facilities

- **More modernized and larger W&Ds** (Dablanc and Ross, 2012)
  - Ship large volumes of goods frequently and reliably
  - Mega DC and automation

- **Land price and availability**
  - Low rent, large parcels, and favorable zoning
Is this really happening since 2000s?

- **For**
  - Distance to the geographical center of W&Ds has increased
    - Los Angeles, Atlanta, Toronto, and Paris (Tokyo)
  - W&Ds have suburbanized
    - In UK metro areas

- **Against**
  - Distance to the geographical center of W&Ds has decreased
    - Seattle (Dablanc, et al. 2014)

- **Other measures**
  - W&D concentrated in counties with airport or more highways

- **No systematic testing of factors for decentralization**
Research Framework
Rationale behind W&D location change

- Pop. & Industry
  - Delivers goods
- Logistics Industry
- W&D capacity
- Warehousing Operators

Latent freight demand
  - When realized
  - Global supply chain, influx of freight

Demand
  - Larger, automated W&Ds
  - More feasible

Land price & availability
  - Land price & availability
  - Metro Area

New, larger W&Ds added:
  - Location patterns changed
Considerations and Research Goals

- **Across metro areas:** Chance of location change varies
  - Global supply chains via select metro areas
    - 78% of all container import through 10 container port systems
    - Much greater demand for larger W&Ds!
  - Land more restricted in certain places
    - Different level/distribution of land rent across metro areas

- **Research Goals**
  - To identify metro-level factors for W&D location change
  - To test if metro-level heterogeneity results in different patterns of W&D location change
  - To test if temporal changes in factors result in different patterns
General Model 1

Freight flows and W&D size – Cross-section (OLS)

- \( \Delta W&D\ SIZE_{(i, \text{from } t \text{ to } t+1)} = F(\text{FLOWS}_{(i,t)}, \text{POP}_{(i,t)}) \)

Diagram:

- Pop. & Industry
  - Delivers goods
    - Logistics Industry
      - W&D capacity
        - Warehousing Operators
          - Larger, automated W&DS
            - More feasible
              - Land price & availability
                - Metro Area
              - New, larger W&DS added:
                - Location patterns changed
General Model 1

Freight flows and W&D size – Cross-section (OLS)

- \( \Delta W&D \text{ SIZE}_{(i, \text{ from } t \text{ to } t+1)} = F(\text{FLOWS}_{(i,t)}, \text{POP}_{(i,t)}) \)

Pop. & Industry \rightarrow Latent freight demand

When realized

Global supply chain, Influx of freight

Demand \( \Leftarrow \) If this holds true?

Larger, automated W&Ds
More feasible
General Model 2

Heterogeneity Across Metro Areas – Cross-section (OLS)

(1) \( \Delta W&D \text{ DIST} \) (i, from t to t+1) = F (SIZE \( i,t \), LAND \( i,t \))

(2) \( \Delta W&D \text{ DIST} \) (i, from t to t+1) = F (FLOW \( i,t \), LAND \( i,t \))

Global supply chain, Influx of freight

Demand

Larger, automated W&Ds
More feasible

Land price & availability

New, larger W&Ds added:
Location patterns changed

(1)
General Model 2

Heterogeneity Across Metro Areas – Cross-section (OLS)

(1) \[ \Delta W&D \text{ DIST}_{(i, \text{from } t \text{ to } t+1)} = F(\text{SIZE}_{(i,t)}, \text{LAND}_{(i,t)}) \]

(2) \[ \Delta W&D \text{ DIST}_{(i, \text{from } t \text{ to } t+1)} = F(\text{FLOW}_{(i,t)}, \text{LAND}_{(i,t)}) \]

Global supply chain, Influx of freight

Demand

Larger, automated W&Ds
More feasible

Land price & availability

If this holds true?

New, larger W&Ds added:
Location patterns changed

Global supply chain, Influx of freight

Demand: Proxy

Larger, automated W&Ds
More feasible

Land price & availability

If this holds true?

New, larger W&Ds added:
Location patterns changed
Measurement

- **W&D distribution**
  - Average distance from the CBD to all W&Ds by metro area
  - Average distance from all employment to all W&Ds by metro area
  - $\Delta W&D$ distribution = Ave. distance in 2013 – Ave. distance in 2003
  - $W&D$ distribution $(t) = Ave. \text{ distance} (t)$ ($t = 2003, 2008, 2013$)

- **W&D size**
  - SIZE = W&D jobs / W&D establishments
  - Expectation: (+) Larger W&Ds $\rightarrow$ MORE decentralization

- **Freight flows** (million tons)
  - Expectation: (+) Greater freight flows $\rightarrow$ MORE decentralization
Spatial distribution of land rent approximated by **negative exponential curve** of employment density by ZIP Code

\[
D(x) = D_0 e^{-\beta x} + u
\]

*Logarithm Transformation*

\[
\log(D(x)) = \log(D_0) - \beta x + u
\]

\[
Y = a - bX
\]

- **Intercept (peak density):** \(\hat{\log}(D_0)\)
- **Slope (density gradient):** \(\hat{\beta}\)

(Clarke, 1951; McDonald, 1989; Anas, Arnott, and Small, 1997)
Controlling for “Gradient”
Greater “Peak Density” → MORE decentralization

Controlling for “Peak Density”
Steeper “Gradient” → LESS decentralization

<table>
<thead>
<tr>
<th></th>
<th>A)</th>
<th>B)</th>
<th>C)</th>
<th>D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak density</td>
<td>7.5</td>
<td>6.5</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Gradient</td>
<td>0.08</td>
<td>0.08</td>
<td>0.12</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Data

ZIP Code Business Patterns
Location of WDCs

- **ZIP Code Business Patterns (2003-2013)**
  - A subset of CBP
  - Business Register: records of known establishments
  - Annual N of establishments, employment, and payroll
  - 6 digit NAICS codes; USPS ZIP Codes; cover entire U.S.

- **Limitations**
  - A large spatial unit; *TeleAtlas* centroids pinpoint location
  - Aggregated addresses, not geographically delimited
  - Size correlates with density, not with political boundaries
Results
## Sample Metropolitan Areas (N=48)

<table>
<thead>
<tr>
<th>Rank 1-22 (N=22)</th>
<th>Combined Statistical Areas &amp; Metropolitan Statistical Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New York, Los Angeles, Chicago, Washington, Boston, San Francisco, Dallas, Philadelphia, Houston, Atlanta, Miami, Detroit, Seattle, Phoenix, Cleveland, Denver, St. Louis, Pittsburgh, San Diego, Portland, Orlando, Tampa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rank 23-48 (N=26)</th>
<th>Combined Statistical Areas &amp; Metropolitan Statistical Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indianapolis, Charlotte, Kansas City, Columbus, Milwaukee, Cincinnati, Salt Lake City, Las Vegas, San Antonio, Nashville, Raleigh, Austin, Louisville, Greensboro, Virginia Beach, Grand Rapids, New Orleans, Richmond, Greenville, Buffalo, Birmingham, Rochester, Tulsa, Albany, Dayton, Tucson</td>
</tr>
</tbody>
</table>
W&D decentralization

Population 2000 (log10)

ΔW&D distribution 2003-2013 (mile)

- Los Angeles
- New York
- Tucson
Non-linear W&D decentralization

ΔW&D distribution 2003-2013 (mile)

Population (log10)

‘Large’
Rank 1-22

‘Small’
Rank 23-48

Large <> Small metro areas
Gradient, Peak density, & Freight flow
Sig. different (P<0.01)
W&D decentralization (Rank 1-22)
W&D decentralization (Rank 23-48)

Average decentralization of W&Ds (mile)

Population (log10)
## Bivariate correlation table

<table>
<thead>
<tr>
<th>Bivariate correlation</th>
<th>All metro areas (N=48)</th>
<th>Metro areas Rank 1-22</th>
<th>Metro areas Rank 23-48</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔW&amp;D distribution 2003-2013</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population 2000 (log)</td>
<td>0.23</td>
<td>0.65</td>
<td>0.28</td>
</tr>
<tr>
<td>W&amp;D Size (Employees per W&amp;D) 2003</td>
<td>0.16</td>
<td>0.20</td>
<td>0.16</td>
</tr>
<tr>
<td>Total freight flow (M-ton) 2002</td>
<td>0.32</td>
<td>0.47</td>
<td>0.49</td>
</tr>
<tr>
<td>Gradient (β)</td>
<td>-0.06</td>
<td>-0.48</td>
<td>0.10</td>
</tr>
<tr>
<td>Peak Density (log(D₀))</td>
<td>0.22</td>
<td>0.19</td>
<td>0.32</td>
</tr>
</tbody>
</table>
## Model 2 results

**OLS (1):** \[ \Delta \text{W&D DIST}^{(i, \text{from } t \text{ to } t+1)} = F(\text{LAND}^{(i,t)}, \text{SIZE}^{(i,t)}, \text{FLOW}^{(i,t)}) \]

**OLS (2):** \[ \Delta \text{W&D DIST}^{(i, \text{from } t \text{ to } t+1)} = F(\text{LAND}^{(i,t)}, \text{FLOW}^{(i,t)}) \]

<table>
<thead>
<tr>
<th>(\Delta\text{W&amp;D Distribution 2003-2013})</th>
<th>(1) (\text{SIZE} \text{ and FLOW})</th>
<th>(2) (\text{FLOW})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\text{Std. Coef.}) (\text{Sig.})</td>
<td>(\text{Std. Coef.}) (\text{Sig.})</td>
</tr>
<tr>
<td>Gradient 2003</td>
<td>-0.566 **</td>
<td>-0.580 **</td>
</tr>
<tr>
<td>Peak density 2003</td>
<td>0.271 *</td>
<td>0.283 **</td>
</tr>
<tr>
<td>Freight flow 2002</td>
<td>0.164 **</td>
<td>0.161 **</td>
</tr>
<tr>
<td>W&amp;D Size 2003</td>
<td>0.124</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>-1.389</td>
<td>-1.250</td>
</tr>
<tr>
<td>Small * Gradient 2003</td>
<td>0.649</td>
<td>0.662</td>
</tr>
<tr>
<td>Small * Peak 2003</td>
<td>0.874</td>
<td>0.799</td>
</tr>
<tr>
<td>Small * Flow 2002</td>
<td>0.403 *</td>
<td>0.415 *</td>
</tr>
<tr>
<td>Small * W&amp;D Size 2003</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.364</td>
<td>0.344</td>
</tr>
<tr>
<td>(N)</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

**P-values:**
- **P<0.01;**
- **P<0.05;**
- + P<0.1
<table>
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<tr>
<th>W&amp;D Distribution 2003-2013</th>
<th>Relationship</th>
<th>Exp. Power</th>
<th>As expected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradient 2003</td>
<td>-</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Peak density 2003</td>
<td>+</td>
<td>Moderate</td>
<td>Yes</td>
</tr>
<tr>
<td>Freight flow 2003</td>
<td>+</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>W&amp;D size 2003</td>
<td>N/S</td>
<td>N/S</td>
<td>No</td>
</tr>
</tbody>
</table>
Discussion

- **W&D SIZE**
  - Jobs per establishment?
  - W&D SIZE in $ft^2$

- **Different location patterns: outward/inward movement**

Source: Benjamin Conwell, Cushman & Wakefield
Future research

- **Sub-metropolitan factors for W&D location?**
  - Land rent/availability, access to market/labor, proximity to freight infrastructure, proximity to similar sector, and land use regulation
  - Discrete location choice factors in Los Angeles
  - Different types of W&Ds at different time periods
Thank you!

W&Ds have decentralized to the urban peripheries to transport large volumes of goods frequently and reliably.

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