Competitors, Complementors, and Parents: Explaining Regional Agglomeration in the U.S. Auto Industry

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Motivation

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  - Detroit (automobile)

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- But, why and how does the concentration take place?

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- **Inter-industry spillovers** (Jacobs 1961)
  – Knowledge spillovers across different industries are crucial
- **Organizational reproduction and heredity** (Klepper 2007, 2010)
  – Many industry entrants result from spinoffs
  – Spinoffs are high performers and they locate near parent firms

Our Contribution

- Seek better understanding of geographic concentration by evaluating competing views:

  (a) intra-industry spillovers (Marshall et al)

  (b) related-industry spillovers (Jacobs et al),

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  – Include every firm during the industry's first 75 years (1895-1969)

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- Main findings from reduced-form regressions

  – Presence of firms from the same industry has little or negative effect

  – Strong evidence of positive spillovers from related industries nearby

  – Spinoffs play a positive role, as a special form of local externalities

Our Contribution (cont.)

- Construct a theoretical model explaining empirical findings
  - Consider two types of entrants: spinoff and non-spinoff entrants
  - Both types of entrants are subject to various local externalities
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- Quantify the relative importance of competing views
  - Conduct structural calibration and counterfactual simulations
  - In the auto industry, related-industry spillovers play the most important role by fostering *new* non-spinoff entrants
  - Spinoffs play a secondary role and contribute to an increased concentration at a later stage of the industry life cycle

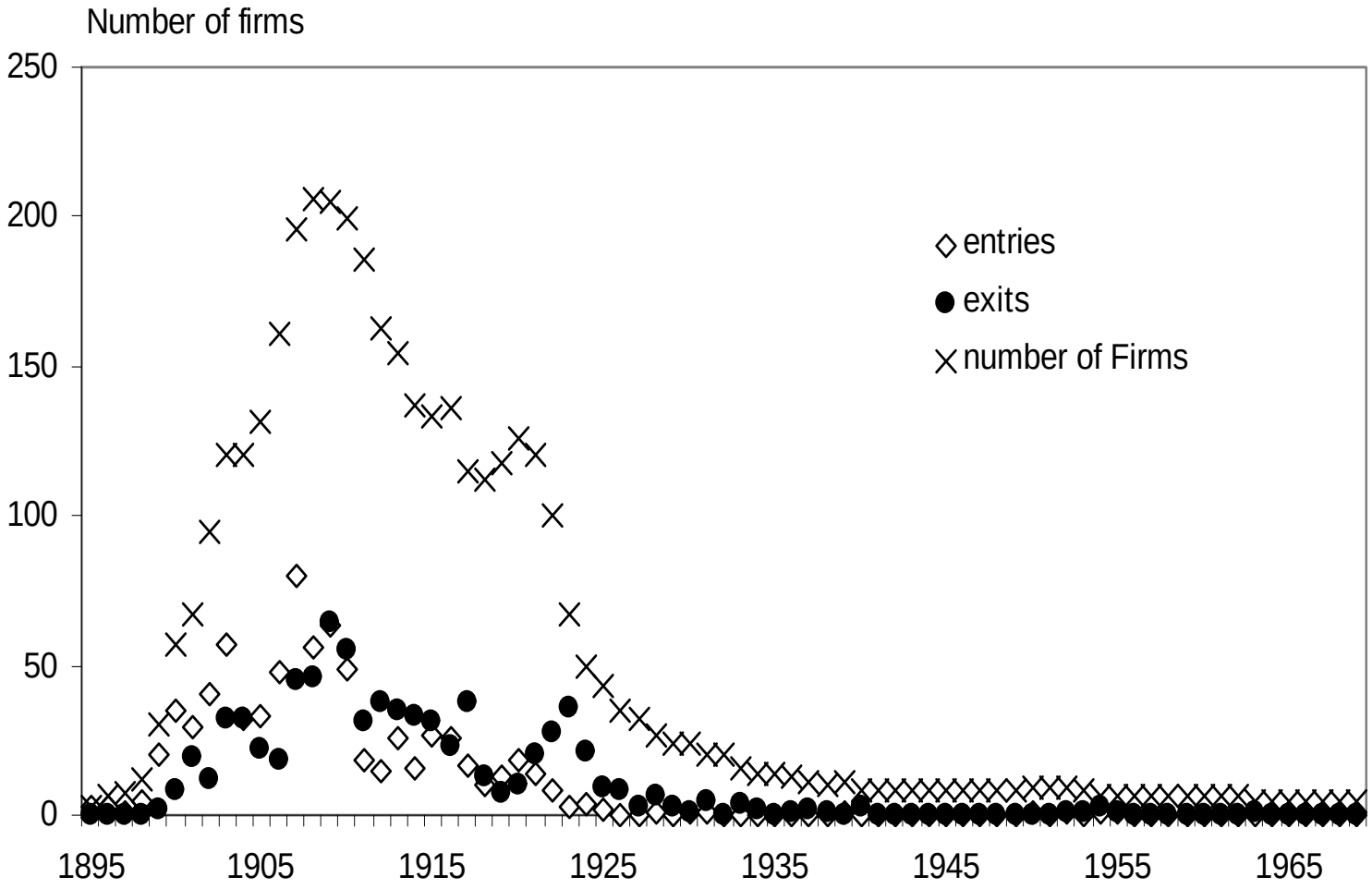
Outline

- Motivation and summary
- The U.S. auto industry: A brief history
- Reduced-form regressions
- A theoretical model
- Structural calibration and simulation
- Conclusion

US Auto Industry: Overview

- **Evolution**: The number of firms initially rose and later fell, which peaked around 1910

U.S. Automobile Producers



US Auto Industry: Overview

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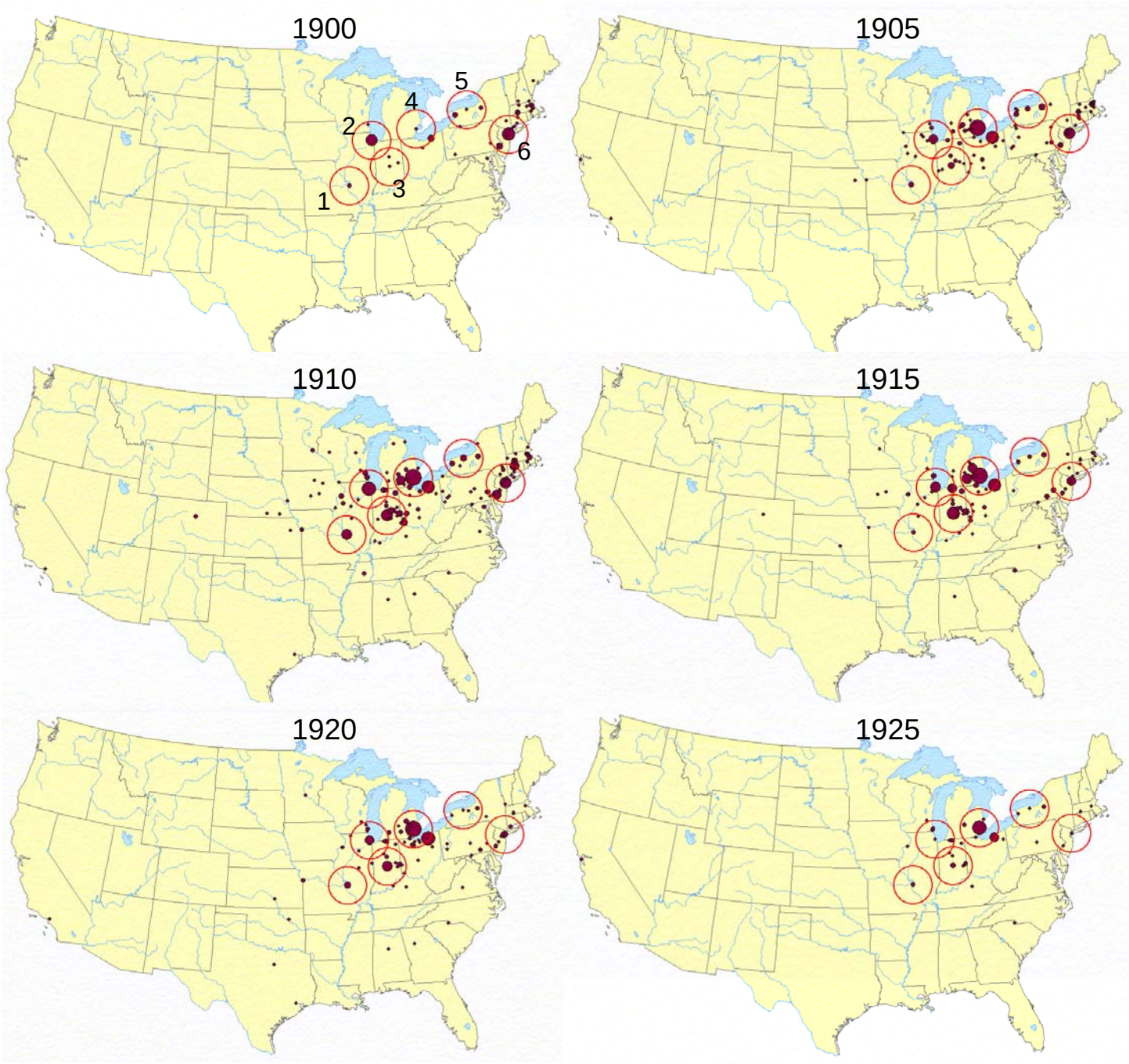
- **Agglomeration**: Six historically important production centers plus some producers scattered across states

Figure A1. Geographic Concentration of US Auto Producers (1900-1925)



Firms in a City

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8-10
- 11-15
- 16+

Production Centers (red circles):

1. Saint Louis
2. Chicago
3. Indianapolis
4. Detroit
5. Rochester
6. New York

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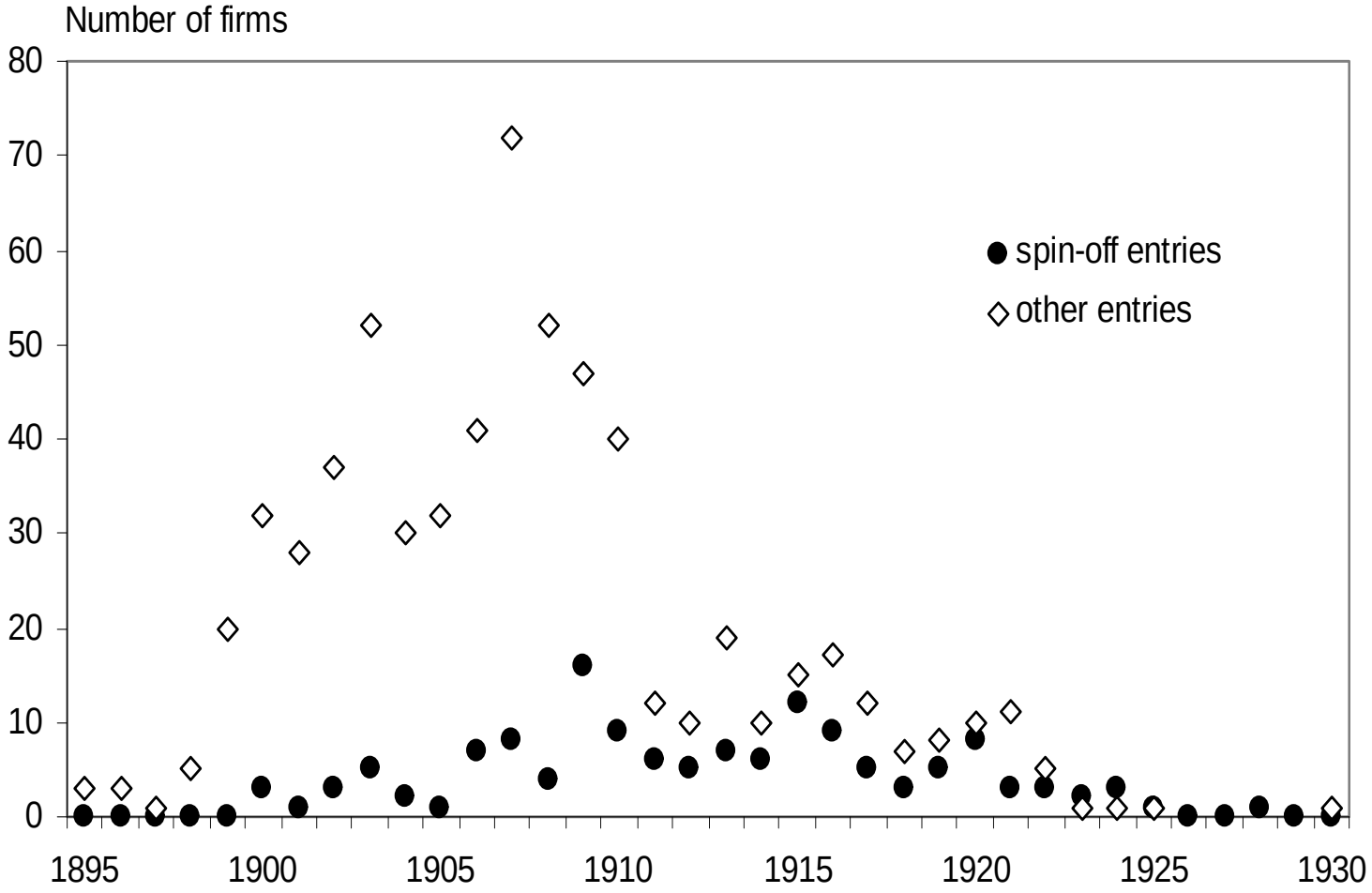
U.S. Auto Entrants by Type



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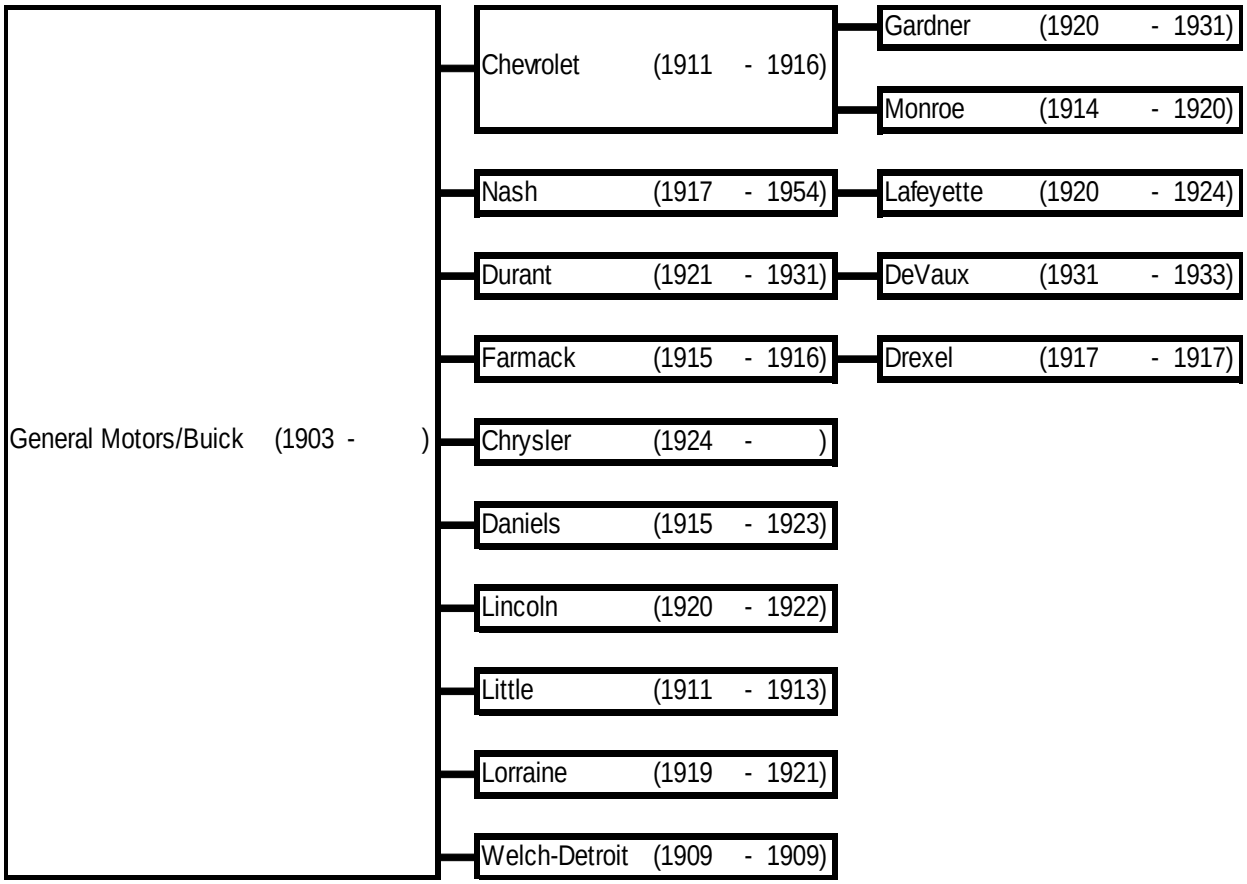
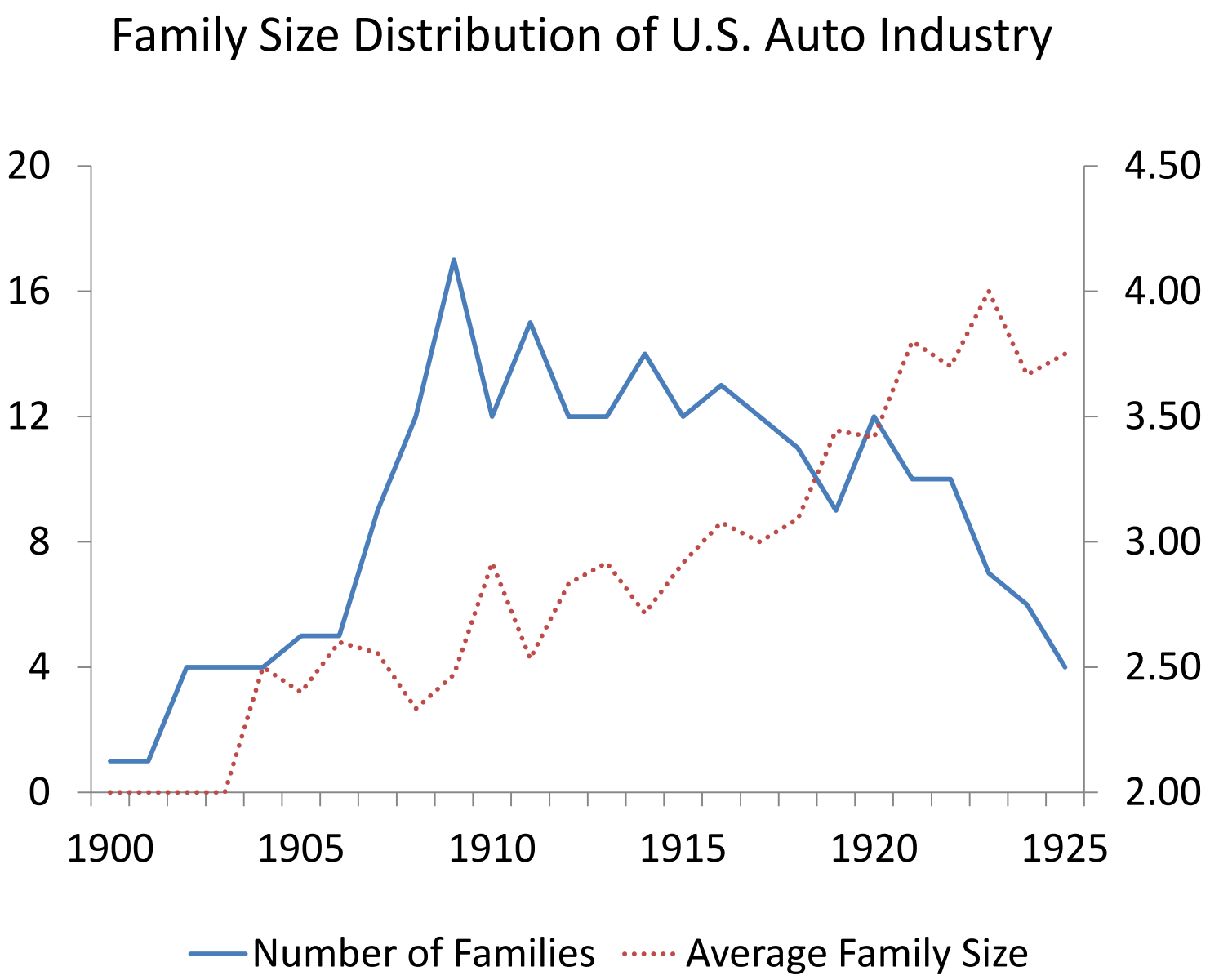
- **Family Networks:** Increasing importance of spinoffs and evolving family network distribution

Table A1. Spinoff Tree of General Motors



Notes: Buick was formed in 1903 before GM was created in 1908 as a holding company for it. Chevrolet was formed by ex-GM president William C. Durant and Louis Chevrolet following Durant's first departure from General Motors. Nash was formed by Charles Nash after a stint as president of General Motors. Durant was formed by William C. Durant following his second departure from General Motors. Farmack was founded by Albert J. Farmer, who had previously designed motors for General Motors. Chrysler was founded by Walter Chrysler, who had had previous experience as president of the Buick Division of General Motors. Daniels was founded by George E. Daniels, a former vice president of General Motors. Lincoln was founded by Henry Martin Leland after he left General Motors in a dispute with William C. Durant. Little was formed by William C. Durant following his first departure from General Motors. He was concurrently involved with Chevrolet, but this was a separate business entity. Lorraine was formed by David Dunbar Buick, who had previously founded Buick. Welch-Detroit was the project of A.B.C. Hardy, who was previously with General Motors. Gardner was founded by Russell E. Gardner after being involved with Chevrolet. Monroe was co-founded by R.F. Monroe and William C. Durant, then of Chevrolet. As with Little, Monroe was a separate business entity from Chevrolet. Lafeyette was founded by Charles Nash. He was then also running the Nash firm as a separate venture. DeVaux was founded by Norman de Vaux, who was involved with the West Coast branch of the Durant company. Drexel was formed by Albert J. Farmer from his financially troubled Farmack venture.


Family Size Distribution of U.S. Auto Industry
20
16
12
8
4
0
4.50
4.00
3.50
3.00
2.50
2.00
1900
1905
1910
1915
1920
1925
Number of Families
Average Family Size

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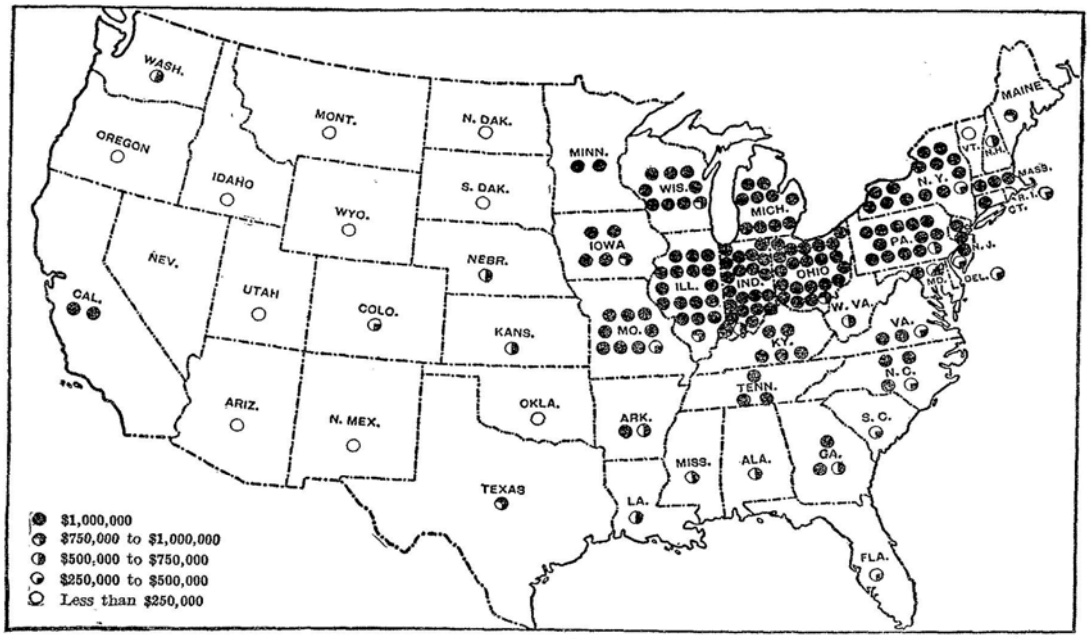
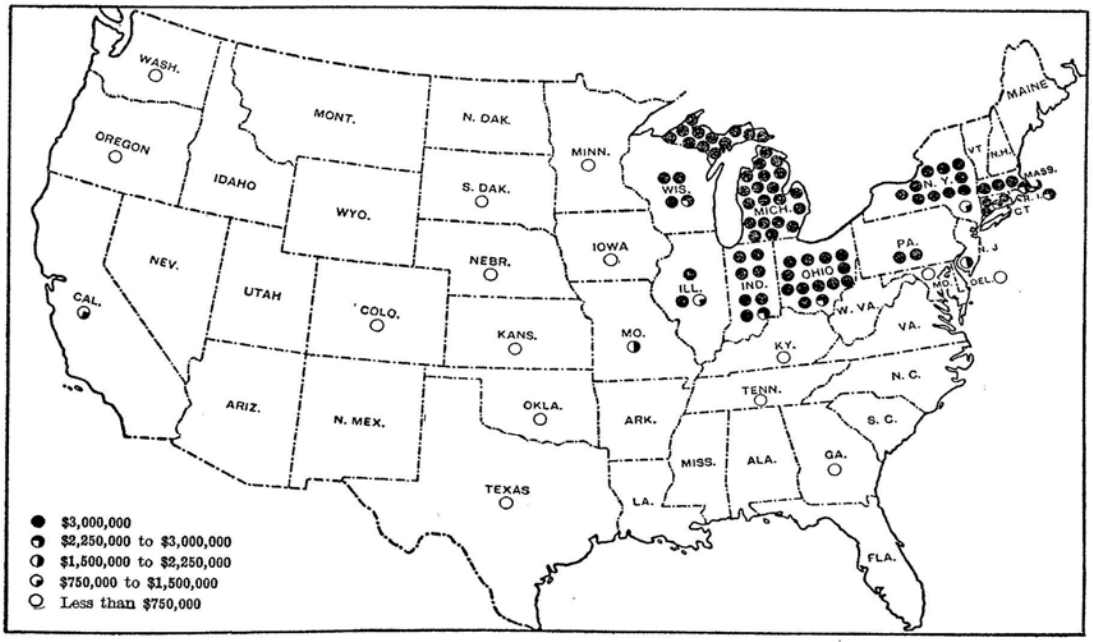
- **Family Networks:** Increasing importance of spinoffs and evolving family network distribution
- **Co-agglomeration**: close relation between auto and carriage & wagon production

Figure A4. Geographic Concentration of Production: Carriage and Wagon *vs.* Automobile



The Carriage and Wagon Industry – Value of Products, By States: 1909



The Automobile Industry – Value of Products, By States: 1909

Source: *The 13th Census of the U.S. Manufactures*, U.S. Census Bureau, 1910.

Data Sources

- Smith (1968): list of every auto make produced in U.S.

  Used to derive firm entry, exit and location
- Kimes (1996): founder's biographical information.

  Used to define spinoffs, *De Alio* and *De Novo* entrants.
- Bailey (1971): annual list of top sellers.

  Used to define firm's type (Top or Bottom).
- Census of the US manufactures and Statistical Abstract of the United States

  State-level info on income, population, carriage & wagon employment
- Data set: a total of 4454 firm year observations, corresponding to 771 firms in the period 1895–1942.

Table A2. Data Summary Statistics: Firm×Year Level

(Sample Range: 1895 – 1942)

Variable	Obs	Mean	Std. Dev.	Min	Max
De Novo	4454	0.21	0.41	0	1
De Alio	4454	0.59	0.49	0	1
Spinoff	4454	0.20	0.40	0	1
Top Firm	4454	0.20	0.40	0	1
Firm Death	4454	0.17	0.38	0	1
Spinoff Birth	4454	0.02	0.13	0	1
Center Size	4454	35.79	23.43	1	96
Family Size	4454	1.53	1.52	1	10
Center Top	4454	6.03	5.55	0	18
Family Top	4454	0.47	1.04	0	5
Local Family Size	4454	1.37	1.25	1	9
Local Family Top	4454	0.41	0.94	0	5
Non-Local Family Size	4454	0.16	0.70	0	9
Non-Local Family Top	4454	0.07	0.39	0	5
Firm Age	4454	6.87	7.24	1	43
Year	4454	1913	8	1895	1942

Table A3. Data Summary Statistics: Firm Level

(Sample Range: 1895 – 1942)

Variable	Obs	Mean	Std. Dev.	Min	Max
De Novo	771	0.30	0.46	0	1
De Alio	771	0.52	0.50	0	1
Spinoff	771	0.17	0.38	0	1
Top Firm	771	0.06	0.24	0	1
Entry Year	771	1908	6	1895	1939

Reduced-form Regressions: Questions

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- What explains auto industry concentration?
- What determines entry rates? Distinguish three types of entry:
  – *De Novo* entry, *De Alio* entry, and Spinoffs
- What determines firm survival?
- Focus on spinoffs:
  – What firms are more likely to give birth to spinoffs?
  – Is there a "family" effect?
  – If so, is it "nature" or "nurture"?

Reduced-form Regressions: Findings

- Non-spinoff entry (quantity and quality) increasing in: (a) income; (b) carriage & wagon employment

Table 3. Negative Binomial Model: Non-Spinoff Entry
(1895 - 1915)

3A. Estimation: Annual Entry

Variable	Non-Spinoff		DeNovo	DeAlio
	Spec. 1	Spec. 2		
Constant	-73.630***	-78.619***	-90.565***	-67.270***
	(20.053)	(19.769)	(27.864)	(21.854)
Year	0.031***	0.034***	0.038***	0.028**
	(0.011)	(0.010)	(0.015)	(0.012)
Log population 1900	0.976***	0.192	-0.119	0.121
	(0.201)	(0.240)	(0.255)	(0.339)
Log per capita income 1900	1.078***	1.150***	1.583***	1.226***
	(0.399)	(0.284)	(0.406)	(0.296)
Log C&W employment 1904		0.722***	1.071***	0.828***
		(0.176)	(0.184)	(0.239)
Log likelihood	-493.383	-485.294	-272.800	-393.696
Number of Observations	735	735	735	735

Notes: Standard errors are in parentheses. One, two and three * indicate statistical significance at the 10, 5, and 1% levels, respectively.

3B. Prediction: Annual Entry

Location	C&W Employment 1904	Per Capita Income 1904	Non-Spinoff Entry	
			Actual	Model (Spec. 2)
New York	21991	287	7.492	6.909
Detroit	19786	208	7.143	3.711
Chicago	10342	236	3.571	2.712
Indianapolis	10601	182	2.381	1.688
St. Louis	3765	188	1.000	0.864
Non-Detroit Centers (average)	11675	223	3.595	3.043
Non-center Locations (average)	794	182	0.171	0.205

Table 4. Logit Model: Top Non-Spinoff Entry
(1895 - 1915)

4A. Estimation: Top Entry

Variable	Spec. 1	Spec. 2	Spec. 3
Constant	530.291***	525.903***	533.575***
	(114.088)	(120.587)	(121.230)
Entry Year	-0.279***	-0.281***	-0.286***
	(0.060)	(0.063)	(0.064)
Per capita income 1900	-0.010**	0.013	0.022
	(0.005)	(0.012)	(0.016)
C&W employment / population ratio 1904		1.142**	1.385**
		(0.474)	(0.640)
Detroit			0.744
			(0.546)
Log likelihood	-92.104	-86.946	-85.959
Number of Observations	560	560	560

Notes: Standard errors are in parentheses. One, two and three * indicate statistical significance at the 10, 5, and 1% levels, respectively.

4B. Prediction: Top Entry

Location [# Entry]	C&W Employment / Population Ratio 1904 ($^0/_{00}$)	Probability of Top Entry		
		Actual	Model (Spec. 2)	Model (Spec. 3)
Indianapolis [50]	4.210	0.100	0.130	0.099
Detroit [150]	3.005	0.073	0.055	0.073
New York [156]	1.342	0.032	0.043	0.039
Chicago [75]	1.499	0.013	0.018	0.011
St. Louis [21]	1.211	0.000	0.007	0.002
Non-Detroit Centers (average) [302]	1.847	0.036	0.049	0.040
Non-center Locations (average) [108]	0.890	0.037	0.028	0.028

Reduced-form Regressions: Findings

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- Spinoff entrants more likely to come out of: (a) older firms; (b) larger and better families; (c) Detroit

Table 2: Logit Models for Spinoff Birth

Spinoff Birth	(1)	(2)	(3)	(4)	(5)	(6)
Chicago	0.608	1.308**	1.180*	0.797	-0.018	0.256
	(0.468)	(0.655)	(0.636)	(0.510)	(0.596)	(0.493)
Indianapolis	0.579	1.027	0.926	0.618	-0.300	-0.064
	(0.457)	(0.627)	(0.609)	(0.502)	(0.601)	(0.532)
Detroit	1.466***	1.743***	1.447***	0.797	1.110***	3.063***
	(0.395)	(0.463)	(0.446)	(0.784)	(0.396)	(0.956)
Rochester	0.255	1.067	0.911	0.489	-0.505	-0.112
	(0.580)	(0.800)	(0.772)	(0.605)	(0.744)	(0.575)
New York	0.738	1.425**	1.250**	0.800	0.242	0.743
	(0.476)	(0.662)	(0.632)	(0.489)	(0.571)	(0.491)
Center Size		0.015	0.012		-0.020	
		(0.011)	(0.010)		(0.015)	
Family Size			0.168***		0.174***	
			(0.049)		(0.055)	
Center Top				0.042		-0.183**
				(0.078)		(0.087)
Family Top				0.291***		0.315***
				(0.090)		(0.095)
Firm Age	0.062***	0.065***	0.072***	0.056**	0.090***	0.079***
	(0.021)	(0.025)	(0.025)	(0.024)	(0.028)	(0.027)
Year	-0.057***	-0.064***	-0.080***	-0.078***		
	(0.021)	(0.024)	(0.025)	(0.024)		
Constant	104.562***	117.157***	146.479***	143.176***	-3.838***	-4.472***
	(40.770)	(45.353)	(46.764)	(44.699)	(1.163)	(1.034)
Year Dummies					Y	Y
Observations	4333	3585	3585	3585	2979	2979

Note: St. Louis is omitted in the regressions due to no spinoff. Robust standard errors (clustered by firm) are reported in parentheses under coefficient values. One, two and three * indicate statistical significance at the 10, 5 and 1% levels, respectively.

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- Firm survival higher if: (a) firm is older; (b) *De Alio* or spinoff entry; (c) family size and quality; (d) location in Indianapolis

Table 1: Logit Models for Firm Death

Firm Death	(1)	(2)	(3)	(4)	(5)	(6)
De Alio	-0.460***	-0.461***	-0.457***	-0.456***	-0.488***	-0.482***
	(0.092)	(0.092)	(0.092)	(0.090)	(0.095)	(0.092)
Spinoff	-0.612***	-0.614***	-0.452***	-0.235*	-0.470***	-0.260*
	(0.126)	(0.124)	(0.140)	(0.138)	(0.143)	(0.140)
St. Louis	0.013	0.303	0.341	0.287	0.009	0.164
	(0.246)	(0.272)	(0.269)	(0.274)	(0.302)	(0.282)
Chicago	-0.160	0.047	0.057	-0.047	-0.154	-0.089
	(0.143)	(0.165)	(0.164)	(0.149)	(0.189)	(0.154)
Indianapolis	-0.450***	-0.268*	-0.281*	-0.414***	-0.502***	-0.489***
	(0.132)	(0.149)	(0.148)	(0.143)	(0.166)	(0.154)
Detroit	-0.292***	-0.247**	-0.199*	-0.765***	-0.252**	-0.555*
	(0.105)	(0.105)	(0.106)	(0.264)	(0.109)	(0.307)
Rochester	-0.182	0.094	0.107	-0.026	-0.169	-0.100
	(0.227)	(0.256)	(0.256)	(0.238)	(0.271)	(0.238)
New York	0.243**	0.461***	0.470***	0.318***	0.289*	0.317***
	(0.116)	(0.143)	(0.144)	(0.117)	(0.167)	(0.122)
Center Size		0.006**	0.006***		0.0005	
		(0.002)	(0.002)		(0.004)	
Family Size			-0.085**		-0.091**	
			(0.036)		(0.041)	
Center Top				0.059***		0.039
				(0.022)		(0.027)
Family Top				-0.370***		-0.373***
				(0.072)		(0.075)
Firm Age	-0.049***	-0.048***	-0.048***	-0.037***	-0.049***	-0.040***
	(0.007)	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)
Year	0.030***	0.036***	0.037***	0.032***		
	(0.007)	(0.007)	(0.007)	(0.007)		
Constant	-58.359***	-69.145***	-71.007***	-61.868***	-1.527***	-1.682***
	(13.123)	(13.411)	(13.437)	(12.626)	(0.406)	(0.391)
Year Dummies					Y	Y
Observations	4454	4454	4454	4454	4360	4360

Note: Robust standard errors (clustered by firm) are reported in parentheses under coefficient values. One, two and three * indicate statistical significance at the 10, 5 and 1% levels, respectively.

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- Firm entry and survival do not depend on center size (in contrast to Marshall's view)
- Family effects only accrue under co-location, suggesting "network" effects rather than "gene" effects

Table 5. Logit Models for Firm Death

Firm Death	(1)	(2)	(3)	(4)
De Alio	-0.457***	-0.458***	-0.488***	-0.483***
	(0.092)	(0.090)	(0.095)	(0.092)
Spinoff	-0.456***	-0.254*	-0.472***	-0.272**
	(0.140)	(0.137)	(0.143)	(0.139)
St. Louis	0.332	0.215	-0.001	0.091
	(0.271)	(0.276)	(0.303)	(0.286)
Chicago	0.055	-0.051	-0.157	-0.095
	(0.164)	(0.149)	(0.189)	(0.155)
Indianapolis	-0.275*	-0.399***	-0.499***	-0.479***
	(0.148)	(0.145)	(0.166)	(0.155)
Detroit	-0.186*	-0.725***	-0.241**	-0.510*
	(0.109)	(0.264)	(0.112)	(0.307)
Rochester	0.109	-0.020	-0.170	-0.095
	(0.256)	(0.237)	(0.271)	(0.237)
New York	0.470***	0.319***	0.288*	0.315***
	(0.143)	(0.114)	(0.166)	(0.120)
Center Size	0.006***		0.001	
	(0.002)		(0.004)	
Local Family Size	-0.101**		-0.106**	
	(0.042)		(0.047)	
Non-Local Family Size	-0.054		-0.064	
	(0.069)		(0.074)	
Center Top		0.062***		0.041
		(0.022)		(0.027)
Local Family Top		-0.484***		-0.485***
		(0.094)		(0.100)
Non-Local Family Top		-0.086		-0.105
		(0.115)		(0.120)
Firm Age	-0.047***	-0.032***	-0.048***	-0.035***
	(0.009)	(0.008)	(0.009)	(0.009)
Year	0.036***	0.028***		
	(0.007)	(0.007)		
Constant	-69.863***	-55.234***	-1.513***	-1.682***
	(13.453)	(12.624)	(0.406)	(0.391)
Year Dummies			Y	Y
Observations	4454	4454	4360	4360

Note: Robust standard errors (clustered by firm) are reported in parentheses under coefficient values. One, two and three * indicate statistical significance at the 10, 5 and 1% levels, respectively.

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- Both $q(s; j, p)$ and $\pi(s; j, p)$ are strictly increasing in s, decreasing in p, continuous and bounded.

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- Potential entrants make their entry decisions at the same time that incumbents are making their exit decisions.

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- The expected number of *new* entrants at each location j is

$$n_j = M_j \Psi_j.$$

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- A potential spinoff entrant shares the same capability s with its parent, and knows its capability while making entry decision.
- Similar to an incumbent's continuing decision, a potential spinoff will enter if its value of entry is higher than the random outside option ϕ^x, i.e.

$$VC(s; j, \bar{p}) \geq \phi^x.$$

A Theoretical Model (cont.)

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- Industry price equates the supply and demand each period

$$p = D^{-1}\{\sum_{s,j} q(s;j,p)m(s,j)\}.$$

Industry Equilibrium

A stationary equilibrium is defined as an output price p^*, a mass of *new* (non-spinoff) entrants n_j^* at each location, a measure of incumbents $m^*(s, j)$, and policy function χ^*, so that

- χ^* solves incumbent firms and potential spinoffs' dynamic optimization problem
- n_j^* satisfies entry condition for *new* (non-spinoff) entrants
- p^* clears product market each period
- m^* is defined recursively given m^*, n_j, and χ^*

Model Implications

- Firm entry
  - The quantity and quality of *new* (non-spinoff) entrants depend on location characteristics (e.g. income, related industries)
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  - A spinoff is less likely to exit than a *new* (non-spinoff) firm
  - A firm in a high-capability family is less likely to exit
- Family network
  - A high-capability family tends to have a bigger size

Model Calibration

- Assume five production locations $j = 1, ..., 5$ and two firm capability levels $s = 1, 2$.

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- Assume that the outside option follows an i.i.d. exponential distribution with parameter σ.

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- First, we estimate the industry demand function using historical annual data of auto price and output.
- Second, we use *new* (non-spinoff) entry rate in each location from reduced-form regressions
- Third, we set the discount factor $\beta = 0.95$, and the production parameter $\alpha = 0.9$.

Model Calibration (Cont.)

- Consider the industry in 1904 as an equilibrium without spinoff. We pick the set of parameters (c_1, σ, μ) to match the following data moments:
  - the distribution of output across the five production centers
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Model Calibration (Cont.)

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  - the distribution of output across the five production centers
  - the firm exit rates at the five production centers
- Consider the industry in 1919 as an equilibrium with spinoff. We then conduct a counterfactual experiment:
  - Take the above parameter values (c_1, σ, μ) as given
  - Pick *ex ante* spinoff rates $(\gamma_{\text{Detroit}}, \gamma_{\text{non-Detroit}})$ to match Detroit and industry *ex post* average spinoff rates in 1910s
  - Compare the model calibration with the data moments

U.S. Automobile Industry, 1895 – 1930

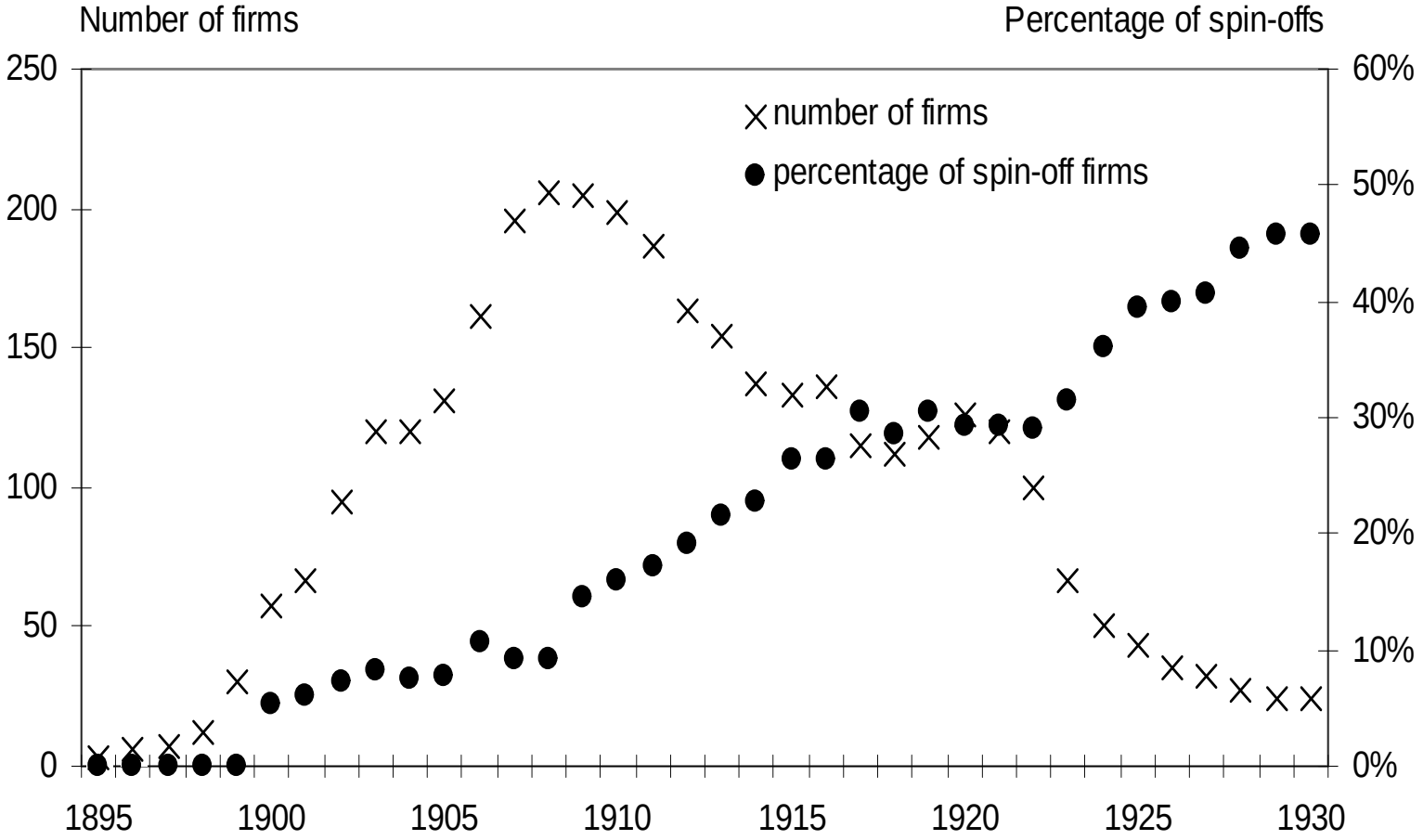

Table 6. Model Fit

	1904		1919	
	Data	Model	Data	Model
Share of output				
St. Louis	0.01	0.07	0.03	0.04
Chicago	0.08	0.11	0.08	0.06
New York	0.31	0.15	0.11	0.08
Indianapolis	0.06	0.10	0.05	0.06
Detroit	0.54	0.56	0.73	0.76
Exit rate				
Non-Detroit	0.18	0.20	0.17	0.22
Detroit	0.11	0.14	0.16	0.15
Spinoff rate				
Center average			0.03	0.03
Detroit			0.07	0.07

Conclusion

- Taking the U.S. auto industry as an example, we evaluate competing views of industry agglomeration:

  (a) intra-industry spillovers (Marshall et al)

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  (c) family network, or spinoff, effects, (Klepper et al)

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  (a) intra-industry spillovers (Marshall et al)
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  (c) family network, or spinoff, effects, (Klepper et al)
- Bottom line (of structural model and reduced-form regressions):
  (a) Marshallian effects don't seem to matter that much
  (b) Related industries matter a lot
  (c) Spinoffs account for about 1/3 of agglomeration

Future Research

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  – profit, output, employment, product variety

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