Product Innovation and Firm Survival in a Network Industry

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Figure: Entry, Exit and Number of Shared Networks
Questions on Industry Evolution

- What drive the shakeout of industry?
  - race of technological innovation (J&M 1994)
  - scale economies in R&D (Klepper 1996)
  - changing consumer demand (Wang 2008)
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  - leapfrogging of leadership (Schumpeter 1942)

- **What is new about the US ATM/Debit industry?**
A major production innovation (introducing the POS debit function) may have driven the shakeout.
The ATM/Debit Industry: A New Story

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The ATM/Debit Industry: A New Story

- A major production innovation (introducing the POS debit function) may have driven the shakeout.
- Industry network effects play important roles.
- Little advantage of being early industry entrants.
- Large networks had better chance to adopt the product innovation and survive the shakeout.
Figure: ATM and Debit Transaction Volumes
A Brief History of the Industry

- The modern ATM/debit industry began in late 1960s
  - The first modern ATM was invented in 1968
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- In 1970s, ATM technology advanced to what we know today
  - ATMs were developed to have full functions
  - ATMs were connected to computers (real-time access)
  - The emergence and growth of shared ATM networks
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- In 1970s, ATM technology advanced to what we know today
  - ATMs were developed to have full functions
  - ATMs were connected to computers (real-time access)
  - The emergence and growth of shared ATM networks
- In mid 1980s, the shakeout of shared ATM network started
  - The POS debit function was introduced
  - Other factors: legal changes, increasing scale economies
The POS Debit Innovation

- Offered a superior product for consumers to substitute the ATM-only cards
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- Created a race among ATM networks to adopt the POS debit innovation
- Due to network effects, large networks had advantage to adopt the innovation and survive the shakeout
Industry Environment

- Competitive market for ATM and debit card services
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- Two generations of cards appear subsequently
  - First: ATM cards offered by networks of two different sizes (large $h$ and small $l$)
  - Second: the ATM/debit cards $s$

Given consumer preference $\theta \sim G(\theta)$, and card service quality $\alpha_i$, consumers maximize utility $u(\theta; \alpha_i, P_i) = \alpha_i \theta P_i$, $i = f(h, l, s)$.
Industry Environment

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- Given consumer preference \( \theta \sim G(\theta) \), and card service quality \( \alpha^i \), consumers maximizes utility

\[
u(\theta; \alpha^i, P^i) = \alpha^i \theta - P^i, \quad i = \{h, l, s\}\]
Industry Environment

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  \]
- Networks maximize the present discounted value of profits
Pre-debit Industry Equilibrium

The profit function for a network of size $i = \{h, l\}$

$$\pi_t^i = \max_{q_t^i} \{P_t^i q_t^i - C(q_t^i)\}$$
Pre-debit Industry Equilibrium

- The profit function for a network of size $i = \{h, l\}$

  $$\pi_t^i = \max_{q_t^i} \{P_t^i q_t^i - C(q_t^i)\}$$

- Networks make entry, exit and size decisions

  $$U_t^o = \pi^o + \max\{\beta U_{t+1}^o, \beta U_{t+1}^l - E^l, \beta U_{t+1}^h - E^h\}$$
  $$U_t^l = \max\{\pi^o + \beta U_{t+1}^o, \pi_t^l + \max[\beta U_{t+1}^l, \beta U_{t+1}^h - (E^h - E^l)]\}$$
  $$U_t^h = \max\{\pi^o + \beta U_{t+1}^o, \pi_t^l + \beta U_{t+1}^l, \pi_t^h + \beta U_{t+1}^h\}$$
Pre-debit Industry Equilibrium

Free entry determines prices $P_h^*$ and $P_l^*$ at which potential networks are indifferent choosing the three types $o$, $h$ and $l$

$$
\pi^h(P_h^*) = \pi^o + \frac{(1 - \beta)}{\beta} E^h, \quad \pi^l(P_l^*) = \pi^o + \frac{(1 - \beta)}{\beta} E^l
$$
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- Consumers choose an ATM card issued by a large network for

$$\alpha^h \theta - P^h > \alpha^l \theta - P^l \implies \theta > \frac{P^h - P^l}{\alpha^h - \alpha^l}$$
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- Consumers choose an ATM card issued by a small network for

$$\alpha^l \theta - P^l^* \geq \max\{0, \alpha^h \theta - P^h^*\} \implies \frac{P^h^* - P^l^*}{\alpha^h - \alpha^l} \geq \theta \geq \frac{P^l^*}{\alpha^l}$$
Pre-debit Industry Equilibrium

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- Consumers choose an ATM card issued by a small network for

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\]

- The market demand equals supply at the equilibrium

\[
1 - G\left(\frac{P^h^* - P^l^*}{\alpha^h - \alpha^l}\right) = N^h q^h(P^h^*), \quad G\left(\frac{P^h^* - P^l^*}{\alpha^h - \alpha^l}\right) - G\left(\frac{P^l^*}{\alpha^l}\right) = N^l q^l(P^l^*)
\]
Post-debit Industry Equilibrium

- The debit innovation arrives at time $T$
Post-debit Industry Equilibrium

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- For $t \geq T$, networks decide on entry, exit and size:

\[
V^o_t = \pi^o + \max\{\beta V^o_{t+1}, \beta V^l_{t+1} - E^l, \beta V^h_{t+1} - E^h, \\
\beta[\sigma^o V^s_{t+1} + (1 - \sigma^o) V^o_{t+1}] - F^o\},
\]

\[
V^l_t = \max\{\pi^o + \beta V^o_{t+1}, \pi^l_t + \max[\beta V^l_{t+1}, \beta V^h_{t+1} - (E^h - E^l), \\
\beta[\sigma^l V^s_{t+1} + (1 - \sigma^l) V^l_{t+1}] - F^l]\},
\]

\[
V^h_t = \max\{\pi^o + \beta V^o_{t+1}, \pi^l_t + \beta V^l_{t+1}, \pi^h_t + \max[\beta V^h_{t+1}, \\
\beta[\sigma^h V^s_{t+1} + (1 - \sigma^h) V^h_{t+1}] - F^h]\},
\]

\[
V^s_t = \max\{\pi^o + \beta V^o_{t+1}, \pi^l_t + \beta V^l_{t+1}, \pi^h_t + \beta V^h_{t+1}, \pi^s_t + \beta V^s_{t+1}\}.
\]
Post-debit Industry Equilibrium

- The debit innovation creates a superior product $\alpha^s > \alpha^h > \alpha^l$. 
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At time $T$, $N^o$ new entrants try offering ATM/debit product $s$. 
The debit innovation creates a superior product $\alpha^s > \alpha^h > \alpha^l$.

At time $T$, $N^0$ new entrants try offering ATM/debit product $s$.

Because of the increasing supply, the ATM-only card prices $P^h$ and $P^l$ fall. Hence, no new entrant would enter as an ATM-only network, and no incumbent $l$ network would invest to become an $h$ network.
The debit innovation creates a superior product \( \alpha^s > \alpha^h > \alpha^l \).

At time \( T \), \( N^o \) new entrants try offering ATM/debit product \( s \).

Because of the increasing supply, the ATM-only card prices \( P^h \) and \( P^l \) fall. Hence, no new entrant would enter as an ATM-only network, and no incumbent \( l \) network would invest to become an \( h \) network.

Meanwhile, all existing ATM-only networks want to adopt the debit innovation.
At time $T + 1$, among all $N^0$ entrants, a fraction $\sigma^0$ succeed and $(1 - \sigma^0)$ fails and exits.
Post-debit Industry Equilibrium

- At time $T + 1$, among all $N^0$ entrants, a fraction $\sigma^0$ succeed and $(1 - \sigma^0)$ fails and exits.

- Among all the $N^h$ ($N^l$) incumbent large (small) networks, a fraction $\sigma^h$($\sigma^l$) succeeds in becoming ATM/debit networks. The rest of the networks try adopting the innovation again in the next period.
Post-debit Industry Equilibrium

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- Among all the $N^h$ ($N^l$) incumbent large (small) networks, a fraction $\sigma^h$ ($\sigma^l$) succeeds in becoming ATM/debit networks. The rest of the networks try adopting the innovation again in the next period.

- After time $T + 1$, as more ATM networks succeed in adopting the innovation, card prices $P^h$, $P^l$ and $P^s$ fall. $P^l$ eventually falls low enough so that small ATM networks start exiting.
Post-debit Industry Equilibrium

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- After time $T + 1$, as more ATM networks succeed in adopting the innovation, card prices $P^h, P^l$ and $P^s$ fall. $P^l$ eventually falls low enough so that small ATM networks start exiting.

- Eventually, all small ATM networks exit. The price then fall again and large ATM networks will exit at some point of time.
The ATM/debit Network Dataset

- EFT Data Books 1985-2006
The ATM/debit Network Dataset

- EFT Data Books 1985-2006
- Information on the leading regional EFT networks
  1) year organized; 2) ownership; 3) headquarter location
  4) membership; 5) the number of card issued
  6) the number of transactions by type (ATM or POS)
  7) the number of terminals by type (ATM or POS)
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  7) the number of terminals by type (ATM or POS)
- 114 among 136 regional EFT networks are in our sample. We excluded
  – credit unions and/or saving and loan banks
  ownership/membership
  – entered market after 1985, the shakeout year
Hypothesis: $\sigma^h > \sigma^l$

- Large incumbent networks are more likely to adopt the debit innovation than small networks.
Debit Innovation

Table 1: Percentage of Networks that have Adopted POS Debit by 1987

1B. By Size and Ownership Type

<table>
<thead>
<tr>
<th>Ownership type</th>
<th>Size</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single owner</td>
<td>71 (17)</td>
<td>26 (54)</td>
<td></td>
<td>37 (71)</td>
</tr>
<tr>
<td>Multiple owners</td>
<td>48 (21)</td>
<td>14 (22)</td>
<td></td>
<td>30 (43)</td>
</tr>
<tr>
<td>Bank-only</td>
<td>61 (31)</td>
<td>20 (61)</td>
<td></td>
<td>34 (92)</td>
</tr>
<tr>
<td>Nonbank</td>
<td>43 (7)</td>
<td>33 (15)</td>
<td></td>
<td>36 (22)</td>
</tr>
</tbody>
</table>

1C. By Size and Location

<table>
<thead>
<tr>
<th>Location</th>
<th>Size</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>47 (15)</td>
<td>8 (13)</td>
<td></td>
<td>29 (28)</td>
</tr>
<tr>
<td>Middle</td>
<td>63 (16)</td>
<td>27 (52)</td>
<td></td>
<td>35 (68)</td>
</tr>
<tr>
<td>West</td>
<td>71 (7)</td>
<td>18 (11)</td>
<td></td>
<td>39 (18)</td>
</tr>
</tbody>
</table>
## Debit Innovation

### 1A. By Size and Cohort

<table>
<thead>
<tr>
<th>Entry year</th>
<th>Large</th>
<th>Small</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>0 (1)</td>
<td>0 (1)</td>
<td>0 (2)</td>
</tr>
<tr>
<td>1973</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974</td>
<td>100 (1)</td>
<td></td>
<td>100 (1)</td>
</tr>
<tr>
<td>1975</td>
<td>100 (1)</td>
<td>14 (7)</td>
<td>25 (8)</td>
</tr>
<tr>
<td>1976</td>
<td>100 (2)</td>
<td>50 (2)</td>
<td>75 (4)</td>
</tr>
<tr>
<td>1977</td>
<td>75 (4)</td>
<td>0 (6)</td>
<td>30 (10)</td>
</tr>
<tr>
<td>1978</td>
<td>50 (2)</td>
<td>80 (5)</td>
<td>71 (7)</td>
</tr>
<tr>
<td>1979</td>
<td>50 (4)</td>
<td>0 (5)</td>
<td>22 (9)</td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td>38 (8)</td>
<td>38 (8)</td>
</tr>
<tr>
<td>1981</td>
<td>40 (5)</td>
<td>17 (12)</td>
<td>24 (17)</td>
</tr>
<tr>
<td>1982</td>
<td>40 (5)</td>
<td>38 (13)</td>
<td>44 (18)</td>
</tr>
<tr>
<td>1983</td>
<td>60 (5)</td>
<td>11 (9)</td>
<td>29 (14)</td>
</tr>
<tr>
<td>1984</td>
<td>57 (7)</td>
<td>0 (4)</td>
<td>36 (11)</td>
</tr>
<tr>
<td>1985</td>
<td>0 (1)</td>
<td>0 (4)</td>
<td>0 (5)</td>
</tr>
<tr>
<td>Early cohort</td>
<td>67 (15)</td>
<td>23 (26)</td>
<td>39 (41)</td>
</tr>
<tr>
<td>Late cohort</td>
<td>52 (23)</td>
<td>22 (50)</td>
<td>32 (73)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>58 (38)</td>
<td>22 (76)</td>
<td>34 (114)</td>
</tr>
</tbody>
</table>

Notes: Numbers in parentheses are the total number of networks. Size, ownership, and location are based on the networks’ 1985 characteristics.
Debit Innovation

Logit model analysis for adoption of debit innovation

Table 2B: POS Debit Adoption by 1987

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specification 1</th>
<th>Specification 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-.693</td>
<td>-1.593**</td>
</tr>
<tr>
<td></td>
<td>(.575)</td>
<td>(.696)</td>
</tr>
<tr>
<td>Early cohort</td>
<td>.295</td>
<td>-.071</td>
</tr>
<tr>
<td></td>
<td>(.440)</td>
<td>(.493)</td>
</tr>
<tr>
<td>Single owner</td>
<td>.170</td>
<td>.849</td>
</tr>
<tr>
<td></td>
<td>(.433)</td>
<td>(.520)</td>
</tr>
<tr>
<td>Bank owner(s)</td>
<td>-.184</td>
<td>-.121</td>
</tr>
<tr>
<td></td>
<td>(.519)</td>
<td>(.582)</td>
</tr>
<tr>
<td>East</td>
<td>-.234</td>
<td>-.973</td>
</tr>
<tr>
<td></td>
<td>(.500)</td>
<td>(.592)</td>
</tr>
<tr>
<td>West</td>
<td>.149</td>
<td>-.265</td>
</tr>
<tr>
<td></td>
<td>(.553)</td>
<td>(.624)</td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td>2.125***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.533)</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-72.514</td>
<td>-63.013</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parentheses. Ownership, location, and size are based on the networks' 1985 characteristics. ***: Significant at the .01 level; **: Significant at the .05 level.
Network Survival

**Hypothesis:** $\pi_s^t > \pi_h^t > \pi_l^t$

- ATM/debit networks are more likely to survive than ATM-only networks and among ATM-only networks large networks are more likely to survive than smaller networks.
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- A surviving network = the one who keeps the network brand in the case of merger and acquisition
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- Two types of “exit”
  - Simply exiting from the market without being acquired or merged with another network
  - Being acquired by or merged with another network
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  - Being acquired by or merged with another network

- 40 networks in our sample terminated their networks as a result of being acquired or merged with another network
Network Survival

Figure: Survival Functions of Networks: M&A Uncensored
Network Survival

Figure: Survival Functions of Networks: M&A Censored
Network Survival

- Semi-parametric Cox Proportional Hazards model

\[ H(t; X) = H_0(t) \exp(X\gamma) \]
Network Survival

- Semi-parametric Cox Proportional Hazards model
  
  \[ H(t; X) = H_0(t) \exp(X \gamma) \]

- The partial likelihood function
  
  \[ L(\gamma) = \prod_{i=1}^{n} \left\{ \frac{\exp(X_i \gamma)}{\sum_{j \in R(t_i)} \exp(X_j \gamma)} \right\}^{\delta_i} \]
### Table 3: Effects on the Hazard of Exit

#### 3A. Mergers and Acquisitions Uncensored

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specification</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early cohort</td>
<td></td>
<td>-.197</td>
<td>-.120</td>
<td>-.090</td>
<td>-.069</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.226)</td>
<td>(.231)</td>
<td>(.230)</td>
<td>(.233)</td>
</tr>
<tr>
<td>Single owner</td>
<td></td>
<td>.154</td>
<td>.122</td>
<td>-.007</td>
<td>.031</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.204)</td>
<td>(.206)</td>
<td>(.216)</td>
<td>(.215)</td>
</tr>
<tr>
<td>Bank owner(s)</td>
<td></td>
<td>.108</td>
<td>-.011</td>
<td>.079</td>
<td>-.051</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.256)</td>
<td>(.260)</td>
<td>(.257)</td>
<td>(.262)</td>
</tr>
<tr>
<td>East</td>
<td></td>
<td>.315</td>
<td>.280</td>
<td>.426*</td>
<td>.381</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.234)</td>
<td>(.235)</td>
<td>(.240)</td>
<td>(.246)</td>
</tr>
<tr>
<td>West</td>
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<td>-.063</td>
<td>-.114</td>
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<tr>
<td></td>
<td></td>
<td>(.268)</td>
<td>(.270)</td>
<td>(.270)</td>
<td>(.269)</td>
</tr>
<tr>
<td>POS</td>
<td></td>
<td>-.473**</td>
<td>-.582***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.206)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td>-.455**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(.222)</td>
<td></td>
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</tr>
<tr>
<td>Large ATM</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>(.317)</td>
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<tr>
<td>Log likelihood</td>
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<td>-445.284</td>
<td>-442.533</td>
<td>-443.117</td>
<td>-441.659</td>
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</tbody>
</table>

Notes: Standard errors are in parentheses. Ownership, location, and size are based on the networks’ 1985 characteristics.
POS=1, if a network adopted POS debit by 1987, otherwise an ATM-only network.
***, **, *: Significant at the .01, .05, and .10 level, respectively.
## Network Survival

### 3B. Mergers and Acquisitions Censored

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specification</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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<td>Early cohort</td>
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<td>.196</td>
<td>.311</td>
<td>.387</td>
<td>.405</td>
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<td></td>
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<td>(.313)</td>
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<td>(.315)</td>
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<tr>
<td>Single owner</td>
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<td>.589*</td>
<td>.244</td>
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<td></td>
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<td>(.319)</td>
<td>(.321)</td>
<td>(.328)</td>
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<td>Bank owner(s)</td>
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<td>-.255</td>
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<td>East</td>
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<td>.696**</td>
<td>.538*</td>
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<td>(.312)</td>
<td>(.311)</td>
<td>(.316)</td>
<td>(.321)</td>
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<td>-.013</td>
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<td></td>
<td></td>
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<td>(.397)</td>
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<td>(.398)</td>
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<td>POS</td>
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<td>-.802*</td>
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<td>Log likelihood</td>
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<td>-245.942</td>
<td>-239.223</td>
<td>-238.903</td>
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</tbody>
</table>

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Network Survival: Summary of Findings

- POS (in spec 2), Large (in spec 3), and POS (in spec 4) are all statistically significantly negative for both uncensored and censored models.

- Large ATM (in spec 4) is negative and becomes significant for the censored model.

- The magnitude of coefficient for POS dummy is much greater than that for Large-ATM dummy in the censored model.

- Variables other than POS, Large, and Large-ATM are insignificant or at most marginally significant. Especially, the coefficients for Early cohort show the opposite signs in the uncensored and censored model.

- Unlike previous studies that found strong effects of a firm's age on its survival, our results suggest firm age plays a very minor role, at least in the ATM/debit industry.
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- Two-sided market network effects play important roles.
- Little advantage of being early industry entrants.
- Large networks had better chance to adopt the product innovation and survive the shakeout.