# The Digital Banking Revolution: Effects on Competition and Stability

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November 17, 2024

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# Introduction

- The Bank industry went through a deregulation process in the 1980s and 1990s.
  - In 1981 a bank could only operate in their home state or county.
  - Deregulation process started in the 1980s with voluntary reciprocal interstate agreements.
  - 1994 Riegle-Neal Act: banks could operate across state lines.

# Introduction

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  - In 1981 a bank could only operate in their home state or county.
  - Deregulation process started in the 1980s with voluntary reciprocal interstate agreements.
  - 1994 Riegle-Neal Act: banks could operate across state lines.
- Goal:
  - Document the evolution of spatial sorting and expansion in response to deregulation.
  - Provide a theory that rationalizes the observed patterns (framework Oberfield et al. (2024)).
    1. "Span-of-control sorting": more productive banks sort into denser more expensive locations.
    2. "Mismatch sorting": banks match the location's characteristics to the funding needs.

# Introduction

- Contribution:
  - Theory that incorporates space and decision to locate branches.[2][3]
  - Understanding location choice of bank through two forms of sorting: span-of-control and mismatch sorting.
  - Literature of expansion of multi-plant firms [4]

[2] Aguirregabiria et al. (2016, 2020), Corbae and E'Erasmos (2021,2021,2022) focus on diversification.
[3] Other recent papers are Ji et al (2023) and d'Avernas et al (2023).
[4] Rossi-Hansberg et al (2021), Hsieh and Rossi-Hansberg (2022)); international context: Antras et al (2017), Tintelnot (2016), and others.

# Data

- Bank branches and deposits from the FDIC (SOD) from 1981 to 2006.
  - county as the geographical unit of analysis
- Bank-level wholesale funding from Call Reports
  - time deposits, FR funds, brokered deposits.
- Aggregate to holding companies.
- County-level data on population and income from the Census and BEA.

# Basic Pattern: Fewer banks with many more branches

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# Basic Pattern: Top banks expanded by growing geographically

For size group $g$, in terms of total deposits, branch growth is:

$$\Delta \log(\text{ branches }_{gt}) = \underbrace{\Delta \log(\text{ branches per county })_{gt}}_{\text{intensive margin growth}} + \underbrace{\Delta \log(\text{ counties })_{gt}}_{\text{extensive margin growth}} .$$

# Basic Pattern: Large banks use more wholesale funding

Wholesale funding exposure, WFE, across banks in each size bin:

$$WFE_{bt} = \frac{FF_{bt} + TD_{bt} + BrokD_{bt}}{\text{Retail Deposits}_{bt}}$$

# A Spatial Theory of Banking

# Households

- Each location $\ell$ is composed of a set households $I_\ell$.

- **Heterogeneous households** choose bank $j$ and branch $o^D_{j\ell} \in O_j$ for deposits, and bank $k$ and branch $o^L_{k\ell}$ for loans,

- given distance to branch and rates $r^D_{j,o^D_{j\ell}}$ and $r^L_{k,o^L_{k\ell}}$,

- common taste for bank $j$ deposit $Q^D_{j\ell}$ and loan $Q^L_{j\ell}$ in $\ell$:

$$Q^D_{j\ell} = \bar{Q}^D_j J^D_{j\ell} \phi_{j\ell} \tag{1}$$

$$Q^L_{j\ell} = \bar{Q}^L_j J^L_{j\ell} \phi_{j\ell}, \tag{2}$$

  - $\bar{Q}^D_j$ and $\bar{Q}^L_j$ are common for bank $j$ (from bank's investment decisions),
  - $J^D_{j\ell}$ and $J^L_{j\ell}$ are decreasing functions of distance to bank $j$ 's headquarters,
  - $\{\phi_{j\ell}\}_\ell$ are idiosyncratic appeal shifters drawn from a multivariate Frechet distribution.

# Households

- Given all banks' location choices and interest rate choices, the **residual demands** are:

$$D_{j\ell} = T^D\left(\delta_{o^D_{j\ell},\ell}\right) Q^D_{j\ell} A^D_\ell \mathcal{D}\left(r^D_{j,o^D_{j\ell}}\right) \tag{3}$$

$$L_{j\ell} = T^L\left(\delta_{o^L_{j\ell},\ell}\right) Q^L_{j\ell} A^L_\ell \mathcal{L}\left(r^L_{j,o^L_{j\ell}}\right) \tag{4}$$

  - $Q^D_{j\ell}$ and $Q^L_{j\ell}$ are common taste for bank $j$ deposit and loan services,
  - $T^D(\delta)$ and $T^L(\delta)$ are decreasing functions of distance $\delta$,
  - $A^D_\ell$ and $A^L_\ell$ are local demand shifters common to all banks (local population, local demand for deposits/loans, and local price levels/competition),
  - $\mathcal{D}\left(r^D_{j,o^D_{j\ell}}\right)$ and $\mathcal{L}\left(r^L_{j,o^L_{j\ell}}\right)$ is the impact of interest rates on demand.

# Households

- Given all banks' location choices and interest rate choices, the **residual demands** are:

$$D_{j\ell} = T^D\left(\delta_{o^D_{j\ell},\ell}\right) Q^D_{j\ell} A^D_\ell \mathcal{D}\left(r^D_{j,o^D_{j\ell}}\right).$$

Microfundation (Appendix):

- From discrete choice model where households choose to bank and branch with idiosyncratic T1EV $\varepsilon_{ij}$.

$$D_{j\ell} = \frac{e^{\eta\left[G^D\left(r^D_{jo^D_{j\ell}}\right) + \tilde{Q}^D_{j\ell} - \tilde{T}^D\left(\delta_{\ell^D_{j\ell}}\right)\right]}}{\sum_k e^{\eta\left[G^D\left(r^D_{ko^D_{k\ell}}\right) + \tilde{Q}^D_{k\ell} - \tilde{T}^D\left(\delta_{\ell^D_{k\ell}}\right)\right]}} \int_{i\in I_\ell} \mathfrak{d}_i \tilde{\mathcal{D}}\left(r^D_{j,o^D_{j\ell}}\right) di$$

# Banks

- Bank $j$ is born with a headquarters location $\ell_j^{HQ}$, has unit costs $\theta_j^D$ and $\theta_j^L$ for deposits and loans, and draw local fixed costs $\psi_\ell$.
- Bank $j$ choose a set of branch locations $O_j$ and deposit and lending rates $r_{jo}^D$ and $r_{jo}^L$.
- If it operates in location $o$, pays a local fixed cost $\Psi_o$.
- To operate branches $O_j$, it must hire $H\left(|O_j|\right)$ workers at its headquarters location.
- Bank chooses bank appeal, $\bar{Q}_j^D$ and $\bar{Q}_j^L$, by hiring $C\left(\bar{Q}_j^D, \bar{Q}_j^L\right)$ workers in its headquarters location.
- Wholesale funding then $W_j = L_j - D_j$
- The interest rate it pays on wholesale funds is $R\left(W_j / D_j\right)$.

# Banks

- Bank $j$'s problem is:

$$\pi_j = \sup_{W_j, D_j, L_j, O_j, \bar{Q}_j^D, \bar{Q}_j^L, \left\{r_{jo}^D, r_{jo}^L\right\}_o, \left\{D_{j\ell}, L_{j\ell}, o_{j\ell}^D, o_{j\ell}^L\right\}_\ell} \int \left[\left(r_{j,o_{j\ell}^L}^L - \theta_j^L\right) L_{j\ell} - \left(r_{j,o_{j\ell}^D}^D + \theta_j^D\right) D_{j\ell}\right] d\ell$$
$$- R\left(\frac{W_j}{D_j}\right) W_j - \sum_{o \in O_j} \Psi_o$$
$$- w_j^* H\left(|O_j|\right) - w_j^* C\left(\bar{Q}_j^D, \bar{Q}_j^L\right)$$

subject to (1), (2), (3), (4), $D_j \equiv \int D_{j\ell} d\ell$ and $L_j \equiv \int L_{j\ell} d\ell$, $W_j = L_j - D_j$, and household decisions of the branch.

- Lemma 1: *Banks choose the same interest rates on deposits across branches (and on loans).*

# Banks

- Let $\omega_j = \frac{W_j}{D_j}$ be the bank's relience on wholesale funding.

- Assumption: fixed local cost and headquarter costs shrink towards zero while households' distaste for branches grows $\rightarrow$ choice of density $n_j$ (Oberfield et al. (2024)).

- Bank $j$'s problem is:

$$\pi_j = \sup_{\omega_j, D_j, L_j, \bar{Q}_j^D, \bar{Q}_j^L, r_j^D, r_j^L, \{n_{j\ell}\}_\ell} \left(r_j^L - \theta_j^L\right) L_j - \left(r_j^D + \theta_j^D\right) D_j - \int \psi_\ell n_{j\ell} d\ell - R\left(\omega_j\right) \omega_j D_j$$
$$- w_j^* h\left(|n_j|\right) - w_j^* C\left(\bar{Q}_j^D, \bar{Q}_j^L\right)$$

subject to (4), (5), $\left(1 + \omega_j\right) D_j = L_j$, and

$$D_j \geq \int Q_{j\ell}^D A_\ell^D \kappa^D\left(n_{j\ell}\right) \mathcal{D}\left(r_j^D\right) d\ell$$
$$L_j \leq \int Q_{j\ell}^L A_\ell^L \kappa^L\left(n_{j\ell}\right) \mathcal{L}\left(r_j^L\right) d\ell$$

where $\kappa^D\left(n_{j\ell}\right)$ and $\kappa^L\left(n_{j\ell}\right)$ are impact of additional branch on local appeal.

# Banks

- Lemma 2: Given its processing costs, $\theta_j^D$ and $\theta_j^L$, a bank's wholesale funding intensity $\omega_j$ is a sufficient statistic for its deposit and lending rates, $r_j^D$ and $r_j^L$, which are the unique solutions to

$$r_j^D = \arg\max_r \left[\rho^D\left(\omega_j\right) - r - \theta_j^D\right] \mathcal{D}(r)$$
$$r_j^L = \arg\max_r \left[r - \theta_j^L - \rho^L\left(\omega_j\right)\right] \mathcal{L}(r).$$

  $r_j^D$ and $r_j^L$ are both increasing functions of $\omega_j$.$\mathcal{D}\left(r_j^D\right)$ is increasing in $\omega_j$ while $\mathcal{L}\left(r_j^L\right)$ is decreasing in $\omega_j$.

- They propose an algorithm to solve the bank's problem.

# Sorting and the determinants of firms' footprints

Forces that determine a bank's geographic footprint:

1. Branches close to headquarters are more appealing.

2. "Span-of-control sorting": More productive banks sort into denser more expensive locations, while less productive banks sort into less attractive cheaper markets.

3. "Mismatch sorting": banks choose locations based on the match of the location's characteristics to the funding needs.

4. Incentives to invest in appeal determine the bank's size and the value of entering locations.

# Span-of-control sorting

- Span-of-control cost $\sigma_j$ is the management resources required by the bank to operate an additional branch, $\sigma_j = w_j^* h\left(|n_j|\right)$.

- Let $z_j^D \equiv \lambda_j^D \bar{Q}_j^D \mathcal{D}\left(r_j^D\right)$ and $z_j^L \equiv \lambda_j^L \bar{Q}_j^L \mathcal{L}\left(r_j^L\right)$.

- Assumption 1: The marginal span of control cost $h'(\cdot)$ is uniformly more elastic than the marginal local efficiencies of branching, $\kappa^{D'}(\cdot)$ and $\kappa^{L\prime}(\cdot)$ .

- Lemma 3: Consider two banks with the same headquarters location and the same local taste shocks, $\{\phi_{j\ell}\}$. Bank 2 is equally more productive than Bank 1, so $z_2^D/z_1^D = z_2^L/z_1^L > 1$. Then $\sigma_2 > \sigma_1$ and, if Assumption 1 holds, $\sigma_2/\sigma_1 > z_2^D/z_1^D = z_2^L/z_1^L$.

# Span-of-control sorting

- Proposition 4: Consider two banks with the same headquarters location and the same local taste shocks, $\{\phi_{j\ell}\}$. Bank 2 is equally more productive than Bank 1, so $z_2^D / z_1^D = z_2^L / z_1^L > 1$, Assumption 1 holds.

  Among locations with the same deposit intensity $\alpha_\ell \equiv \frac{A_\ell^D}{A_\ell^L}$, there is a cutoff $\bar{\psi}$ such that

  - if $\psi_\ell = \bar{\psi}$ then $n_{2\ell} = n_{1\ell}$,
  - if $\psi_\ell > \bar{\psi}$ then $n_{2\ell} > n_{1\ell}$ or $n_{2\ell} = n_{1\ell} = 0$, and
  - if $\psi_\ell < \bar{\psi}$ then $n_{2\ell} < n_{1\ell}$ or $n_{2\ell} = n_{1\ell} = 0$.

# Mismatch sorting

- Proposition 5: Consider two banks with the same span of control cost $\sigma_1 = \sigma_2$ and the same efficiency of processing deposits and loans, $\theta_1^D = \theta_2^D$ and $\theta_1^L = \theta_2^L$. Assume that Bank 2 is more reliant on wholesale funding than Bank 1 , so $\omega_2 > \omega_1$, then

  1. there are cutoffs $\bar{\alpha} \geq \underline{\alpha}$ such that

     - if $\alpha_\ell = \bar{\alpha}$ then $n_{2\ell} = n_{1\ell}$,

     - if $\alpha_\ell > \bar{\alpha}$ then $n_{2\ell} > n_{1\ell}$ or $n_{2\ell} = n_{1\ell} = 0$,

  2. If distance for lending is the same as borrowing, i.e., $\kappa^D(n) = \kappa^L(n), \forall n$, then there is a single cutoff $\hat{\alpha}$ such that if local appeal the same across banks and uses, i.e., $Q_{1\ell}^D = Q_{2\ell}^D = Q_{1\ell}^L = Q_{2\ell}^L$, then

     - if $\alpha_\ell > \hat{\alpha}$ then $n_{2\ell} > n_{1\ell}$ or $n_{2\ell} = n_{1\ell} = 0$,

     - if $\alpha_\ell < \hat{\alpha}$ then $n_{1\ell} > n_{2\ell}$ or $n_{2\ell} = n_{1\ell} = 0$.

# Evidence of Sorting

# Evidence of spatial sorting

- Largest banks were in the densest counties in 1981.
- Relative sorting: banks in group sort across space.
- Absolute sorting: changes in bank size with county density.

# Evidence of spatial sorting

- Define the average local population density of bank $j$ in state $s$ in year $t$ to be

$$\log(\text{ Density }_{jst}) = \sum_{c \in \mathcal{C}_s} \left( \frac{b_{jct}}{\sum_{c' \in \mathcal{C}_s} b_{jc't}} \right) \log(\text{ Density }_{ct}),$$

where Density $_{ct}$ is the population density of county $c$ in year $t, \mathcal{C}_s$ is the set of counties in state $s$, and $b_{jct}$ is the number of branches of bank $j$ in county $c$ in year $t$.

- Main regression specification is

$$\log(\text{ Density }_{jst}) = \beta \text{ Size }_{jt} + \gamma_{st} + \varepsilon_{jst}$$

where $\text{Size}_{jt}$ is measured as log deposits of bank $j$ at time $t$ across all of its bank branches.

→ $\beta > 0$ coefficient is evidence of span-of-control sorting.

→ Larger banks are located disproportionately in dense counties.

# Evidence of spatial sorting

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# Evidence of spatial sorting: Role of distance

- $\text{dist}_{js}^{q} = \mathbf{1}\{\log(\text{dist}_{js})\ \text{in quartile}\ q\}$ for $q = 2, 3, 4$ and dist $_{js}$ to be the avg dist. to HQ.

$$\log(\text{ Density })_{jst} = \beta\,\text{Size}_{jt} + \sum_{q=2}^{4} \theta_q\,\text{dist}_{js}^{q} + \sum_{q=2}^{4} \beta_q\,\text{Size}_{jt} \times \text{dist}_{js}^{q} + \gamma_{st} + \varepsilon_{jst}.$$

- Sorting declines with distance and faraway banks are in more dense counties.

# Evidence of spatial sorting

- Estimate the Poisson regression

$$\log\left(\mathbb{E}\left[\text{Branches}_{jct}\right]\right) = \underbrace{\delta\, \text{Size}_{jt} \times \log\left(\text{Density}_{ct}\right)}_{\text{sorting motives}} + \underbrace{\theta \log\left(\text{Miles}_{jc}\right)}_{\text{distance effect}} + \gamma_{ct} + \gamma_{jt} + \varepsilon_{jct}.$$

  - where Branches $_{jct}$ is the total number of branches of bank $j$ in county $c$ in year $t$,
  - $\text{Miles}_{jc}$ is the distance in miles from centroid of bank $j$ 's headquarter county and the centroid of $c$.
  - Standardize both bank size and log county population density.

→ $\delta > 0$ coefficient is evidence of span-of-control sorting.

→ Larger banks have more branches, but especially so in dense counties.

# Evidence of spatial sorting

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# Sorting over time and impact of deregulation

- Top 1% of banks grew in the densest counties, but lost branch share in the most dense counties.

# Sorting over time and impact of deregulation

- Decline in relative sorting patterns until 1998. Staggered changes

$$\log(\text{ Density })_{jst} = \beta_t \text{ Size }_{jt} + \gamma_{st} + \varepsilon_{jst}, \quad t = 1981, \ldots, 2006.$$

# Sorting over time and impact of deregulation: Event study

- Weakened sorting patterns after deregulation.

$$\log\left(\text{ Density }_{jst}\right)=\beta\,\text{Size}_{jt}+\sum_{\substack{-5\leq h\leq 10\\ h\neq -1}}\beta_h\,\text{Size}_{jt}\times\text{ Open }_{st+h}+\gamma_{st}+\varepsilon_{jst},$$

where $\text{Open}_{st+h}$ is equal to 1 if $\text{Recip}_{st+h}>0$, $h=0$ the first period in which a state opened up.

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# Connecting mismatch sorting to the level of wholesale funding

Mismatch sorting: Banks choose locations based on the match of the location's characteristics to the funding needs.

- Denser locations are less deposit intensive Regression
- Banks that were headquartered in counties with more loan opportunities used more wholesale funding in 1984. Regression
- Banks with more exposure to wholesale funding expanded into locations that were deposit-abundant. Poisson regression

# The impact of deregulation on bank expansion and wholesale funding

- What was the effect of expansion on the dynamics of a bank's reliance on wholesale funding?
- Regress the change in a bank's outcome variable on WSF. Specification details
- Results:
    - Large firms decrease their wholesale funding exposure immediately after deregulation.
    - Number of branches and active counties have positive cumulative effects from wholesale funding.
    - Geographic deregulation relaxed liquidity constraints for banks, allowing them to raise deposits through branching and reduce their exposure to wholesale funding.

# The impact of deregulation on bank expansion and wholesale funding

- What was the effect of expansion on the dynamics of a bank's reliance on wholesale funding?

# Conclusion

- Paper proposes a model of spatial sorting of banks.
- Banks sort into locations based on mismatch sorting and span-of-control sorting.
- Evidence evidence seems to support the model.
- Deregulation relaxed liquidity constraints for banks through branching.

Thank you!

# Appendix

# Impact of deregulation: Staggered changes in deregulation back

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# Connecting mismatch sorting to the level of wholesale funding Back

- Denser locations are less deposit intensive.

$$\log(D/L)_{ct} = \phi \log(\text{ Density }_{ct}) + \text{controls }_{ct} + \gamma_t + \varepsilon_{ct}$$

imgs/tab4.png

# Headquarter location and the use of wholesale funding

Back

- Less wholesale funding in counties that are deposit intensive.

$$\mathrm{WFE}_{j,1984} = \beta \log(D/L)_{c_j^{HQ}} + \text{controls}_{j,1984} + \varepsilon_{j,1984}.$$

where $\mathrm{WFE}_{j,1984}$ denotes the log of bank $j$ 's wholesale funding exposure in 1984.

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# Spatial expansion patterns and the level of wholesale funding Back

- Estimate the Poisson regression:

$$\begin{aligned}\log\left(\mathbb{E}\left[\text{ branches }_{jct}\right]\right) = & \beta_0 \mathrm{WFE}_{j,1984} \times \log(D/L)_c + \beta_1 \mathrm{WFE}_{j,1984} \times \log\left(\text{ Density }_{ct}\right) \\ & + \phi_0 \, \text{Size}_{jt} \times \log(D/L)_c + \phi_1 \, \text{Size}_{jt} \times \log\left(\text{ Density }_{ct}\right) \\ & + \delta \log\left(\text{ Dist }_{jc}\right) + \gamma_{jt} + \gamma_{ct} + \varepsilon_{jct}.\end{aligned}$$

→ Banks with more exposure to wholesale funding expanded into locations that were deposit-abundant.

# Spatial expansion patterns and the level of wholesale funding

Back

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# Spatial expansion patterns and the level of wholesale funding

$$\log(D/L)_{jst} = \beta_0\,\text{Size}_{jt} + \beta_1\,\text{Size}_{jt} \times \text{Recip}_{st} + \beta_2 \mathrm{WFE}_{j,1984} + \beta_3 \mathrm{WFE}_{j,1984} \times \text{Recip}_{st} + \gamma_{st} + \varepsilon_{jst}$$

Standard errors are reported in parentheses and are two-way clustered at the state and bank level.

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# The impact of deregulation on bank expansion and wholesale funding

Back

- What was the effect of expansion on the dynamics of a bank's reliance on wholesale funding?
- Regress the change in a bank's outcome variable on the change in wholesale funding.

$$
\begin{aligned}
Y_{jt+h} - Y_{jt} = {} & \underbrace{\beta_{0h}\,\text{Recip}_{jt}}_{\substack{\text{baseline}\\ \text{effect}}} + \underbrace{\beta_{1h}\,\text{Recip}_{jt} \times \mathrm{WFE}_{jt}}_{\substack{\text{additional effect}\\ \text{of wholesale funding}}} + \underbrace{\beta_{2h}\,\text{Recip}_{jt} \times \text{Large}_j}_{\substack{\text{additional}\\ \text{size effect}}} \\
& + \underbrace{\beta_{3h}\,\text{Recip}_{jt} \times \mathrm{WFE}_{jt} \times \text{Large}_j}_{\substack{\text{additional size effect}\\ \text{of wholesale funding}}} \\
& + \beta_{4h}\mathrm{WFE}_{jt} + \beta_{5h}\mathrm{WFE}_{jt} \times \text{Large}_j + \gamma_t + \gamma_j + \varepsilon_{jt}
\end{aligned}
$$

where $h = 1, \dots, 7$, $\text{Large}_j$ is equal to 1 if bank $j$ is in the top 5% of banks by deposits in the first sample year, 1984; $\text{Recip}_{jt}$ is equal to 1 if bank $j$ is in a state that has opened up to any other state by year $t$.