New Estimates of Broadband Supply and Demand

Wei-Min Hu and James E. Prieger
Department of Economics
University of California, Davis
jeprieger@ucdavis.edu

Broadband Access to the Internet

- **The Latest Dimension of the Digital Divide**
  - Telecommunications Act of 1996: encourages the “reasonable and timely” deployment of broadband to all Americans.
  - FCC has considered whether to add broadband to the Universal Service program.
  - Therefore, the diffusion of broadband requires measurement and scrutiny.

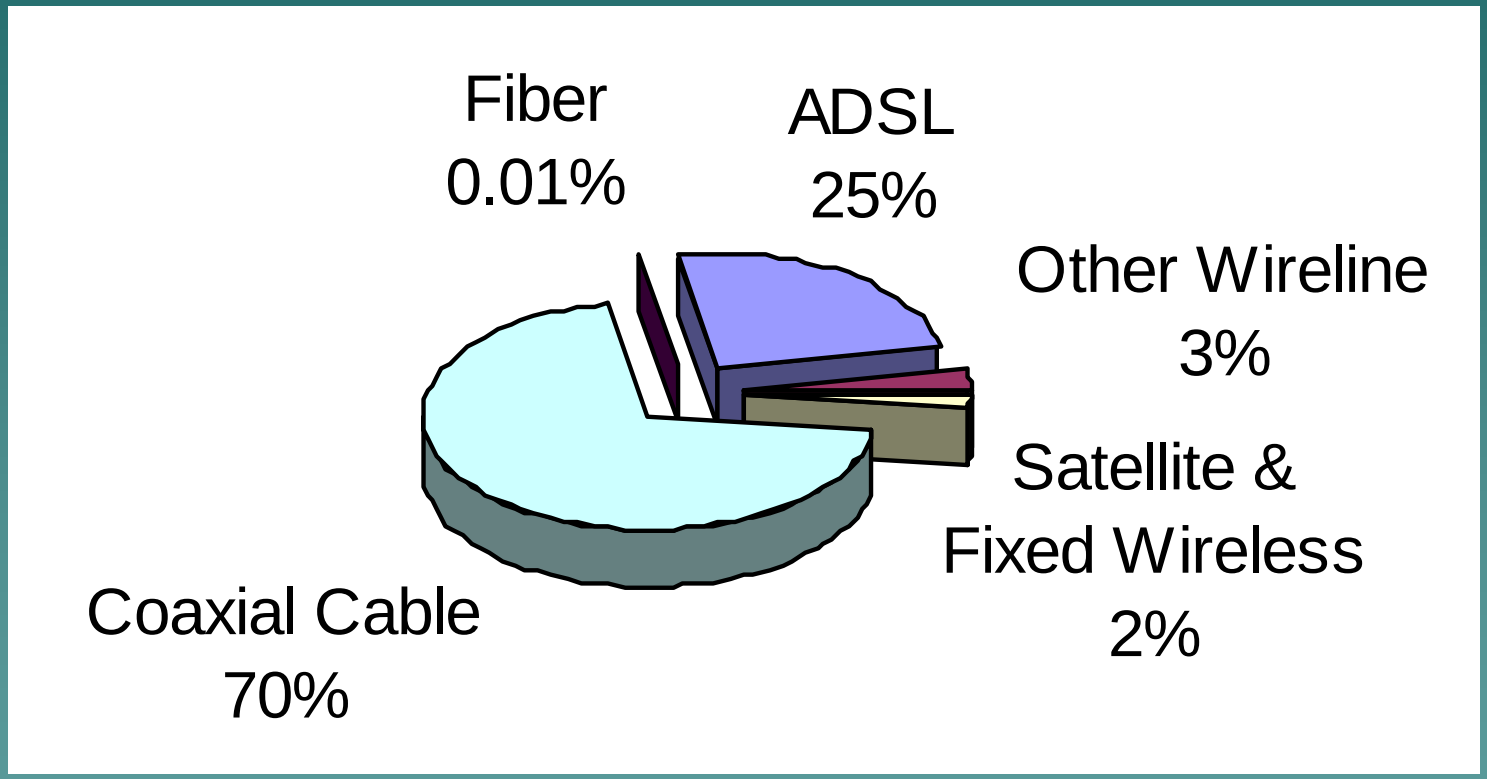
This Study

- Examines the supply and demand sides of the end-user broadband market.
- Uses an unexploited dataset of where DSL is available and where it is subscribed to.
- Research Questions:
  - What role do race, ethnicity, and income play in the supply and demand decisions?
  - What is the role of competition in telecommunications for broadband S&D?

Plan of Talk

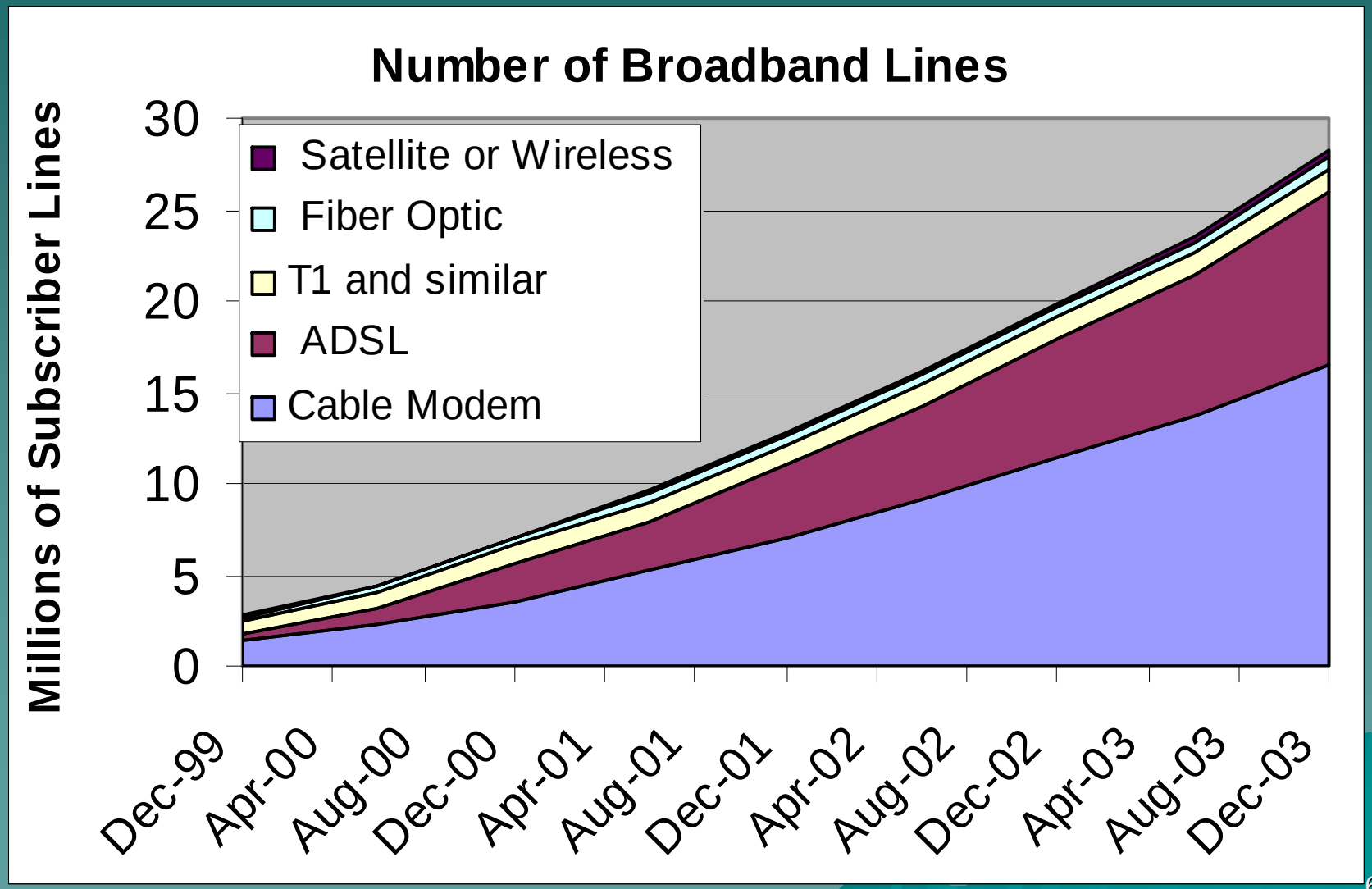
- Background on Broadband Internet Access
- Literature
- Describe the Data
- Preliminary Results
  - Supply
  - Demand in areas where DSL is supplied

Market Shares of Broadband Technologies

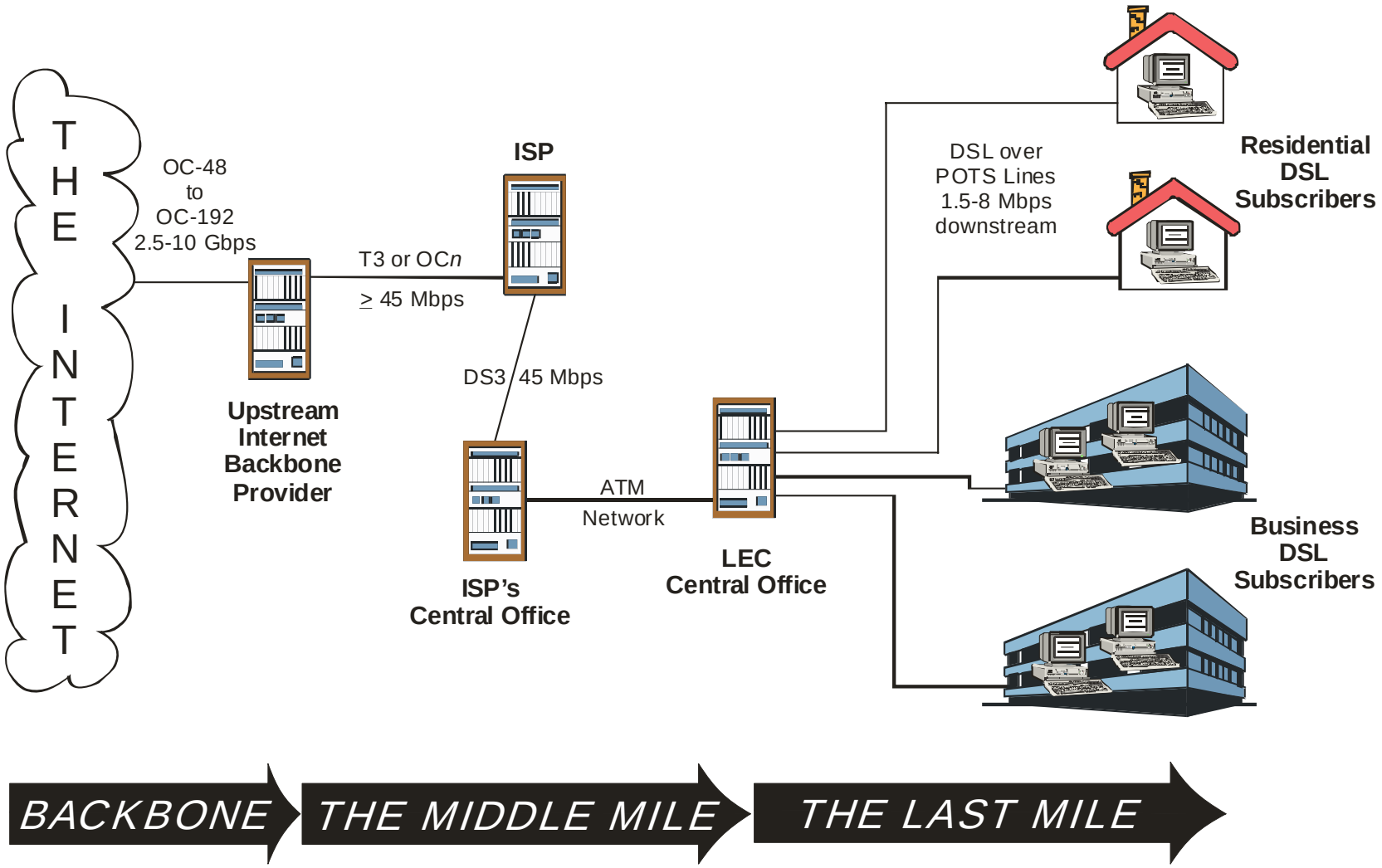


Residential and Small Business Broadband Lines (National, 2000)

Broadband is Increasing in the U.S.



A DSL Network



The Literature on Broadband Supply

- Gillett and Lehr (1999); cable modems only. Observations: 3,133 counties.
  - Problem: counties are much too big.
- NTIA and RUS (2000); DSL and cable.
  - Informal data collection.
- Gabel and Kwan (2000); DSL and cable. Observations: 287 telco central office areas.
  - Problem: know nothing about where in the CO area DSL is available.

The Literature on Broadband Supply

- Studies using the FCC broadband data
  - Prieger (2003), Flamm (2005)
  - Issues:
    - ZIP codes do not match telecommunications geography
    - Cable vs. DSL isn't distinguishable

The Literature on Broadband Demand

- Madden *et al*., 2000.
  - Western Australia
- NTIA, 2000
  - Uses Consumer Expenditure Survey
  - Do not know what options are available.
- Rappoport *et al*., 2003.
  - Know where cable and DSL are available, but assume DSL available in entire central office area

The Data

- In 2000, Ameritech was required by regulators to say where DSL was available.
  - Condition for merger approval with SBC
- Ameritech provided a list of their DSL subscribers by ZIP+4.
  - Data are binary: DSL is subscribed to by at least one household in the ZIP+4 area
  - Also know the earliest subscription date.

Why Did the Regulators Care?

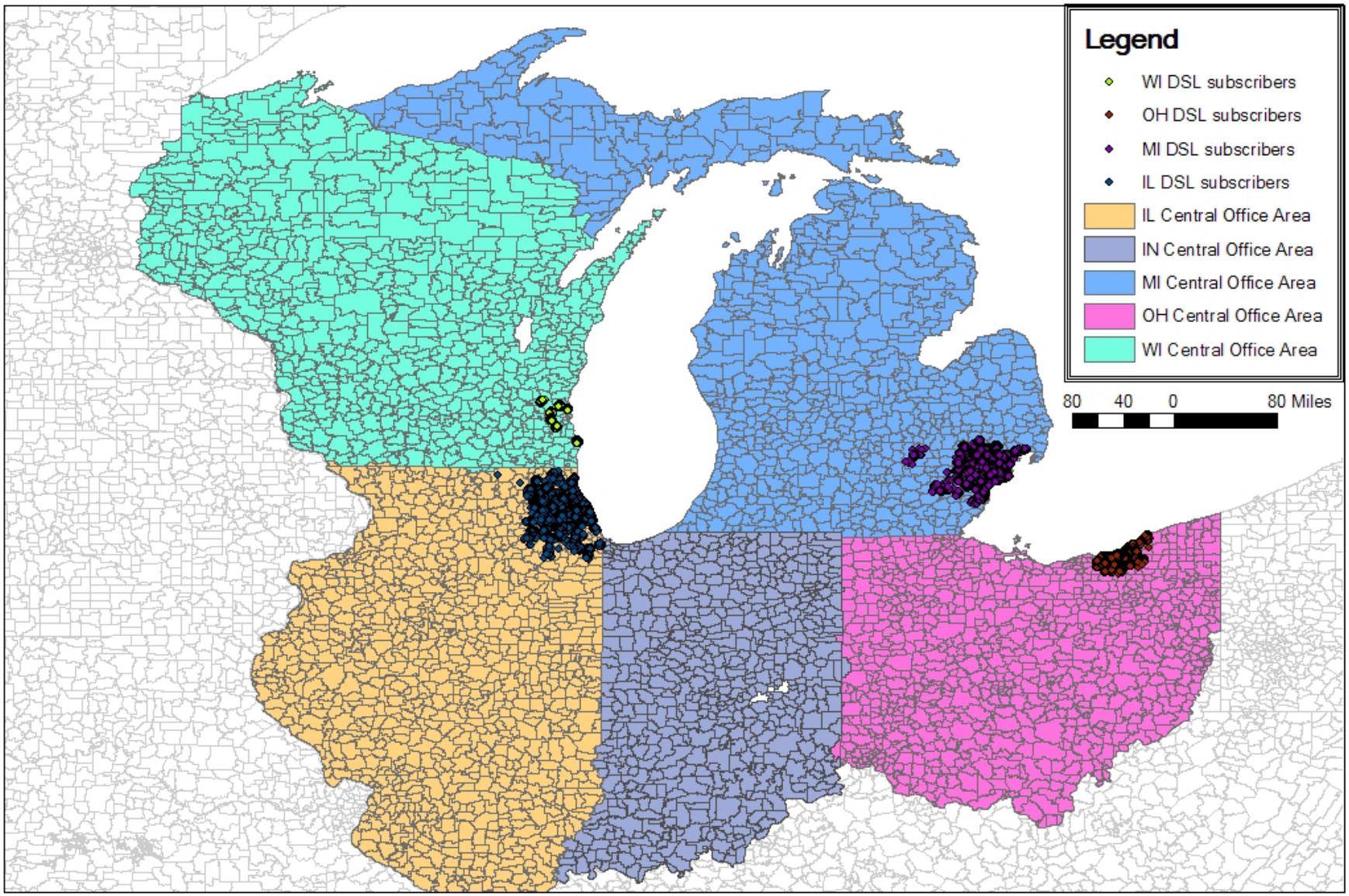
- Ameritech lagged behind other BOCs:

Bell Operating Company	Monthly price (transport and ISP service from the BOC), $	Number of DSL provisioned (12/99), Million
Ameritech	59.95	0.045
Bell Atlantic	49.95-189.95	17
Bell South	59.95	5
SBC/Pacific Bell	49.95-339.00	9.8
US West	49.95-859.95	2.2

The Data

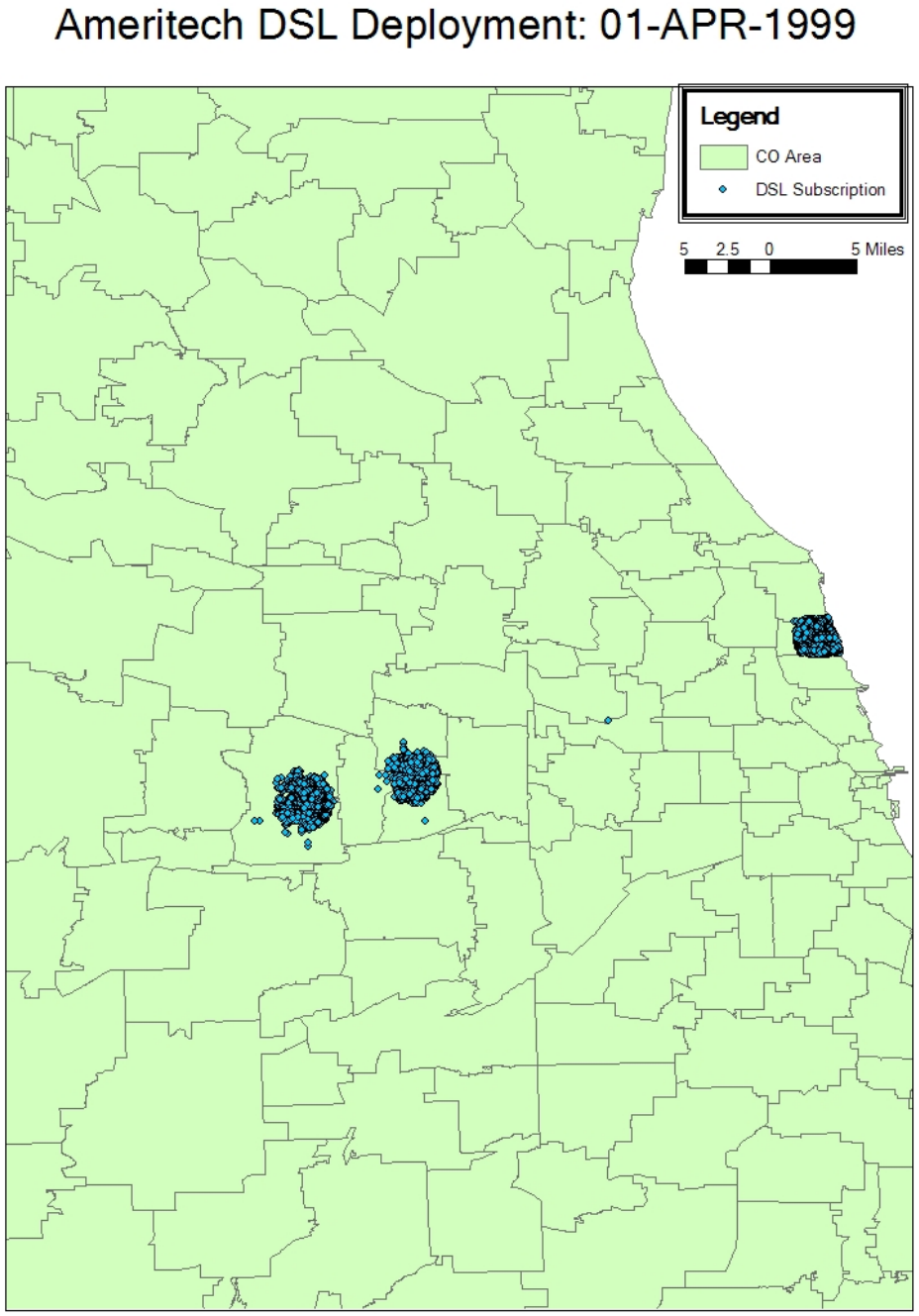
- Supplement with:
  - GIS data on ZIP+4 locations
  - A telecommunications central office database (GIS)
  - Census data on demographics (block level)
  - Census data on business characteristics (ZIP code level)
  - FCC list of ZIP codes with at least one CLEC.
- Eventually will add:
  - Cable company information (cable modem)
  - Service prices (maybe…)

DSL Subscribers in the Ameritech Region



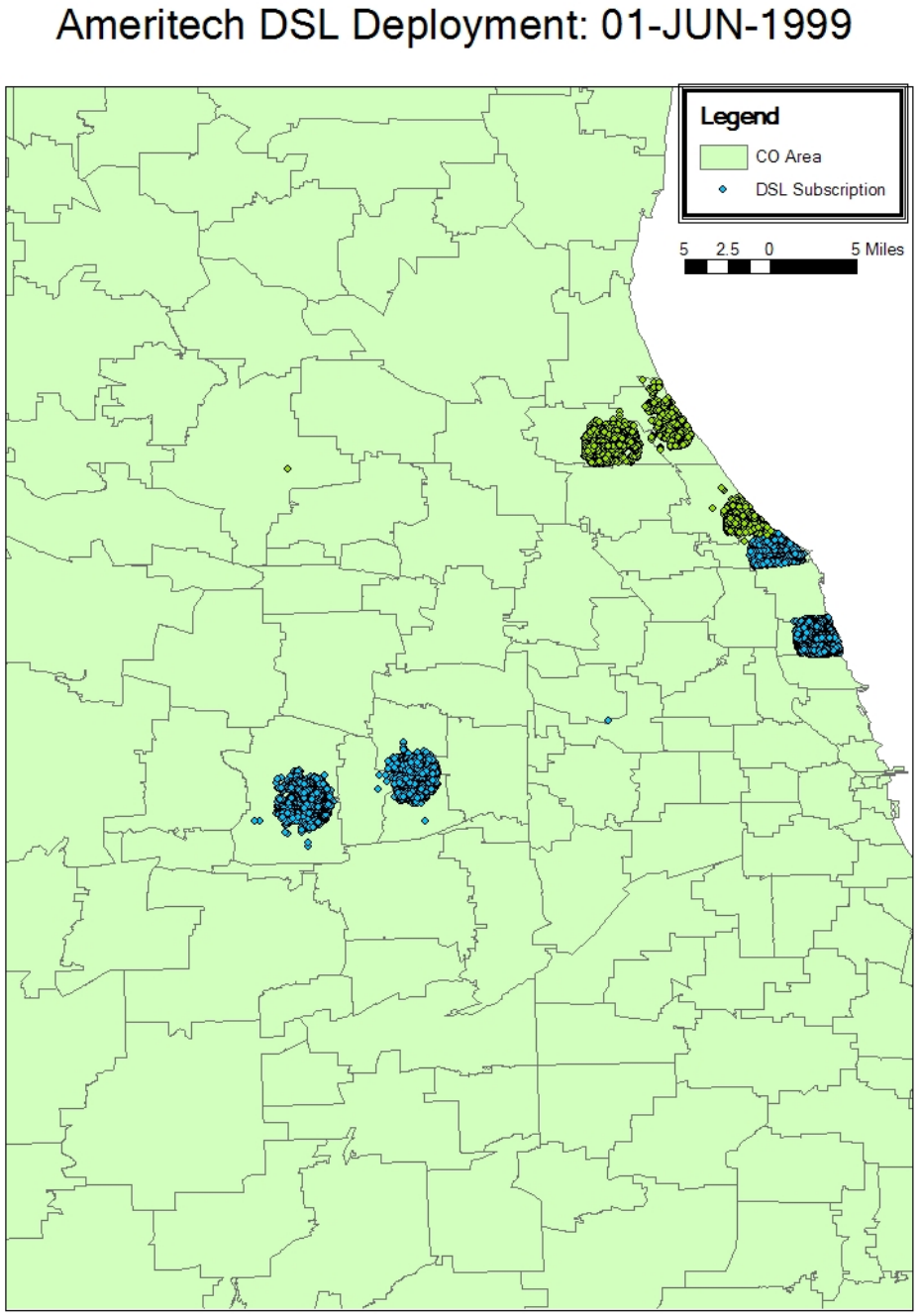
DSL Diffusion in Illinois:

April 1999



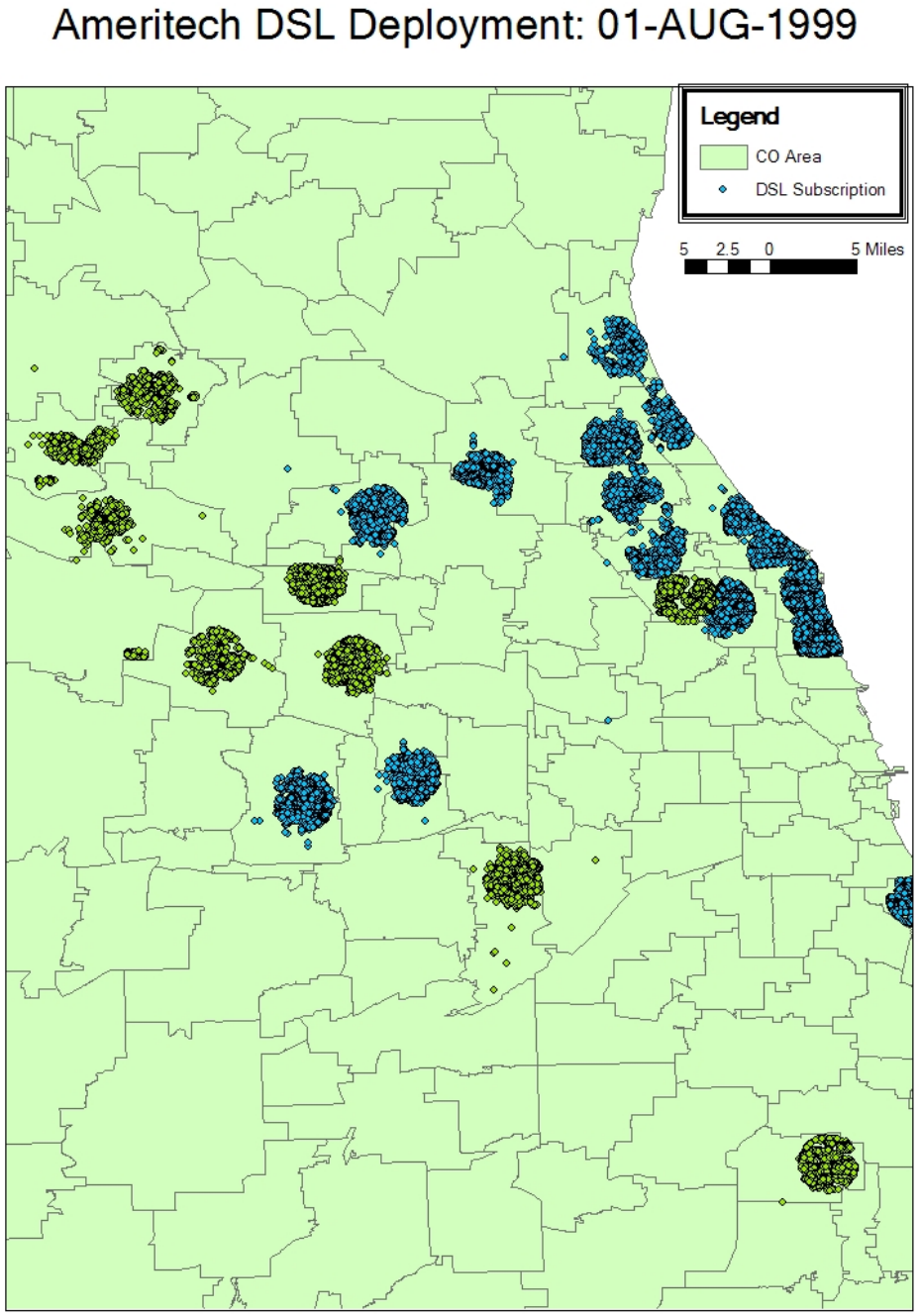
DSL Diffusion in Illinois:

June 1999



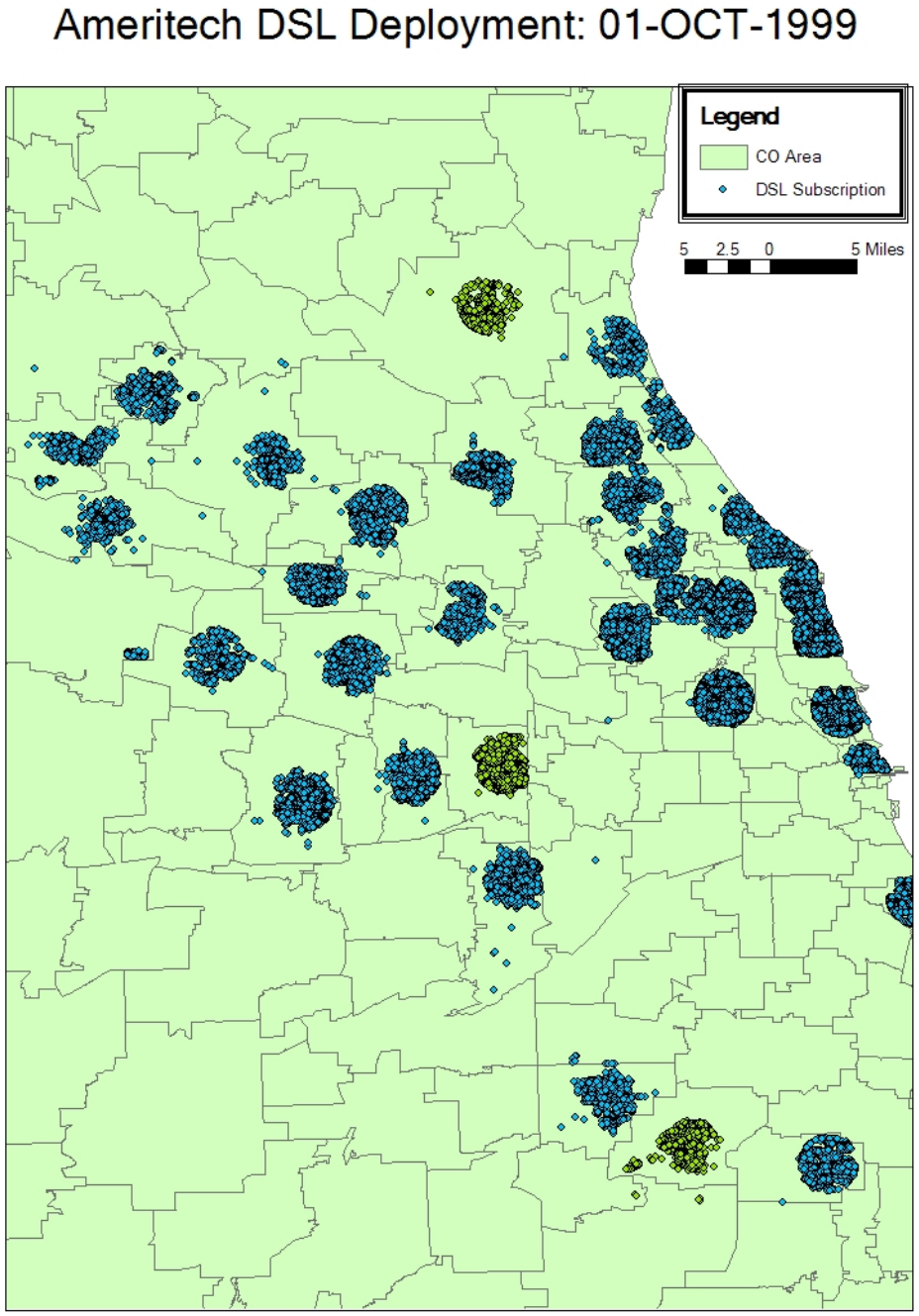
DSL Diffusion in Illinois:

August 1999



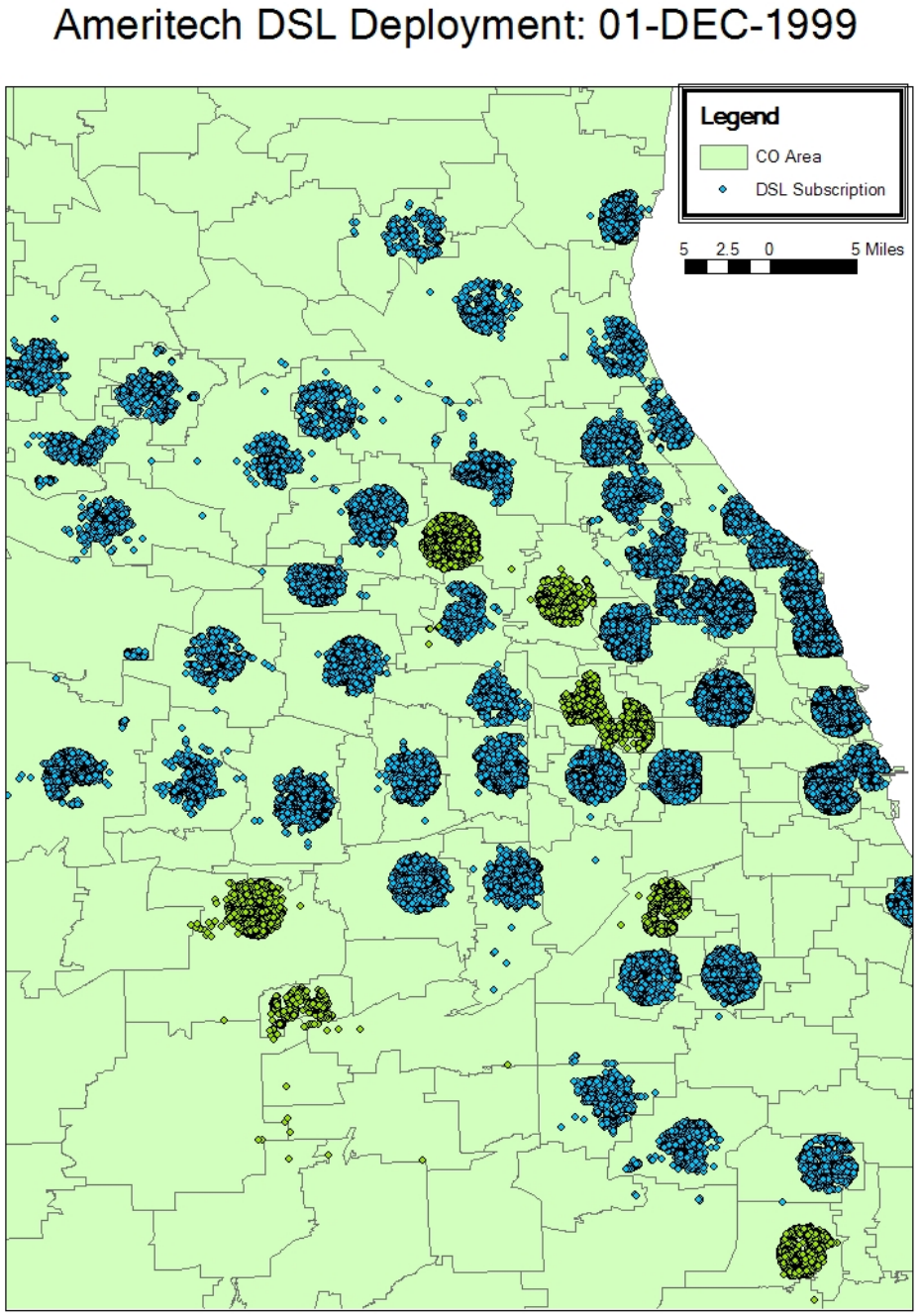
DSL Diffusion in Illinois:

Oct. 1999



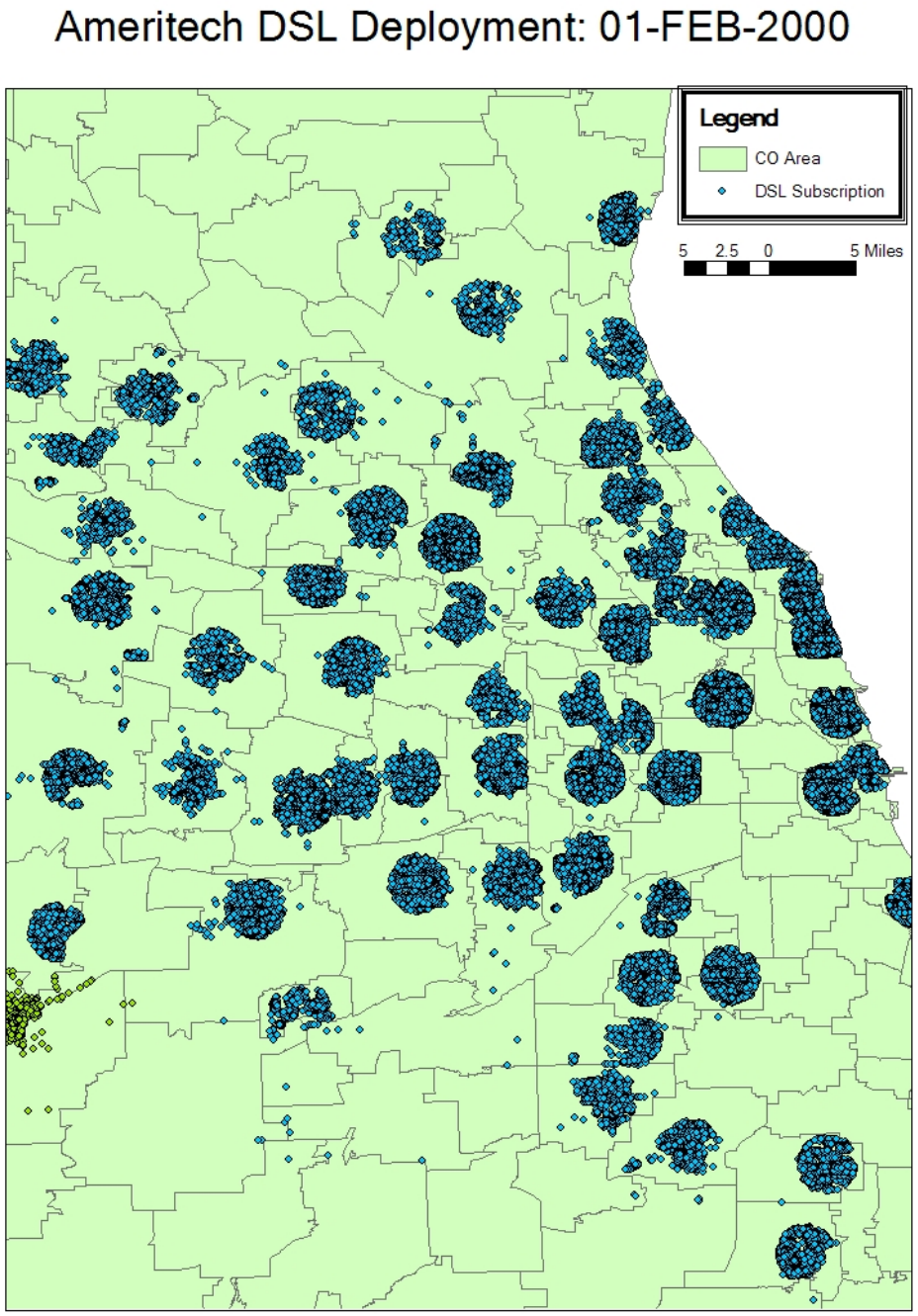
DSL Diffusion in Illinois:

Dec. 1999

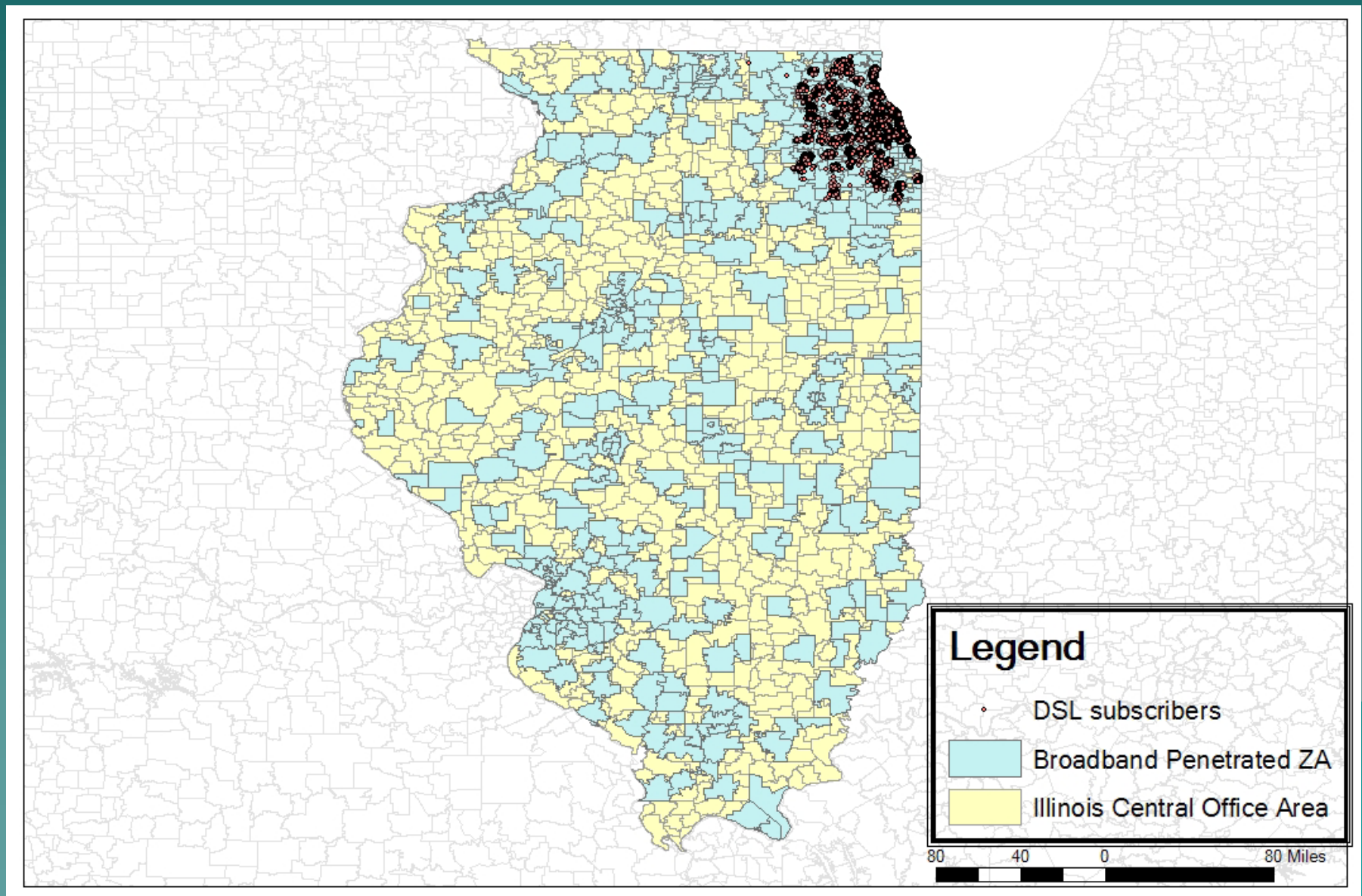


DSL Diffusion in Illinois:

Feb. 2000



Comparison with FCC Data for Illinois

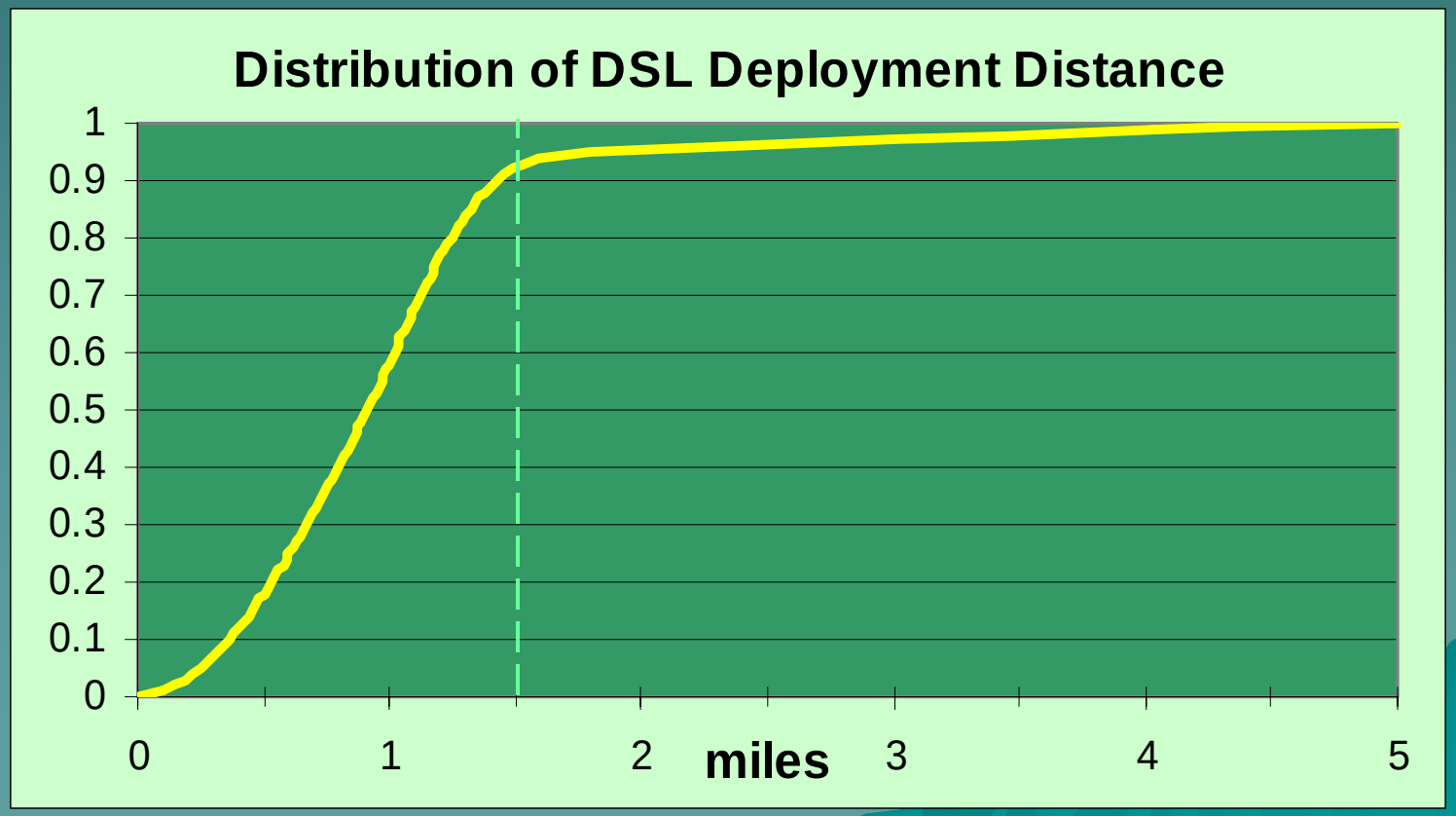


Technological Characteristics of DSL Deployment

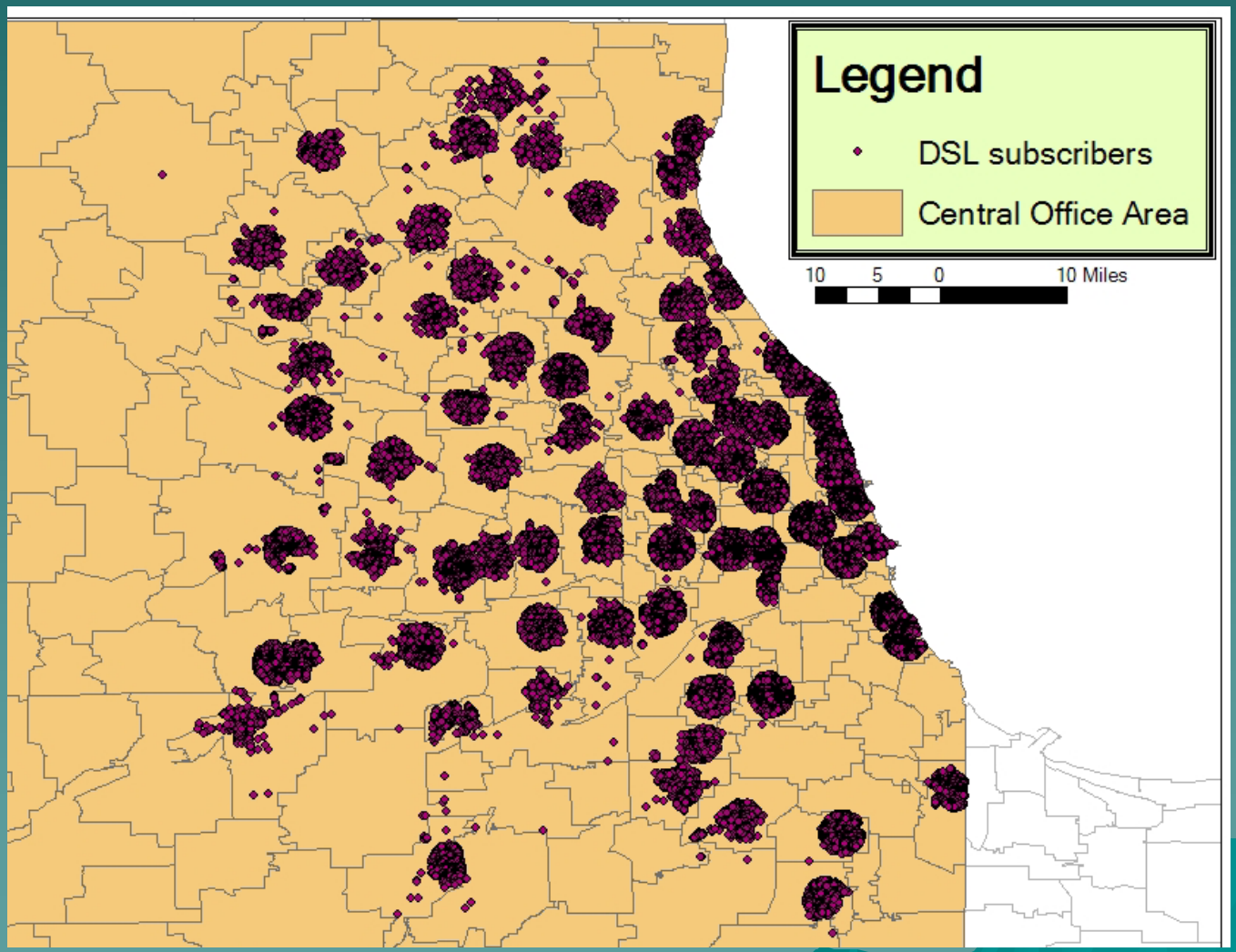
- DSL is implemented in the LEC's Central Office
  - As a marketing decision, is available to all neighborhoods in area...
  - but only if they are close enough to CO
  - Transmission speeds degrade beyond 2.2 miles.

Technological Characteristics of DSL Deployment

- Ameritech clearly had 1.5 miles as a threshold



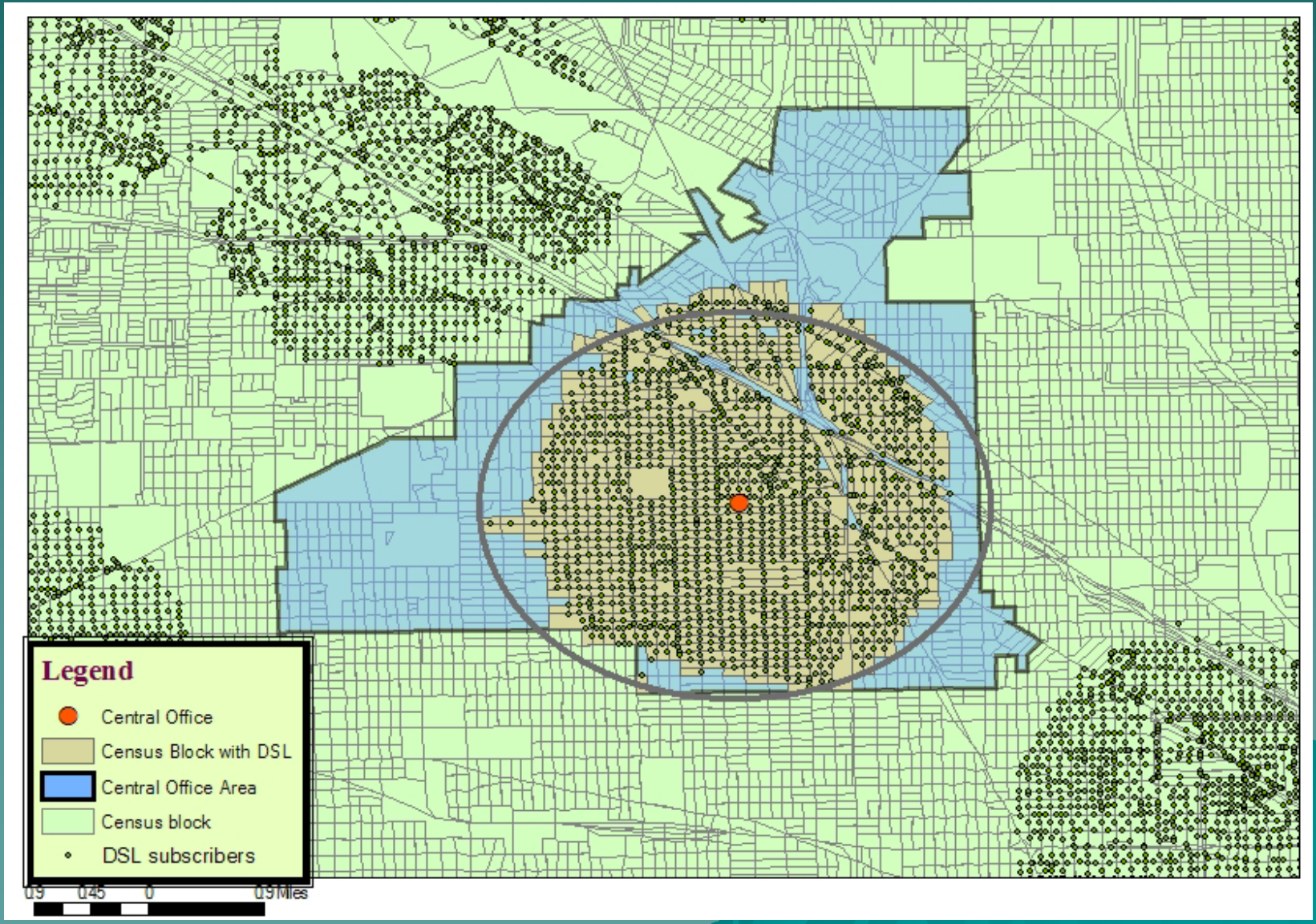
Distance Threshold is Clearly Visible



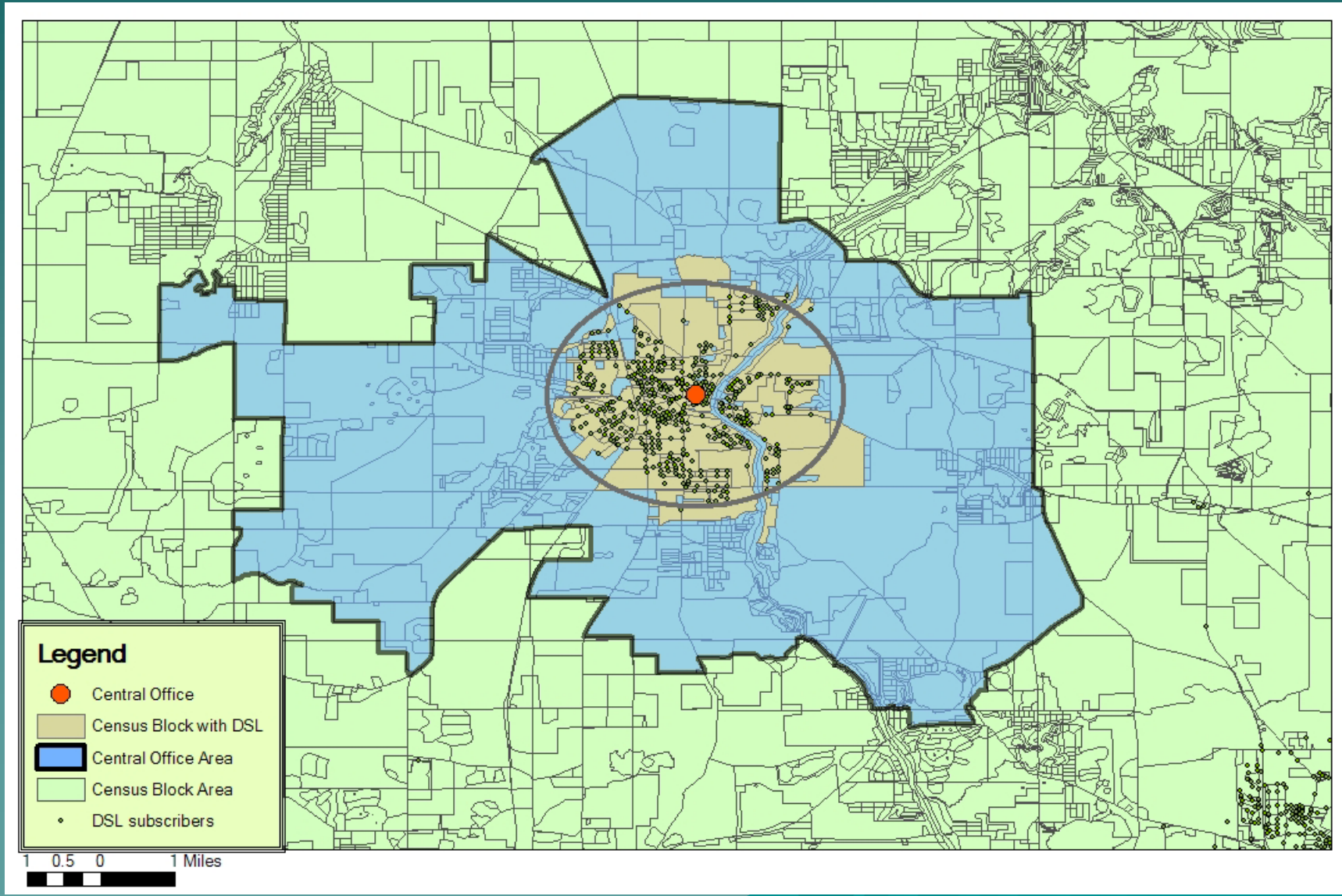
Implications for Supply and Demand Estimations

- Supply decision:
  - The marketing characteristics of the whole central office area aren't relevant, just a subset.
- Demand decision:
  - Need to restrict attention to households within 1.5 miles of the central office.
- This matters most in non-urban COs

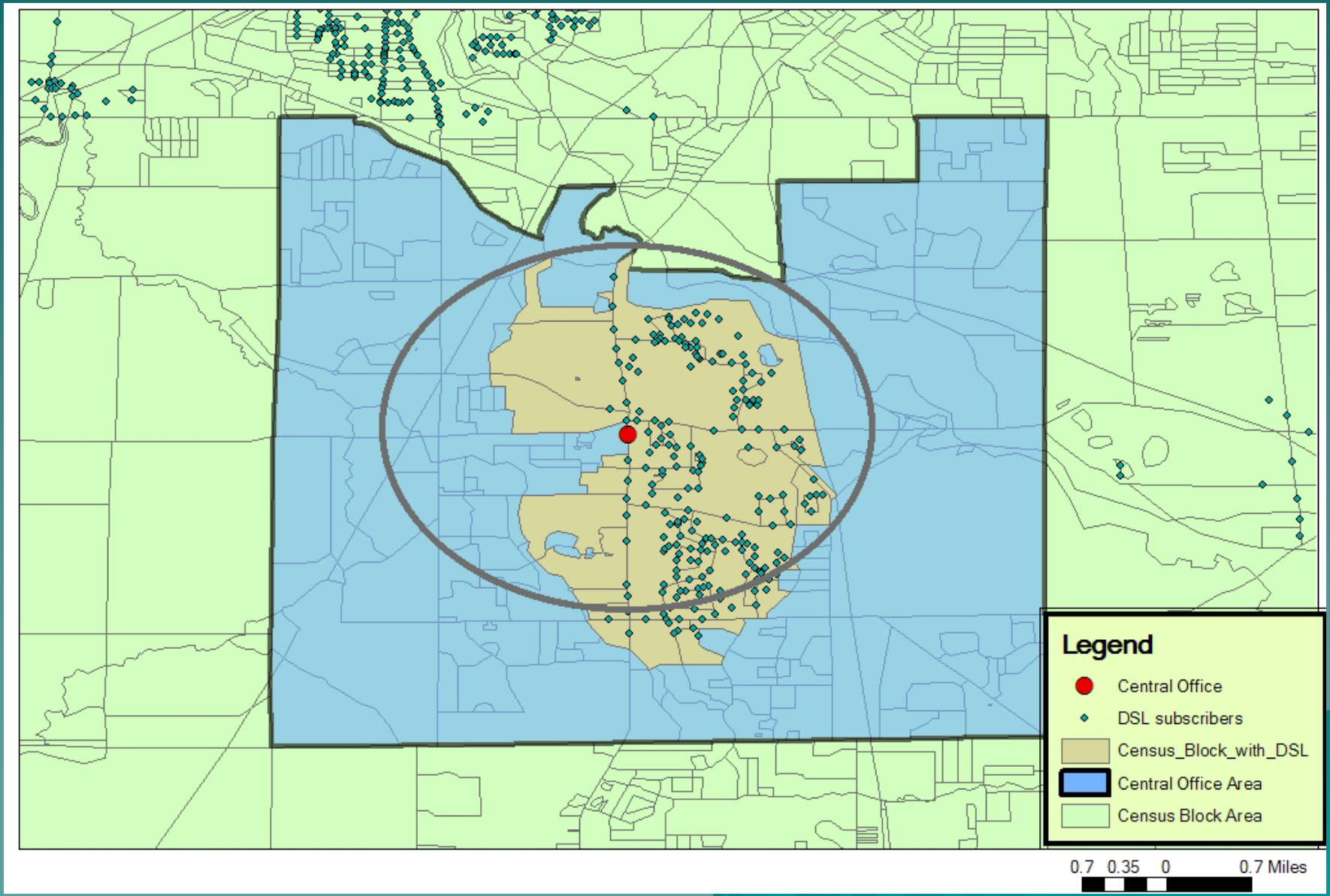
A Chicago Suburban Central Office Area



A Rural Central Office: McHenry, IL



A Rural Central Office: Strongsville, OH



Estimation Strategy – Supply Side

- The supply decision is a function of the expected profits:

$$E\left(\Pi(t^*, x, z(t))\right) = 0$$

  defines the optimal adoption time t^*, where x is a vector of demographics of the area, z is the competitors supply decisions

- Unit of decision-making: central office area.
- Model Pr($t^* < 3/15/00$) as a probit regression of DSL availability on x and z.

Supply Estimation #1

Variable	Estimation 1: Race		
	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity			
% Asian	13.030***	0.621	0.000
% Black	-0.701**	-0.033	0.034
% NativeAmerican	-127.046***	-6.057	0.002
% Other	-13.682**	-0.652	0.017
% Hispanic	8.591***	0.410	0.008
Income and Poverty			
Income (log)			
% in poverty			
Size of Market			
Households (log)	0.216**	0.010	0.018
Pop. density (log)	0.692***	0.033	0.000
Intercept	-7.364***		0.000
LogL	-264.793		
N	1,120		
Pseudo R^2	0.490		

Supply Estimation #2

Variable	Estimation 2: Race and Income		
	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity			
% Asian	7.408**	0.155	0.013
% Black	1.199***	0.025	0.008
% NativeAmerican	-19.546	-0.410	0.510
% Other	2.192	0.046	0.725
% Hispanic	-0.219	-0.005	0.951
Income and Poverty			
Income (log)	2.227***	0.047	0.000
% in poverty	-0.269	-0.006	0.253
Size of Market			
Households (log)	0.157	0.003	0.174
Pop. density (log)	0.852***	0.018	0.000
Intercept	-33.406***		0.000
LogL	-220.818		
N	1,119		
Pseudo R^2	0.575		

Supply Estimation #3

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity			
% Asian	9.475*	0.032	0.056
% Black	-0.582	-0.002	0.469
% NativeAmerican	-15.320	-0.051	0.758
% Other	-5.212	-0.017	0.531
% Hispanic	-2.252	-0.008	0.640
Income and Poverty			
Income (log)	2.388***	0.008	0.006
% in poverty	0.354	0.001	0.364
Size of Market			
Households (log)	0.366*	0.001	0.052
Number of firms (log)	0.190	0.001	0.202
LogL	-220.818		
N	1,119		
Pseudo R^2	0.575		

Supply Estimation #3, cont.

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value of Coef.
Education profile			
% Less than H.S.	19.710***	0.066	0.000
% Some College	12.152***	0.041	0.007
% College Degree	2.707	0.009	0.433
% Graduate Degree	5.810	0.019	0.129
Commuting Profile			
% Work at home	20.023**	0.067	0.047
% Commute 20-40 mins	2.645*	0.009	0.086
% Commute 40-60 mins	17.050***	0.057	0.000
% Commute > 60 mins	-8.327*	-0.028	0.011
Other Demographics			
% Female	-7.862*	-0.026	0.082
Median Age	0.048	0.000	0.236
Business Market			
Ave. workers/firm	0.685***	0.002	0.004

Supply Estimation #3, cont.

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value of Coef.
Cost variables			
Pop. density (log)	0.892***	0.003	0.000
Phone density	0.557***	0.002	0.004
Structure Age < median (log)	0.891**	0.003	0.047
CLEC Presence	-0.082	0.000	0.846

- Not sure what's going on with structure age
  - proxy for age of communications infrastructure
  - Older infrastructure: expect higher per-line cost of deploying DSL
  - Get this results for the oldest areas, but not the youngest.
- CLEC presence doesn't matter. Contrasts with finding of Prieger (2003).

Estimation Strategy – Demand Side

- Reduced Form Approach:
  - Simple probit at the Census block level
  - Y=1 if any of the DSL ZIP+4's fall into that block
  - So at least on household or business subscribes in the block
  - Include only blocks that are within 1.5 miles of a CO in which DSL is deployed.

Estimation Strategy – Demand Side

- Structural Approach
  - The demand decision is a function of the utility of the relevant options:

    DSL: $U_{DSL} = \beta_{DSL}'x + \varepsilon_{DSL}$

    No DSL: $U_0 = 0$
  - The "outside option" has to stand in for dial-up, cable modem, and no access.
  - Household subscribes to DSL if it gives the most utility:

    $U_{DSL} > 0$

Estimation Strategy – Demand Side

- Specify ε_{DSL} as standard normal: probit binary choice model
- Then Prob(at least one HH in ZIP+4 area *j* has DSL) is

$$P_j = 1 - \prod_{i=1}^{N_j} (1 - P_i)$$

where P_i is $\Phi(-\beta'x)$.

- Use this to do MLE.

Reduced Form Demand Estimation #1

Variable	Estimation 1: Race		
	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity			
% Asian	-0.734***	-0.259	0.000
% Black	-0.293***	-0.103	0.000
% NativeAmerican	-0.498	-0.176	0.150
% Other	-0.631***	-0.223	0.000
% Hispanic	-0.359***	-0.127	0.000
Income and Poverty			
Income (log)			
% in poverty			
Size of Market			
Households (log)	0.127***	0.045	0.000
Intercept	0.258***		0.000
LogL	-36460.33		
N	59,799		
Pseudo R^2	0.020		

Reduced Form Demand Estimation #3

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value of Coef.
Race and Ethnicity			
% Asian	-0.699***	-0.241	0.000
% Black	-0.068***	-0.023	0.005
% NativeAmerican	-0.066	-0.023	0.859
% Other	-0.479***	-0.165	0.000
% Hispanic	-0.181***	-0.063	0.001
Income and Poverty			
Income (log)	0.290***	0.100	0.000
% in poverty	-0.018***	-0.006	0.003
Size of Market			
Households (log)	0.161***	0.055	0.000
Number of firms (log)	-0.046***	-0.016	0.000
LogL	-33673.45		
N	59,730		
Pseudo R^2	0.094		

Reduced Form Demand Estimation #3 (cont.)

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value of Coef.
Education profile			
% Less than H.S.	-0.370***	-0.128	0.000
% Some College	-0.172	-0.059	0.113
% College Degree	-0.147	-0.051	0.134
% Graduate Degree	0.162	0.056	0.102
Commuting Profile			
% Work at home	0.916***	0.316	0.000
% Commute 20-40 mins	0.071	0.024	0.247
% Commute 40-60 mins	-0.346***	-0.119	0.000
% Commute > 60 mins	-0.062	-0.021	0.493
Other Demographics			
% Female	0.032	0.011	0.601
Median Age	-0.003***	-0.001	0.000
Business Market			
Ave. workers/firm	0.073***	0.025	0.000

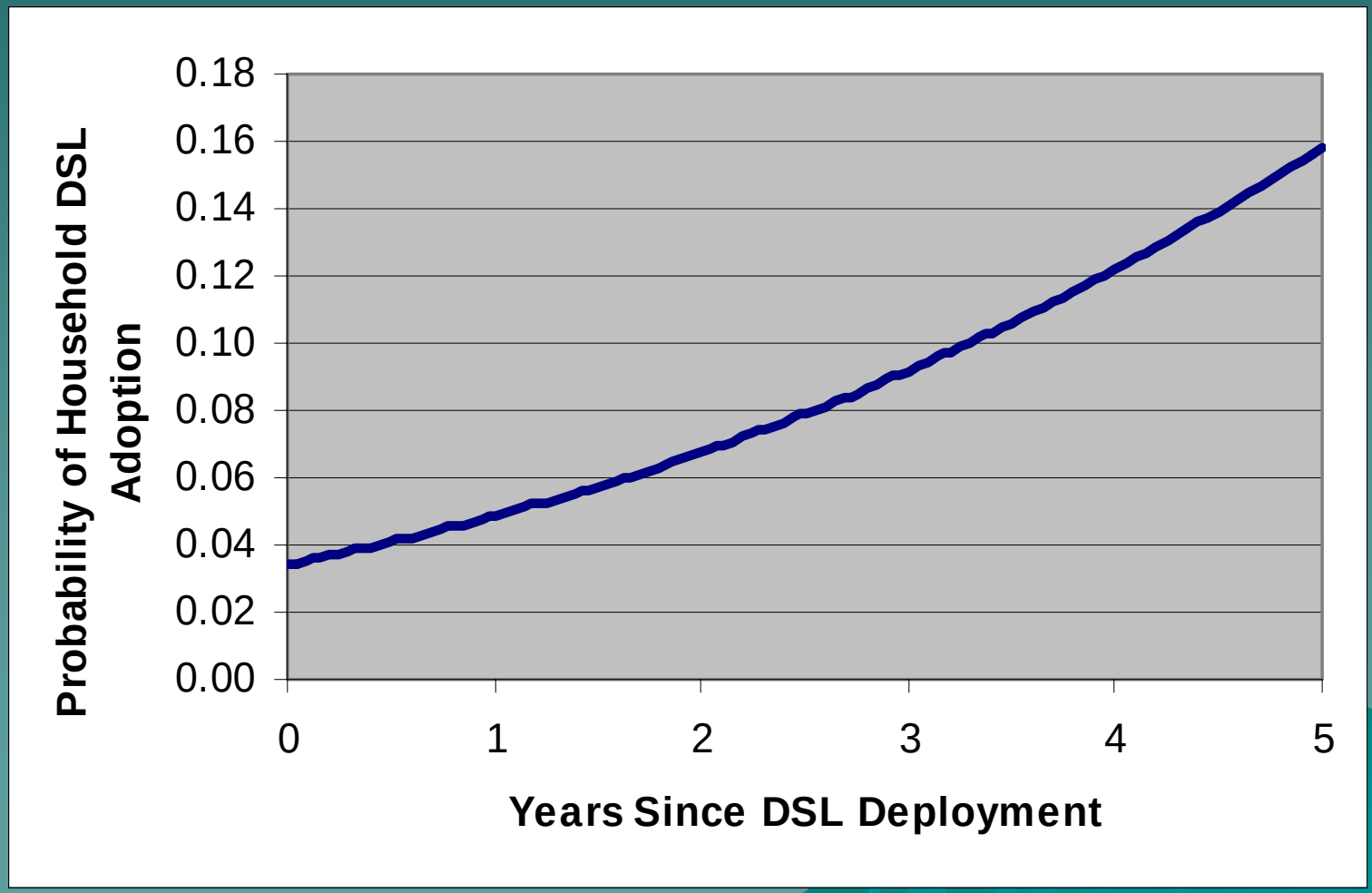
Reduced Form Demand Estimation #3 (cont.)

Variable	Estimation 3: All Variables		
	Coefficient	Marginal Effect	P-Value
Other Variables			
Rural	0.161***	0.053	0.002
Phone density	-0.005	-0.002	0.202
CLEC Presence	0.203***	0.073	0.000
Distance from CO	-1.009***	-0.348	0.000
Time deployed in CO	0.236***	0.081	0.000

- CLEC presence: cannot be causal.
- Distance from the CO: quality?
- Diffusion over time is non-ignorable.

Diffusion Curve over Time

- The coefficient on time since DSL deployed in the area implies a diffusion curve:



Structural Demand Estimations

- Generally similar to reduced form, except:
  - The marginal effects are smaller (expected).
  - Black and Native American lose significance once control for income, other demographics.

Conclusions

- This is an interesting, unique dataset to explore.
- Race doesn’t matter in supply
- Race matters in reduced form demand estimations.
- Asian, other race, and Hispanic matter in structural demand estimations.
- Income matters in both supply and demand.

Extensions

- Structural modeling of the supply decision
  - Cable entry decision vs. Ameritech's decision vs. CLECs decisions
- More advanced structural modeling of the demand side
  - Draw representative households from the distribution for each block, instead of using average x's.