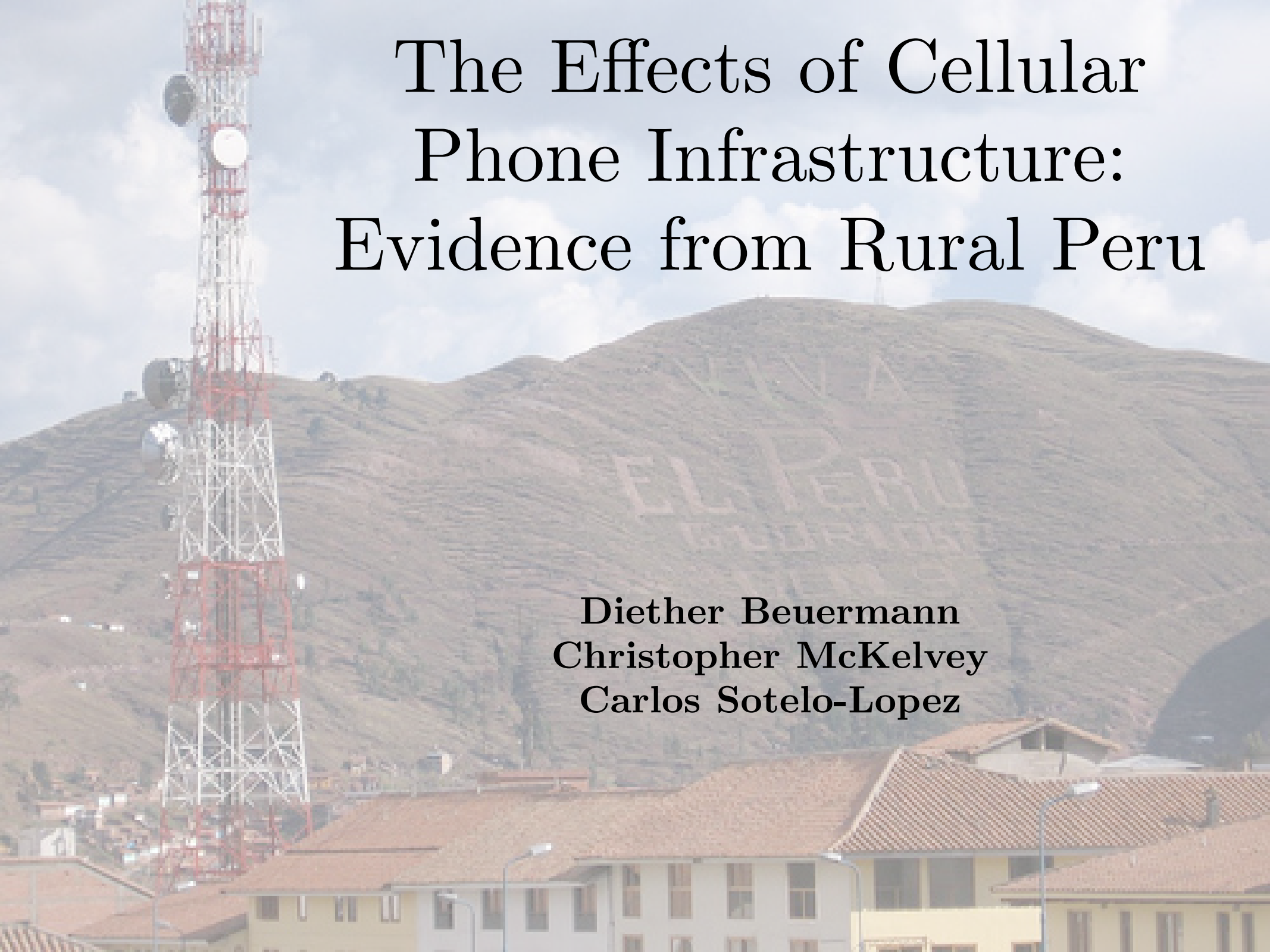
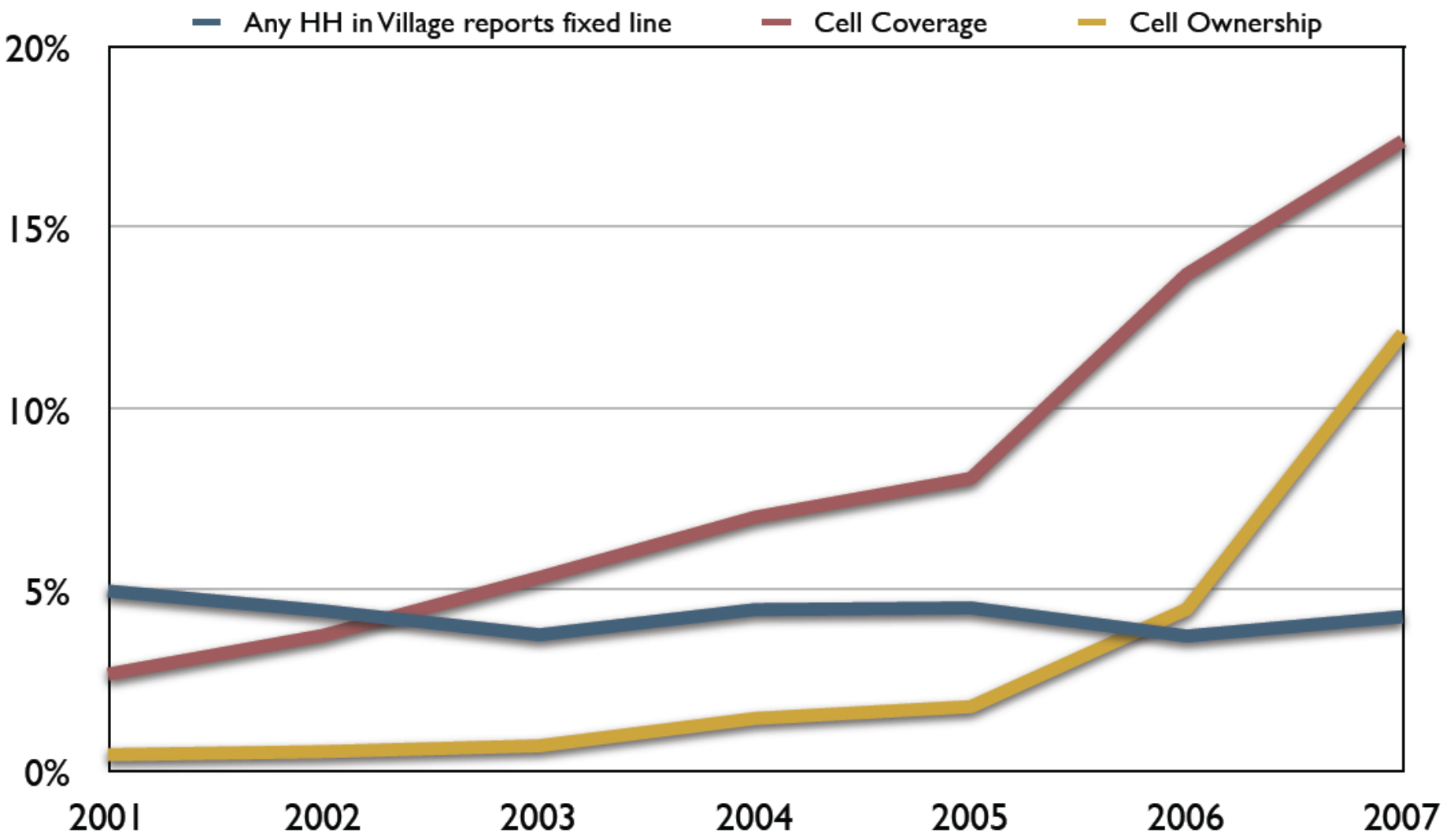


The Effects of Cellular Phone Infrastructure: Evidence from Rural Peru

Diether Beuermann
Christopher McKelvey
Carlos Sotelo-Lopez

Motivation

- Cell phone penetration rates are skyrocketing worldwide, particularly in developing countries.
- Increasingly, those getting service have had no prior telephone service (leap-frogging)
- Rural Peru is no the exception…



Source: Encuesta Nacional de Hogares (ENAHO); Fund for Investment in Telecommunications (FITEL) tower data

Motivation

- So there is:
  - explosive growth in cell phone use
  - where land-line phone technology is being “leap-frogged”
- Much hope that these trends will lead to income/welfare growth
- Begs the question – what is known about the extent to which phones foster development?

How will this impact HH in developing countries?

- Early evidence – cross-country regression models (Roller and Waverman, 2001):
  - ICT infrastructure associated with faster growth among OECD countries, 1970-90
  - But countries with better ICT may be unobservably different than those without

How will this impact HH in developing countries?

- Improved Market Efficiency (Jensen, 2007)
  - Cell phones help fishermen in Kerala, India get price information
  - Led to reduced price variation across markets and eliminated waste
  - This increased production & profits (net of cell phone costs)
  - Led to a reduction in price, increasing consumer welfare

How will this impact HH in developing countries?

- Improved Market Efficiency (Aker, 2008)
  - Similar results for grain markets in Niger following cell phone roll-out
  - Reduced price dispersion
  - No increase in production, but consumer prices decrease
  - Net consumers better off; Net producers worse off

Through what mechanism?

- Reduced search costs
  - cell phones make it cheaper for buyers & sellers to search for the best price
- Greater bargaining power
  - knowing prevailing prices may strengthen one's bargaining position
- Better diffusion of non-price information
  - e.g., technological innovations, best farming practices, weather forecasts

Research Questions I

- There is a range of mechanisms and predict the direction of the effect is difficult
- So the impact may vary by commodity/context:
  - Jensen finds an increase in fishing profits, while Aker's results suggests that net grain producers are worse off
- This is the first study to look across commodities and gauge the overall impact of cell phones on income and welfare
  - Fundamental for understanding the impact of cellular infrastructure on development

Outcomes of interest

- In order to fully assess the impact on welfare we need to look at the impact on:
  - consumption prices & quantity consumed → expenditures
  - employment & wage rate → labor income
  - output prices & quantity sold → farm production
  - input prices & utilization → farm expenditures
- We've just begun the empirical analysis, so for now we can only tell the beginning of this story...

Research Questions II

- If cell phones do result in increased profit and welfare, how are gains distributed across society?
  - Producers vs. consumers
  - Cell phone owners vs. non-cell phone owners
  - Wealthy vs. poor
  - Those in areas with land-lines vs. those with no prior service

Strategy:

- Use nationally representative data from Peru to examine the impacts of the cell phone build-out in Peru
  - Annual HH survey from 2001-2007
  - The location and construction date of every tower in Peru
- Look at effect of rural cell phone tower construction has on neighboring villages

Strategy

- Why only rural villages?
  - Most cities had already been treated by 2001, so no treatment variation
- Why the impact of cell phone towers and not ownership?
  - Easier to deal with the non-random placement of towers
  - But we do plan to look at heterogeneity in treatment for owners/non-owners

Data:

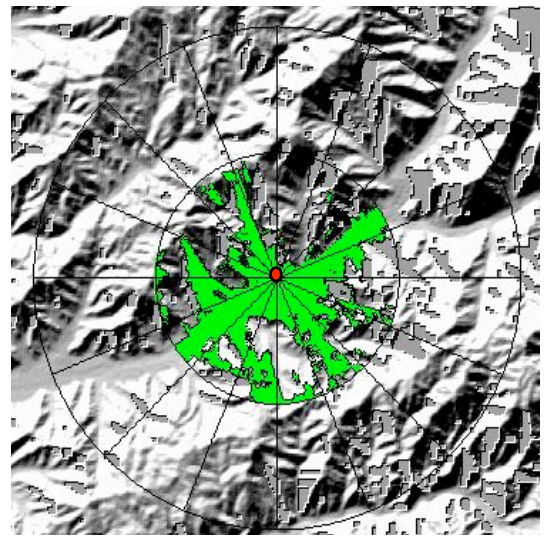
- Annual HH survey data from 2001-2007:
  - Encuesta Nacional de Hogares (ENAHO)
  - Design is repeated cross-section (5,000 to 7,000 HH per year, for a total of 49,697); also has a small rotating panel
- Cellular tower data:
  - Data from the Fund for Investment in Telecommunications (FITEL)
  - Includes: tower location, construction date, company, height, transmission frequency & strength

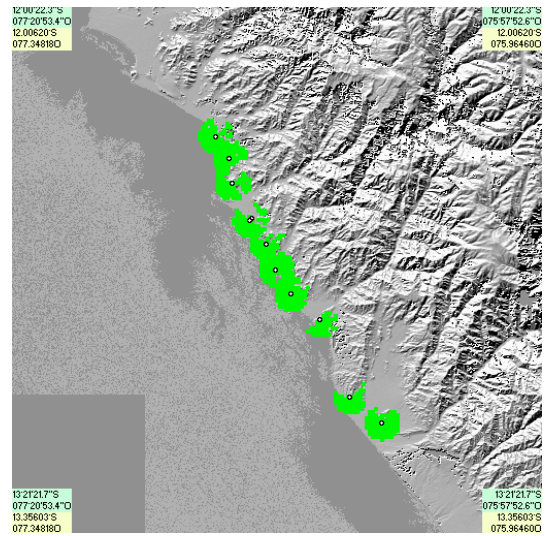
Context: Rural Peru

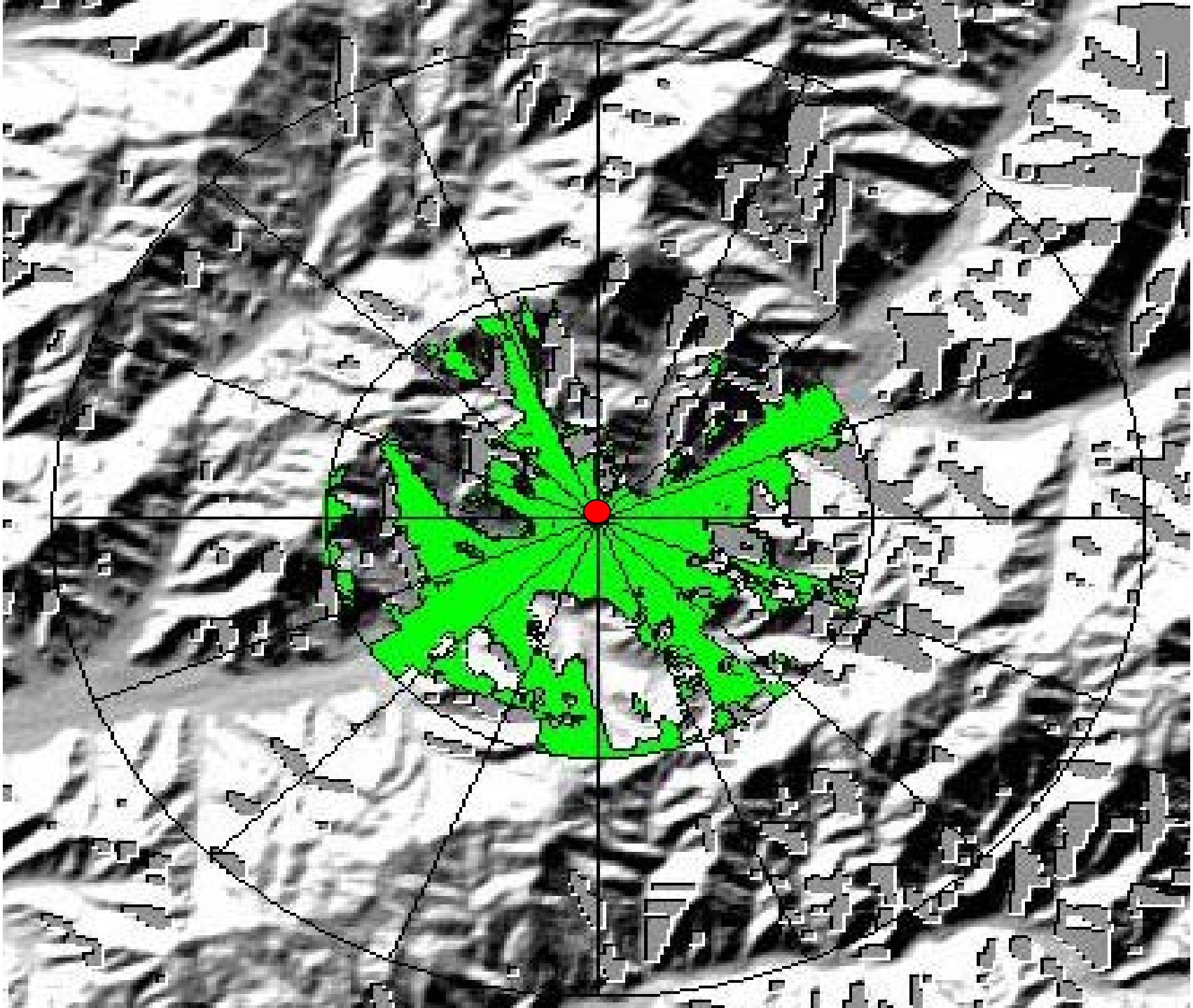
- 85% of HH run a home farm
  - Typical crops include: wheat, corn, potato, lima beans, barley, plantains
- For those who own a cell phone, cell expenditure is about $9 per month, while average monthly income is about $170
- Most people use pre-paid cellular plans

Methodology for simulating coverage areas

- Coverage simulation was done using the radio propagation software: Radio Mobile
- Implements Longley-Rice model, also known as the Irregular Terrain Model (ITM)
- We use the Shuttle Radar Topography Mission (SRTM) −90m resolution elevation data
- Taking into account terrain and earth curvature, coverage areas projected using
  - base station and phone: transmission strength; antenna type, height, and gain; reception limit
- Coverage maps are patched together, and we then determine which villages have coverage







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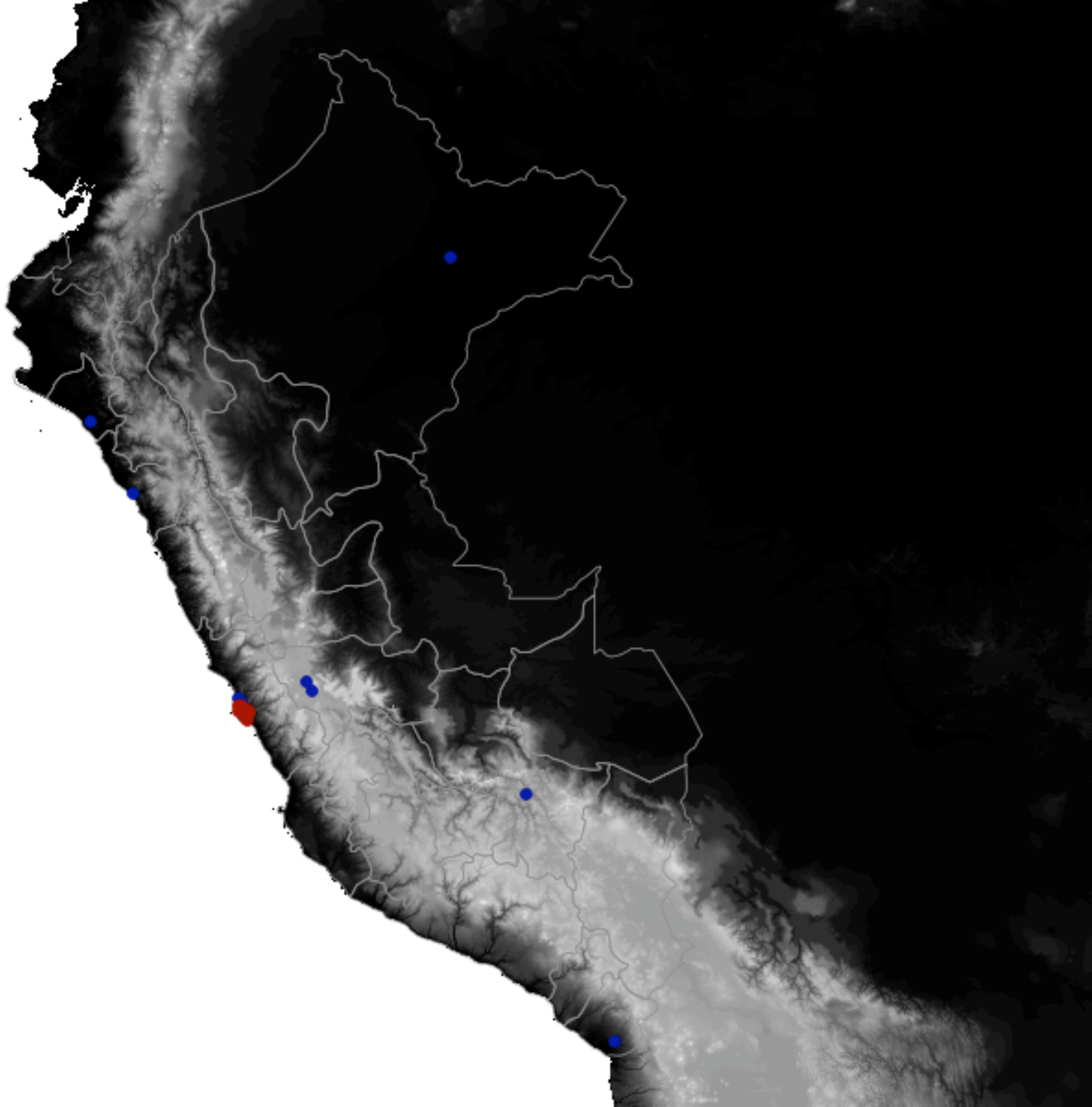

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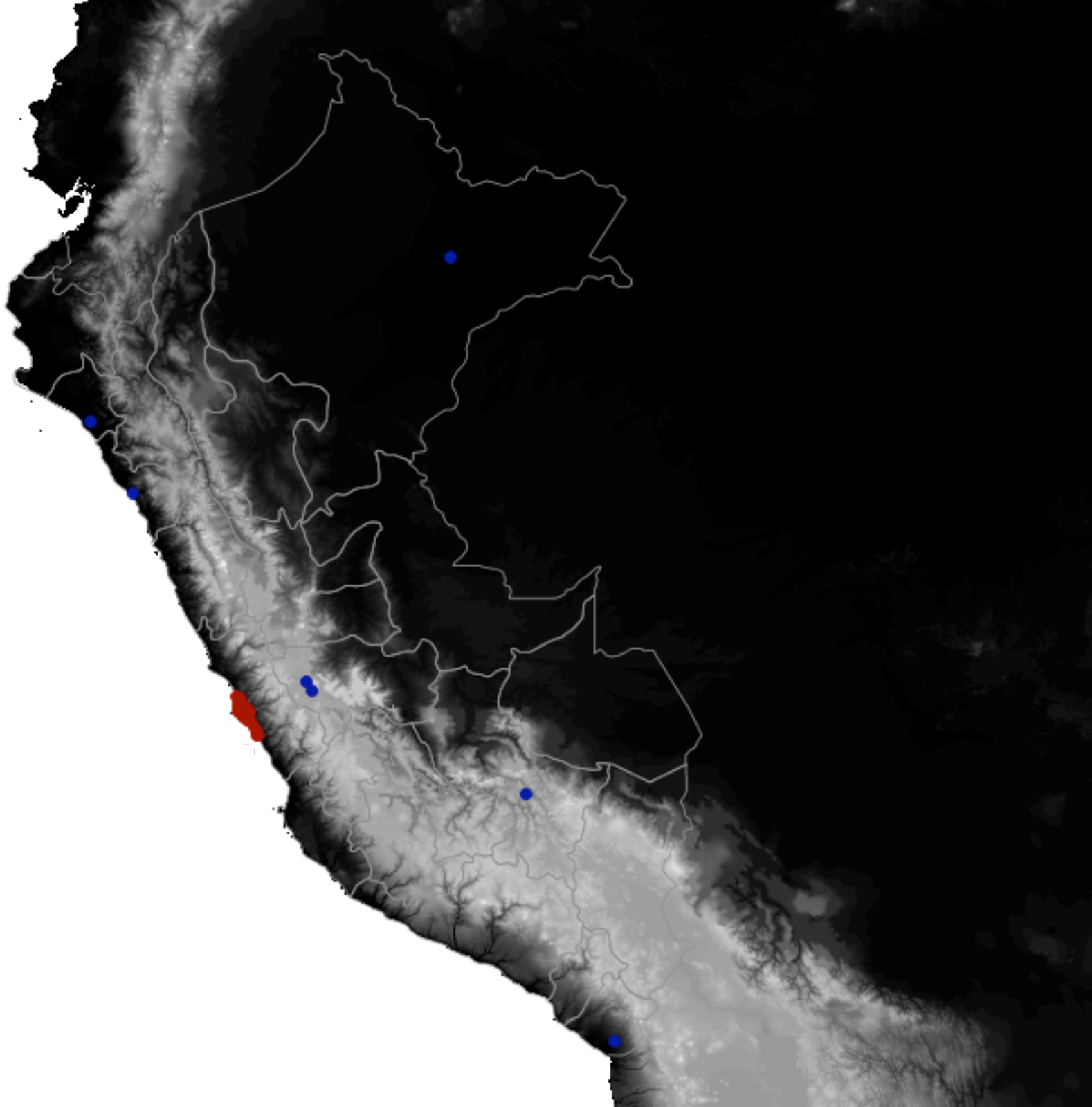

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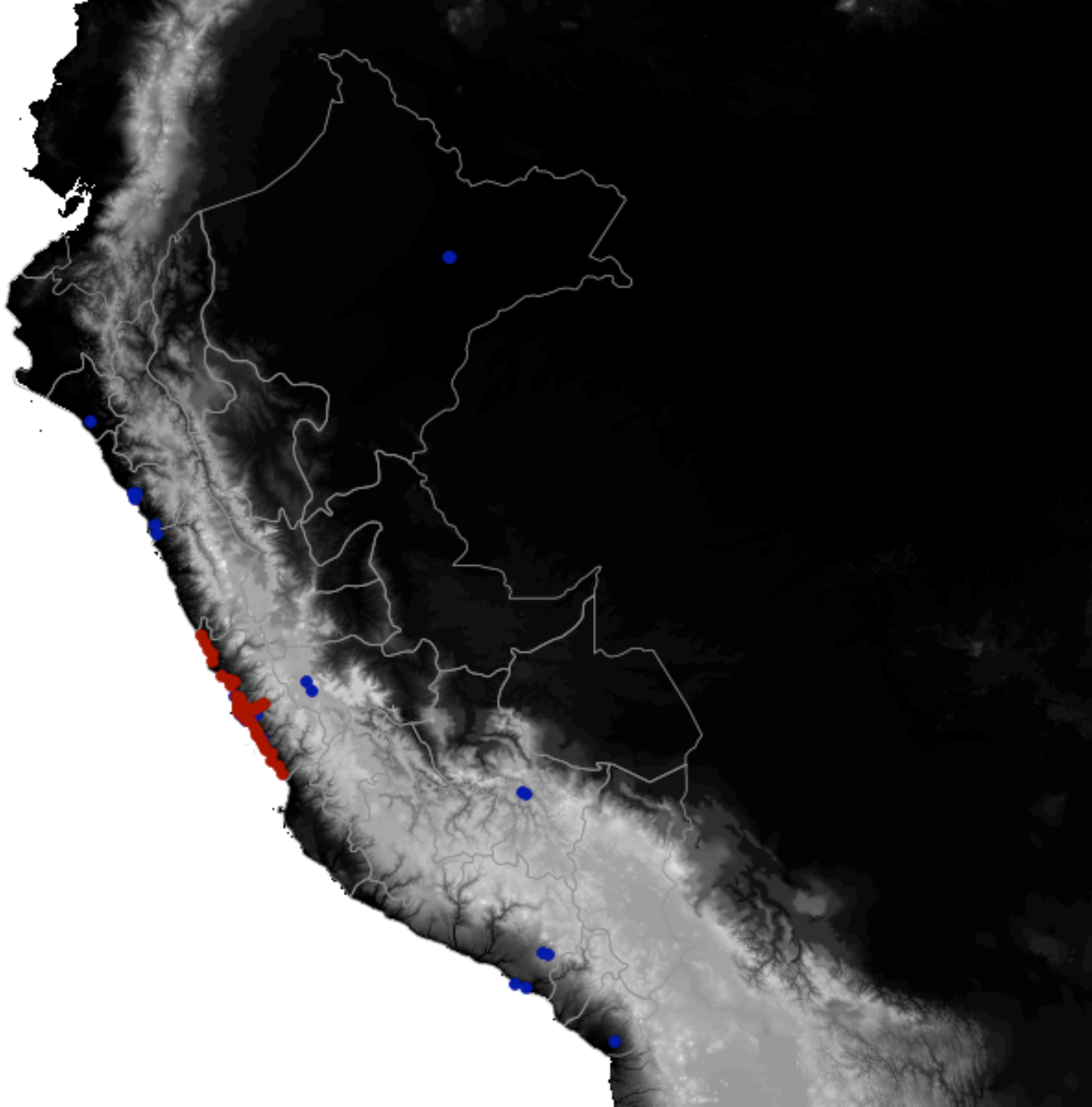

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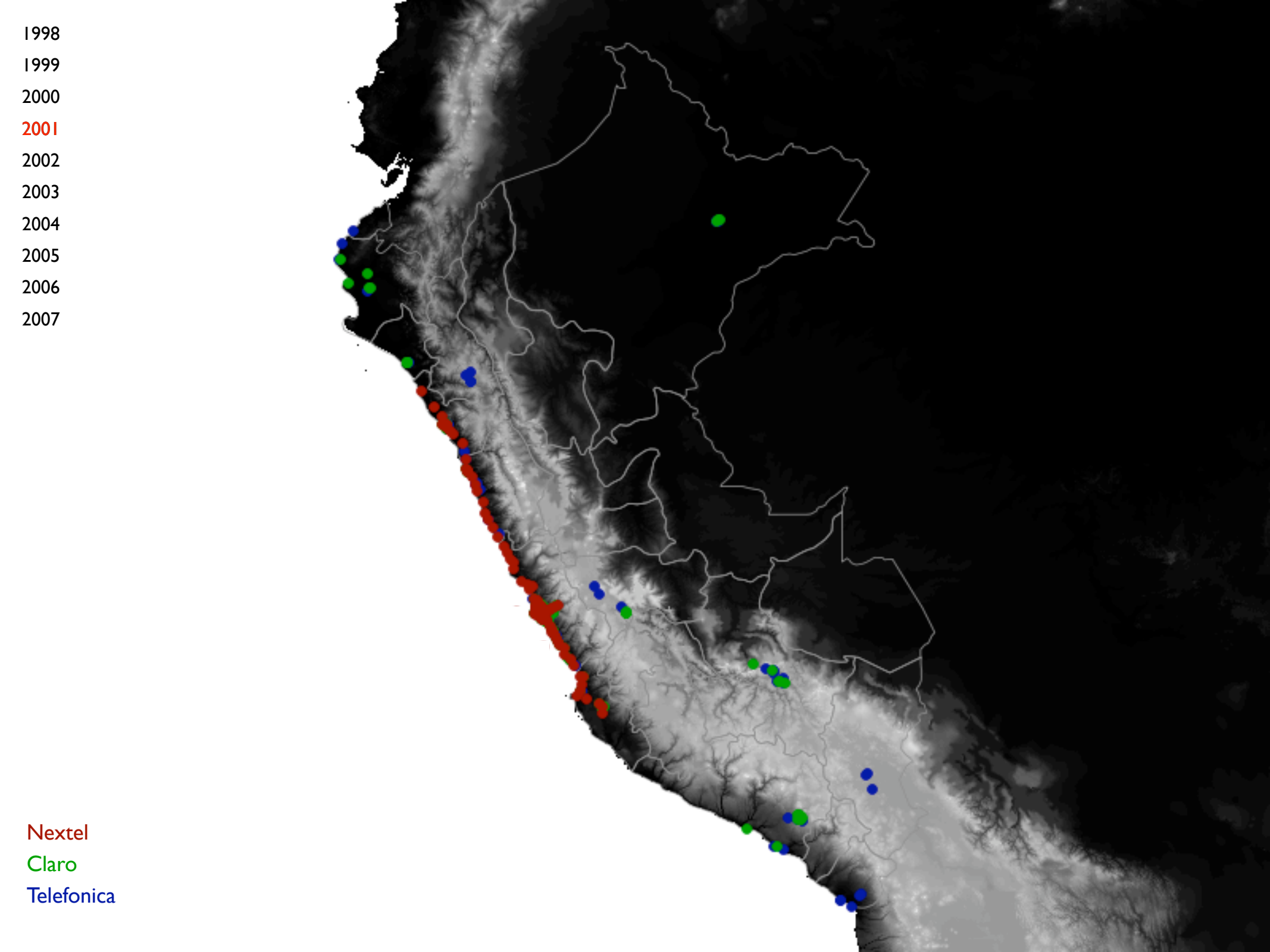
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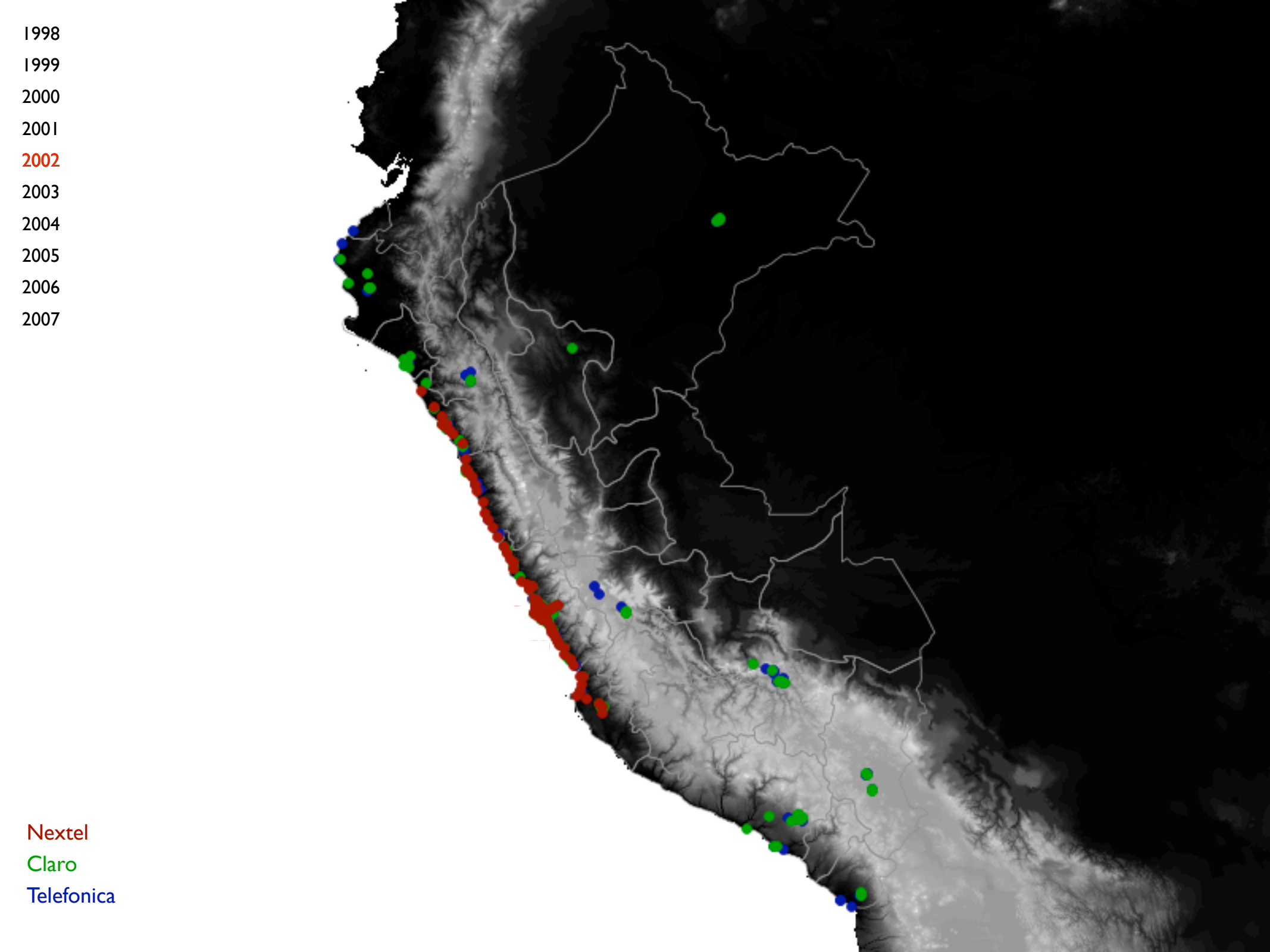
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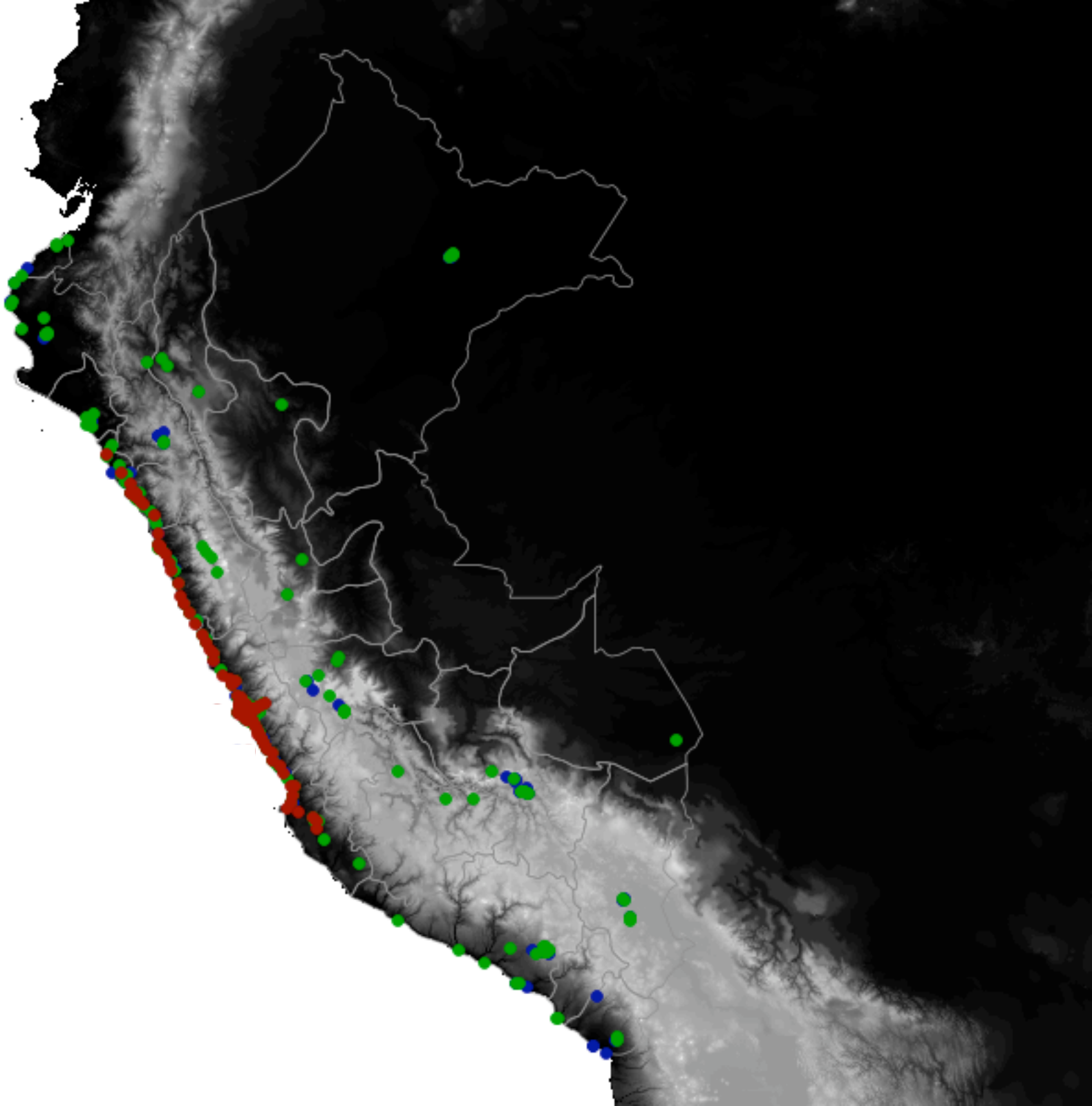

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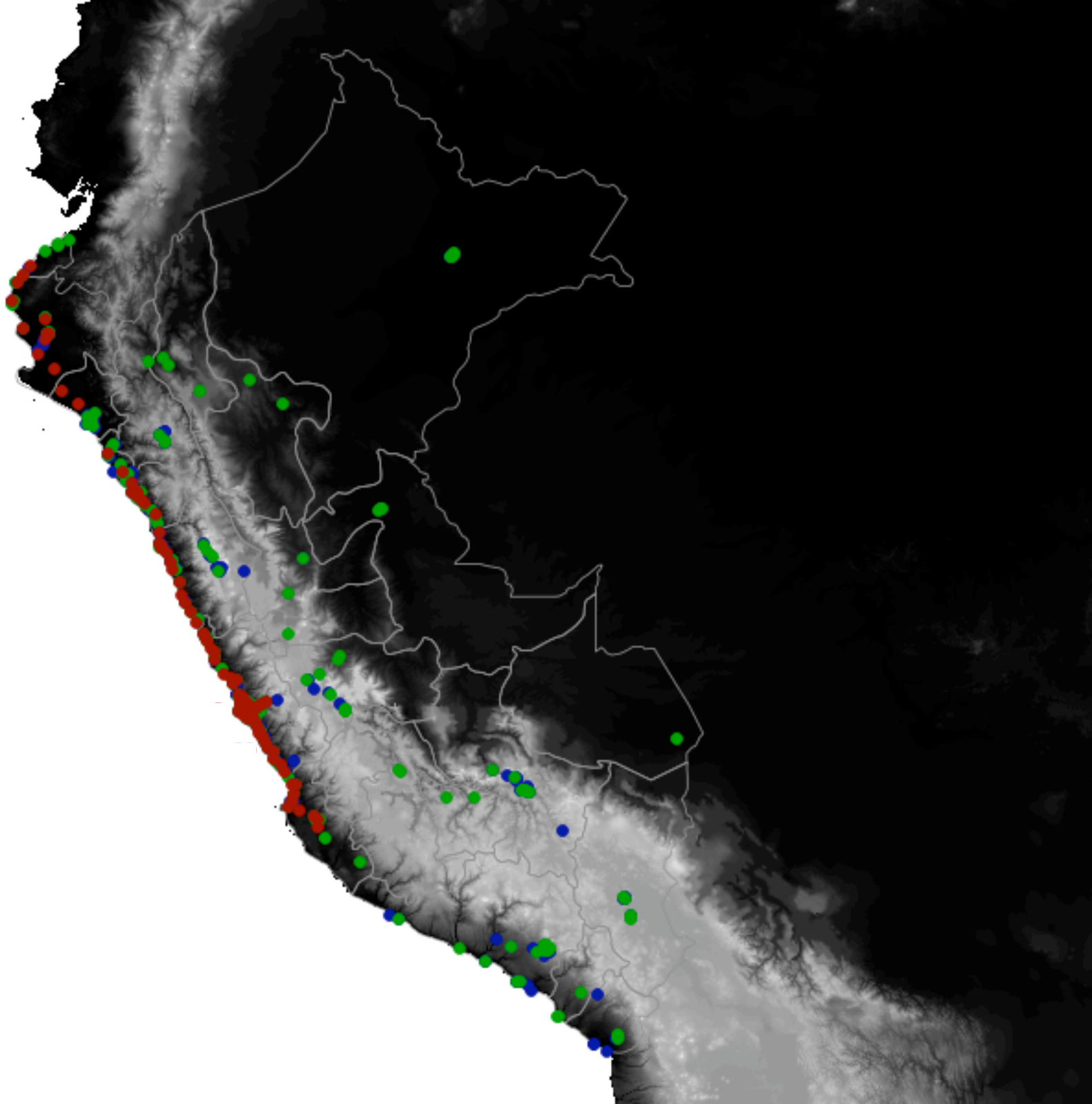

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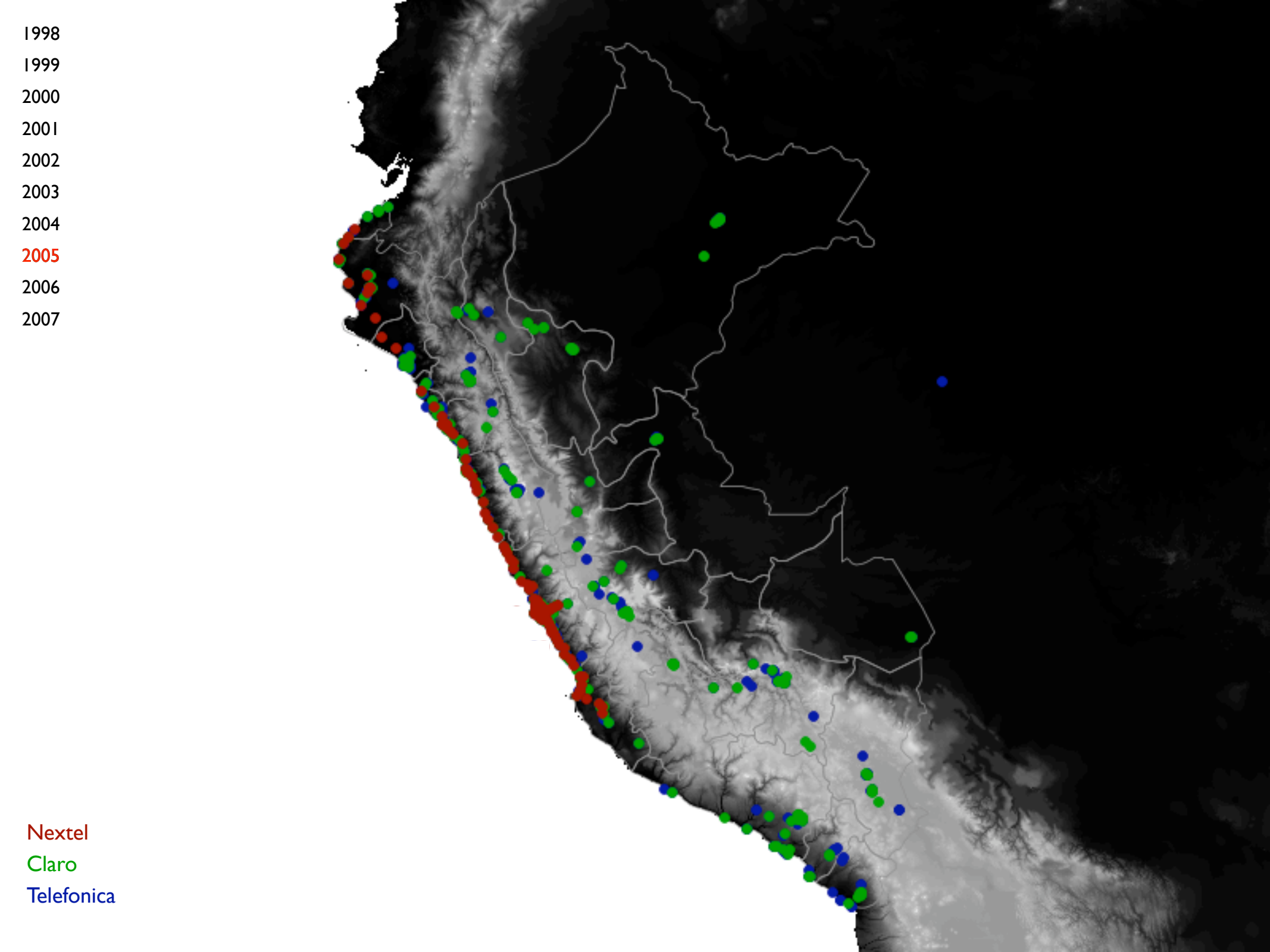
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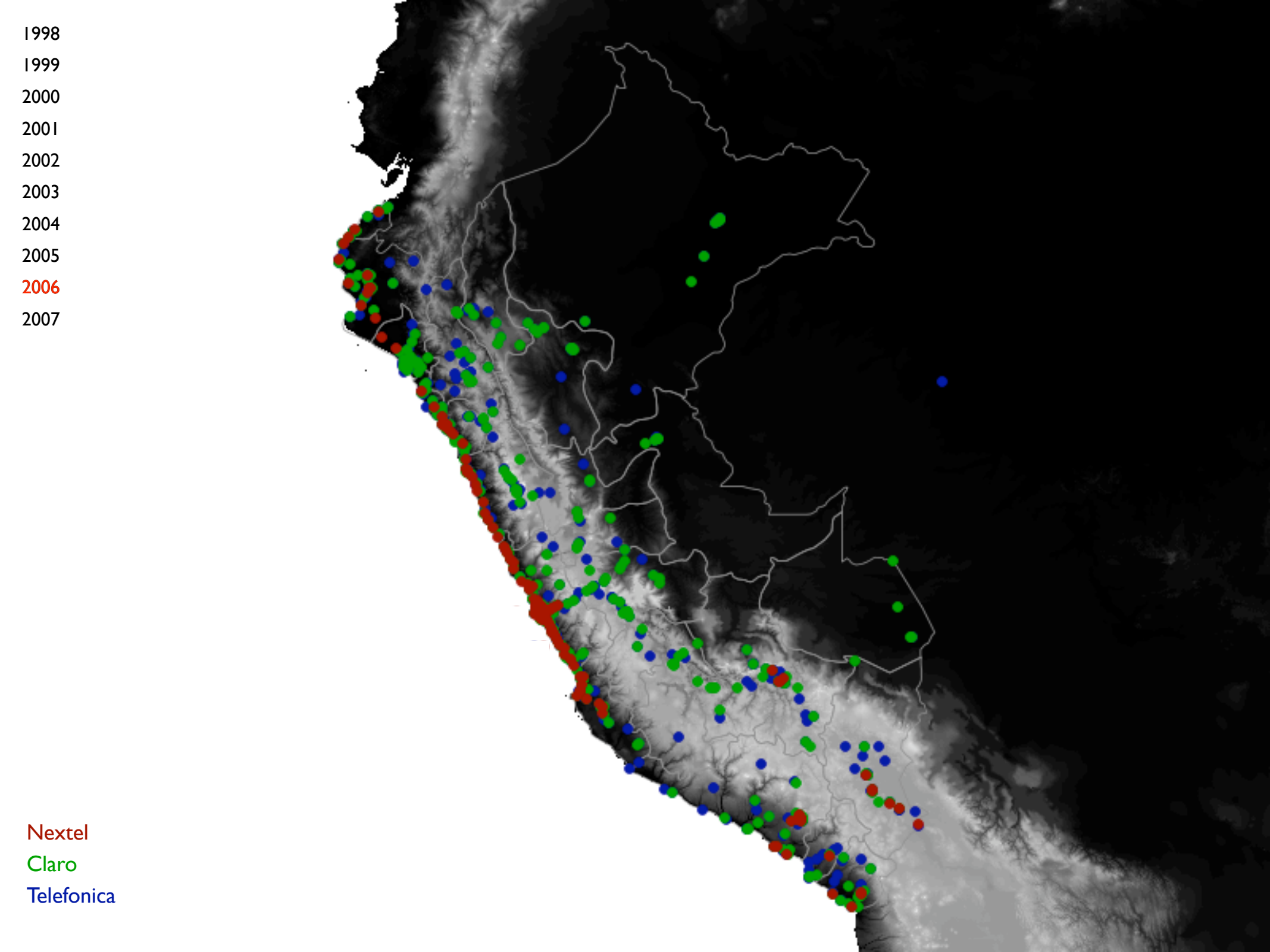
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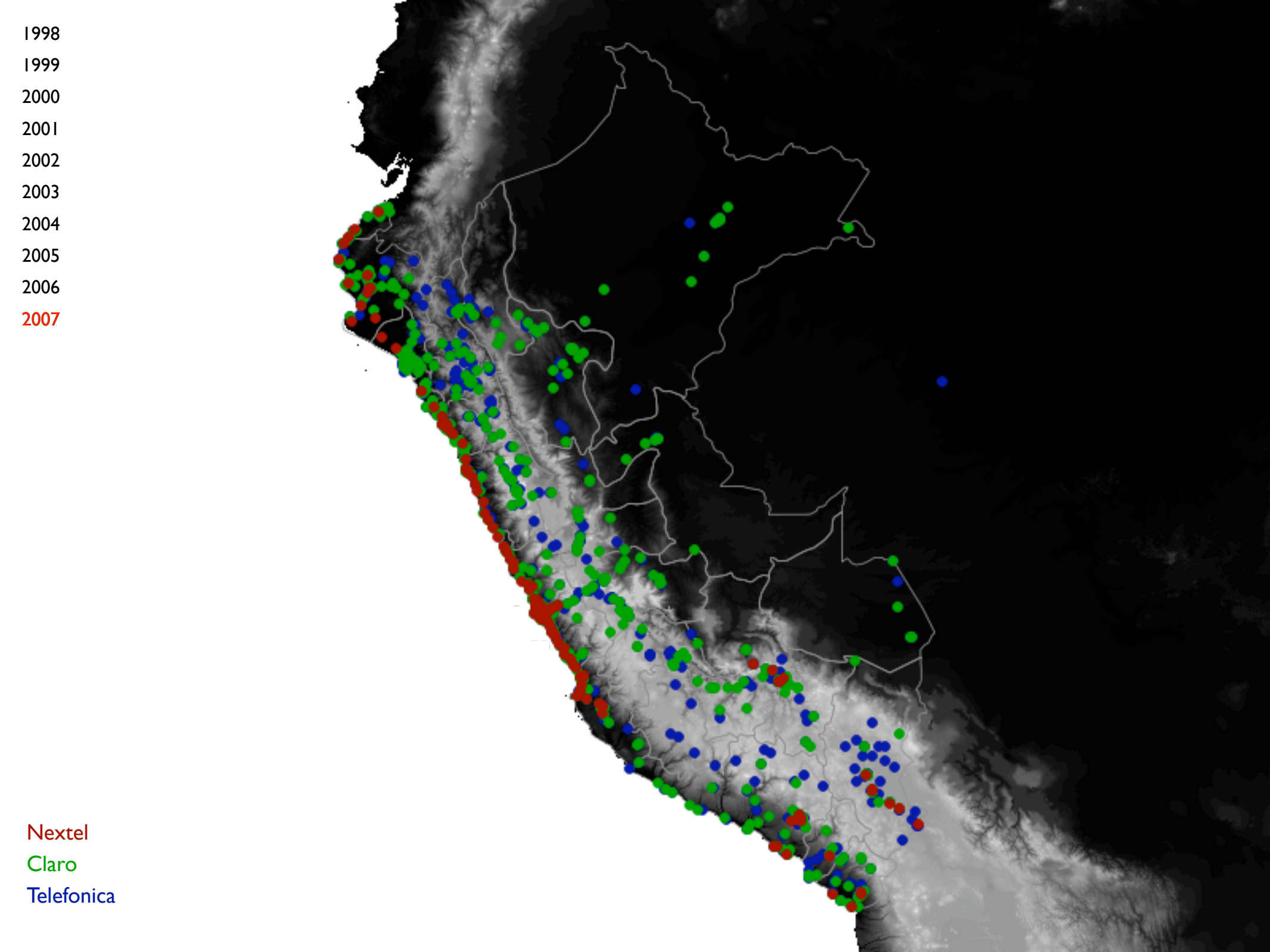
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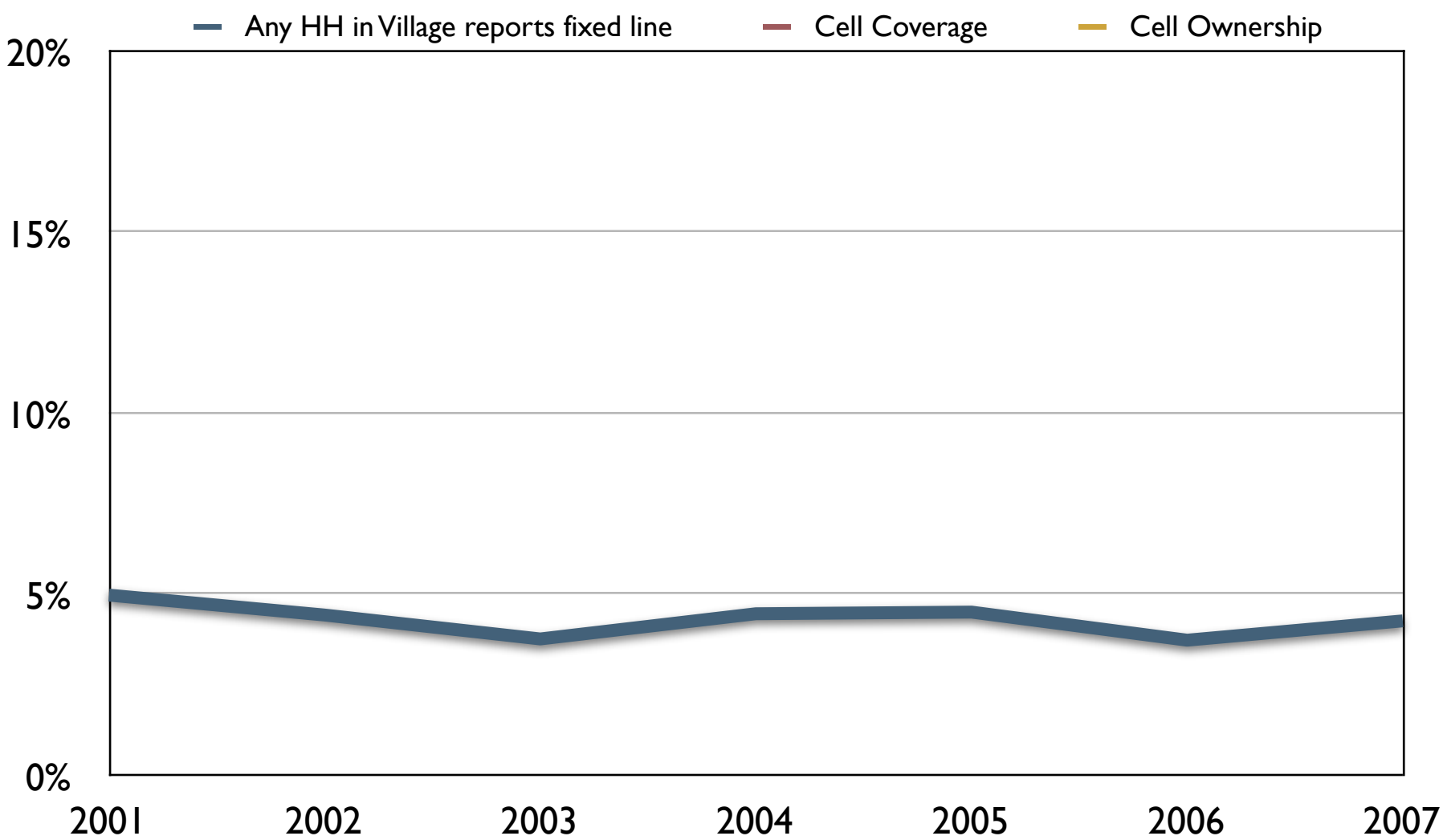
Context: Rural Peru

Source: Encuesta Nacional de Hogares (ENAHO); Fund for Investment in Telecommunications (FITEL) tower data

Context: Rural Peru



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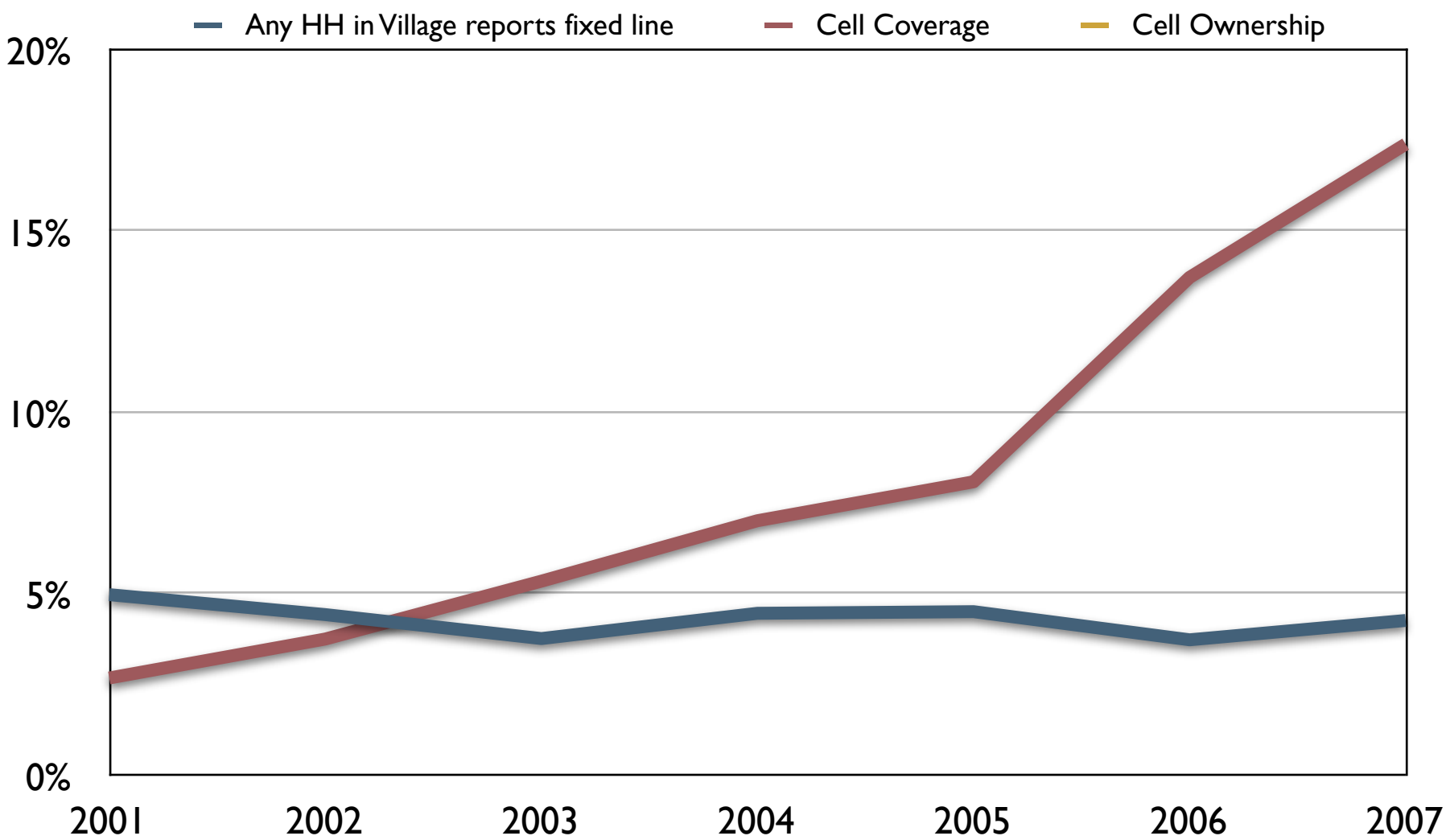
Context: Rural Peru



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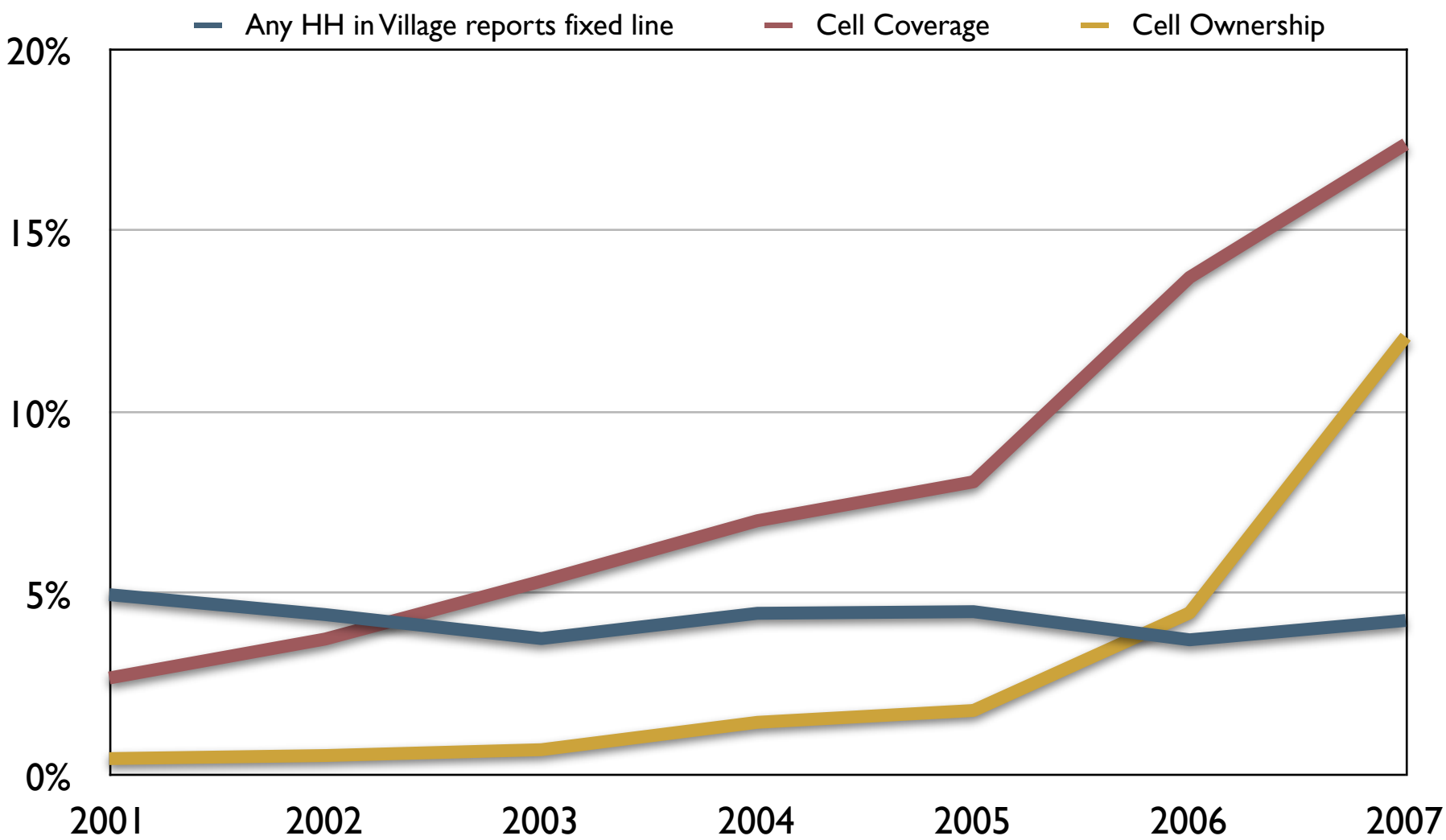
Context: Rural Peru



Source: Encuesta Nacional de Hogares (ENAHO); Fund for Investment in Telecommunications (FITEL) tower data

Matching Coverage Simulation with HH Cell Ownership Data

Year	Cell Phone Ownership	
	Areas without coverage	Areas with coverage
2001	0.35%	3.75%
2002	0.28%	4.72%
2003	0.44%	5.08%
2004	1.00%	12.39%
2005	1.07%	9.72%
2006	2.43%	17.55%
2007	7.74%	32.83%

Empirical Strategy: OLS

- As a baseline empirical strategy, we regress outcomes of interest on village coverage status:

$$y_{tci} = \text{coverage}_{tc} + \mu_t + \varepsilon_{tci}$$

Empirical Strategy: OLS

	HH Cell Phone Ownership	Log HH income	Any Assets	Log HH Assets	Log HH Expenditures			
					Total	Food	Non-Food	Durables
Coverage	0.151	0.565	0.119	0.711	0.606	0.712	0.503	0.158
	(15.43)**	(18.82)**	(12.96)**	(14.92)**	(23.72)**	(26.38)**	(16.25)**	(3.83)**
N (Households)	42335	40093	42335	28508	42148	41248	41850	32689

Potential Concern: Selection into Treatment

- To interpret results as causal, we'd need to believe coverage is uncorrelated with other factors influencing HH well-being
  - Unlikely, since coverage providers select coverage areas that maximize profits
- Descriptive statistics make it clear that treated areas are better-off...

Pre-Treatment Descriptives

	Pre-Treatment Mean	
	Not Covered by 2007	**Covered by 2007**
Household Expenditures	228.9	303.0
(SE)	(1.1)	(3.6)
Household Income	459.5	585.7
(SE)	(3.4)	(13.8)
N (Households)	33683	4505

Empirical Strategy: Village FE

- As a second strategy, we employ village fixed effects to wash out time-invariant factors that are correlated with coverage

$$y_{tci} = \text{coverage}_{tc} + \mu_c + \mu_t + \varepsilon_{tci}$$

Empirical Strategy: Village FE

	HH Cell Phone Ownership	Log HH income	Any Assets	Log HH Assets	Log HH Expenditures			
					Total	Food	Non-Food	Durables
Coverage	0.072	0.040	-0.029	0.135	0.075	0.061	0.089	-0.095
	(5.12)**	(0.91)	(1.62)	(2.16)*	(2.17)*	(1.71)	(1.90)	(1.13)
N (Households)	42335	40093	42335	28508	42148	41248	41850	32689

Empirical Strategy: Treatment Duration

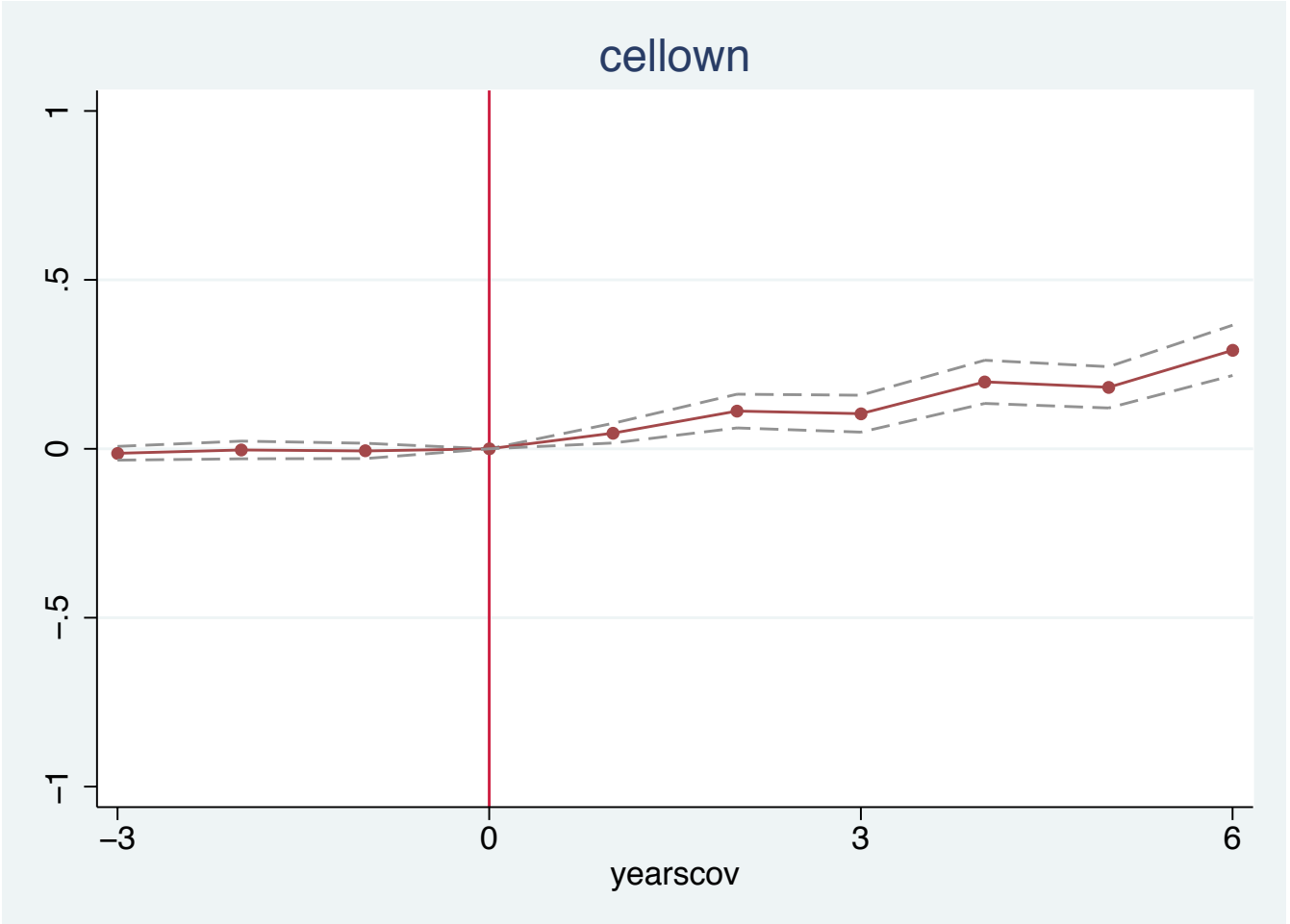
- Still need to believe that there are no time-varying community characteristics that are correlated with coverage
- Possible to check this by seeing if there are any pre-treatment trends
- Moreover, some benefits of coverage may take time –so we allow treatment effect to vary with duration:

$$y_{tci} = \Sigma_{j \neq 0} \text{duration}_{tcj} + \mu_c + \mu_t + \varepsilon_{tci}$$

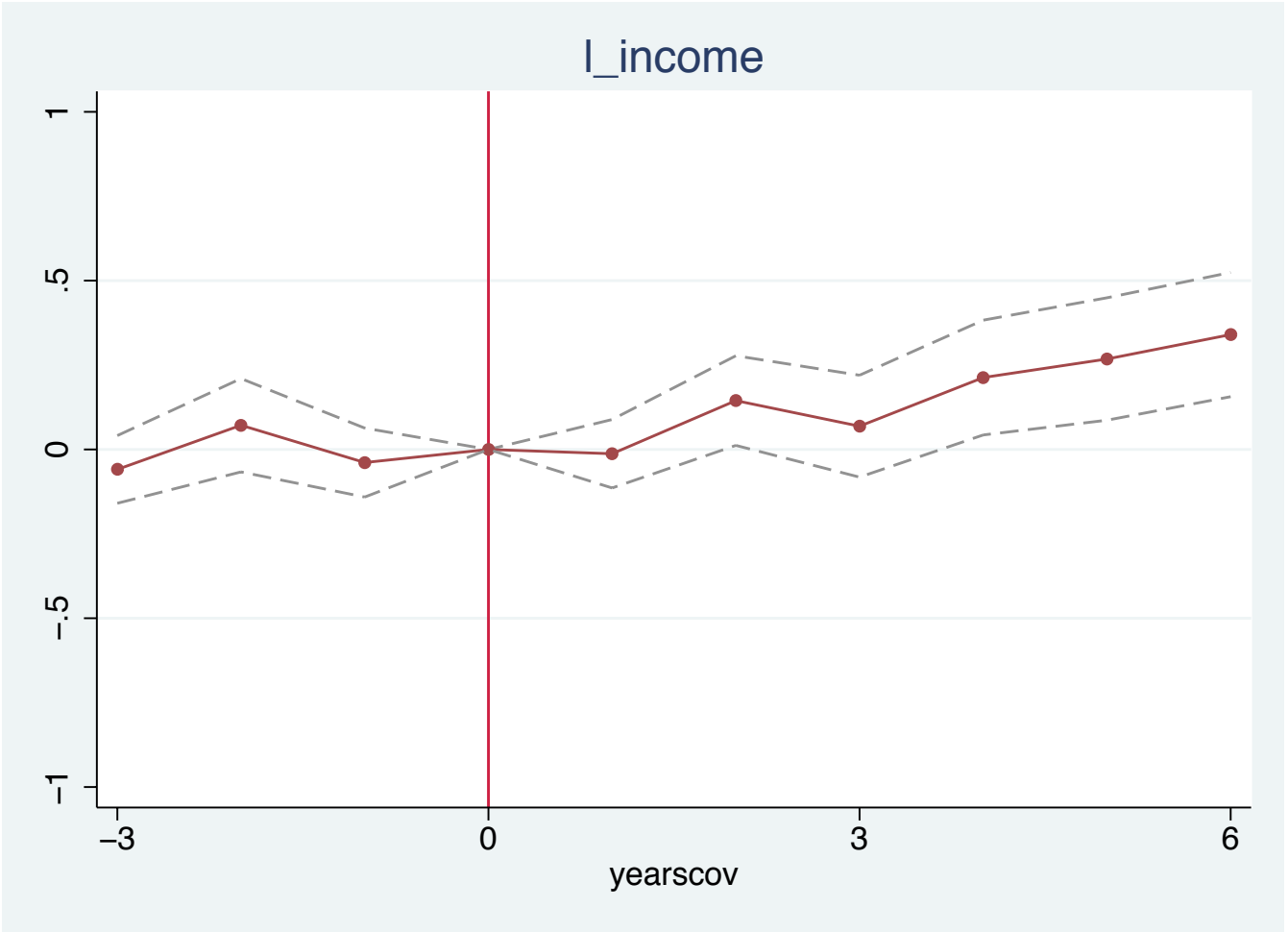
- where duration = [t = treatment year - j]

Years of Treatment	HH Cell Phone Ownership	Log HH income	Any Assets	Log HH Assets	Log HH Expenditures			
					Total	Food	Non-Food	Durables
Before: 3+ Years	-0.013	-0.059	0.005	-0.037	-0.063	-0.036	-0.045	-0.122
	(1.28)	(1.16)	(0.19)	(0.53)	(1.32)	(0.77)	(0.65)	(1.13)
Before: 2 Years	-0.003	0.072	0.005	0.059	-0.009	0.038	0.011	0.055
	(0.25)	(1.02)	(0.14)	(0.56)	(0.14)	(0.67)	(0.13)	(0.43)
Before: 1 Year	-0.006	-0.039	-0.029	-0.092	-0.009	-0.000	-0.007	0.009
	(0.54)	(0.74)	(1.08)	(1.21)	(0.19)	(0.00)	(0.11)	(0.09)
After: 1 Year	0.046	-0.013	-0.027	0.082	0.049	0.047	0.066	-0.151
	(3.12)**	(0.24)	(1.16)	(1.05)	(1.09)	(1.02)	(1.09)	(1.50)
After: 2 Years	0.112	0.145	-0.043	0.229	0.105	0.112	0.126	0.024
	(4.39)**	(2.14)*	(1.32)	(2.06)*	(1.96)*	(2.12)*	(1.68)	(0.18)
After: 3 Years	0.104	0.069	-0.037	0.233	0.094	0.094	0.155	0.021
	(3.73)**	(0.89)	(1.32)	(1.86)	(1.60)	(1.58)	(1.84)	(0.13)
After: 4 Years	0.198	0.213	-0.069	0.156	0.188	0.114	0.193	0.317
	(6.08)**	(2.45)*	(1.19)	(0.96)	(2.79)**	(1.61)	(2.08)*	(2.08)*
After: 5 Years	0.182	0.268	-0.044	0.430	0.384	0.361	0.290	0.319
	(5.84)**	(2.90)**	(0.95)	(2.88)**	(5.26)**	(4.87)**	(2.96)**	(2.02)*
After: 6+ Years	0.291	0.340	-0.038	0.538	0.446	0.369	0.372	0.446
	(7.67)**	(3.63)**	(0.97)	(3.21)**	(6.11)**	(5.07)**	(3.71)**	(2.56)*
Observations	42335	40093	42335	28508	42148	41248	41850	32689

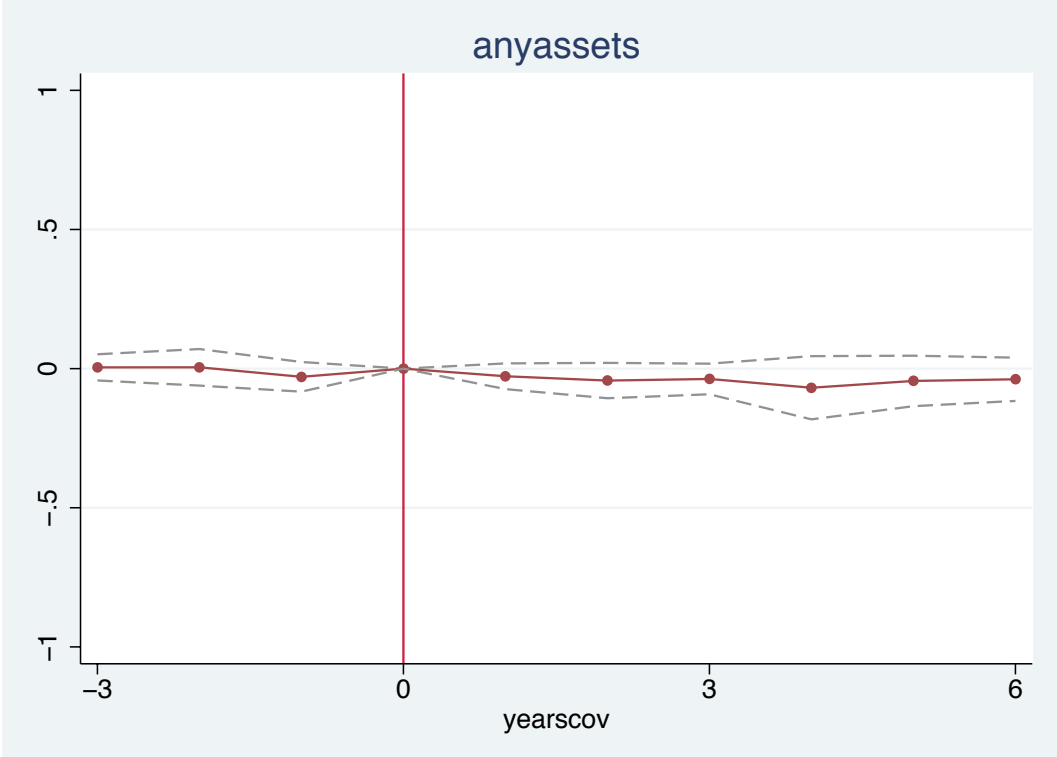
Years Treatment	HH Cell Phone Ownership
Before: 3+ Years	-0.013
	(1.28)
Before: 2 Years	-0.003
	(0.25)
Before: 1 Year	-0.006
	(0.54)
After: 1 Year	0.046
	(3.12)**
After: 2 Years	0.112
	(4.39)**
After: 3 Years	0.104
	(3.73)**
After: 4 Years	0.198
	(6.08)**
After: 5 Years	0.182
	(5.84)**
After: 6+ Years	0.291
	(7.67)**
Observations	42335

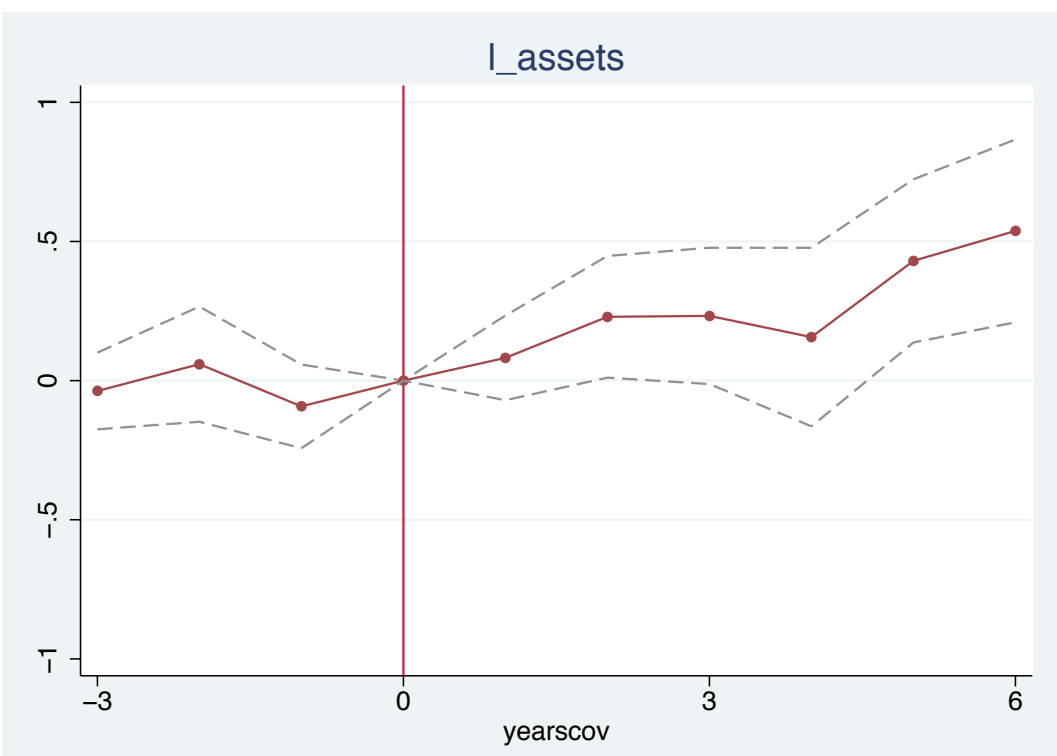


Years Treatment	Log HH income
Before: 3+ Years	-0.059
	(1.16)
Before: 2 Years	0.072
	(1.02)
Before: 1 Year	-0.039
	(0.74)
After: 1 Year	-0.013
	(0.24)
After: 2 Years	0.145
	(2.14)*
After: 3 Years	0.069
	(0.89)
After: 4 Years	0.213
	(2.45)*
After: 5 Years	0.268
	(2.90)**
After: 6+ Years	0.340
	(3.63)**
Observations	40093

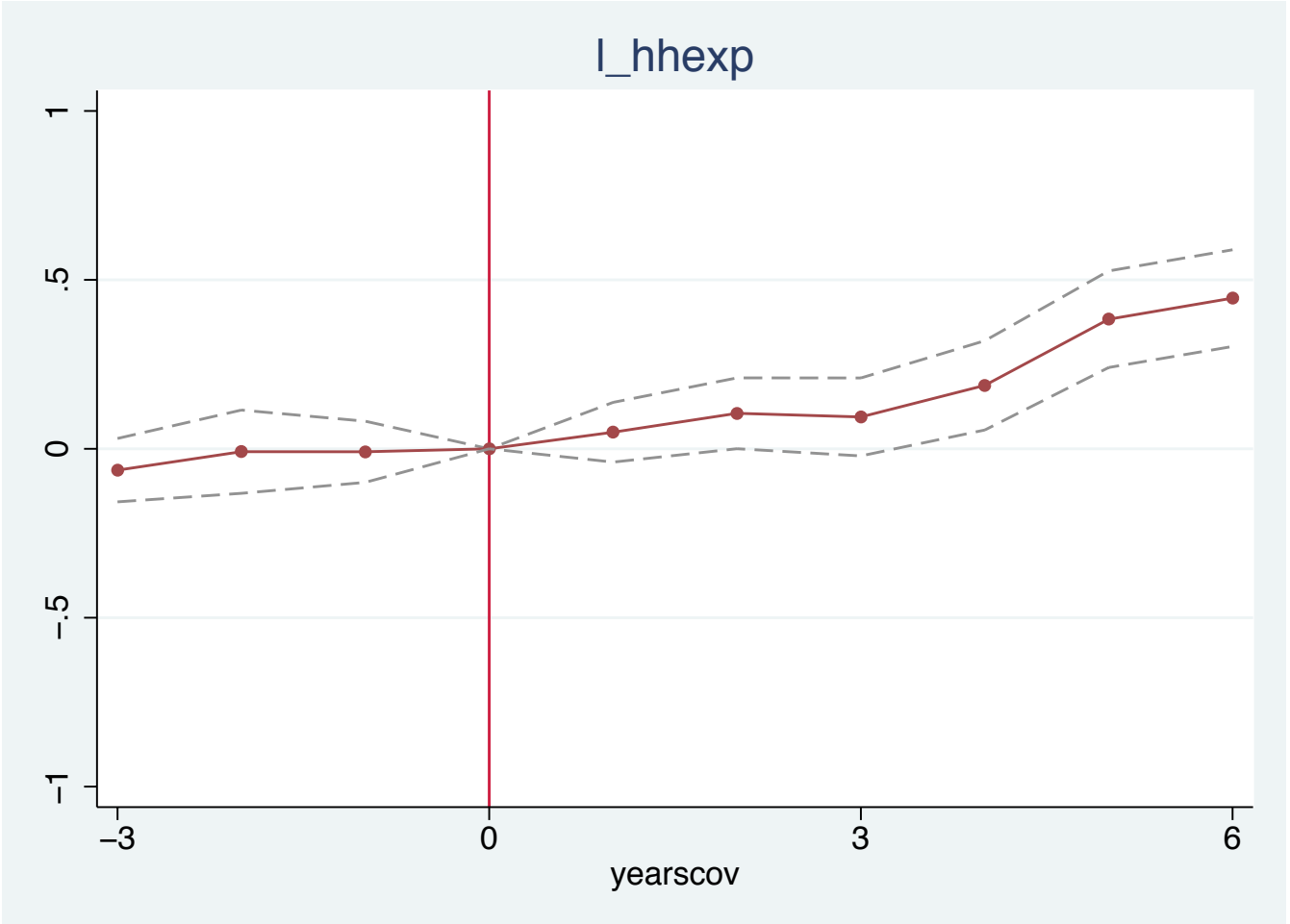


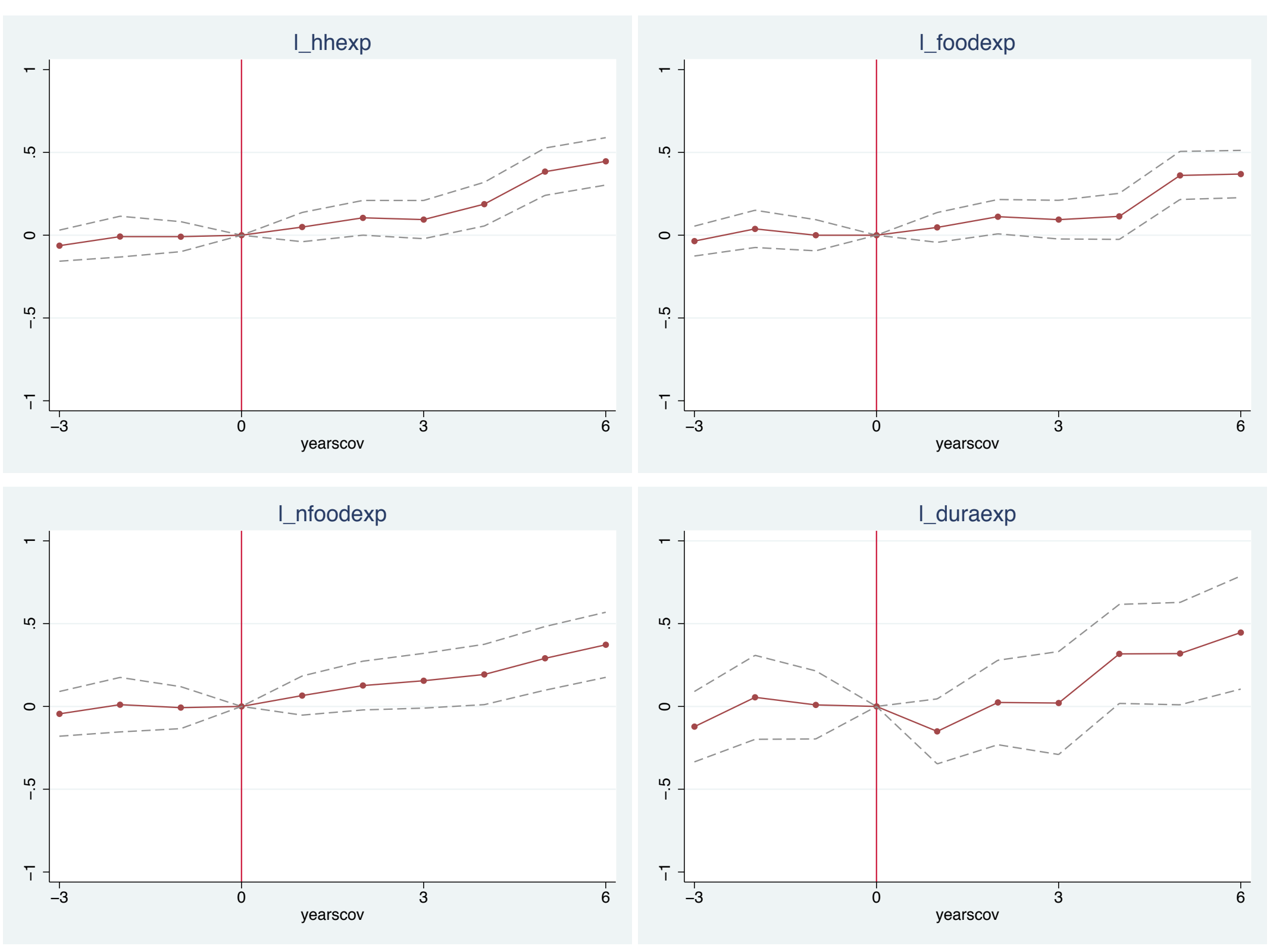
Years Treatment	Any Assets	Log HH Assets
Before: 3+ Years	0.005	-0.037
	(0.19)	(0.53)
Before: 2 Years	0.005	0.059
	(0.14)	(0.56)
Before: 1 Year	-0.029	-0.092
	(1.08)	(1.21)
After: 1 Year	-0.027	0.082
	(1.16)	(1.05)
After: 2 Years	-0.043	0.229
	(1.32)	(2.06)*
After: 3 Years	-0.037	0.233
	(1.32)	(1.86)
After: 4 Years	-0.069	0.156
	(1.19)	(0.96)
After: 5 Years	-0.044	0.430
	(0.95)	(2.88)**
After: 6+ Years	-0.038	0.538
	(0.97)	(3.21)**
Observations	42335	28508





Years Treatment	Log HH Expenditures
Before: 3+ Years	-0.063
	(1.32)
Before: 2 Years	-0.009
	(0.14)
Before: 1 Year	-0.009
	(0.19)
After: 1 Year	0.049
	(1.09)
After: 2 Years	0.105
	(1.96)*
After: 3 Years	0.094
	(1.60)
After: 4 Years	0.188
	(2.79)**
After: 5 Years	0.384
	(5.26)**
After: 6+ Years	0.446
	(6.11)**
Observations	42148

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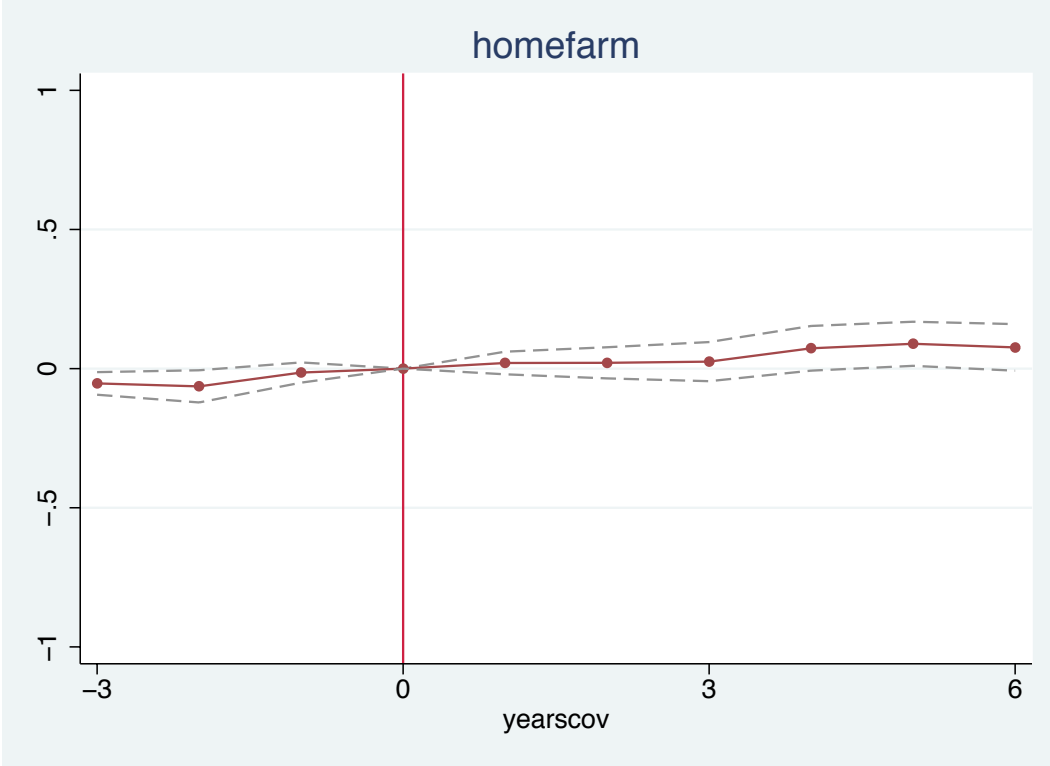
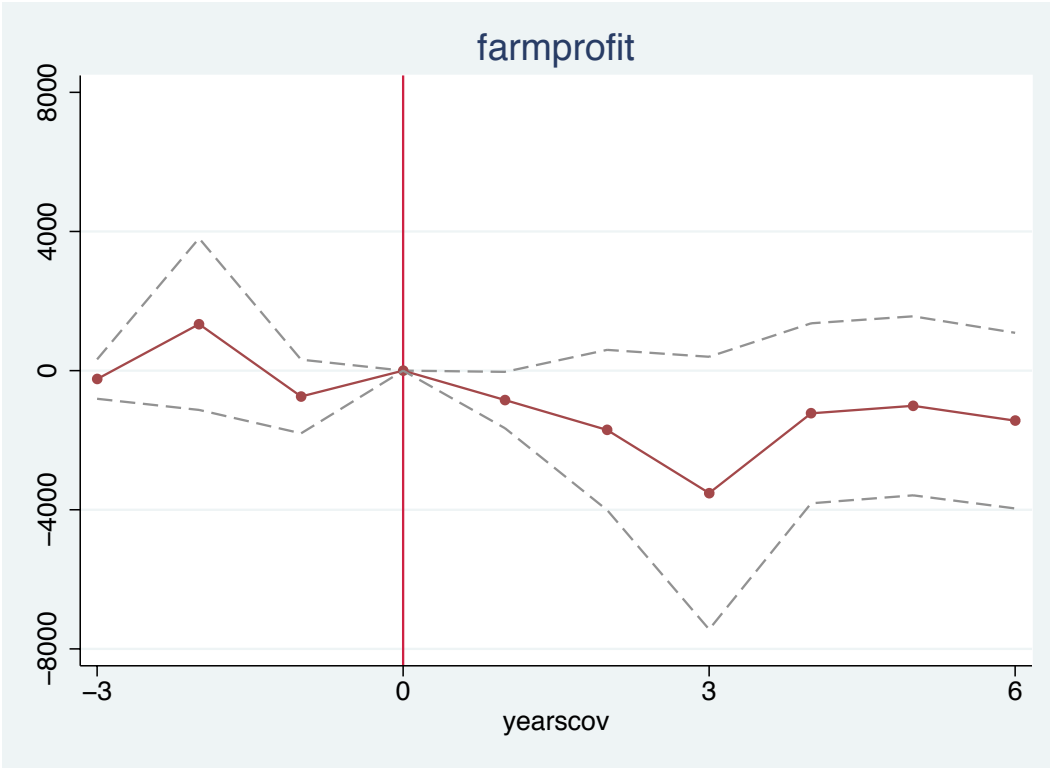
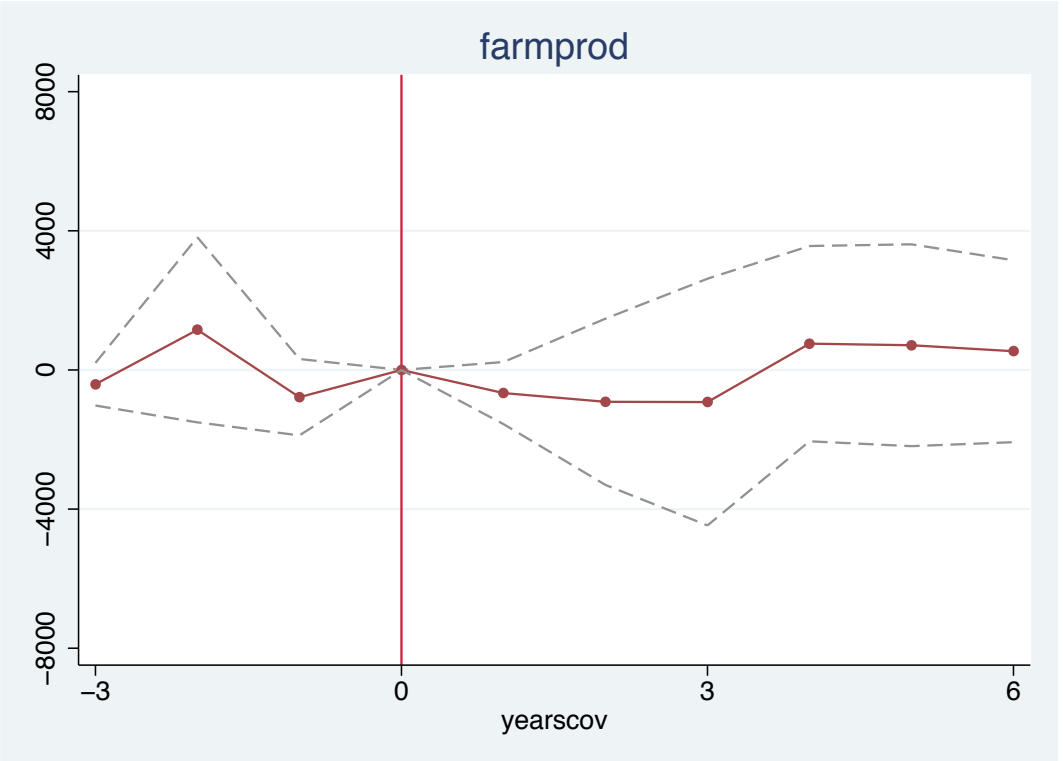
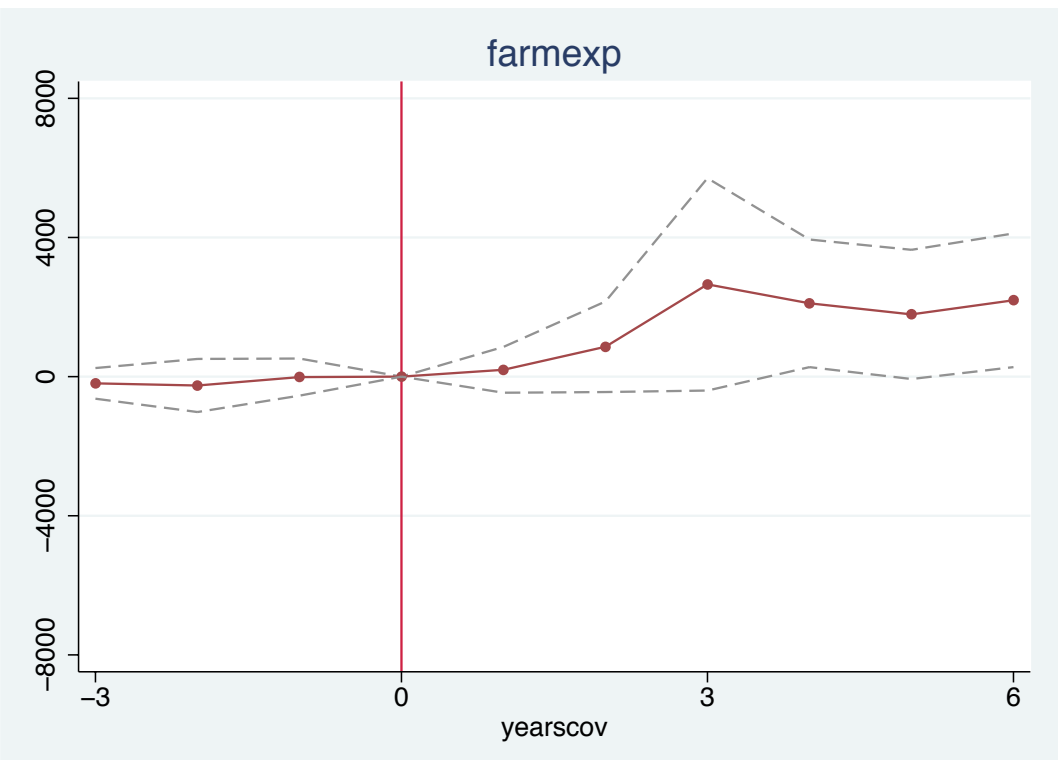
Years Treatment	Home Farm	Farm Profits
Before: 3+ Years	-0.053	-243
	(2.57)*	(0.84)
Before: 2 Years	-0.064	1,337
	(2.16)*	(1.06)
Before: 1 Year	-0.014	-744
	(0.76)	(1.38)
After: 1 Year	0.020	-846
	(0.98)	(2.04)*
After: 2 Years	0.021	-1,706
	(0.73)	(1.45)
After: 3 Years	0.025	-3,520
	(0.70)	(1.76)
After: 4 Years	0.073	-1,227
	(1.78)	(0.93)
After: 5 Years	0.089	-1,012
	(2.21)*	(0.77)
After: 6+ Years	0.076	-1,438
	(1.79)	(1.12)
Observations	42334	33687





Years Treatment	Farm Production	Farm Expenditures
Before: 3+ Years	-410	-194
	(1.31)	(0.86)
Before: 2 Years	1,154	-255
	(0.85)	(0.65)
Before: 1 Year	-783	-13
	(1.40)	(0.05)
After: 1 Year	-664	196
	(1.46)	(0.58)
After: 2 Years	-915	859
	(0.75)	(1.29)
After: 3 Years	-923	2,653
	(0.51)	(1.70)
After: 4 Years	756	2,108
	(0.53)	(2.25)*
After: 5 Years	711	1,789
	(0.48)	(1.89)
After: 6+ Years	539	2,195
	(0.40)	(2.24)*
Observations	33687	33813





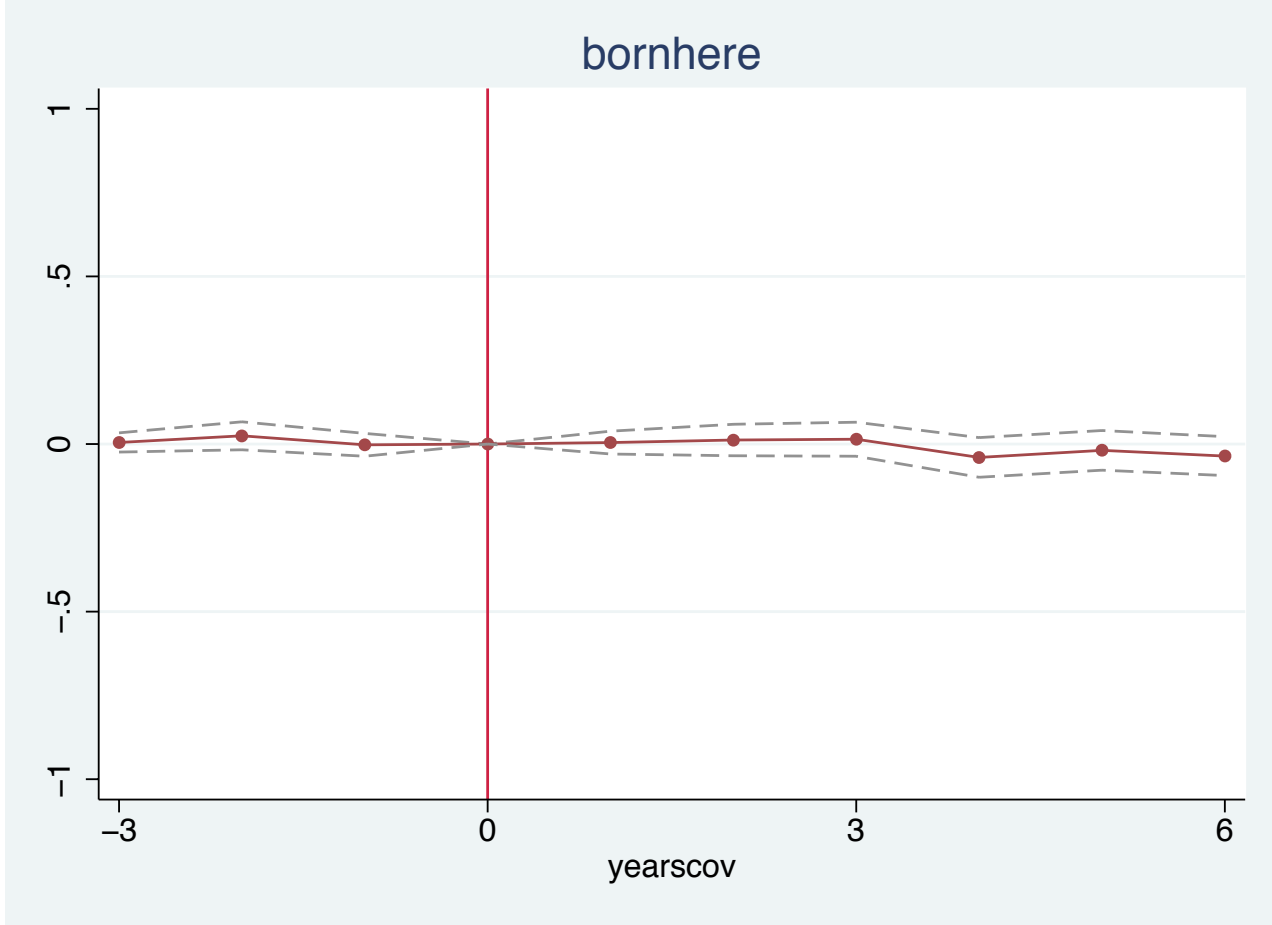
Preliminary Conclusions

- Early evidence points toward:
  - producers are not worse off:
    - no statistically significant impact on profits
  - consumers are better off:
    - large gains in HH resources
- Will continue to hone this story:
  - in particular, prices

Potential Concern: Migration to Treatment Area

- Another potential concern is migration to the treatment area
  - Suppose more entrepreneurial or wealthier households migrated to areas with cell phone service
  - These results could simply reflect the changing demographics of these towns

Years Treatment	Born in District
Before: 3+ Years	0.005
	(0.32)
Before: 2 Years	0.025
	(1.16)
Before: 1 Year	-0.002
	(0.13)
After: 1 Year	0.004
	(0.25)
After: 2 Years	0.012
	(0.50)
After: 3 Years	0.014
	(0.55)
After: 4 Years	-0.040
	(1.32)
After: 5 Years	-0.019
	(0.62)
After: 6+ Years	-0.036
	(1.21)
Observations	187378



- Another robustness check we're pursuing:
  - Household fixed effects

Conclusions & Implications

- Producers are no worse off, consumers are better off
- If cell phones generate income growth, this is great news for the development community:
  - Adoption is skyrocketing
  - Interventions have cost nothing, since they are funded by the private sector
- But we need to be careful about concluding that development should fund cell tower construction

Future Work

- Prices
- Heterogeneity:
  - Cell phone owners vs. non-cell phone owners
  - Wealthy vs. poor
  - Those in areas with land-lines vs. those with no prior service

	[1] l_income	[2] anyassets	[3] l_assets	[4] l_hhexp	[5] l_foodexp	[6] l_nfoodexp	[7] l_duraexp
Before: 3+ Years	-0.05	0.007	-0.026	-0.053	-0.022	-0.037	-0.109
	[0.92]	[0.28]	[0.37]	[1.04]	[0.45]	[0.52]	[1.02]
Before: 2 Years	0.077	0.007	0.072	0.004	0.062	0.015	0.058
	[1.04]	[0.21]	[0.66]	[0.05]	[1.00]	[0.17]	[0.45]
Before: 1 Year	-0.02	-0.023	-0.101	0.018	0.032	0.013	0.019
	[0.36]	[0.85]	[1.31]	[0.38]	[0.65]	[0.20]	[0.19]
After: 1 Year	-0.057	-0.028	-0.042	0.02	0.036	0.01	-0.221
	[1.03]	[1.17]	[0.50]	[0.41]	[0.73]	[0.15]	[2.11]*
After: 2 Years	0.066	-0.054	0.064	0.075	0.116	0.065	-0.103
	[0.90]	[1.66]	[0.52]	[1.27]	[2.00]*	[0.79]	[0.76]
After: 3 Years	0.006	-0.043	-0.004	0.057	0.057	0.094	-0.09
	[0.07]	[1.47]	[0.03]	[0.86]	[0.89]	[1.02]	[0.52]
After: 4 Years	0.068	-0.093	-0.185	0.065	0.029	0.033	0.098
	[0.72]	[1.64]	[1.05]	[0.83]	[0.38]	[0.31]	[0.59]
After: 5 Years	0.165	-0.062	0.248	0.339	0.328	0.206	0.16
	[1.44]	[1.34]	[1.47]	[4.00]**	[3.69]**	[1.90]	[0.91]
After: 6 Years	0.118	-0.07	0.031	0.298	0.252	0.19	0.142
	[1.16]	[1.71]	[0.17]	[3.64]**	[3.03]**	[1.75]	[0.74]
Observations	40093	42335	28508	42148	41248	41850	32689
R-squared	0.38	0.32	0.37	0.42	0.45	0.34	0.26

	[1] l_income	[2] anyassets	[3] l_assets	[4] l_hhexp	[5] l_foodexp	[6] l_nfoodexp	[7] l_duraexp
Before: 3+ Years	-0.05	0.007	-0.026	-0.053	-0.022	-0.037	-0.109
	[0.92]	[0.28]	[0.37]	[1.04]	[0.45]	[0.52]	[1.02]
Before: 2 Years	0.077	0.007	0.072	0.004	0.062	0.015	0.058
	[1.04]	[0.21]	[0.66]	[0.05]	[1.00]	[0.17]	[0.45]
Before: 1 Year	-0.02	-0.023	-0.101	0.018	0.032	0.013	0.019
	[0.36]	[0.85]	[1.31]	[0.38]	[0.65]	[0.20]	[0.19]
After x Own: 1 Year	0.802	0.104	1.43	0.728	0.528	0.976	0.866
	[7.72]**	[3.19]**	[7.79]**	[7.67]**	[5.59]**	[8.34]**	[3.64]**
After x Own: 2 Years	0.71	0.15	0.973	0.469	0.295	0.593	0.893
	[7.46]**	[5.87]**	[4.77]**	[5.21]**	[3.74]**	[6.28]**	[4.83]**
After x Own: 3 Years	0.514	0.076	1.28	0.424	0.467	0.504	0.597
	[4.19]**	[2.22]*	[7.03]**	[3.53]**	[5.12]**	[3.42]**	[2.27]*
After x Own: 4 Years	0.464	0.093	0.956	0.496	0.386	0.641	0.674
	[4.16]**	[1.62]	[4.28]**	[5.38]**	[4.45]**	[5.30]**	[3.93]**
After x Own: 5 Years	0.617	0.168	0.534	0.449	0.35	0.535	0.539
	[4.89]**	[4.05]**	[2.35]*	[4.44]**	[3.46]**	[3.20]**	[2.24]*
After x Own: 6 Years	0.59	0.092	1.184	0.419	0.327	0.48	0.588
	[6.64]**	[3.27]**	[6.34]**	[5.44]**	[3.81]**	[5.41]**	[4.04]**
Observations	40093	42335	28508	42148	41248	41850	32689
R-squared	0.38	0.32	0.37	0.42	0.45	0.34	0.26