

# Supplemental Appendix for Local Networks and Technology Adoption during Industry-Wide Technological Change

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## OA.1 Overview

This supplemental appendix presents the discussion first and collects all figures and tables after the prose. Section OA.2 reports additional evidence on the empirical framework and identification. Section OA.3 provides supplemental results for the pooled, calendar and formation-vintage analyses. Section OA.4 organizes the remaining robustness evidence around expiration-driven drilling, dynamic patterns, alternative explanations and measurement. Section OA.5 reports additional illustrations for the conceptual framework. Complete formation-block signal estimates and the full lease-link distance specification grid, descriptive and sample-accounting tables and complete four-margin results are reported in the Web Appendix, available on the author’s website.

## OA.2 Empirical Framework and Identification

Figure OA.1 illustrates the technology distinction used to measure adoption. A horizontal well turns through the target formation and combines a lateral wellbore with staged hydraulic fracturing. A conventional vertical well accesses only the rock surrounding its vertical bore.

Figure OA.2 reports the distribution of the one-quarter-lagged, firm-excluded peer-activity measure across response samples and formations.

County-quarter drilling conditions could create apparent expiration bunching without a distinct lease deadline response. Table OA.2 adds county-by-quarter fixed effects to the event-time count model and varies the link radius and event window. The increase in drilling near expiration remains under these specifications.

### OA.2.1 Polynomial Order for the Bunching Counterfactual

The baseline event-time specification in Appendix A uses a fifth-order polynomial. I re-estimate the national excess counts with polynomials of order three, seven, and nine, holding the expiration window and the 0.25-mile sample fixed. The excess count in the expiration quarter is 339.8 at

order three, 322.8 at order five, and 510.7 at order seven, with standard errors of 75.4, 90.3, and 123.7. The excess count one quarter before expiration is 299.0, 305.7, and 552.5, with standard errors of 75.9, 102.7, and 146.0. The ninth-order specification has one residual degree of freedom. Its corresponding estimates are 2,994.7 and 3,380.2, with standard errors of 1,529.2 and 1,696.5. The ninth-order estimates are uninformative. The baseline weights and response estimates use the fifth-order specification.

The spatial lease assignment may incorrectly link wells to nearby leases. Table OA.3 instead links operators and lessees by name. Panel A reports an expiration-quarter excess share of 62.75 percent under this alternative construction, compared with 37.14 percent one quarter before expiration. Panel B rebuilds peer activity from the name-matched links and re-estimates the pooled response. The signs of the peer-performance, peer-technique breadth and technique-intensity estimates agree with the baseline, although the alternative measure has a different scale and produces less precise estimates.

Peer activity is estimated from the lease-expiration bunching curve. Table OA.4 accounts for this generated regressor by resampling counties, re-estimating the bunching curve and reconstructing peer activity in each draw. The percentile intervals preserve the principal extensive-adoption results and the technique-intensity result for intensive investment.

Web Appendix Table W.1 reports all four preferred network measures for each completed formation block.

Table OA.5 compares each alternative spatial weight with the preferred measure on the same completed formation blocks. The table reports correlations in signal values and agreement in the positive-signal classification used to define the response samples. Holding the formation block fixed separates sensitivity to spatial weights from changes in local development.

Signals are updated when a formation completes another 2,000-well block. Peer activity from the block-closing quarter could enter the first outcome quarter that uses the newly estimated signal. Table OA.6 drops that outcome quarter after every block closure. The principal pooled signs remain unchanged.

### OA.3 Supplemental Empirical Results

The pooled magnitude calculations use the distributions of peer activity and network signals within their respective response samples. Web Appendix Table W.3 reports the outcome, peer-activity and signal distributions for the peer-performance and technique-intensity samples.

The network signals use different units. Their raw coefficients are not directly comparable. Table OA.7 standardizes peer activity and each signal within its estimation sample. The estimates describe a one-standard-deviation change in each component, although differences in the signal-specific samples still limit comparisons across signals.

Technique intensity is built from indicators for whether peers report each drilling and completion attribute. Disclosure rules vary across states and over time. The number of reported attributes changes across formation-blocks. Table OA.8 replaces technique intensity with the average number

of attributes reported per well in the formation-block. Reporting volume does not reproduce the baseline response in the full panel. Within the positive technique-intensity sample, reporting volume and intensity are too closely related to separate their effects.

Peer-technique breadth and technique intensity capture different features of reported technique information. Table OA.9 describes the attributes added when breadth increases and the extent to which those attributes overlap in what they explain. Table OA.10 reports whether the four network signals change the design and execution of firms’ own wells.

The baseline estimates use peer activity from the preceding quarter. Table OA.11 enters lags one through four jointly to examine persistence for the two headline signals and outcomes. The technique-intensity response is concentrated at the first lag, while the peer-performance adoption response persists at longer lags. Web Appendix Table W.7 reports the complete four-signal, four-outcome grid.

The preferred period specification allows the controls and fixed effects to vary across eras. Table OA.12 compares it with a specification that holds both common across eras. The choice matters most for the early technique-intensity response, which is  $-0.174^{***}$  under the preferred specification and 0.228 and imprecise under common controls. Peer performance retains a positive middle-period estimate and a negative later estimate under both specifications.

The main period figure displays extensive adoption and intensive investment for peer performance and technique intensity. Table OA.13 reports intensive investment for all three signals, the two margins not plotted in the main paper and the period estimates for peer-technique breadth. It suppresses only the peer-performance and technique-intensity extensive-adoption estimates already shown in the main figure.

The main formation-vintage table reports the aligned extensive-adoption comparisons. Web Appendix Table W.6 reports the corresponding aligned intensive-investment estimates, including the 2019 onward comparison.

## OA.4 Robustness

### OA.4.1 Endogeneity of Expiration-Driven Drilling

The baseline removes firm-county-quarters in which the responding firm has a same-county lease expiration. This restriction removes 0.31 percent of the full panel. A stricter restriction removes every observation for a firm-quarter in which the firm has an expiration anywhere in its portfolio, eliminating 13.3 percent of the panel. Table OA.14 re-estimates the pooled responses under that portfolio-wide restriction. It also allows the responding firm’s own deadline pressure to extend beyond the expiration quarter and applies a full-window same-county exclusion, which removes 1.03 percent of the panel, to the pooled and vintage-block specifications. The principal pooled signs and first-block vintage contrasts remain similar. Web Appendix Table W.4 provides the full sample accounting for these exclusions.

A leaseholder facing a deadline chooses whether to drill or let the lease lapse. If that choice fa-

vored places with strong local returns, county-quarters with heavy expiration-driven drilling would also be places with good local conditions. Table OA.15 reports three analyses. Panel A tests whether expiration-driven drilling coincides with new lease acquisition in the same county. Panel B tests whether higher exercise rates select wells with greater first-year output. Panel C tests whether recent productivity improvements predict more expiration-driven drilling among counties with leases scheduled to expire. None of the three analyses indicates that favorable contemporaneous information generates greater expiration-driven drilling.

## OA.4.2 Calendar and Formation-Vintage Patterns

The calendar reversal overlaps with large changes in oil prices. Table OA.16 allows prices to change the response to peer activity and network signals. The pooled signal interactions remain close to the baseline estimates. The triple interactions with oil prices are imprecise.

The oil-price analysis depends on how exposed each formation is to oil rather than gas prices. Table OA.17 reports the cross-formation correlation between each principal signal and the formation’s pre-2014 gas share. Peer performance and technique intensity are more strongly associated with oil-heavy formations in both 2008–14 and 2015–17. The correlations are near zero after 2018.

The block-vintage comparison could also reflect fixed differences across formations. Table OA.18 compares signal levels and well productivity in the first blocks of early- and late-vintage formations.

### OA.4.2.1 Local Signal Trajectory Robustness

The trajectory exercise is a robustness check on whether the timing results are driven only by calendar period. Figure OA.3 uses network signal trajectories instead of formation vintage. For each formation and signal, I classify the path across successive 2,000-well blocks as decreasing, flat or increasing. I then estimate the peer-activity response separately for decreasing, flat and increasing paths, within early and late cohorts. The classification is done separately for each network signal, so a formation can be increasing for peer performance but flat for technique intensity.

Formations with decreasing peer-performance trajectories do not have falling productivity. In these formations, nearby peer productivity becomes less predictive of cross-sectional productivity differences as local development advances. Productivity growth is larger in these formations than in flat peer-performance formations in a block-level diagnostic.<sup>1</sup> The responses in these formations are not weaker than in flat paths. For extensive adoption, the decreasing-path estimate exceeds the flat-path estimate in both cohorts, at 0.93\*\*\* against 0.14\*\* in 2008–14 and 0.16 against –0.03 from 2015 onward. For intensive investment in 2008–14, it is 400.4\*\*\* against 14.8\*. From 2015 onward neither intensive-investment estimate is significant.

<sup>1</sup>The diagnostic groups formation blocks by the peer-performance trajectory classification and computes productivity growth relative to each formation’s first block. Mean log-productivity growth is 0.448 in decreasing peer-performance paths and 0.351 in flat peer-performance paths. The analogous well-FE growth is 0.326 and 0.234. In blocks 2, 3 and 4, log-productivity growth is 0.511, 0.713 and 0.753 for decreasing peer-performance paths, compared with 0.279, 0.448 and 0.542 for flat peer-performance paths.

For technique-based signals, the trajectory split distinguishes broader disclosure from more informative implementation content. Increasing peer-technique breadth fails to generate stronger adoption or intensive-investment responses. More measured attributes are not enough. Technique intensity is different. The late-period adoption response is positive and significant in increasing-intensity paths, consistent with the cohort result. The opposite appears in decreasing-intensity paths. Where technique intensity declines across blocks, the late adoption response is strongly negative, at  $-9.07^{***}$ . The early intensive-investment response is also negative, at  $-197.3^{***}$ . I do not use the early increasing-intensity group as a clean contrast because that group has little support. The useful reading is narrower. Technique intensity matters for adoption when the implementation signal is still strengthening locally, while the intensive-investment response to technique intensity is concentrated earlier.

The trajectory results support the main timing evidence without carrying the main argument. Expiration-driven peer activity becomes more relevant after 2015, but its response depends on the local signal's information content. Where nearby peer productivity becomes less predictive of cross-sectional productivity differences, peer-performance responses do not weaken. Those formations also continue to become more productive. They do not rise merely because more technique attributes become productivity-related. They persist where the highest-loading technique choices become more predictive. Local networks do not mechanically amplify the national episode. They matter when the local network state is informative for the relevant adoption or investment margin.

### OA.4.3 Alternative Explanations and Placebos

A general local drilling boom could increase both horizontal and vertical activity. Table OA.19 replaces the horizontal outcomes with vertical drilling outcomes while retaining the expiration-driven peer-activity measure and network signals. The estimates do not show a parallel positive response in vertical drilling.

A positive interaction need not imply that peer activity or the signal has a positive lower-order coefficient. Table OA.20 reports the peer-activity, signal and interaction coefficients from each pooled specification. The lower-order peer-activity coefficient is the intercept of the marginal response over signal strength and is evaluated outside the support of the positive-signal estimation samples.

Measured network signals may not account for every response to peer activity. Table OA.21 estimates the peer-activity response where none of the four signals is statistically distinguishable from zero and compares this group with the full panel and each signal-specific sample. Peer activity is positively associated with the two extensive outcomes in this small and unusually active comparison group. The intensive-adoption response is also positive at the 10 percent level, while the intensive-investment response is imprecise. The group contains 2.7 percent of the panel and about 6 percent of observed adoption and investment.

Figure OA.4 compares the response across firm size and prior horizontal-production experience. The response gaps change over the episode, although the evidence does not establish whether

changing firm composition explains the aggregate reversal or accompanies it.

Adoption records any upward shift in a firm’s horizontal share. A firm can adopt more than once. Table OA.22 separates firms by their horizontal experience before the response quarter and re-estimates the vintage-block responses within each group. The responses differ across prior experience groups, although the estimates do not establish whether changing firm composition explains the aggregate timing pattern.

#### OA.4.4 Measurement of Peer Activity and Network Signals

The baseline assigns an expiration weight to every well linked to a lease, including later wells drilled after an earlier well may have held the lease. Table OA.23 rebuilds peer activity from the first well on each lease. This restriction removes 58 percent of bunching-weighted peer activity but preserves the principal pooled signs. The period and vintage comparisons are less stable under this restricted measure.

The baseline constructs peer activity from wells linked to leases within 0.25 miles. Web Appendix Table W.2 varies that radius from 0.10 miles to the unrestricted spatial match. The pooled responses are strongest under tighter links between wells and leases. The table reports the coefficient, standard error,  $p$ -value and sample size for every specification.

A peer’s drilling and completion attributes become public only after its well is completed. Table OA.24 compares peer activity dated at spud with peer activity dated at completion and describes when responding firms complete their wells relative to these disclosures. Completion dating preserves the pooled signs but reduces precision. Among responding wells, 71 percent are completed at least 60 days after the median peer well is completed.

### OA.5 Conceptual Framework Illustrations

Table OA.25 reports the parameter values used in the counterfactual exercise. Figure OA.5 recalibrates the model after removing one component at a time. The peer-performance calibration uses adoption alone because the late-vintage adoption and investment estimates have opposite signs. A common conversion factor would be negative. Table OA.26 reports the five adoption targets.

With adoption alone and two local-development states, the five estimates identify four parameter combinations. Setting  $m_1 = 0$  gives  $(m_0, b, f, d) = (1.09, +\infty, 4.75, 3.41)$ . Setting  $m_0 = 0$  gives  $(m_1, b, f, d) = (1.09, +\infty, 3.66, 3.14)$ . Both normalizations predict  $-0.14$ ,  $-0.07$ ,  $-0.02$ ,  $0.23$ , and  $-0.01$  for the five groups in Table OA.26, with calendar responses of  $-0.38$ ,  $0.26$ , and  $0.02$ . The five-parameter loss has a flat direction. The same mechanisms match the qualitative peer-performance pattern only at  $b = +\infty$ , so the saturation parameter has no interior estimate.

# Supplemental Figures

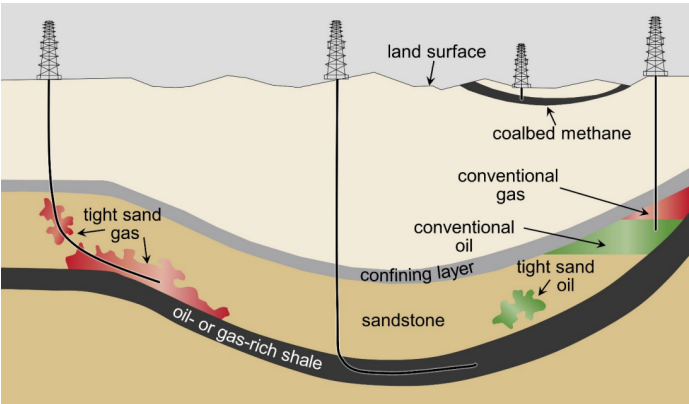


Figure OA.1: Conventional vertical and horizontal extraction

*Notes.* A conventional vertical well produces from the rock it passes through. A horizontal well bends near the target depth and runs laterally through the shale, fractured at many stages along the lateral, reaching resources a vertical well cannot economically produce. *Source.* U.S. Environmental Protection Agency.

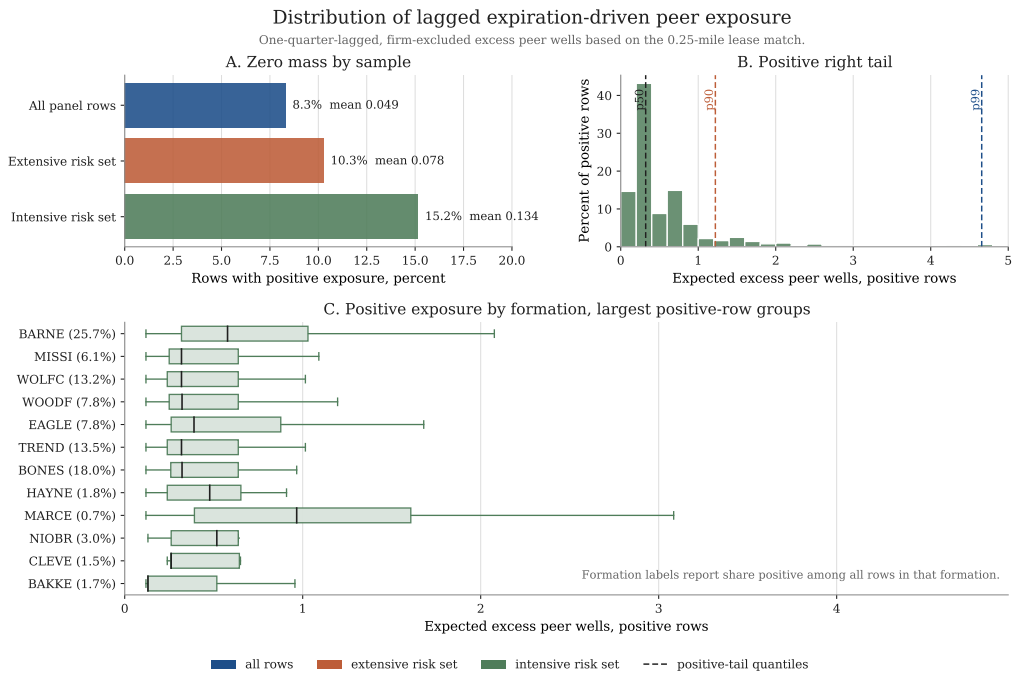


Figure OA.2: Distribution of expiration-driven peer activity

*Notes.* The figure summarizes the one-quarter-lagged, firm-excluded peer-activity measure in the response panel. The measure sums assigned peer wells in the county-quarter using each well's estimated excess share near lease expiration as its weight. It removes wells operated or leased by the responding firm. Panel A reports the share of observations with positive peer activity and its unconditional mean in the full panel and in the extensive and intensive risk sets. Panel B shows the distribution conditional on positive peer activity. Panel C reports that positive distribution by formation for the formations with the largest positive samples.

## Network-signal strength by local trajectory and national cohort

Filled markers:  $p < 0.05$ . Hollow markers: not significant. Whiskers: 95% CIs.

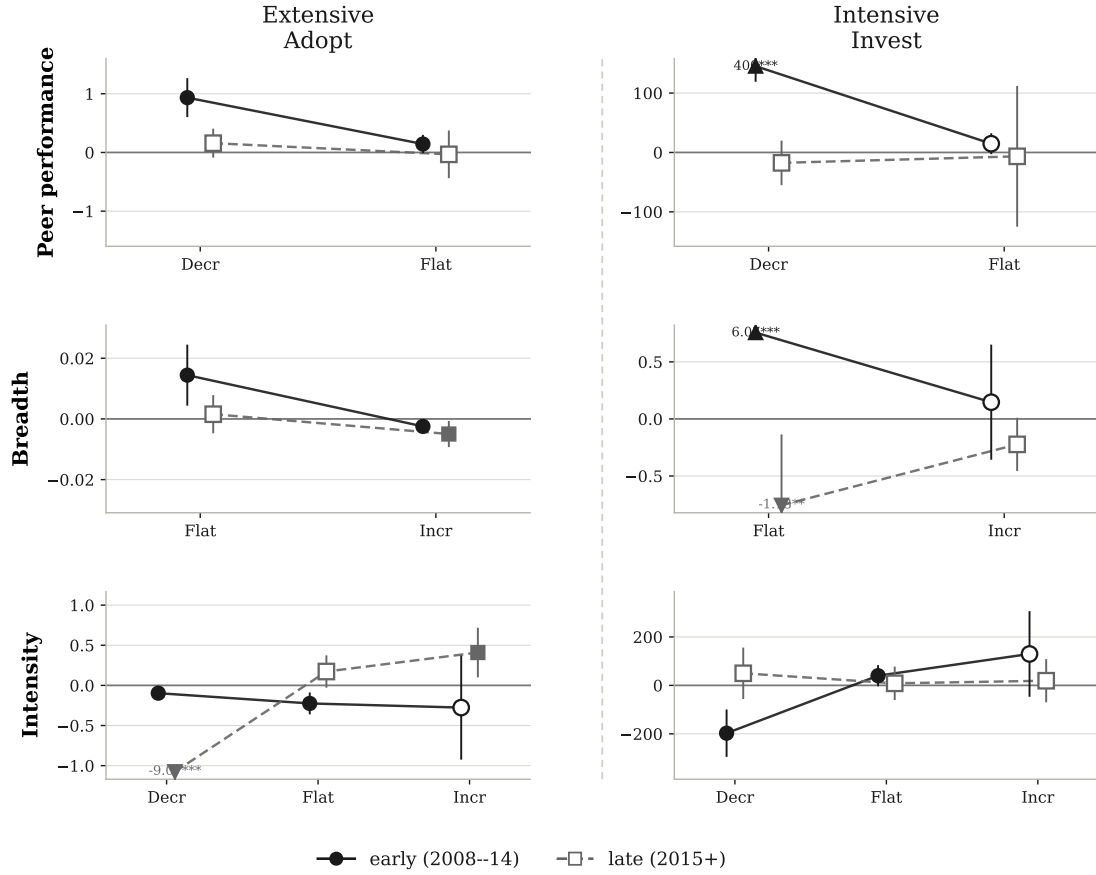


Figure OA.3: Response by the signal's own local trajectory

*Notes.* The sample applies the same-county own-expiration exclusion. The unit is a firm-county-formation-quarter. Each marker reports the coefficient on one-quarter-lagged expiration-driven peer activity interacted with the listed network signal. The regressions are estimated separately by the signal's path across successive 2,000-well formation blocks, classified as decreasing, flat, or increasing, and by calendar cohort, 2008-14 or 2015 onward. The outcomes are extensive adoption and horizontal-well counts among firms with positive horizontal investment. Each specification includes the lower-order peer-activity and signal terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm's county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Filled markers are statistically different from zero at the 5 percent level. Whiskers are 95 percent confidence intervals based on formation-block-clustered standard errors. Off-scale estimates are printed beside their markers.

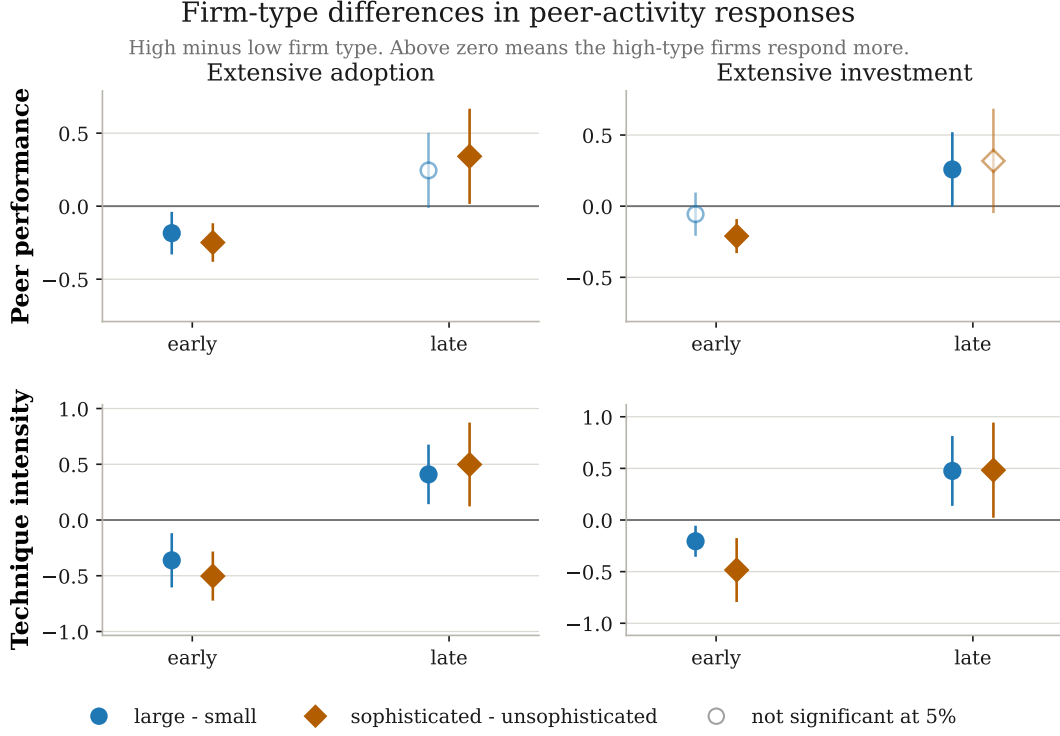


Figure OA.4: Firm-type differences in the response by cohort

*Notes.* Each point is the high-minus-low difference in the coefficient on one-quarter-lagged expiration-driven peer activity interacted with the listed network signal. The regressions are estimated separately for 2008–14 and 2015 onward, for peer performance and technique intensity and for the two extensive outcomes. Both signals use distance-time weights. Large firms are classified once using the cross-firm median of firms' average total well stocks over the full sample. Sophisticated firms are classified separately within each cohort using the cross-firm median of firms' average horizontal-production shares. Every regression includes all lower-order interaction terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm's county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Each signal-specific sample contains observations for which that signal is positive and statistically different from zero. Positive values indicate a larger response among the high-type firms. Whiskers are 95 percent confidence intervals based on formation-block-clustered standard errors.

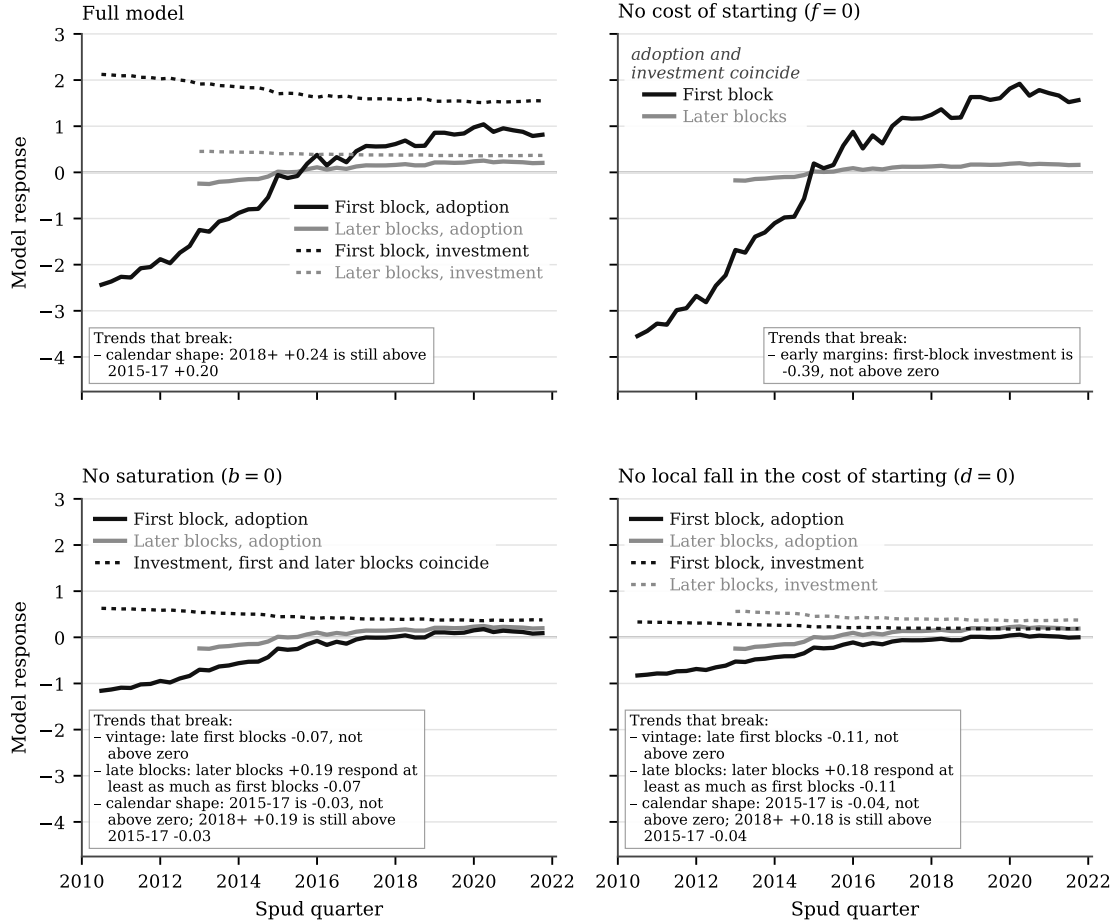


Figure OA.5: Removing one mechanism at a time

*Notes.* Each panel evaluates a calibrated model at the industry-wide horizontal share observed in each quarter. Black curves hold local development at a formation's first 2,000-well block,  $n = 0$ . Gray curves hold it at subsequent blocks,  $n = 1$ . Solid lines report the normalized adoption response and dotted lines report the normalized investment response. Panel (a) is the full model. Panels (b)–(d) set the starting-cost term to zero ( $f = 0$ ), remove local attenuation ( $b = 0$ ), and prevent the starting-cost response from falling with local development ( $d = 0$ ), respectively. Each restricted model is recalibrated to the same ten technique-intensity estimates. Panel text identifies the empirical pattern missed by each restricted model. No empirical estimates are plotted.

## Supplemental Tables

Table OA.1: Dispersion around contemporaneous national engineering practice

|                                            | Interval-length gap |       | Spud-to-completion gap |       | Wells  |        |
|--------------------------------------------|---------------------|-------|------------------------|-------|--------|--------|
|                                            | Early               | Late  | Early                  | Late  | Early  | Late   |
| <i>Panel A. Peer-performance sample</i>    |                     |       |                        |       |        |        |
| First-block state                          | 0.403               | 0.355 | 0.694                  | 0.673 | 7,932  | 11,245 |
| Later blocks, through 2014                 | 0.349               | –     | 0.769                  | –     | 11,278 | –      |
| Later blocks, 2015–16                      | 0.337               | –     | 0.805                  | –     | 3,173  | –      |
| Later blocks, 2017 onward                  | 0.365               | 0.313 | 0.669                  | 0.578 | 4,725  | 9,135  |
| Later blocks, 2019 onward                  | 0.356               | 0.310 | 0.659                  | 0.581 | 3,607  | 5,866  |
| <i>Panel B. Technique-intensity sample</i> |                     |       |                        |       |        |        |
| First-block state                          | 0.268               | 0.351 | 0.693                  | 0.670 | 7,460  | 7,855  |
| Later blocks, through 2014                 | 0.294               | –     | 0.803                  | –     | 9,233  | –      |
| Later blocks, 2015–16                      | 0.396               | –     | 0.797                  | –     | 4,153  | –      |
| Later blocks, 2017 onward                  | 0.365               | 0.334 | 0.634                  | 0.606 | 11,090 | 16,259 |
| Later blocks, 2019 onward                  | 0.354               | 0.301 | 0.642                  | 0.588 | 5,863  | 9,877  |

*Notes.* The table reports within-group standard deviations of two well-level gaps from contemporaneous national practice. The interval-length gap is the log perforated interval of a horizontal well minus the log median among horizontal wells drilled outside its formation in the same quarter. The spud-to-completion gap is the log number of days from spud to completion minus the value predicted from log interval length among those same-quarter national wells. Each national benchmark requires at least 30 wells. The sample contains wells matched to the same-county own-expiration-restricted response panel with positive interval length and spud-to-completion time between 1 and 3,000 days. The match retains 78,028 of the 169,374 otherwise eligible wells. Completion times for wells spudded near the end of the sample may be selected toward wells completed before the data end. Panel A uses the peer-performance response sample, and Panel B uses the technique-intensity response sample. Early-vintage formations completed their first 2,000-well block by 2012Q3. Late-vintage formations completed it in 2014Q1 or later. The 2019-onward rows are subsets of the 2017-onward rows. Late-vintage formations have no later-block wells before 2017. The entries are descriptive point estimates without standard errors.

Table OA.2: Expiration bunching conditional on county-quarter drilling activity

| Specification                   | $\tau = -4$           | $\tau = -3$           | $\tau = -2$           | $\tau = -1$           | $\tau = 0$            | $\tau = 1$            | Cells   |
|---------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|---------|
| No FE PPML                      | 0.2705***<br>(0.0995) | 0.1221<br>(0.1291)    | 0.2926**<br>(0.1458)  | 0.3808***<br>(0.1336) | 0.3762***<br>(0.1186) | 0.1337<br>(0.0851)    | 54,111  |
| County and quarter FE PPML      | 0.2705***<br>(0.0995) | 0.1221<br>(0.1291)    | 0.2926**<br>(0.1458)  | 0.3808***<br>(0.1336) | 0.3762***<br>(0.1186) | 0.1337<br>(0.0851)    | 54,111  |
| County-quarter FE PPML          | 0.2705***<br>(0.0995) | 0.1221<br>(0.1291)    | 0.2926**<br>(0.1458)  | 0.3808***<br>(0.1336) | 0.3762***<br>(0.1186) | 0.1337<br>(0.0851)    | 54,111  |
| County-quarter FE OLS           | 0.0528***<br>(0.0194) | 0.0240<br>(0.0227)    | 0.0658**<br>(0.0278)  | 0.0960***<br>(0.0252) | 0.1014***<br>(0.0246) | 0.0344*<br>(0.0176)   | 54,111  |
| Full-distance county-quarter FE | 0.0783<br>(0.0483)    | 0.0587<br>(0.0500)    | 0.0228<br>(0.0579)    | 0.1286**<br>(0.0619)  | 0.1759***<br>(0.0504) | 0.0276<br>(0.0365)    | 143,259 |
| Wider-window county-quarter FE  | 0.5012***<br>(0.0822) | 0.4453***<br>(0.1009) | 0.6616***<br>(0.1065) | 0.7345***<br>(0.1012) | 0.6522***<br>(0.0763) | 0.2860***<br>(0.0704) | 67,662  |

Table OA.3: Name-matched lease links and peer-activity responses

*Panel A. Well bunching around lease expiration*

| Event time to expiration | Observed assigned wells | Counterfactual | Excess | Excess / observed (%) |
|--------------------------|-------------------------|----------------|--------|-----------------------|
| $[-8, -5]$               | 6,862                   | 6741.1         | 120.9  | 1.76                  |
| -4                       | 2,267                   | 1835.0         | 432.0  | 19.06                 |
| -3                       | 2,265                   | 1887.9         | 377.1  | 16.65                 |
| -2                       | 2,690                   | 1979.4         | 710.6  | 26.41                 |
| -1                       | 3,394                   | 2133.4         | 1260.6 | 37.14                 |
| 0                        | 6,354                   | 2366.6         | 3987.4 | 62.75                 |
| 1                        | 3,026                   | 2684.3         | 341.7  | 11.29                 |
| $[2, 5]$                 | 10,513                  | 10503.7        | 9.3    | 0.09                  |

*Panel B. Pooled response estimates*

|                           | Adopt (ext)           | Invest (ext)          | Adopt (int)           | Invest (int)       |
|---------------------------|-----------------------|-----------------------|-----------------------|--------------------|
| Peer performance ( $WY$ ) | 0.0159*<br>(0.0087)   | 0.0191<br>(0.0116)    | 0.4062***<br>(0.1544) | 0.4824<br>(0.7552) |
| Peer skill ( $WZ$ )       | -0.0088<br>(0.0071)   | -0.0120*<br>(0.0065)  | -0.0713<br>(0.2076)   | 2.797**<br>(1.405) |
| Peer-technique breadth    | -0.0002**<br>(0.0001) | -0.0002**<br>(0.0001) | 0.0002<br>(0.0006)    | 0.0003<br>(0.0021) |
| Technique intensity       | 0.0273*<br>(0.0159)   | 0.0339*<br>(0.0197)   | 0.2835<br>(0.5278)    | 1.215<br>(1.262)   |

*Notes.* In Table OA.2, the unit is a county-quarter-event-time bin, where event time is quarters from lease expiration to spud. The dependent variable is the count of uniquely assigned wells. Expiration-window indicators for  $\tau = -4, \dots, 1$  enter with a fifth-degree event-time polynomial; rows vary fixed effects, estimator, match distance or estimation window. Standard errors cluster by county. In Table OA.3, Panel A aggregates wells under the operator-lessee name-match construction and compares observed drilling with the fitted profile outside the expiration window. Panel B reconstructs firm-excluded peer activity from those links and reports its one-quarter-lagged interaction with each signal. The response regressions use the baseline controls, fixed effects, signal-specific samples and same-county own-expiration restriction. Intensive outcomes condition on positive activity. Standard errors cluster by formation-block. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.4: County bootstrap for estimated peer activity

| Signal                 | Outcome              | Estimate | Clustered SE | Bootstrap SE | Percentile interval  |
|------------------------|----------------------|----------|--------------|--------------|----------------------|
| Peer performance       | Extensive adoption   | 0.1531   | 0.0649       | 0.0975       | [0.0400, 0.3817]     |
|                        | Intensive investment | 5.6188   | 6.6970       | 10.6539      | [−12.0137, 28.6767]  |
| Peer skill             | Extensive adoption   | 0.0404   | 0.1688       | 0.7767       | [−0.4847, 1.0885]    |
|                        | Intensive investment | −37.4633 | 15.5702      | 46.9102      | [−106.9768, 58.8724] |
| Peer-technique breadth | Extensive adoption   | −0.0020  | 0.0006       | 0.0008       | [−0.0039, −0.0008]   |
|                        | Intensive investment | −0.3267  | 0.1741       | 0.2091       | [−0.7658, 0.0438]    |
| Technique intensity    | Extensive adoption   | 0.2661   | 0.0955       | 0.1457       | [0.0265, 0.5800]     |
|                        | Intensive investment | 37.6117  | 27.1502      | 19.2656      | [4.6418, 80.9920]    |

*Notes.* The unit in the response regression is a firm–county–formation–quarter. Each estimate is the coefficient on one-quarter-lagged expiration-driven peer activity interacted with the listed network signal for extensive adoption or intensive investment. Every regression includes the lower-order peer-activity and signal terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Signal-specific samples require the listed signal to be positive and statistically different from zero. Intensive investment also requires positive horizontal investment. Peer performance, peer skill and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. The table reports 499 county-bootstrap draws. Each draw resamples counties, re-estimates the national lease-expiration bunching curve, reconstructs the firm-excluded peer-activity measure and re-estimates the pooled response equation. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. The network signals are held fixed. Clustered SE is the formation-block-clustered standard error reported with the baseline estimate. Bootstrap SE is the standard deviation of the bootstrap estimates. The final column gives the 2.5th and 97.5th percentiles of their distribution.

Table OA.5: Network-signal sensitivity to alternative spatial weights

| Signal                 | Alternative weight | $N$ | Correlation | Sign agreement (%) | Sample agreement (%) |
|------------------------|--------------------|-----|-------------|--------------------|----------------------|
| Peer performance       | Inverse distance   | 49  | 0.869       | 89.8               | 85.7                 |
| Peer performance       | Equidistant        | 46  | 0.640       | 80.4               | 65.2                 |
| Peer performance       | Residual skill     | 49  | 0.288       | 67.3               | 67.3                 |
| Peer skill             | Inverse distance   | 49  | 0.901       | 79.6               | 93.9                 |
| Peer skill             | Equidistant        | 46  | 0.767       | 87.0               | 89.1                 |
| Peer skill             | Residual skill     | 49  | 0.043       | 57.1               | 77.6                 |
| Peer-technique breadth | Inverse distance   | 54  | 0.517       | –                  | 74.1                 |
| Peer-technique breadth | Distance-time      | 54  | 0.674       | –                  | 77.8                 |
| Peer-technique breadth | Residual skill     | 54  | 0.417       | –                  | 63.0                 |
| Technique intensity    | Inverse distance   | 37  | 0.916       | –                  | 94.6                 |
| Technique intensity    | Equidistant        | 38  | 0.781       | –                  | 97.4                 |
| Technique intensity    | Residual skill     | 37  | 0.500       | –                  | 89.2                 |

*Notes.* Each row compares an alternative spatial weight with the preferred measure using the same completed formation blocks. Distance-time is preferred for peer performance, peer skill and technique intensity. Equidistant is preferred for peer-technique breadth. Residual skill weights peer wells by differences in operator skill and is distinct from the peer-skill signal. Correlation is the Pearson correlation between the two signal values. Same sign is reported for the signed peer-performance and peer-skill coefficients and omitted for the nonnegative breadth and intensity measures. Sample agreement is the share of common blocks assigned to the same positive-signal sample under both weights. A positive signal requires a positive coefficient significant at the 10 percent level for peer performance and peer skill, at least one positive and statistically distinguishable attribute for breadth, and a joint Wald test significant at the 10 percent level for technique intensity.

Table OA.6: Signal timing buffer

|                        | Extensive adoption  |                     | Intensive investment  |                       |
|------------------------|---------------------|---------------------|-----------------------|-----------------------|
|                        | Baseline            | Timing buffer       | Baseline              | Timing buffer         |
| Peer performance       | 0.1531<br>(0.0649)  | 0.1850<br>(0.0540)  | 5.6188<br>(6.6970)    | 8.7573<br>(6.5659)    |
| Peer skill             | 0.0404<br>(0.1688)  | -0.0614<br>(0.2471) | -37.4633<br>(15.5702) | -43.6748<br>(20.3489) |
| Peer-technique breadth | -0.0020<br>(0.0006) | -0.0017<br>(0.0007) | -0.3267<br>(0.1741)   | -0.3681<br>(0.1793)   |
| Technique intensity    | 0.2661<br>(0.0955)  | 0.2377<br>(0.1008)  | 37.6117<br>(27.1502)  | 26.7706<br>(22.6036)  |

Table OA.7: Standardized pooled responses to peer activity

|                                                   | Adopt (ext)            | Invest (ext)           | Adopt (int)           | Invest (int)          |
|---------------------------------------------------|------------------------|------------------------|-----------------------|-----------------------|
| <i>Peer performance (WY)</i> [distance-time]      |                        |                        |                       |                       |
| $z(\hat{E}_{c,q-1}^{-i}) \times z(\text{signal})$ | 0.0008**<br>(0.0004)   | 0.0010**<br>(0.0004)   | 0.1000***<br>(0.0285) | 0.0607<br>(0.0723)    |
| $N$                                               | 582,531                | 582,531                | 7,234                 | 8,565                 |
| $R^2$                                             | 0.381                  | 0.402                  | 0.911                 | 0.641                 |
| <i>Peer skill (WZ)</i> [distance-time]            |                        |                        |                       |                       |
| $z(\hat{E}_{c,q-1}^{-i}) \times z(\text{signal})$ | 0.0003<br>(0.0013)     | 0.0002<br>(0.0008)     | -0.0140<br>(0.0186)   | -0.3039**<br>(0.1263) |
| $N$                                               | 152,297                | 152,297                | 912                   | 1,080                 |
| $R^2$                                             | 0.536                  | 0.541                  | 0.980                 | 0.866                 |
| <i>Peer-technique breadth</i> [equidistant]       |                        |                        |                       |                       |
| $z(\hat{E}_{c,q-1}^{-i}) \times z(\text{signal})$ | -0.0021***<br>(0.0007) | -0.0027***<br>(0.0008) | -0.0396<br>(0.0654)   | -0.5919*<br>(0.3155)  |
| $N$                                               | 683,440                | 683,440                | 7,058                 | 8,420                 |
| $R^2$                                             | 0.354                  | 0.370                  | 0.957                 | 0.579                 |
| <i>Technique intensity</i> [distance-time]        |                        |                        |                       |                       |
| $z(\hat{E}_{c,q-1}^{-i}) \times z(\text{signal})$ | 0.0009***<br>(0.0003)  | 0.0010**<br>(0.0004)   | 0.0417<br>(0.0345)    | 0.1845<br>(0.1332)    |
| $N$                                               | 778,002                | 778,002                | 8,704                 | 10,348                |
| $R^2$                                             | 0.358                  | 0.378                  | 0.862                 | 0.615                 |
| Controls                                          | Yes                    | Yes                    | Yes                   | Yes                   |

*Notes.* The unit in both tables is a firm-county-formation-quarter. Each entry is the coefficient on one-quarter-lagged, firm-excluded peer activity interacted with the listed signal. Table OA.6's timing-buffer columns drop the first response quarter after each 2,000-well block closes, removing 119,687 of 1,002,519 panel rows before signal-specific restrictions. Signals are not re-estimated. Table OA.7 instead replaces peer activity and the signal with within-sample z-scores, so its coefficient is the interaction of one-standard-deviation changes; rescaling leaves  $R^2$  unchanged. Both tables use the baseline lower-order terms, controls, fixed effects, signal-specific samples and same-county own-expiration restriction. Intensive investment conditions on positive horizontal investment. Standard errors cluster by formation-block. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.8: Response to peer activity by attributes reported

|                                            | Extensive<br>adoption | Extensive<br>investment | Intensive<br>adoption | Intensive<br>investment |
|--------------------------------------------|-----------------------|-------------------------|-----------------------|-------------------------|
| <i>Panel A. All rows</i>                   |                       |                         |                       |                         |
| Peer activity $\times$ attributes reported | -0.0011<br>(0.0012)   | -0.0013<br>(0.0014)     | 0.0351<br>(0.0357)    | -0.1261<br>(0.1123)     |
| Observations                               | 1,002,243             | 1,002,243               | 11,808                | 14,078                  |
| <i>Panel B. Technique-intensity sample</i> |                       |                         |                       |                         |
| Peer activity $\times$ attributes reported | 0.0031**<br>(0.0015)  | 0.0039**<br>(0.0017)    | 0.1347<br>(0.1874)    | 0.5388*<br>(0.2866)     |
| Observations                               | 778,002               | 778,002                 | 8,704                 | 10,348                  |

*Notes.* The unit is a firm-county-formation-quarter. The coefficient is on one-quarter-lagged expiration-driven peer activity interacted with the average number of drilling and completion attributes reported per horizontal well in the formation-block whose network signal the observation uses. Every regression includes the lower-order peer-activity and attribute-reporting terms. The specification otherwise follows the pooled response specification, with the full control set, operator, county, operator-by-county and quarter fixed effects and the same-county own-expiration restriction. Panel A uses every observation. Panel B uses the technique-intensity sample, where that signal is positive and statistically different from zero. Extensive adoption indicates a positive change in the firm's horizontal share. Intensive adoption is the size of that change conditional on positive adoption. Extensive investment indicates positive horizontal drilling. Intensive investment is the number of horizontal wells conditional on positive horizontal investment. Standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.9: Peer-technique breadth and attribute redundancy

| Breadth path | Formations | Blocks | Breadth | New attr. | Redundancy | Abs. corr. |
|--------------|------------|--------|---------|-----------|------------|------------|
| Increasing   | 8          | 26     | 2.50    | 2.36      | 1.17       | 0.64       |
| Flat         | 4          | 22     | 1.45    | 0.95      | 0.79       | 0.64       |
| Unclassified | 3          | 6      | 4.50    | 4.50      | 1.62       | 0.54       |

*Notes.* The unit is a formation by completed 2,000-well development block. The table is descriptive. It compares blocks in formations where peer-technique breadth increases across successive blocks with blocks in formations where breadth remains flat. Breadth is the number of observable peer-technique attributes whose productivity coefficient is positive and statistically different from zero at the 5 percent level under the preferred equidistant weight. New attributes satisfy this criterion in the current block but not in an earlier block from the same formation. Redundancy divides the sum of the attributes' separate explanatory contributions by their joint explanatory contribution. Larger values indicate that the attributes overlap more in what they explain. Abs. corr. is their mean absolute pairwise correlation within the block.

Table OA.10: Peer activity and own well design

|                                                 | L1                        | L2                        | L3                         | L4                        |
|-------------------------------------------------|---------------------------|---------------------------|----------------------------|---------------------------|
| <i>Panel A. Own perforated interval (ln ft)</i> |                           |                           |                            |                           |
| Peer performance (WY) ( $N=32,223$ )            | -0.7921*<br>(0.3851)      | -0.1919<br>(0.3916)       | 0.0898<br>(0.1876)         | -0.7179***<br>(0.1602)    |
| Peer skill (WZ) ( $N=6,041$ )                   | 1.8220**<br>(0.3818)      | 1.7607*<br>(0.5629)       | 2.7432**<br>(0.5884)       | 2.4293**<br>(0.4767)      |
| Peer-technique breadth ( $N=35,619$ )           | 0.0040<br>(0.0103)        | 0.0218***<br>(0.0068)     | 0.0120*<br>(0.0059)        | 0.0023<br>(0.0052)        |
| Technique intensity ( $N=44,460$ )              | -0.0937<br>(0.8768)       | 1.0234<br>(0.6701)        | -0.0950<br>(0.5365)        | 0.4523<br>(0.6441)        |
| <i>Panel B. Own drill time (days)</i>           |                           |                           |                            |                           |
| Peer performance (WY) ( $N=32,703$ )            | -430.3124**<br>(206.3184) | 146.2428<br>(94.7101)     | 232.1192<br>(136.0729)     | -64.1576<br>(111.0667)    |
| Peer skill (WZ) ( $N=5,750$ )                   | -267.3334<br>(162.6886)   | 1096.9645**<br>(340.5243) | -1244.1648**<br>(216.9755) | -803.9316***<br>(91.2761) |
| Peer-technique breadth ( $N=35,950$ )           | 2.6639<br>(2.7347)        | 4.4747<br>(4.0829)        | 2.1810<br>(3.6359)         | 0.6792<br>(2.0898)        |
| Technique intensity ( $N=44,770$ )              | 1303.0812<br>(836.4630)   | 619.7703<br>(488.5318)    | 784.5314**<br>(361.3846)   | 271.7350<br>(338.9526)    |
| Firm-quarter controls                           | Yes                       | Yes                       | Yes                        | Yes                       |
| County-quarter controls                         | Yes                       | Yes                       | Yes                        | Yes                       |
| Firm / county / firm-county / quarter FE        | Yes                       | Yes                       | Yes                        | Yes                       |
| Standard errors                                 | formation-block           | formation-block           | formation-block            | formation-block           |

*Notes.* The unit is a horizontal well drilled from 2014Q4 through 2022Q4 and matched to the firm-county-formation-quarter response panel. Each row reports an interaction coefficient from a regression that jointly includes lags one through four of expiration-driven peer activity interacted with the listed network signal. The corresponding lower-order peer-activity and signal terms are included. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm's county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Each signal-specific sample contains wells for which that signal is positive and statistically different from zero under its preferred weight. Peer performance, peer skill and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. Perforated interval is the log length in feet of the completed horizontal section that is fractured. Drill time is the number of days from spud to completion. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. Standard errors are clustered by formation-block and reported in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.11: Headline pooled responses with lags one through four

|                                              | Adopt (ext)           | Invest (int)          |
|----------------------------------------------|-----------------------|-----------------------|
| <i>Peer performance (WY)</i> [distance-time] |                       |                       |
| <i>L1</i>                                    | 0.1103**<br>(0.0439)  | 10.8842**<br>(4.5347) |
| <i>L2</i>                                    | 0.0332<br>(0.0755)    | 6.4468<br>(8.6082)    |
| <i>L3</i>                                    | 0.1392***<br>(0.0392) | −17.6677<br>(14.3150) |
| <i>L4</i>                                    | 0.0905<br>(0.0675)    | −32.1251<br>(27.2803) |
| <i>Technique intensity</i> [distance-time]   |                       |                       |
| <i>L1</i>                                    | 0.2477***<br>(0.0884) | 40.8280<br>(28.6120)  |
| <i>L2</i>                                    | 0.0257<br>(0.0712)    | 3.7816<br>(11.7856)   |
| <i>L3</i>                                    | 0.0663<br>(0.0883)    | 1.4570<br>(15.3864)   |
| <i>L4</i>                                    | −0.0107<br>(0.0900)   | −28.9124<br>(24.3881) |

*Notes.* The unit is a firm–county–formation–quarter. Rows report the coefficient on  $\widehat{E}_{c,q-k}^{-i} \times S_{gq}$ , with lags  $k = 1, \dots, 4$  entered jointly. Each regression includes the corresponding lower-order peer-activity terms, the signal term, baseline controls and fixed effects, the signal-specific sample and the same-county own-expiration restriction. Intensive investment conditions on positive horizontal investment. Both signals use distance-time weights. Standard errors cluster by formation-block. Web Appendix Table W.7 reports all four signals and all four outcomes. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.12: Period responses under alternative control specifications

| Signal              | Period / contrast                  | Era-specific controls |                       | Common controls     |                      |
|---------------------|------------------------------------|-----------------------|-----------------------|---------------------|----------------------|
|                     |                                    | Adopt (ext)           | Invest (int)          | Adopt (ext)         | Invest (int)         |
| Peer performance    | 2008–14                            | −0.046<br>(0.057)     | 10.317<br>(9.463)     | 0.094<br>(0.078)    | 15.100*<br>(8.626)   |
|                     | 2015–17                            | 0.282***<br>(0.078)   | 11.013<br>(12.761)    | 0.286***<br>(0.067) | 2.247<br>(24.274)    |
|                     | 2018+                              | −0.327*<br>(0.194)    | 66.071***<br>(20.803) | −0.063<br>(0.191)   | 37.664*<br>(21.805)  |
|                     | <i>Rise: (2015–17) – (2008–14)</i> | 0.328***<br>(0.097)   | 0.696<br>(16.029)     | 0.192*<br>(0.105)   | −12.853<br>(27.111)  |
|                     | <i>Fall: (2018+) – (2015–17)</i>   | −0.610***<br>(0.194)  | 55.058**<br>(24.988)  | −0.349<br>(0.209)   | 35.417<br>(34.508)   |
|                     |                                    |                       |                       |                     |                      |
|                     |                                    |                       |                       |                     |                      |
| Technique intensity | 2008–14                            | −0.174***<br>(0.035)  | 29.324<br>(22.499)    | 0.228<br>(0.174)    | 42.842**<br>(19.206) |
|                     | 2015–17                            | 0.357*<br>(0.211)     | −18.525<br>(25.286)   | 0.281*<br>(0.150)   | −5.049<br>(28.581)   |
|                     | 2018+                              | 0.280*<br>(0.145)     | −24.868<br>(52.654)   | 0.322**<br>(0.144)  | −27.489<br>(51.627)  |
|                     | <i>Rise: (2015–17) – (2008–14)</i> | 0.531**<br>(0.215)    | −47.849<br>(32.579)   | 0.053<br>(0.184)    | −47.890<br>(37.199)  |
|                     | <i>Fall: (2018+) – (2015–17)</i>   | −0.077<br>(0.245)     | −6.343<br>(57.570)    | 0.041<br>(0.201)    | −22.441<br>(62.392)  |
|                     |                                    |                       |                       |                     |                      |
|                     |                                    |                       |                       |                     |                      |
| Standard errors     |                                    | formation-block       |                       |                     |                      |

*Notes.* The unit is a firm–county–formation–quarter. Columns 1 and 2 report the preferred specification, which allows the control coefficients and operator, county, operator-by-county and calendar-quarter fixed effects to vary across eras. Columns 3 and 4 hold those coefficients and fixed effects common across eras while allowing the peer-activity, signal and interaction coefficients to vary. Each entry is the coefficient on one-quarter-lagged, firm-excluded expiration-driven peer activity interacted with the listed network signal. All regressions include the lower-order peer-activity and signal terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. Intensive investment conditions on positive horizontal investment. Both signals use distance-time weights. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. The rise and fall rows are directly tested contrasts. Standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.13: Additional responses by period

| Signal              | Period / contrast                        | Unplotted breadth outcomes      |                              | Additional margins              |                              |
|---------------------|------------------------------------------|---------------------------------|------------------------------|---------------------------------|------------------------------|
|                     |                                          | Adopt (ext)                     | Invest (int)                 | Invest (ext)                    | Adopt (int)                  |
| Peer performance    | 2008–14                                  | —                               | 10.317<br>(9.463)            | 0.0009<br>(0.0702)              | 1.715<br>(1.776)             |
|                     | 2015–17                                  | —                               | 11.013<br>(12.761)           | 0.2807***<br>(0.0919)           | 15.422<br>(9.726)            |
|                     | 2018+                                    | —                               | 66.071***<br>(20.803)        | −0.3430<br>(0.2608)             | −0.236<br>(3.415)            |
|                     | <i>Rise: (2015–17) – (2008–14)</i>       | —                               | 0.696                        | 0.2798**                        | 13.707                       |
|                     | <i>Fall: (2018+) – (2015–17)</i>         | —                               | (16.029)<br>55.058**         | (0.1167)<br>−0.6237**           | (9.241)<br>−15.658           |
|                     |                                          |                                 | (24.988)                     | (0.2521)                        | (10.396)                     |
|                     | 2008–14                                  | —                               | 29.324<br>(22.499)           | −0.1530**<br>(0.0740)           | 4.782<br>(3.779)             |
|                     | 2015–17                                  | —                               | −18.525<br>(25.286)          | 0.2962<br>(0.2427)              | 7.995<br>(15.994)            |
|                     | 2018+                                    | —                               | −24.868<br>(52.654)          | 0.3191**<br>(0.1599)            | 4.019<br>(27.112)            |
|                     | <i>Rise: (2015–17) – (2008–14)</i>       | —                               | −47.849                      | 0.4491*                         | 3.213                        |
| Technique intensity | <i>Fall: (2018+) – (2015–17)</i>         | —                               | (32.579)<br>−6.343           | (0.2512)<br>0.0229              | (16.693)<br>−3.976           |
|                     |                                          |                                 | (57.570)                     | (0.2773)                        | (31.621)                     |
|                     | 2008–14                                  | −0.0006                         | 0.213                        | −0.0009*                        | −0.035                       |
|                     | 2015–17                                  | (0.0005)<br>−0.0007<br>(0.0006) | (0.159)<br>−0.397<br>(0.405) | (0.0005)<br>−0.0007<br>(0.0007) | (0.027)<br>−0.238<br>(0.159) |
|                     | 2018+                                    | −0.0030*<br>(0.0018)            | −0.283<br>(0.187)            | −0.0039**<br>(0.0019)           | 0.031<br>(0.033)             |
|                     | <i>Rise: (2015–17) – (2008–14)</i>       | −0.0000                         | −0.610                       | 0.0002                          | −0.203                       |
|                     | <i>Fall: (2018+) – (2015–17)</i>         | (0.0008)<br>−0.0024             | (0.432)<br>0.114             | (0.0010)<br>−0.0031             | (0.162)<br>0.269             |
|                     |                                          | (0.0019)                        | (0.446)                      | (0.0020)                        | (0.165)                      |
|                     | Firm-quarter and county-quarter controls | Yes                             |                              |                                 |                              |
|                     | Era-specific fixed effects and controls  | Yes                             |                              |                                 |                              |
|                     | Standard errors                          | formation-block                 |                              |                                 |                              |

*Notes.* The first outcome column reports peer-technique breadth’s extensive-adoption response, which is not plotted in the main-paper period figure; dashes suppress the corresponding peer-performance and technique-intensity estimates. The intensive-investment column reports all three signals, including the peer-performance and technique-intensity estimates shown in that figure. The final two columns report extensive investment and intensive adoption for all three signals. The interaction coefficient  $\beta$  is estimated at the one-quarter lag, separately by period, under the separate-fit specification of the main paper, in which the control coefficients are estimated within each period. Every regression includes the lower-order peer-activity and signal terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects within each period. Peer performance, peer skill and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. The rise and fall rows are directly tested contrasts. Standard errors clustered by formation-block are in parentheses. Each specification is estimated on the formation-block observations in which its own signal is positive and individually significant, which is why sample sizes differ across signals. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.14: Own-expiration exclusions in pooled and vintage-block estimates

| <i>Panel A. Pooled response, excluding any own expiration</i> |                        |                        |                     |                      |
|---------------------------------------------------------------|------------------------|------------------------|---------------------|----------------------|
|                                                               | Adopt (ext)            | Invest (ext)           | Adopt (int)         | Invest (int)         |
| Peer performance (WY)                                         | 0.1423**<br>(0.0632)   | 0.1754**<br>(0.0743)   | 9.965***<br>(2.559) | −3.655<br>(8.671)    |
| Peer skill (WZ)                                               | 0.0459<br>(0.1167)     | 0.0288<br>(0.0444)     | −2.493<br>(2.398)   | −41.14***<br>(10.55) |
| Peer-technique breadth                                        | −0.0019***<br>(0.0006) | −0.0025***<br>(0.0007) | −0.0363<br>(0.0440) | −0.3221*<br>(0.1770) |
| Technique intensity                                           | 0.2392***<br>(0.0799)  | 0.2835**<br>(0.1112)   | 13.86<br>(10.05)    | 34.79<br>(34.27)     |

| <i>Panel B. Pooled response, exclusion over the full bunching window</i> |                        |                        |                     |                      |
|--------------------------------------------------------------------------|------------------------|------------------------|---------------------|----------------------|
|                                                                          | Extensive adoption     | Extensive investment   | Intensive adoption  | Intensive investment |
| Peer performance                                                         | 0.142**<br>(0.0598)    | 0.179**<br>(0.0721)    | 10.66***<br>(2.813) | 6.389<br>(6.944)     |
| Peer skill                                                               | 0.0799<br>(0.264)      | 0.0621<br>(0.193)      | −2.588<br>(2.076)   | −43.06***<br>(15.51) |
| Peer-technique breadth                                                   | −0.0020***<br>(0.0006) | −0.0024***<br>(0.0007) | −0.0193<br>(0.0361) | −0.248<br>(0.177)    |
| Technique intensity                                                      | 0.247***<br>(0.0901)   | 0.286**<br>(0.122)     | 11.51<br>(8.902)    | 34.41<br>(25.38)     |

| <i>Panel C. Vintage-block estimates, exclusion over the full bunching window</i> |                      |                     |                      |                     |
|----------------------------------------------------------------------------------|----------------------|---------------------|----------------------|---------------------|
|                                                                                  | Technique intensity  |                     | Peer performance     |                     |
|                                                                                  | Ext. adoption        | Int. investment     | Ext. adoption        | Int. investment     |
| Early vintage, first block                                                       | −0.493**<br>(0.229)  | 64.34<br>(85.80)    | −0.163**<br>(0.0794) | −13.93**<br>(5.533) |
| Early vintage, later blocks, ≤2014                                               | −0.176**<br>(0.0743) | 33.57***<br>(12.10) | −0.0712<br>(0.0632)  | 36.29**<br>(15.99)  |
| Early vintage, later blocks, 2015+                                               | 0.219*<br>(0.115)    | −43.34**<br>(18.46) | 0.197<br>(0.291)     | −70.02<br>(70.72)   |
| Late vintage, first block                                                        | 0.783<br>(0.565)     | 29.81<br>(149.23)   | 0.206**<br>(0.0870)  | 40.42**<br>(19.98)  |
| Late vintage, later blocks, 2017+                                                | 0.248*<br>(0.142)    | −22.39<br>(80.65)   | −0.690**<br>(0.286)  | 113.94*<br>(63.56)  |

| <i>Panel D. First-block vintage contrast, late minus early, extensive adoption</i> |                                  |                                 |                             |
|------------------------------------------------------------------------------------|----------------------------------|---------------------------------|-----------------------------|
|                                                                                    | Same county,<br>response quarter |                                 | Same county,<br>full window |
|                                                                                    | (baseline)                       | Any county,<br>response quarter |                             |
| Technique intensity                                                                | 1.422*<br>(0.774)                | 1.456*<br>(0.772)               | 1.401*<br>(0.732)           |
| Peer performance                                                                   | 0.320**<br>(0.124)               | 0.351***<br>(0.108)             | 0.309***<br>(0.119)         |
| Share of panel rows dropped                                                        | 0.31%                            |                                 | 1.03%                       |
| Share of positive-peer-activity rows dropped                                       | 0.67%                            |                                 | 2.18%                       |

*Notes.* The unit is a firm–county–formation–quarter. Each response coefficient is on one-quarter-lagged, firm-excluded expiration-driven peer activity interacted with the listed network signal. Panel A follows the pooled specification after dropping every observation from a firm-quarter in which the firm has any matched lease expiration, regardless of county. Panels B and C instead drop firm-county-quarters with a matched same-county lease expiring from one quarter before through four quarters after the response quarter; Panel B is pooled and Panel C follows the vintage-block specification. Panel D reports the first-block late-minus-early vintage contrast. All regressions include the lower-order peer-activity and signal terms, the main controls and operator, county, operator-by-county and quarter fixed effects, and use the corresponding signal-specific samples. Standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . The baseline response-quarter same-county, portfolio-wide and full-window same-county restrictions remove 0.31, 13.3 and 1.03 percent of the full panel, respectively. Web Appendix Table W.4 reports the complete sample accounting.

Table OA.15: Lease exercise and local conditions

*Panel A. New leases signed in the county-quarter*

|                                                  | (1)             | (2)                   | (3)             | (4)                   |
|--------------------------------------------------|-----------------|-----------------------|-----------------|-----------------------|
| Expiration-driven peer activity, quarter $q$     | 143.8<br>(96.6) | 145.6<br>(98.0)       | 67.3<br>(45.9)  | 68.1<br>(46.6)        |
| Expiration-driven peer activity, quarter $q + 1$ |                 |                       | 75.1*<br>(40.0) | 78.0*<br>(42.1)       |
| Expiration-driven peer activity, quarter $q - 1$ |                 |                       | 68.7<br>(50.2)  | 67.8<br>(49.5)        |
| Scheduled lease expirations, quarter $q$         |                 | 0.0835***<br>(0.0236) |                 | 0.0845***<br>(0.0269) |
| County-quarters                                  | 17,181          | 17,181                | 16,683          | 16,683                |
| Counties                                         | 249             | 249                   | 249             | 249                   |
| Mean of outcome                                  | 73.3            | 73.3                  | 74.3            | 74.3                  |
| Fixed effects                                    |                 | County and quarter    |                 |                       |

*Panel B. Log first-year output of wells drilled in the expiration window*

|                                            | (1)                   | (2)                 | (3)                    | (4)                 | (5)                 | (6)                 |
|--------------------------------------------|-----------------------|---------------------|------------------------|---------------------|---------------------|---------------------|
| Exercise rate                              | -0.0249**<br>(0.0112) | -0.0096<br>(0.0075) | -0.0292***<br>(0.0099) | -0.0129<br>(0.0078) |                     |                     |
| Share of at-risk leases drilled in window  |                       |                     |                        |                     | -0.1342<br>(0.3103) | -0.2219<br>(0.4574) |
| Wells                                      | 3,545                 | 3,286               | 3,545                  | 3,286               | 3,545               | 3,286               |
| Counties                                   | 165                   | 139                 | 165                    | 139                 | 165                 | 139                 |
| Formation and quarter fixed effects        | Yes                   | No                  | Yes                    | No                  | Yes                 | No                  |
| County-formation and quarter fixed effects | No                    | Yes                 | No                     | Yes                 | No                  | Yes                 |
| Well-type fixed effects                    | No                    | No                  | Yes                    | Yes                 | No                  | No                  |

*Notes.* Panel A uses a county-quarter panel of 249 counties from 2005Q1 through 2022Q1. The outcome is the number of new leases signed in the county-quarter. Expiration-driven peer activity is the county-quarter sum of bunching weights over wells linked to a lease within 0.25 miles, before the responding firm's own wells are removed. Scheduled lease expirations count the leases whose primary term ends in the quarter. Panel B uses wells linked to a lease within 0.25 miles and spudded between four quarters before and one quarter after that lease's expiration. The outcome is the log of the well's first twelve months of output in barrels of oil equivalent. The exercise rate is the number of such wells in a county and expiration quarter divided by the number of leases expiring there with no linked well spudded before the window. Columns 5 and 6 replace it with the share of those leases drilled in the window. Standard errors clustered by county are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.15 (continued): Lease exercise and local conditions

*Panel C. Expiration-driven drilling and recent productivity*

|                                          | Excess expiration-<br>driven wells<br>(1) | Any expiration-<br>driven drilling<br>(2) | Wells per scheduled<br>expiration<br>(3) |
|------------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------|
| Recent productivity innovation           | −0.0071***<br>(0.0024)                    | −0.0089***<br>(0.0033)                    | −0.0007*<br>(0.0003)                     |
| Mean of outcome                          | 0.0941                                    | 0.1436                                    | 0.0056                                   |
| County fixed effects                     | Yes                                       | Yes                                       | Yes                                      |
| Quarter-by-expiration-band fixed effects | Yes                                       | Yes                                       | Yes                                      |
| Scheduled-expiration control             | Yes                                       | Yes                                       | Yes                                      |
| Observations                             | 10,955                                    | 10,955                                    | 10,955                                   |
| Counties                                 | 198                                       | 198                                       | 198                                      |

*Notes.* The sample contains county-quarters with at least one scheduled lease expiration and observed county productivity in the preceding two quarters. For outcome quarter  $q$ , recent productivity innovation is the change from quarter  $q - 2$  to quarter  $q - 1$  in the county-quarter effect estimated from decline-adjusted well output after controlling for firm effects. The variable is standardized within the estimation sample. Column 1 uses the county-quarter sum of the bunching weights assigned to wells linked to expiring leases. Column 2 is an indicator for positive expiration-driven drilling. Column 3 divides excess expiration-driven wells by the number of leases scheduled to expire. All specifications control for the log number of scheduled expirations and include county fixed effects. Quarter-by-expiration-band fixed effects compare counties in the same quarter with similar numbers of scheduled expirations. The bands are 1, 2–4, 5–9, 10–24, 25–49, 50–99 and 100 or more leases. Standard errors clustered by county are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.16: Oil-price controls and price interactions

| Signal                 | Term                                               | Coef.   | SE     | $p$   |
|------------------------|----------------------------------------------------|---------|--------|-------|
| Peer performance (WY)  | Peer activity $\times$ signal, with price controls | 0.1596  | 0.0693 | 0.021 |
| Peer performance (WY)  | Peer activity $\times$ signal $\times$ WTI         | −0.0275 | 0.0538 | 0.610 |
| Peer performance (WY)  | Peer activity $\times$ signal $\times$ vintage     | −0.0486 | 0.0517 | 0.347 |
| Technique intensity    | Peer activity $\times$ signal, with price controls | 0.2635  | 0.0963 | 0.006 |
| Technique intensity    | Peer activity $\times$ signal $\times$ WTI         | 0.0050  | 0.0849 | 0.953 |
| Technique intensity    | Peer activity $\times$ signal $\times$ vintage     | 0.2056  | 0.2137 | 0.336 |
| Peer-technique breadth | Peer activity $\times$ signal, with price controls | −0.0018 | 0.0006 | 0.004 |
| Peer-technique breadth | Peer activity $\times$ signal $\times$ WTI         | −0.0001 | 0.0003 | 0.765 |
| Peer-technique breadth | Peer activity $\times$ signal $\times$ vintage     | 0.0002  | 0.0003 | 0.427 |

*Notes.* The unit is a firm–county–formation–quarter and the outcome is extensive adoption. Rows labeled peer activity  $\times$  signal, with price controls, report the coefficient on  $\hat{E}_{c,q-1}^{-i} \times S_{gq}$  after adding peer activity interacted with standardized quarterly WTI. Rows labeled peer activity  $\times$  signal  $\times$  WTI report the triple interaction from a regression containing all lower-order terms. The vintage rows replace WTI with standardized formation vintage. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Each signal-specific sample requires the listed signal to be positive and statistically different from zero. Peer performance and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. Standard errors are clustered by formation-block.

Table OA.17: Network signals and pre-2014 formation gas share

|                     | 2008–14       | 2015–17        | 2018 onward   |
|---------------------|---------------|----------------|---------------|
| Peer performance    | −0.771<br>(9) | −0.647<br>(12) | 0.087<br>(15) |
| Technique intensity | −0.444<br>(7) | −0.297<br>(11) | 0.035<br>(14) |

*Notes.* Each entry is the cross-formation correlation between the listed network signal and a fixed formation gas share for the indicated period. The gas share is calculated from horizontal-well production through 2013. Gas is converted to barrels of oil equivalent at six thousand cubic feet per barrel. Signals are averaged within formation and period before calculating the correlation. Parentheses report the number of formations with nonmissing values for both measures. A negative correlation indicates that stronger signals are associated with formations whose pre-2014 production was more oil intensive.

Table OA.18: Signal levels and well productivity in first blocks by formation vintage

|                       | Early-vintage first blocks | Late-vintage first blocks |
|-----------------------|----------------------------|---------------------------|
| Technique intensity   | 0.0267<br>(0.0154)         | 0.0197<br>(0.0110)        |
| Peer performance      | 0.0501<br>(0.0190)         | 0.0442<br>(0.0264)        |
| Well productivity     | 0.568<br>(0.932)           | 0.186<br>(1.102)          |
| Log first-year output | 11.373<br>(0.932)          | 11.253<br>(1.091)         |

*Notes.* The unit is a firm–county–formation–quarter in a formation’s first completed 2,000-well development block. The table reports the mean signal value over response-panel observations, with standard deviations in parentheses. Early-vintage formations complete their first block by 2012Q3. Late-vintage formations complete it in 2014Q1 or later. Each signal is summarized over observations for which that signal is positive and statistically different from zero under its preferred distance-time weight. The means weight formation blocks by their numbers of response-panel observations instead of weighting formations equally. The two productivity rows instead average over the 14,000 horizontal wells that make up each vintage’s first blocks. Well productivity is the well-level productivity measure used as the outcome in the network estimates. First-year output is the log of the well’s first twelve months of output in barrels of oil equivalent.

Table OA.19: Vertical-drilling placebo

|                        | Vertical county (ext) | Vertical county count |
|------------------------|-----------------------|-----------------------|
| Peer performance (WY)  | −0.1355**<br>(0.0633) | −1.324***<br>(0.3356) |
| Peer skill (WZ)        | 0.1055<br>(0.0803)    | 0.2876<br>(0.7054)    |
| Peer-technique breadth | 0.0007<br>(0.0006)    | 0.0045<br>(0.0036)    |
| Technique intensity    | −0.1199<br>(0.1399)   | −1.139<br>(0.7027)    |

*Notes.* The unit is a firm–county–formation–quarter. The dependent variables are vertical drilling outcomes measured at the firm–county–quarter level. Vertical county extensive is an indicator for positive vertical investment in the firm–county–quarter, and vertical county count is the corresponding vertical well count. The regressor of interest is the interaction between the expiration-driven peer-activity measure and the listed local network signal, measured before the response quarter. Every regression includes the lower-order peer-activity and signal terms. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Signal-specific samples require the listed signal to be positive and statistically different from zero. Peer performance, peer skill and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. Standard errors are clustered by formation-block and shown in parentheses. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.20: Lower-order terms in the pooled response specification

|                                              | Adopt (ext)            | Invest (ext)           | Adopt (int)           | Invest (int)            |
|----------------------------------------------|------------------------|------------------------|-----------------------|-------------------------|
| <i>Peer performance (WY)</i> [distance-time] |                        |                        |                       |                         |
| Peer activity                                | −0.0068*<br>(0.0038)   | −0.0074<br>(0.0044)    | −0.5016**<br>(0.1913) | −0.1997<br>(0.4412)     |
| Signal                                       | 0.0921<br>(0.1107)     | 0.1016<br>(0.1238)     | −4.6797**<br>(1.9357) | −30.4128**<br>(13.9067) |
| Peer activity × signal                       | 0.1531**<br>(0.0649)   | 0.1835**<br>(0.0756)   | 9.4487***<br>(2.6951) | 5.6188<br>(6.6970)      |
| <i>N</i>                                     | 582,531                | 582,531                | 7,234                 | 8,565                   |
| <i>Peer skill (WZ)</i> [distance-time]       |                        |                        |                       |                         |
| Peer activity                                | −0.0079<br>(0.0345)    | −0.0051<br>(0.0208)    | −0.1183<br>(0.2869)   | −1.8250<br>(3.6747)     |
| Signal                                       | 0.0074<br>(0.0277)     | 0.1256**<br>(0.0318)   | —                     | —                       |
| Peer activity × signal                       | 0.0404<br>(0.1688)     | 0.0272<br>(0.1014)     | −1.7864<br>(2.3706)   | −37.4633*<br>(15.5702)  |
| <i>N</i>                                     | 152,297                | 152,297                | 912                   | 1,080                   |
| <i>Peer-technique breadth</i> [equidistant]  |                        |                        |                       |                         |
| Peer activity                                | 0.0131***<br>(0.0042)  | 0.0170***<br>(0.0049)  | 0.0002<br>(0.0561)    | 1.8470***<br>(0.4328)   |
| Signal                                       | −0.0009***<br>(0.0003) | −0.0011***<br>(0.0004) | 0.0006<br>(0.0056)    | −0.0611<br>(0.0618)     |
| Peer activity × signal                       | −0.0020***<br>(0.0006) | −0.0025***<br>(0.0007) | −0.0222<br>(0.0367)   | −0.3267*<br>(0.1741)    |
| <i>N</i>                                     | 683,440                | 683,440                | 7,058                 | 8,420                   |
| <i>Technique intensity</i> [distance-time]   |                        |                        |                       |                         |
| Peer activity                                | −0.0076***<br>(0.0028) | −0.0076*<br>(0.0040)   | −0.0883<br>(0.2869)   | −0.9504<br>(0.9070)     |
| Signal                                       | 0.0697<br>(0.0707)     | 0.0873<br>(0.0885)     | 4.2210<br>(6.5340)    | 7.5661<br>(9.4924)      |
| Peer activity × signal                       | 0.2661***<br>(0.0955)  | 0.2988**<br>(0.1249)   | 8.8524<br>(7.3287)    | 37.6117<br>(27.1502)    |
| <i>N</i>                                     | 778,002                | 778,002                | 8,704                 | 10,348                  |

*Notes.* The unit is a firm–county–formation–quarter. The table reports all three coefficients from the pooled one-quarter response specifications underlying the main paper’s pooled response table. The peer-activity and signal rows are the lower-order terms in the interacted specification. Their coefficients are evaluated at a signal or peer-activity value of zero. The interaction row is the coefficient reported in the main table. Extensive adoption indicates a shift in the firm’s technology mix toward horizontal wells. Extensive investment indicates positive horizontal drilling. Intensive adoption is the change in the firm’s horizontal share conditional on positive adoption. Intensive investment is the number of horizontal wells conditional on positive horizontal investment. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm’s county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Signal-specific samples require the listed signal to be positive and statistically different from zero. Peer performance, peer skill and technique intensity use distance-time weights. Peer-technique breadth uses equidistant weights. Standard errors are clustered by formation-block and shown in parentheses. Dashes indicate coefficients absorbed in the intensive peer-skill samples. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.21: Peer activity where no network signal is measurable

| <i>Panel A. Response estimates</i> |  |                       |                      |                     |                    |  |  |
|------------------------------------|--|-----------------------|----------------------|---------------------|--------------------|--|--|
|                                    |  | Adopt (ext)           | Invest (ext)         | Adopt (int)         | Invest (int)       |  |  |
| No measurable signal               |  | 0.0113***<br>(0.0042) | 0.0108**<br>(0.0045) | 0.1995*<br>(0.1035) | 1.7065<br>(1.6684) |  |  |
| <i>N</i>                           |  | 26,567                | 26,567               | 655                 | 798                |  |  |

| <i>Panel B. Sample composition</i> |           |                                       |                               |                                |                                 |                                  |                       |
|------------------------------------|-----------|---------------------------------------|-------------------------------|--------------------------------|---------------------------------|----------------------------------|-----------------------|
| Sample                             | <i>N</i>  | County-formation<br>years<br><i>N</i> | Adoption<br>rate<br>(percent) | Total<br>adoptions<br><i>N</i> | Investment<br>rate<br>(percent) | Total<br>investments<br><i>N</i> | Mean peer<br>activity |
| Full panel                         | 1,002,519 | 3,221                                 | 1.21                          | 12,116                         | 1.44                            | 14,410                           | 0.049                 |
| No measurable signal               | 26,852    | 178                                   | 2.78                          | 746                            | 3.37                            | 905                              | 0.157                 |
| Peer performance                   | 583,019   | 2,092                                 | 1.29                          | 7,503                          | 1.52                            | 8,861                            | 0.051                 |
| Peer skill                         | 152,673   | 471                                   | 0.66                          | 1,008                          | 0.78                            | 1,185                            | 0.033                 |
| Peer-technique breadth             | 683,705   | 2,257                                 | 1.07                          | 7,338                          | 1.28                            | 8,739                            | 0.044                 |
| Technique intensity                | 778,269   | 2,574                                 | 1.15                          | 8,950                          | 1.37                            | 10,625                           | 0.036                 |

*Notes.* The unit in both panels is a firm-county-formation-quarter. In Panel A, the sample is restricted to observations in which none of the preferred peer-performance, peer-skill, peer-technique breadth or technique-intensity signals is statistically distinguishable from zero in either direction. The row reports the coefficient on  $\hat{E}_{c,q-1}^{-i}$ , expiration-driven peer activity lagged one quarter, from the pooled response specification without a network interaction. The sample excludes firm-county-quarters in which the responding firm has a same-county lease expiration. Controls include firm and county horizontal-production shares, firm horizontal and total well stocks, the firm's county-level horizontal well stock, a firm-quarter productivity index and annual county size. The regressions absorb operator, county, operator-by-county and calendar-quarter fixed effects. Intensive outcomes condition on positive activity in the corresponding outcome. Standard errors are clustered by formation-block and shown in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . In Panel B, the four signal samples require the listed signal to be positive and statistically distinguishable from zero. These samples overlap and their totals are not additive. The no-measurable-signal sample requires that none of the four signals be statistically distinguishable from zero in either direction. Adoption and investment rates are percentages. Peer activity is the mean of  $\hat{E}_{c,q-1}^{-i}$ . All rows use the main sample restriction that excludes firm-county-quarters in which the responding firm has a same-county lease expiration.

Table OA.22: Vintage-block responses by prior horizontal experience

|                                                                             | Never drilled<br>horizontally | Drilled horizontally<br>elsewhere, not here | Already drilling<br>in this market |
|-----------------------------------------------------------------------------|-------------------------------|---------------------------------------------|------------------------------------|
| <i>Panel A. Technique intensity, extensive adoption</i>                     |                               |                                             |                                    |
| Early vintage, first block                                                  | -0.189**<br>(0.079)           | 0.001<br>(0.059)                            | -3.072**<br>(1.294)                |
| Early vintage, later blocks, $\leq 2014$                                    | 0.229***<br>(0.017)           | 0.012<br>(0.050)                            | -1.779***<br>(0.644)               |
| Early vintage, later blocks, 2015+                                          | -0.019<br>(0.018)             | 0.028<br>(0.022)                            | -0.095<br>(0.420)                  |
| Late vintage, first block                                                   | -0.296<br>(0.231)             | 0.309<br>(0.222)                            | -0.531<br>(3.313)                  |
| Late vintage, later blocks, 2017+                                           | -0.003<br>(0.024)             | 0.054<br>(0.035)                            | -1.738<br>(2.948)                  |
| <i>Panel B. Peer performance, extensive adoption</i>                        |                               |                                             |                                    |
| Early vintage, first block                                                  | -0.074*<br>(0.040)            | 0.035<br>(0.058)                            | -1.003<br>(0.745)                  |
| Early vintage, later blocks, $\leq 2014$                                    | 0.103*<br>(0.062)             | -0.060<br>(0.072)                           | 0.205<br>(0.696)                   |
| Early vintage, later blocks, 2015+                                          | -0.001<br>(0.010)             | 0.053<br>(0.062)                            | -1.470<br>(1.841)                  |
| Late vintage, first block                                                   | 0.006<br>(0.038)              | 0.112***<br>(0.037)                         | 2.145*<br>(1.129)                  |
| Late vintage, later blocks, 2017+                                           | 0.337***<br>(0.124)           | 0.110*<br>(0.059)                           | -0.697<br>(3.382)                  |
| <i>Panel C. Intensive investment, firms already drilling in this market</i> |                               |                                             |                                    |
|                                                                             | Technique intensity           | Peer performance                            |                                    |
| Early vintage, first block                                                  | 17.4<br>(33.4)                | 33.0<br>(22.2)                              |                                    |
| Early vintage, later blocks, $\leq 2014$                                    | 36.8***<br>(12.4)             | 37.1**<br>(18.3)                            |                                    |
| Early vintage, later blocks, 2015+                                          | -40.9**<br>(20.7)             | 10.4<br>(50.6)                              |                                    |
| Late vintage, first block                                                   | 159.6<br>(132.9)              | 52.6***<br>(15.4)                           |                                    |
| Late vintage, later blocks, 2017+                                           | 17.9<br>(70.7)                | 117.0*<br>(68.5)                            |                                    |

*Notes.* The unit is a firm-county-formation-quarter. Each coefficient is on one-quarter-lagged expiration-driven peer activity interacted with the network signal, estimated separately within each vintage-block group and firm group. Firms are divided according to their horizontal drilling before the response quarter. The groups are firms that have never drilled horizontally, firms that have drilled horizontally elsewhere but not in the current county and formation, and firms that have already drilled horizontally in the current county and formation. The vintage-block groups follow the main table. Intensive investment can be estimated only for firms already drilling in the market, because the other groups have fewer than 500 observations in each group. Controls, fixed effects and the signal-specific samples follow the main specification. The sample excludes firm-county-quarters in which the firm has an own lease expiring in the same county and quarter. Every regression includes the lower-order peer-activity and signal terms. Extensive adoption indicates a positive change in the firm's horizontal share. Intensive investment is the number of horizontal wells among observations with positive horizontal investment. These estimates use the full panel without the own-expiration restriction. Standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.23: Peer activity from the first well on each lease

| <i>Panel A. Pooled response</i>                                                    |                        |                       |                        |                       |                      |                       |
|------------------------------------------------------------------------------------|------------------------|-----------------------|------------------------|-----------------------|----------------------|-----------------------|
|                                                                                    | Ext. adoption          |                       | Ext. investment        |                       | Int. investment      |                       |
|                                                                                    | All wells              | First wells           | All wells              | First wells           | All wells            | First wells           |
| Peer performance                                                                   | 0.1531**<br>(0.0649)   | 0.5467**<br>(0.2618)  | 0.1835**<br>(0.0756)   | 0.6653**<br>(0.2709)  | 5.62<br>(6.70)       | 48.23***<br>(15.89)   |
| Peer-technique breadth                                                             | -0.0020***<br>(0.0006) | -0.0037**<br>(0.0016) | -0.0025***<br>(0.0007) | -0.0044**<br>(0.0019) | -0.3267*<br>(0.1741) | -0.9592**<br>(0.3953) |
| Technique intensity                                                                | 0.2661***<br>(0.0955)  | 0.4724***<br>(0.1749) | 0.2988**<br>(0.1249)   | 0.4541*<br>(0.2481)   | 37.61<br>(27.15)     | 64.10<br>(39.80)      |
| <i>Panel B. Extensive adoption by period</i>                                       |                        |                       |                        |                       |                      |                       |
|                                                                                    | 2008–14                |                       | 2015–17                |                       | 2018 onward          |                       |
|                                                                                    | All wells              | First wells           | All wells              | First wells           | All wells            | First wells           |
| Peer performance                                                                   | -0.0458<br>(0.0573)    | -0.0685<br>(0.1285)   | 0.2822***<br>(0.0780)  | 0.9641***<br>(0.1568) | -0.3274*<br>(0.1938) | 0.6760***<br>(0.2484) |
| Technique intensity                                                                | -0.1736***<br>(0.0354) | -0.2351<br>(0.1495)   | 0.3572*<br>(0.2107)    | 0.4950*<br>(0.2995)   | 0.2802*<br>(0.1447)  | -0.2100<br>(0.5580)   |
| <i>Panel C. First-block vintage contrast, late minus early, extensive adoption</i> |                        |                       |                        |                       |                      |                       |
|                                                                                    | All wells              | First wells           |                        |                       |                      |                       |
| Technique intensity                                                                | 1.42*<br>(0.7743)      | 2.32<br>(1.81)        |                        |                       |                      |                       |
| Peer performance                                                                   | 0.3197**<br>(0.1242)   | 0.8428***<br>(0.2693) |                        |                       |                      |                       |

*Notes.* “All wells” is the main county-level peer-activity measure. “First wells” keeps only the first well on each lease, ranking the wells linked to a lease by spud date. It keeps the event-time bunching weights unchanged and removes 58 percent of bunching-weighted peer activity. Both versions use the same-county own-expiration exclusion, the full control set and operator, county, operator-by-county and quarter fixed effects. Every response regression includes the lower-order peer-activity and signal terms and uses the corresponding signal-specific sample. Extensive adoption indicates a positive change in the firm’s horizontal share. Extensive investment indicates positive horizontal drilling. Intensive investment is the number of horizontal wells conditional on positive horizontal investment. Coefficient magnitudes are larger under the first-well measure partly because the measure is smaller in scale. Standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.24: Peer activity dated at completion and disclosure timing

| <i>Panel A. Pooled response, peer activity dated at spud or at completion</i> |                        |                        |                        |                        |                      |                     |
|-------------------------------------------------------------------------------|------------------------|------------------------|------------------------|------------------------|----------------------|---------------------|
|                                                                               | Ext. adoption          |                        | Ext. investment        |                        | Int. investment      |                     |
|                                                                               | Spud                   | Completion             | Spud                   | Completion             | Spud                 | Completion          |
| Peer performance                                                              | 0.1531**<br>(0.0649)   | 0.1745<br>(0.1214)     | 0.1835**<br>(0.0756)   | 0.2133<br>(0.1376)     | 5.62<br>(6.70)       | 2.68<br>(11.65)     |
| Peer-technique breadth                                                        | -0.0020***<br>(0.0006) | -0.0020***<br>(0.0005) | -0.0025***<br>(0.0007) | -0.0023***<br>(0.0005) | -0.3267*<br>(0.1741) | -0.1367<br>(0.1166) |
| Technique intensity                                                           | 0.2661***<br>(0.0955)  | 0.1166<br>(0.0838)     | 0.2988**<br>(0.1249)   | 0.0910<br>(0.0900)     | 37.61<br>(27.15)     | 8.13<br>(11.17)     |

Table OA.24 (continued): Peer activity dated at completion and disclosure timing

| <i>Panel B. Responder wells completed after peers' attributes would be public</i> |        |                              |                                |                      |
|-----------------------------------------------------------------------------------|--------|------------------------------|--------------------------------|----------------------|
|                                                                                   | Wells  | After first peer<br>+60 days | After typical peer<br>+60 days | Median slack<br>days |
| All responders                                                                    | 15,213 | 0.83                         | 0.71                           | 67                   |
| Technique-intensity sample                                                        | 9,312  | 0.81                         | 0.73                           | 82                   |
| Peer-performance sample                                                           | 11,348 | 0.82                         | 0.70                           | 73                   |
| Breadth sample                                                                    | 7,391  | 0.83                         | 0.72                           | 69                   |
| Technique intensity, above median                                                 | 5,300  | 0.80                         | 0.72                           | 86                   |
| Technique intensity, at or below median                                           | 4,012  | 0.83                         | 0.73                           | 77                   |

| <i>Panel C. Drilling speed and crowding, horizontal wells</i> |         |                                    |                                                 |                                                  |
|---------------------------------------------------------------|---------|------------------------------------|-------------------------------------------------|--------------------------------------------------|
|                                                               | Wells   | Median spud-to-<br>completion days | Next spud by another<br>operator within 90 days | Operators per county-<br>formation-quarter, mean |
| All county-formation-quarters                                 | 104,281 | 153                                | 0.93                                            | 3.47                                             |
| Technique-intensity sample                                    | 77,733  | 158                                | 0.93                                            | 3.38                                             |
| Peer-performance sample                                       | 64,349  | 150                                | 0.93                                            | 3.48                                             |
| Breadth sample                                                | 59,758  | 162                                | 0.93                                            | 3.59                                             |
| Technique intensity, above median                             | 50,662  | 171                                | 0.94                                            | 3.50                                             |
| Technique intensity, at or below median                       | 27,071  | 137                                | 0.93                                            | 3.21                                             |

*Notes.* Panel A reports the pooled response with county-level peer activity dated at the peer well's spud, as in the main text, or at its completion, the spud date plus reported spud-to-completion days. Wells without a completion date are dropped from the completion-dated measure. They carry 8 percent of the bunching-weighted peer activity. Both columns use the full control set, the same fixed effects, the lower-order peer-activity and signal terms, the signal-specific samples, and the same-county own-expiration exclusion. Panel B covers horizontal wells of firms that drill horizontally in a quarter after expiration-driven peer activity in the previous quarter. It reports the share of those wells completed after the first and after the median peer well's completion date plus 60 days, and the median number of days between the median peer's completion plus 60 days and the responder's completion. Panel C covers horizontal wells in the county-formation-quarters of each signal's sample. It reports the median time from spud to completion, the share of wells followed within 90 days by a horizontal spud of another operator in the same county and formation, and the mean number of operators spudding horizontal wells per county-formation-quarter. Signal samples overlap. Technique intensity is split at its median in the technique-intensity sample. Panel A standard errors clustered by formation-block are in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Table OA.25: Parameter values used in the counterfactual exercise

| Parameter | What it governs                                       | Value |
|-----------|-------------------------------------------------------|-------|
| $m_0$     | Base return value of local evidence                   | 2.73  |
| $m_1$     | Change in that return value with industry maturity    | -1.29 |
| $b$       | Saturation as local development accumulates           | 1.44  |
| $f$       | Cost of starting in a young industry                  | 8.62  |
| $d$       | Decline in that cost as local development accumulates | 1.51  |

*Notes.* The table reports the rounded parameter values used in the counterfactual exercise. The values minimize the inverse-variance-weighted sum of squared deviations between the model responses and ten technique-intensity estimates reported in main Appendix Table E.1. The targets are extensive adoption and horizontal well counts conditional on positive horizontal investment for five vintage-block groups. Investment estimates and standard errors are multiplied by 0.018588 to express both outcomes on a common scale. Local development is normalized to  $n = 0$  for first blocks and  $n = 1$  for later blocks. Industry maturity  $N$  is the industry-wide horizontal share averaged over each target's estimation sample. The values are illustrative, not structural estimates. Main Appendix E.3 reports the calibration procedure and fitted responses.

| Target                                   | $n_k$ | $N_k$ | Adoption             |
|------------------------------------------|-------|-------|----------------------|
| Early vintage, first block               | 0     | 0.741 | -0.1440*<br>(0.0776) |
| Early vintage, later blocks through 2014 | 1     | 0.564 | -0.0687<br>(0.0656)  |
| Early vintage, later blocks from 2015    | 1     | 0.896 | 0.3433<br>(0.2971)   |
| Late vintage, first block                | 0     | 0.820 | 0.2342**<br>(0.0947) |
| Late vintage, later blocks from 2017     | 1     | 0.919 | -0.6771*<br>(0.3563) |

Table OA.26: Peer-performance targets

*Notes.* The five targets are peer-performance extensive-adoption responses for the listed formation-vintage, local-block, and calendar-period groups. Local development is normalized to  $n_k = 0$  for first blocks and  $n_k = 1$  for later blocks. Industry maturity  $N_k$  is the industry-wide horizontal share averaged over target  $k$ 's adoption estimation sample. Standard errors clustered by formation-block are in parentheses. Stars denote significance at the 10, 5, and 1 percent levels.