Preliminary – do not cite

Housing value, sorting effects and point-source pollution: Did the Clean Water Act Amendments localize the disamenity?

Chen-Ti Chen
The Ohio State University

Yongjie Ji
Iowa State University

Tracy M. Turner
Iowa State University

Jingke Wu
The Ohio State University

August 18, 2026

Contact Information:

Tracy M. Turner
Finance Department
Ivy College of Business
2330 Gerdin Business Building
Iowa State University
Ames, IA 50011

JEL Classification: R21, R31, Q51, Q53

Acknowledgement: There are no financial relationships or other potential conflicts of interest that apply to the authors.

1. Introduction

Local land use patterns can change over time. Production processes may establish or expand near existing residential housing. While local residents may benefit from new job opportunities, they may become exposed to production disamenities, with exposure varying by proximity. Extensive research documents adverse property value impacts related to local environmental disamenities (i.e., Lawley 2021; Taylor et al. 2016, Currie et al. 2016; Isakson and Ecker 2008; McCluskey and Rausser 2003). In this paper, we examine local land use in the form of concentrated animal feeding operations (CAFOs), which often establish near existing residential housing.[1] We focus on house transaction prices as an equilibrium metric for local economy well-being. If a CAFO establishment increases economic activity and desirability of a location, we expect to see in-migration, a positive impact on house prices and new housing construction. However, if disamenities such as unpleasant odors, water pollution, potential diseases (as documented in Gollehon et al. 2001; Sneeringer 2009; 2010; Raff and Meyer 2021; Hochard et al. 2023) outweigh local economic benefits of establishment, we expect downward pressure on property prices in locations post-establishment.

We hypothesize that the 2003 Clean Water Act amendments (CWAA) may have exacerbated property value discounts through unintended regulatory channels. As we detail in Appendix A1, under the CWAA, nitrogen and phosphorus land-application limits forced facilities to spread manure, bringing it closer to previously unaffected residential property lines. The CWAA required larger holding lagoons, intensifying localized odor, bioaerosol, and groundwater contamination risks near the immediate facility perimeter. Finally, high fixed costs of compliance may have accelerated industry consolidation, replacing smaller operations with CAFOs that carry significantly larger disamenity radii.

To evaluate these impacts, we construct a novel panel dataset combining administrative facility records from the Iowa Department of Natural Resources (DNR), the universe of Iowa residential property transactions from CoreLogic, and U.S. Census tract demographic data spanning the year 1993 to 2023. Iowa provides an ideal empirical setting as the nation's leading producer, housing over 4,000 registered CAFOs (EPA, 2024).[2] Leveraging precise establishment dates over time, we designate each CAFO opening as a discrete treatment event within a staggered design. Using a stacked difference-in-difference strategy, we compare properties transacted in close proximity to a CAFO opening to a set of control transactions. The control group includes properties transacted in close proximity to a site that will become a future CAFO or to a site that is 'always treated.' This approach mitigates concerns about using the recently treated as a control group as

[1] CAFOs are industrialized facilities that house a large number of animals in relatively small and confined facilities.
[2] The importance of CAFOs to the Iowa agricultural economy, US consumption and global markets cannot be overstated. The Iowa hog and pig industry currently maintains an inventory of 24.3 million head, estimated to contribute $9.29 billion to sales (Plastina et al. 2025; USDA-NASS 2025). It ranked first in hog inventory in the United States, accounting for 33 percent of the nation's 2023 inventory, as well as first in red meat and egg production (USDA-NASS 2025).

in a two-way fixed effects setting and is demonstrated in Dooley and Gallagher (2024). Using close proximity to a past or future CAFO also mitigates concerns about non-random assignment: the event and control groups are the locations in which CAFO establishment occurs. Thus, in our study, the identifying assumption is that, in the absence of treatment, two areas within the same county that experience a CAFO opening at different times would have followed similar trends.

2. Literature review and regulatory background

2.1 Livestock production and CAFOs in Iowa

Over the last several decades, the U.S. livestock production has shifted toward fewer and larger operations, with a growing share of animals produced in confined systems. Between 1982 and 1997, the number of livestock operations fell by 24%, while the number of large, confined operations, or CAFOs, increased by more than 50% (Copeland 2010). These patterns are mostly attributed to the scale economies and improved productivity of specialized large operations (Crespi and MacDonald 2022). Currently, there are more than 21 thousand CAFOs in the nation, where the majority of these operations locate in the Midwestern states (EPA 2025).

This structural change is especially pronounced in Iowa, which leads the nation with 4 thousand CAFOs, nearly one-fifth of the total number of CAFOs (EPA, 2025). The importance of CAFOs to the Iowa economy, US consumption and global markets cannot be overstated. The Iowa hog and pig industry currently maintains an inventory of 24.3 million head, estimated to contribute $9.29 billion to sales (Haeun et al. 2025; USDA-NASS 2025). It ranked first in hog inventory in the United States, accounting for 33 percent of the nation's 2023 inventory, as well as first in red meat and egg production. (USDA-NASS 2025).

2.2 (Dis-)amenity effects of CAFOs on local residential markets

The confined production system, while more efficient, also concentrates waste and emissions in small areas. EPA estimated that a CAFO is responsible around 190 thousand tons annually, three times greater than human sanitary waste in the United States (EPA, 2003). The excessive amount of animal manure can pose negative environmental externalities on nearby residents, including unpleasant odors, water pollution, potential diseases, and among other things (Gollehon et al. 2001; Sneeringer 2009; 2010; Raff and Meyer 2021; Hochard et al. 2023). If these environmental disamenities are capitalized into nearby residential markets, bids for local housing would likely fall.

Prior studies have examined the externalities of CAFOs on house prices in various regions (Palmquist et al. 1997, Herriges et al. 2005; Ready and Abdalla 2005; Isakson and Ecker 2008; Kim and Goldsmith 2009; Kuethe and Keeney 2012; Jowers et al. 2024). For example, Palmquist et al. (1997) established the benchmark spatial hedonic framework for livestock disamenities in southeastern North Carolina. By constructing a manure-production index based on proximity and animal density, they found that nearby hog CAFOs reduced surrounding property values by up to

9%, with marginal price discounts heavily dependent on pre-existing local livestock density. Herriges et al. (2005) incorporated prevailing wind patterns and facility scale across rural Iowa. They documented property value reductions of 10% to 16% for residences situated downwind within 0.5 to 1.5 miles of swine feedlots. Ma et al. (2024) examined environmental exposure channels using North Carolina housing transactions near poultry CAFOs. They found property price drops of 30% to 32% for homes reliant on private well water due to perceived groundwater contamination risks, compared to significantly smaller discounts for homes connected to municipal water lines.

Most of these earlier studies were either conducted in one or few counties within a state, or limited to cross-sectional data of transacted property and CAFO locations. Jowers et al. (2024) is the closest to ours and use repeated sales data. They found that CAFOs had a larger negative impact on house prices for properties relying on private wells than those relying on community water in North Carolina. This study extends the literature by examining the CWAA impacts, employing a research design that accounts for heterogeneous treatment effects, examining wind exposure as the channel that CAFOs impact house prices. Moreover we examine demographic changes in the vicinity of a CAFO opening.

House prices need not absorb the full local effect of a CAFO. Large-scale livestock production may also increase local economic activity and incomes in ways that could support housing demand. For example, new operations may create jobs directly (e.g., operation and maintenance) and indirectly (e.g., construction and trucking services). Sneeringer and Hertz (2013) estimate that each additional 1,000 head hogs at large-scale operations generates 0.57 jobs on those operations and 0.59 non-farm jobs in the local county. If employment opportunities rise, nearby population may change through in-migration or changes in the composition of nearby residents

2.3. Federal and Iowa regulation of CAFOs and implications for local externalities

At the federal level, CAFOs are currently designated as a point-source polluter and regulated under the EPA Clean Water Act (CWA) pertaining to their water pollution control. The EPA designates a livestock operation as an animal feeding operation (AFO) if animals are confined for at least 45 days in a year where during the normal growing season there are no crops, vegetation, forage growth, or post-harvest residues sustained in the facility, and it is further categorized as a CAFO if it houses more than 1,000 animal units (AU). Historically, the CWA required CAFOs discharging wastewater into waterbodies to obtain the National Pollutant Discharge Elimination System (NPDES) permits. Less focus was on the manure management to prevent runoffs onsite or on nearby fields. In 2003, the agency updated the CAFO rules, expanding and clarifying the existing regulations by changing permitting expectations. First, "duty-to-apply" required all CAFOs to obtain NPDES permits regardless of their discharge intent; furthermore, all CAFOs were required to develop the comprehensive nutrient management plans (CNMPs) that would specify how manure will be stored and disposed appropriately.

While EPA has the ultimate regulatory authority, it often devolves enforcement to state agencies, so long as state-level regulations are at least as stringent as the federal ones. Some states issue their own state-level permits in replacement of the NPDES permits. For Iowa, the Department of Natural Resources (DNR) implements the state CAFO rules, where majority of the CAFOs in the state need both the construction permit and manure management plan to build and operate a CAFO, rather than the federal permit. Out of around 4,000 CAFOs in Iowa, only 160 of them need a NPDES. In this study, we define all CAFOs as operations that are above 1,000 AU, regardless of whether they are regulated under the states issued permits or the NPDES permits.

There is a wide variation in implementation and enforcement of CAFO rules across states (GAO 2003). In Iowa, no CAFOs are allowed to discharge into nearby riverways – CAFOs must follow their approved manure management plans to land apply manure in ways that will not pollute nearby waterbodies. For example, CAFOs are prohibited from applying excessive amounts of manure that is above the agronomically friendly level, which leads to surface runoffs. While the structure of the NMP rule began in Iowa as early as 1985, the CWAA mandated the modern intensity and the specific federal requirement to use NMP s to prevent land-application runoff. This means that CAFOs would have to secure enough crop fields for land application, either through contracting with farmers, or owning enough fields themselves. Animal wastes, especially liquid manure, is heavy and costly to haul. Ali et al. (2012) shows that hog and cattle manure tend to be shipped only a few miles off farm. For these reasons, there may also be incentives for CAFOs to secure cropland just nearby the facilities for regulatory compliance, and on-site containment and local land application would concentrate manure locally. Consequently, while the regulations abated downstream surface water disamenities (Chen et al., 2025), they may have intensified localized air quality and odor disamenities in the immediate vicinity of the facilities.

As part of the regulations, most Iowa CAFOs also need to have an approved Master Matrix, a scoring system used to evaluate the potential impacts of a proposed CAFO on the environment and local communities. The proposed site is approved if it scores at least 50% of available points and 25% for each of the three subcategories. The evaluation of a CAFO's environmental and community impacts is determined by its proposed location (e.g., distance from water sources or commercial facilities), facility design (e.g., covered liquid manure storage structures), and size.

3. Data

3.1 House transactions and attributes

We use CoreLogic Owner Transfer data and Historical Property data for the state of Iowa, covering the universe of Iowa housing transactions. The Historical Property data include detailed housing attributes at the time of property sale, while the Owner Transfer data records

transaction-level information, including sale date and sale price. We link transactions from the Owner Transfer file to housing attributes in the Historical Property file by matching each sale to the same property id and the closest tax assessment year. We then restrict the sample to arm's-length transactions and exclude non-market sales, investor purchases, inter-family transfers, foreclosures, and short sales. We further require key housing attributes to be non-missing and apply data cleaning filters: total living area, building area, and land area must be at least 500 square feet (with total living area no more than 10,000 square feet); the number of bedrooms and bathrooms must each be no more than 10; home age must be greater than −2; and sale prices must fall between $10,000 and $2,000,000. After applying these cleaning filters, the final dataset contains 668,589 cleaned housing transaction observations from 1993 to 2023. Figure 1 shows house price movements over time in Iowa and the nine largest Iowa metropolitan areas. As can be seen from Figure 1, house prices generally moved in tandem across Iowa locations and reflect national housing market trends.

3.2 CAFOs and neighborhoods

We use administrative data from the Iowa DNR that includes CAFO size, year of establishment and location. We construct a facility-by-year CAFO panel covering our study period from 1993 to 2023. Using DNR CAFO latitude/longitude location data and CoreLogic Property transactions address data, we identify house transactions within a 5-mile radius of past, current or future CAFO openings. To control for CAFO neighborhood heterogeneity, we use Census tract–level data drawn from the 1990 and 2000 Decennial Census and the American Community Survey (ACS) 5-years for 2009–2023 via IPUMS. These data include tract-level population counts, educational attainment and employment levels.[3] Using geographic crosswalks produced by IPUMS, we harmonize these demographic information to 2010 census tract boundaries.[4] To examine if CAFO impacts vary by wind intensity, we use historical data from the Climatology Lab's gridMET product, which covers contiguous US with 4-km-resolution during our study period. To examine the neighborhood impacts from CAFO establishment, we use the Gridded Environmental Impacts Frame (EIF) annual data, US Census Bureau, which provides granular population counts and allow tabulations of age and income decile.[5] Finally, to explore the relationship between the CWA amendments and local disamenity concentration, we study CAFO establishment effects on nearby corn acreage using the Iowa Cropland Data Layer (CDL), a high-resolution, crop-specific land cover dataset produced annually by the USDA National Agricultural Statistics Service (NASS). Wind intensity, EIF and CDL data are described in detail in Appendix A2.

4. Empirical approach

[3] https://data2.nhgis.org/main

[4] We use 1990 census tract characteristics for the tract characteristics from 1990 to 1999, 2000 census tract characteristics for tract characteristics from 2000 to 2008, and ACS characteristics are used for tract characteristics after 2009.

[5] https://www.census.gov/data/experimental-data-products/gridded-eif.html

4.1 Methodology and stack construction

We use a stacked difference-in-differences DiD design with staggered treatment timing to examine house price changes (and other outcomes) within a 5 mile radius of a CAFO at the time of establishment. We exploit spatial-temporal variation in the treated by comparing micro-regions within fixed spatial radii to control pools comprised of future-treated and already-treated locations aligned in relative event time, following the spatiotemporal method of Dooley and Gallagher (2024). By restricting controls to geographic areas that undergo treatment in surrounding years, the design lessens unobserved location-level heterogeneity concerns while avoiding dynamic treatment contamination within the focal event window.

To build the stacked dataset, we treat each CAFO facility as a separate cohort, define its opening year as the event year, and keep observations within a symmetric event window from three years before to three years after the event (t = −3,…,3). The control group is drawn from all other facilities, for which we retain the same ±3-year window and align observations to the treated cohort's event time. To prevent contamination from control facilities' opening events, we require that a control facility's opening year lies outside the treated cohort's event window. Specifically, for a given treatment cohort opening in calendar year *t*, eligible control facilities in stack *t* must satisfy two strict temporal conditions. First, for clean window status, future-treated controls must receive treatment at least 4 years after the focal treatment year. This is because the focal event window spans $[t-3, t+3]$ and candidate future controls cannot be used if they experienced an event within the focal window. Always-treated controls are included if received treatment occurred at least 4 years prior to the focal treatment year. This helps ensure that already-treated units have stabilized dynamics throughout the focal stack. Second, we use a temporal proximity restriction ($\leq$ 13-year boundary) to preserve common-trend plausibility and avoid comparing units across distance time periods. In other words, the treatment year for both future-treated and already-treated controls must fall within 13 years of the focal treatment year. Combining the clean window and proximity rules restricts the eligible set of controls to two symmetric 4-year control cohorts for focal event at time *t*:

$$E_{\text{control}} \in [t-13, t-4] \cup [t+4, t+13]$$

To minimize localized spillovers and spatial correlation in micro-shocks, we enforce a 10-mile minimum separation distance between focal treated facilities and candidate control facilities. This guarantees that the 5-mile buffers of treated and control units do not overlap.

Figure 2 summarizes the cohort construction and event-time alignment used in the stacked CAFO dataset. The top timeline shows the opening years for different CAFOs. The bottom part illustrates two examples, using CAFO *c* and CAFO *d* as two treated facilities: for each treated facility, observations from eligible control facilities are aligned to a common event window around the treated opening year, and controls are classified into two groups. Facilities opened before the event window serve as always-treated controls (e.g., CAFO *b* relative to treated

CAFO *c*), while facilities opened after the event window serve as not-yet-treated controls (e.g., CAFO *e* relative to treated CAFO *c*). The figure also illustrates the temporal filtering rules: potential controls whose opening years are too close to the treated event are excluded to avoid overlapping event windows (e.g., CAFO *d* relative to treated CAFO *c*), and only controls whose opening years fall within the 13-year rolling window are retained (for example, CAFO *a* may be an eligible control for treated CAFO *c* but not for treated CAFO *d*). These restrictions are designed to maintain cohort-level comparability across treated and control facilities.

After merging the stacked CAFO dataset with the cleaned house transactions, the treated house transactions are defined as transactions within a 5-mile radius of a newly established CAFO. Control observations are house transactions within 5 miles of CAFO that is either "always treated" (opened at least 4 years before the event) or "future treated" (opened at least 4 years after the event). To ensure that each cohort has sufficient treated transactions in each event year, we calculate treated transactions at the cohort level and keep only cohorts in the top quartile (above the 75th percentile) of treated transaction counts. We also restrict the size of the control group at the cohort level to avoid cohorts with an excessively large number of control facilities. Using a fixed random seed, we randomly draw 10 control CAFOs for each cohort, creating a stacked dataset with at most 10 control facilities per cohort (within the same county as the treated). Symmetrically, for cohorts with fewer than three eligible control CAFOs, we supplement the control set by randomly drawing additional eligible control facilities from counties adjacent to the treated CAFO's county until at least three controls are reached. As a result, each cohort includes between three and ten control CAFOs, reducing variation in control-group size across cohorts and limiting its influence on the estimated effects.

Our final stacked dataset includes 1013 CAFO opening events with over 1.2 million housing transactions from 1993 to 2023, for which we can construct the cohorts that meet both the spatial and temporal requirements. Figure 3 shows the distribution of (treated) CAFO openings in the analysis sample by establishment year. Each bar represents the number of treated CAFOs entering the stacked sample in any given year. We see that, in the analysis sample, the treated are more heavily skewed toward later years of the study. Referring to Figure 4, we see that there is striking geographic diversity in the spatial distribution of CAFOs, cohorts, and house transactions in Iowa. Outside of the souther border, CAFO openings and house transactions in occur across areas of the state. Appendix Figure A1 depicts demographics over time of locations where CAFOs open. Many demographics are stable with respect to CAFO openings at different points in time, such as homeownership, education, population density and total number of households. Marked differences occur for the household age distribution (34 to 64), when comparing earlier versus post-2010 CAFO openings.

Table 1 reports summary statistics for the stacked analysis sample for all transactions and by treatment status. The final stacked sample contains 1,206,614 housing transaction observations,

including 187,909 treated observations and 1,018,705 control observations.[6] Real house prices are similar across treated and control observations on average. Housing and tract characteristics are also broadly comparable, although treated observations tend to be located in somewhat newer, denser, and slightly lower-income tracts. These patterns suggest that the sample construction yields treated and control groups that are broadly similar along observable dimensions while still allowing meaningful differences in local conditions. Table 2 reports balance in housing attributes by treatment status. Appendix Table 1 reports the number of transactions per event year by cohort and group.

4.2 Baseline model

For transaction *i* in calendar year *t* that appears in cohort *c*, we estimate:

$$ln(y_{ict}) = \beta(Treated_{ic} \times Post_{ct}) + X'_{it}\theta + Z'_{igt}\pi + \mu_g + \lambda_t + \alpha_{ic} + \epsilon_{ict} \quad (1)$$

where, $y_{ict}$is the outcome of interest within 5 miles of a treated/control CAFO. $Treat_{ic}$ is an indicator that equals 1 for transaction *i* in cohort *c* that is exposed to an opening treatment, and 0 otherwise. $Post_{ct}$ is an indicator that equals 1 after an opening in cohort *c*, and 0 otherwise. X_{it} is a vector of housing attributes, and Z_{igt} is a vector of time-varying census-tract controls for tract g. We include census-tract fixed effects μ_g to absorb time-invariant tract attributes and sale-year fixed effects λ_t to absorb common shocks to the housing market and broader macroeconomic conditions. α_{ic} denotes CAFO-by-cohort fixed effects, which absorb all time-invariant differences across CAFOs within each cohort. The variation comes from differential changes in outcomes at treated versus control transactions after the cohort's CAFO opening. The coefficient of interest, β, captures the average change in outcomes for transactions near newly opened CAFOs relative to transactions near comparison sites within the same county that are either not yet treated (in the future) or already treated,. The identifying assumption is that, in the absence of treatment, two areas within the same county that experience an opening at different times would have followed similar trends. We further examine calendar-year by CAFO fixed effects to allow macroeconomic, agricultural, or environmental shocks to vary within stacks. We report robust standard errors clustered at the cohort level, allowing for arbitrary correlation in residuals within each stacked cohort over event time. We consider specifications that examine if the disamenity intensified by wind (i.e., Herriges et al., 2005). We estimate a specification of equation (1) that allows treatment effect to vary by wind intensity.

To test whether the CWAA intensified the impact of CAFO establishment on house prices, by increasing localized manure intensity, we conduct three exercises. First, we look for indirect evidence that the CWAA passage altered the manure disamenity. We check for expanded corn

[6] Our cleaned CoreLogic sample includes 668,589 transactions; the stacked DiD includes over 1.2 million transactions, which means that some transactions appear in more than one focal cohort. We account for CAFO locations appearing in more than one stack using with cohort-by-calendar year and cohort-by-CAFO fixed effects.

acreage relative to soybeans. An increase in corn production surrounding a CAFO post-establishment—offset by a corresponding decline in soybean acreage—is consistent with intensified localized land application of manure.[7] Using Equation (1), we estimate the impact of CAFO establishment on two-year continuous corn acreage measured within 1-, 3-, and 5-mile buffers around each CAFO. Second, we directly examine the CWAA passage on house prices by defining a post-2003 cohort dummy variable equaling one for cohorts whose treated CAFO opening occurs after 2003 and zero for cohorts whose treated opening occurs before 2003. We exclude cohorts with treated openings in 2003 and drop observations from post-2003 cohorts with sale dates prior to 2003. We then split the sample using the post-2003 indicator and estimate equation (1) separately in the two subsets, comparing the estimated treatment effect β across 2003. Third, we take a different approach to examine the CWAA passage on house prices. We estimate a stacked DiD version wherein the treated group are houses near CAFOs operating throughout 2000–2006 (established on or before 2000, hence directly subject to the 2003 manure-disposal restrictions); the control group are houses near future CAFO sites (established 2013–2019) whose 2000–2006 sales would not be impacted by the CWAA.

We examine additional outcome measures. We estimate the baseline specification in equation (1) using the same final stacked CAFO dataset as the observation unit, but replace the outcome variable, $ln(y_{ict})$, with measures constructed from the Gridded EIF data. These outcomes include log total population within 5 miles, age-group shares of total population, and log population counts for income groups (top 20%, top 40%, middle 20%, and bottom 40%) within the 5-mile buffer. Each variable is measured using a 5-mile buffer around treated and control CAFOs within the focal event window. This setup allows us to compare demographic outcomes in treated areas with those in areas treated versus control locations, thus testing whether CAFO openings change local population levels, age composition, or the income distribution.

4.3 Dynamic effects

We replace the single interaction term $Treated_{ic} \times Event\ year_{ct}$ with interactions between $Treated_{ic}$ and event year dummies to study the dynamic effects of CAFO openings across event time and to assess pre-trends under our stacked DID design. We estimate the following event-study model:

$$ln(y_{ict}) = \Sigma^{3}{}_{t=-3}\beta_t(Treated_{ic} \times Event\ year_{ct}) + X'_{it}\theta + Z'_{igt}\pi + \mu_g + \lambda_t + \alpha_{ic} + \varepsilon_{ict} \quad (2)$$

where $Event\ year_{ct}$ is a dummy variable for each event year relative to the opening (with t=0 denoting the CAFO opening year, benchmark year t=-1). The event-study specification yields a separate coefficient β_t for each event time. We expect the pre-opening coefficients (t < 0) to be small and statistically indistinguishable from zero, which would indicate no pre-trends. We then

[7] Corn demonstrates significantly greater nitrogen uptake and manure nutrient utilization efficiency than soybeans because it is a non-leguminous grass with an absolute requirement for soil-applied nitrogen. (Singer et al., 2004).

examine how β_t evolves for t ≥ 0 to characterize the timing, magnitude, and persistence of the impacts of CAFO openings on the outcome variables.

5. Empirical results (preliminary, subject to change)

5.1 House price effects

We first examine average house price trends. Figure 5 plots the mean real house price path for treated and control groups over event time in the stacked CAFO dataset. We see the importance of controls for attributes. Table 3 reports the baseline difference-in-differences results. Overall, CAFO openings are associated with a stable and statistically significant decline in nearby housing prices. The coefficient on the key interaction term, *Treated* × *Post*, is significantly negative in all specifications, with point estimates ranging from about −0.018 to −0.020. These estimates imply that, after a CAFO opens, housing prices in treated areas fall by roughly 1.8% to 2.0% relative to the control group. Importantly, the sign, magnitude, and significance of this coefficient remain very similar as the model sequentially adds housing attributes, census tract fixed effects and tract-level controls, which supports the robustness of the baseline finding. In contrast, the coefficient on *Post* alone is not statistically significant across columns, suggesting that common time shocks do not explain the relative price decline in treated locations.

Table 4 and Appendix Tables 2-5 report baseline results controlling for multiple downwind exposure measures. Across specifications, the coefficient on *Treated* × *Post* remains negative and statistically significant. The estimates are stable, ranging roughly from −0.017 to −0.024, regardless of whether we use direction-sector indicators in Table 4, based on near-table bearings (NW or SE) or continuous measures based on 2-month or 3-month prevailing winds (appendix Tables 2-5). This indicates that the negative capitalization effect of CAFO openings is robust to controlling for alternative definitions of wind exposure.

Some wind-exposure variables themselves are occasionally significant—particularly in Appendix Tables2-5, where several 2-month or 3-month wind measures are negatively correlated with housing prices. However, the key interaction term, *Treated* × *Post* × *wind exposure*, is not statistically significant in most specifications. The sector-based interactions in Table 5 show a similar pattern: a few simple models yield weak significance, but these results disappear once richer controls are included. Overall, while the negative impact of CAFO openings is robust, we find little evidence that the effect is systematically larger for houses classified as downwind.

The absence of robust downwind heterogeneity suggests that the negative effect is not confined to a narrow downwind corridor. This contrasts with prior studies, which report larger price impacts for homes located downwind of CAFOs (Herringes et al., 2005; Isakson and Ecker, 2008). Those studies focus on earlier periods (1992–2002 and 2000–2004) and on one or a small number of Iowa counties. This raises the possibility that broader changes in environmental regulation during our study period may have altered the pattern of impacts. In particular, the

2003 amendments to the Clean Water Act requires all animal operations to obtain discharge permits and reduce nonpoint runoff from livestock operations through comprehensive nutrient management plans. Increased regulatory stringency could have changed how CAFO waste is managed, which in turn may have contributed to a more generalized negative capitalization effect following CAFO openings.

Table 5 reports the dynamic regression results, which we use to test the parallel-trends assumption and to show the timing of impacts after a CAFO opening. The pre-treatment coefficients for *Treated* × *Event year* t = -3 and t = -2 are statistically insignificant and close to zero, indicating no clear differential trend between treated and control areas prior to the opening. This pattern supports the parallel-trends assumption. After the opening, the negative effect emerges and becomes larger over time. At t=0, the estimate is already negative and is marginally significant in some specifications. By t=1, the implied price decline increases to roughly 1.9%–2.0%. At t=2 and t=3, the coefficients are approximately −0.022 to −0.029 and are statistically significant. Taken together, these results suggest that the negative capitalization effect of CAFO openings is not fully realized immediately but instead strengthens gradually over the subsequent years.

Figure 6, corresponding to Table 5 column (4), provides a figure summary of the event-study dynamics, normalize the coefficient at t =-1 to zero. Before treatment, the estimates fluctuate around zero, and the 95% confidence intervals for t=-3 and t=-2 include zero, showing no clear evidence of pre-trends. After the CAFO opening, the coefficients shift downward and remain negative. The estimate turns negative at t=0 and becomes larger in magnitude from t=1 to t=3. The point estimates at t=2 and t=3 are clearly below the pre-treatment level, indicating that the negative effect of CAFO openings on nearby housing prices is delayed and accumulates over time. Overall, the graphical evidence further supports the conclusion that CAFO openings lead to price declines in surrounding areas.[8]

To consider CWAA impacts, we split treated CAFO openings into pre-2003 and post-2003 cohorts (excluding 2003 itself) and estimate equation (1) separately in the two subsamples. Table 6 reports the results. The separate regression estimates suggest some heterogeneity. For the pre-2003 cohorts (1996–2002), the *Treated* × *Post* coefficients are negative in all columns, ranging from −0.017 to −0.029, but they are not statistically significant. In contrast, for the post-2003 cohorts (2004–2020), the *Treated* × *Post* coefficients are tightly clustered between −0.017 and −0.019 and are statistically significant at least at the 10% level in all five specifications. These estimates indicate that after 2003, CAFO openings remain significantly associated with lower nearby housing prices. Overall, the separate regressions do not show a clear pattern of a weaker

[8] In Appendix Table 6 and Appendix Figure A3, we drop the always-treated controls and re-estimate both the baseline and dynamic regressions, and we reproduce the event-study figure. The baseline results continue to indicate a negative effect of CAFO openings on nearby housing prices. The dynamic estimates and the event-study figure still show a post-opening decline in prices that grows over the following years. Overall, results using only not-yet-treated controls are consistent in direction with the main findings and support the conclusion that CAFO openings depress nearby housing prices.

post-2003 effect but show more precise and more consistently negative significant after 2003. At the same time, this pattern must be interpreted cautiously. The pre-2003 subsample is much smaller—about 43,000 observations—while the post-2003 subsample contains more than 1.14 million observations. The limited size of the pre-2003 sample reduces statistical power, and larger standard errors may obscure meaningful effects.

We next consider the following exercise with respect to the CWAA. Using our current stack, we select a subsample to evaluate the impact of the 2003 CWAA on property values across a 2000–2006 observation window. The treated group consists of properties near CAFOs that were operational during 2000–2006 and directly subject to the 2003 policy change. The control group comprises properties near future CAFO sites established after the study period (between 2013 and 2019), meaning that during the 2000–2006 window, these control properties were "not yet treated"—unaffected by nearby active CAFOs, the 2003 regulations, or the Great Financial Crisis. Referring to Table 7, we see a stable and statistically significant discount to nearby house prices with the CWAA is enacted. The coefficient on the key interaction term, *Treated* × *Post*, is statistically significant and negative in all specifications, with point estimates ranging from about −0.060 to −0.079. These are suggestive that the CWAA passage caused housing prices to fall by roughly 6% to 7.9% relative to the control group.

The observed effect in Table 7 is consistent with an increased intensity of the disamenity. We therefore consider evidence of more localized manure application. Nearby farms may generate localized but widespread impacts that are not confined to a narrow downwind corridor, which could help explain the weak downwind heterogeneity. Because transporting manure is costly, CAFO operators may rely on nearby farmland to absorb nutrients through agreements with local farmers. If so, CAFO openings could increase nutrient use intensity and induce changes in local cropping patterns. Although we do not directly observe manure production or land application, we can use corn acreage—especially two-year continuous corn acreage—as an indirect proxy, because corn typically requires higher nutrient inputs than soybeans. We therefore estimate equation (1) using continuous corn acreage within 1-, 3-, and 5-mile buffers around CAFOs as outcomes. In this way, we test whether CAFO openings are associated with changes in local cropping patterns and use post-opening land-use adjustments to provide indirect evidence of localized effects.

Tables 8-10 show a clear spatial pattern. In the 1-mile buffer, the Treated × Post coefficient is roughly 0.101–0.120 and is significant at the 1% level in all specifications. In the 3-mile buffer, the estimates remain positive and are significant in most cases, around 0.024–0.032. In the 5-mile buffer, the effect is substantially weaker and is only marginally significant in the most restrictive specification. These land use results indicate that CAFO openings are associated with highly localized land-use adjustments. In particular, within 1 mile of a facility, nearby farmland is more likely to shift toward continuous corn. This pattern is consistent with the idea that CAFO openings increase the local supply of nutrients and expand the role of nearby farmland in

managing CAFO-related waste, leading farmers to adjust land use and crop choice to increase nutrient demand. Such broader local adjustment may help explain the earlier wind results and the post-2003 comparisons. If CAFO-related disamenities increasingly operate through dispersed changes in manure management and land use across the surrounding landscape, the negative capitalization effect need not be concentrated only in the downwind direction. Similarly, even if the 2003 Clean Water Act amendment tightened discharge requirements for water and runoff, it may not reduce the overall disamenity experienced by nearby residents; instead, the amendment may have altered waste management in ways that shift impacts toward local land application and related land-use changes, making them more spatially diffuse.

5.2 Other economic outcomes

Because CAFOs appear to generate highly localized impacts, we next assess the magnitude of these effects from a socioeconomic perspective. Using the Gridded EIF data, we construct measures of total population, population by age group, and population by income decile within a 5-mile radius of each CAFO for each event year. We then use these variables as outcomes in equation (1) to estimate how CAFO openings affect nearby population levels, demographic composition, and the local income distribution.

Tables 11-15 show that the localized impacts of CAFO openings extend beyond housing prices and are accompanied by changes in population size and composition. Table 11 indicates that within the 5-mile band, the *Treated* × *Post* coefficient is positive in all five specifications, with estimates around 0.005–0.006, and it is significant at the 1% level. This implies that total population within 5 miles does not decline after a CAFO opens; instead, it increases slightly by about 0.5%–0.6%. Taken together with the price results, this pattern suggests that the negative capitalization effect does not necessarily reflect overall population loss, but may instead operate through changes in who lives nearby.

The age-composition results in Table 12 support this interpretation. The *Treated* × *Post* coefficient for the under-18 population is positive and significant in all five specifications, around 0.009–0.011. The coefficient for the 18–65 population is also consistently positive, approximately 0.005–0.007, and statistically significant in every specification. In contrast, the Treated × Post coefficient for the 65-and-over population is close to zero and not statistically significant across columns. Overall, these results indicate that the total population increase within 5 miles is driven mainly by 1.1% growth among children and 0.6% growth among working-age residents, with no detectable change among older residents. Put differently, CAFO openings are not followed by broad population loss. Instead, they coincide with growth among younger and labor-force-age groups.

Table 13 shows that compositional adjustment also appears in the income distribution. For the highest-income quintile, the *Treated* × *Post* coefficient is close to zero and not statistically significant across specifications, suggesting little change among the highest-income residents.

The coefficient for the fourth-income quintile is positive but small and also not significant. In contrast, the coefficients for the middle-income quintile are significantly positive (about 0.008) in all specifications. The second-income quintile also has a positive coefficient, roughly 0.007, and is statistically significant in most columns. For the lowest-income quintile, the point estimates are again positive (about 0.005–0.006) but not statistically significant. Taken together, these results imply that CAFO openings are not followed by broad population out-migration within 5 miles. Instead, they are associated with modest population growth and a shift in local composition toward younger and relatively lower- and middle-income groups, rather than the highest-income group. This pattern is consistent with the observed decline in housing prices and suggests that CAFO-related disamenities may be reflected partly through changes in the socioeconomic composition of nearby communities.

6. Conclusion

This paper investigates how the establishment of industrial agriculture in the form of CAFOs affects local real estate values and socioeconomic conditions, while specifically testing how the 2003 Clean Water Act Amendments (CWAA) intensified these localized disamenities. The 2003 CWAA aimed to reduce water pollution by imposing strict nutrient-management rules. We find evidence that the regulatory structure of the CWAA inadvertently forced operators to spread manure over larger tracts of nearby land to comply with nitrogen and phosphorus limits. To evaluate these dynamics, we construct a comprehensive panel spanning 1993 to 2023 that merges facility records, satellite land-cover data, Census demographics, and over 1.2 million cleaned CoreLogic residential property transactions.

Using a stacked difference-in-differences with staggered event timing, the empirical framework compares housing transactions within 5 miles of a new establishment against control properties near "future-treated" or "always-treated" facilities within a rolling 13-year window. This stacked methodology avoids dynamic treatment contamination and controls for unobserved spatial heterogeneity, relying on the identifying assumption that nearby residential areas would have followed parallel trends in the absence of a CAFO opening.

The empirical findings reveal that CAFO openings cause a persistent, statistically significant 1.8% to 2.0% decline in nearby housing prices, an effect that accumulates over time rather than occurring instantaneously. Crucially, the authors find that the regulatory shift in 2003 significantly amplified this price penalty: evaluating operational facilities subject to the 2003 CWAA rules against future CAFO sites yields a dramatic housing price discount of 6.0% to 7.9%. Contrary to earlier literature, the authors find little evidence that this price penalty is confined to downwind properties, suggesting that the disamenity has become spatially diffuse. The mechanism behind this broader spatial impact is directly linked to local land application of manure: following a CAFO establishment, nearby land experiences a statistically significant shift

toward continuous corn acreage—a high-nutrient crop—to absorb the spread manure. It does not, however, absorb the odor. Finally, evaluating demographic outcomes reveals that CAFO openings do not cause overall population flight, but instead trigger a shift in local neighborhood composition. Nearby areas experience a modest total population growth of 0.5% to 0.6% that is primarily driven by an influx of families with children and lower- to middle-income households, suggesting that CAFO-related environmental externalities drive down housing costs and reshape local socioeconomic demographics.

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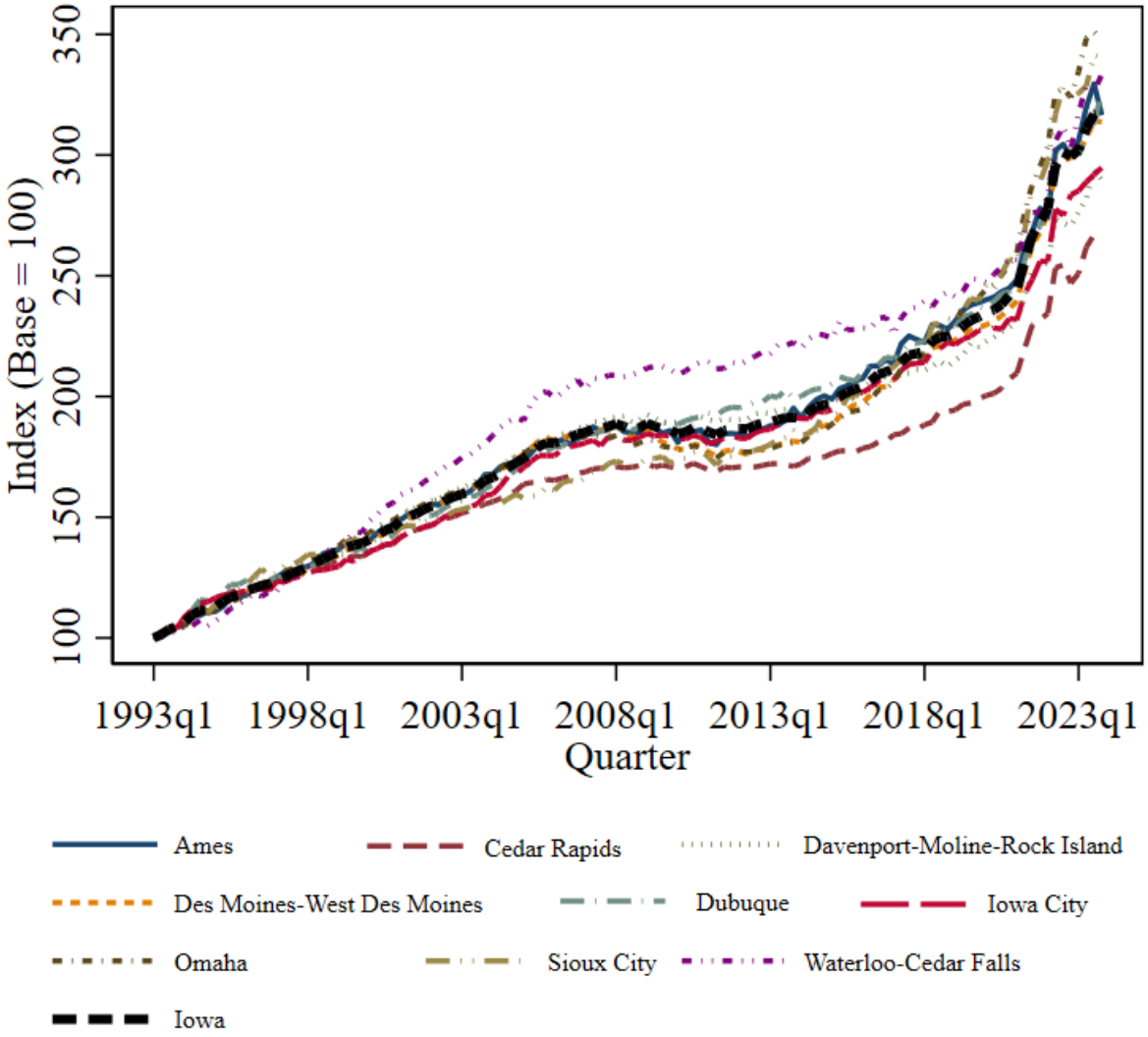
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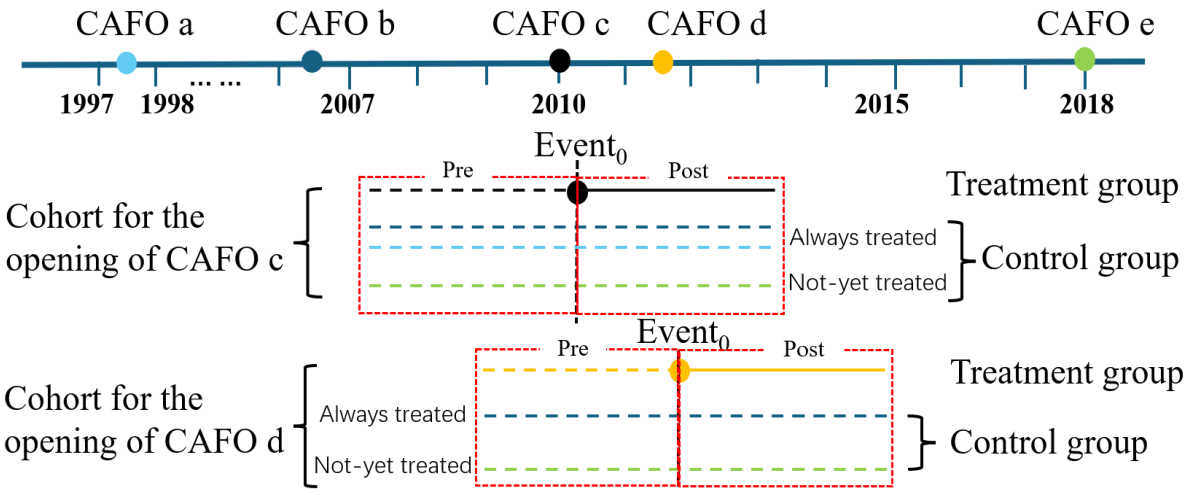
Figures and Tables

Figure 1 Housing price movements across Iowa location.



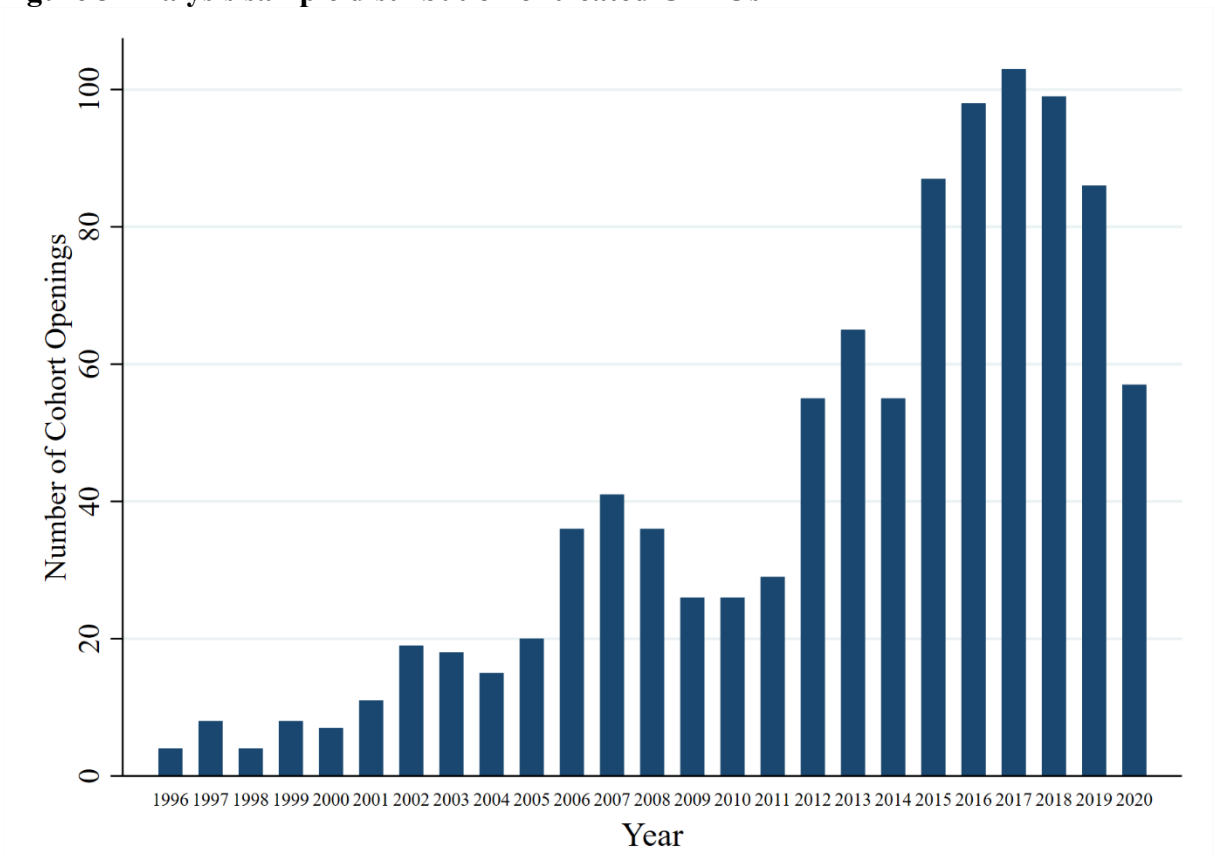
Notes: This figure plots the evolution of the FHFA All-Transactions House Price Index for Iowa metropolitan statistical areas (MSAs) from 1993q1 to 2023q4. Each MSA series is rebased to 100 in 1993q1 to facilitate comparisons of relative house price growth over time. The thick black dashed line represents the statewide Iowa HPI, while the colored lines represent individual Iowa MSAs. Source: FHFA House Price Index (All-Transactions), Quarterly, not seasonally adjusted. MSA series rebased to 100 at 1993q1.

Figure 2 Temporal structure of CAFO stack



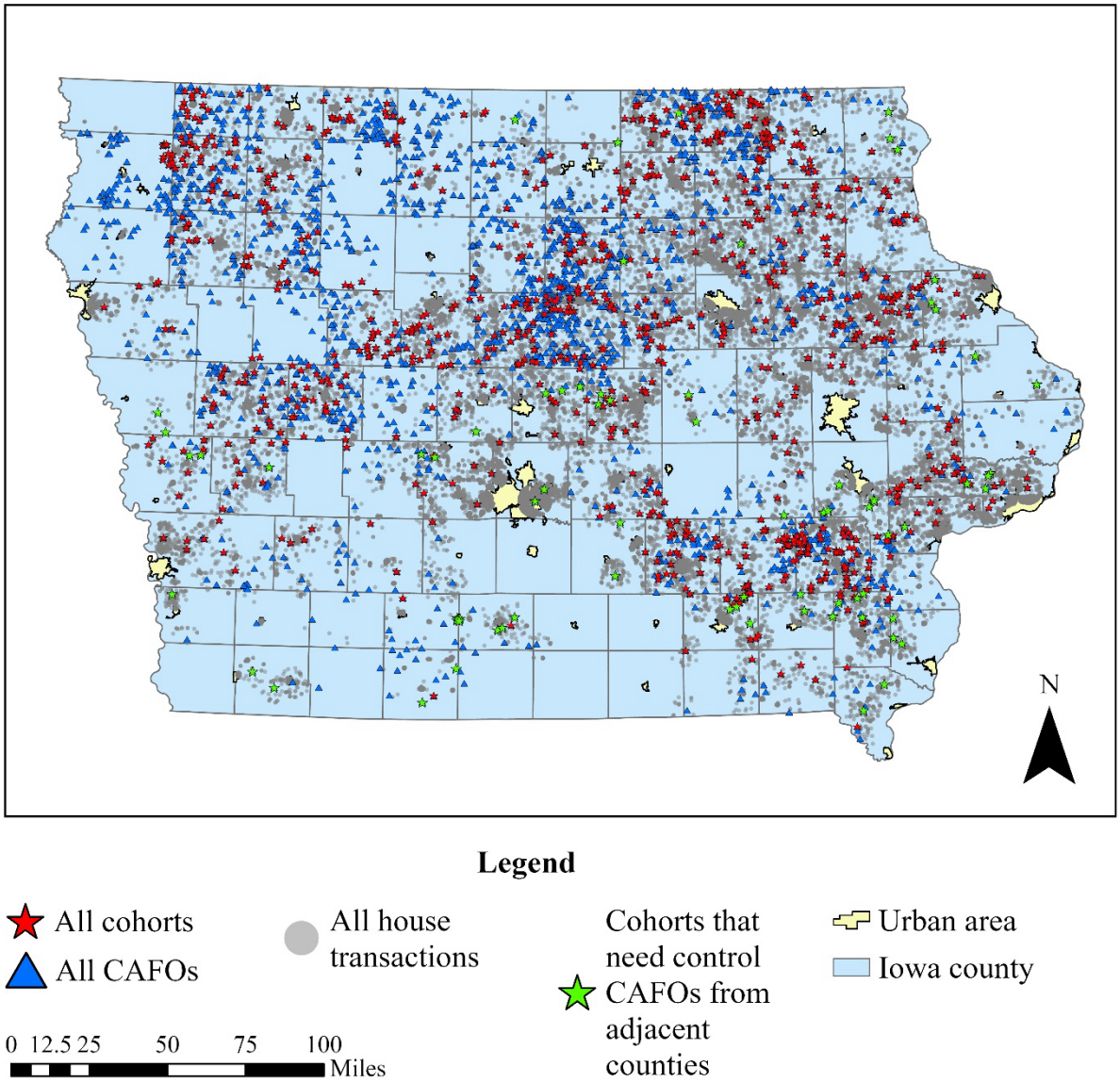
Notes: This figure illustrates the timing structure of the stacked difference-in-differences design. 1. CAFO a and CAFO b are always treated controls for Cohort CAFO c. CAFO e is not-yet treated control for Cohort CAFO c; 2. CAFO b is always treated control for Cohort CAFO d. CAFO e is not-yet treated control for Cohort CAFO d; 3. We do not use CAFO d for Cohort CAFO c because its opening is within 3 years of the opening of CAFO c. We use CAFO a because its opening is within 13 years rolling window of the opening of CAFO c; 4. We also do not use CAFO c for Cohort CAFO d because its opening is within 3 years of the opening of CAFO d. We do not use CAFO a because its opening is beyond 13 years rolling window of the opening of CAFO d.

Figure 3 Analysis sample distribution of treated CAFOs



Notes: This bar figure shows the distribution of treated CAFO cohort openings in the analysis sample by establishment year. Each bar reports the number of treated CAFOs entering the stacked sample in a given year. The number of cohort openings is relatively small in the late 1990s and early 2000s, rises gradually after the mid-2000s, and becomes much larger after 2012, peaking in the late 2010s. This pattern indicates that the analysis sample is more heavily concentrated in later years of the study period.

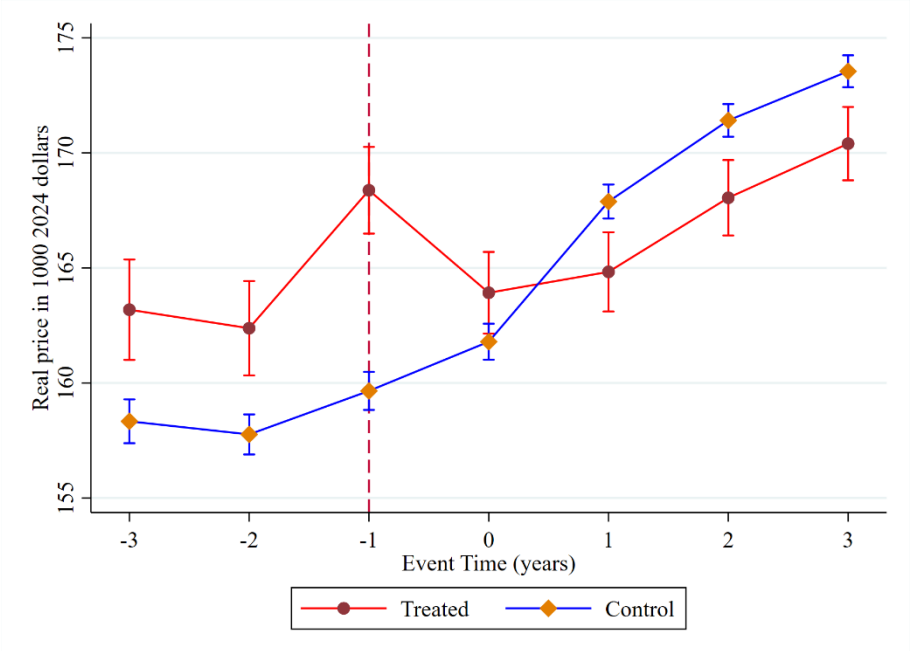
Figure 4 Analysis sample spatial distribution of CAFOs and house transactions



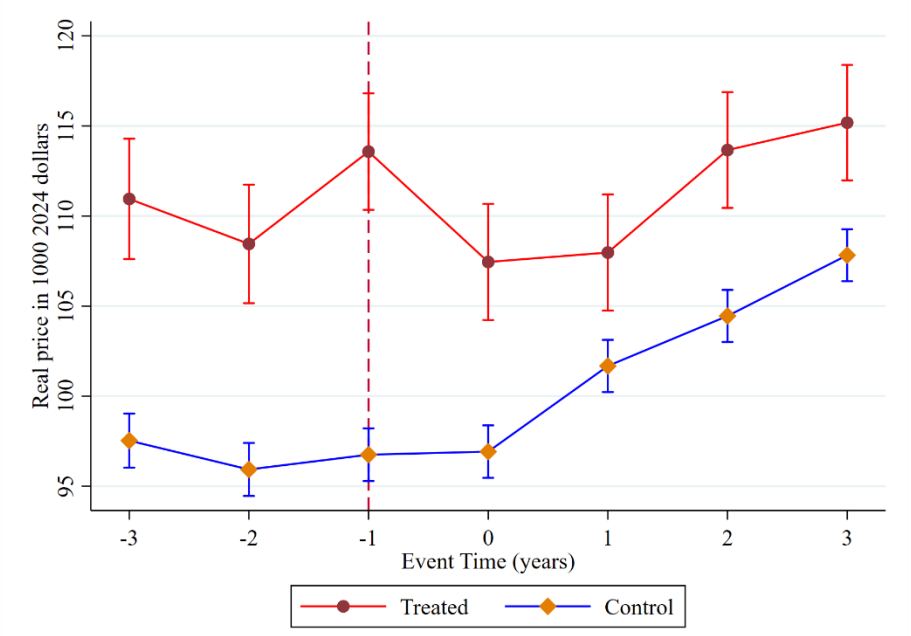
Notes: This figure shows the spatial distribution of CAFOs, cohorts, and house transactions in Iowa. Red stars denote treated CAFO openings used to define cohorts in the stacked DID analysis, blue triangles denote all CAFOs in the sample, and gray dots denote all house transactions. Green stars indicate treated cohorts that require additional control CAFOs from adjacent counties because the number of eligible control CAFOs within the treated county is less than three. Light yellow polygons mark urban areas, and light blue polygons mark Iowa counties.

Figure 5 Pre-trend figures

Panel A. Dynamic Effects by Group without Fixed Effects

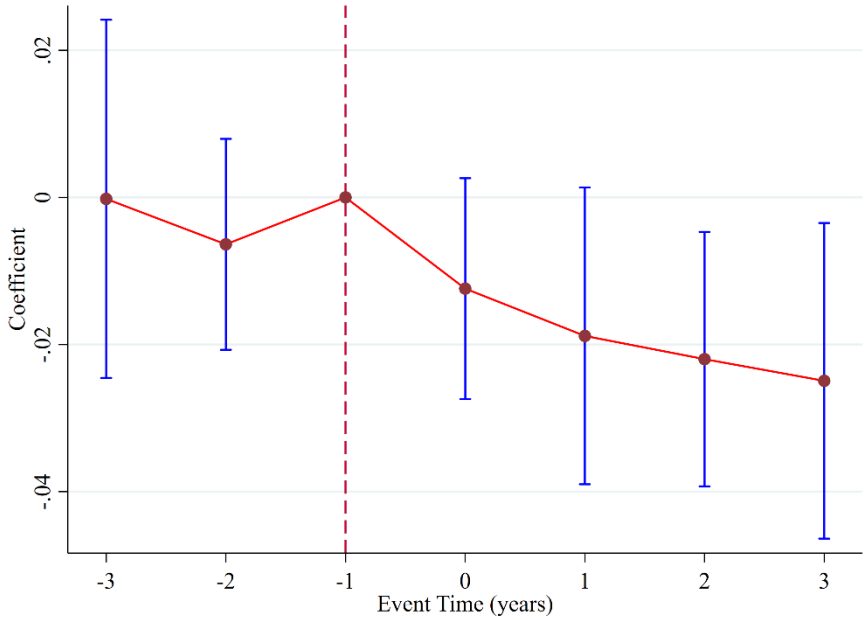


Panel B. Dynamic Effects by Group with House Controls



Notes: This figure plots the mean real house price path for treated (red) and control (blue) groups over event time in the stacked CAFO dataset. The horizontal axis reports event time in years, where $t = -1$ is the year immediately before the treated CAFO opening and the dashed vertical line marks the treatment timing. The vertical axis reports real sale prices in 1,000 2024 dollars. Points show group-specific estimated mean prices in each event year, and the bars indicate 95% confidence intervals. **Panel A** presents estimates without fixed effects or additional controls. **Panel B** adds housing attribute controls.

Figure 6 Event study figure with census tract characteristics controls



Notes: This figure presents the event-study estimates reported in Table 6. In both panels, the omitted category is event time $t = -1$, so coefficients are normalized relative to the year immediately before the CAFO opening. The vertical bars denote 95% confidence intervals, and the dashed vertical line marks the baseline event year. Panel A corresponds to column (4) and includes census tract-specific linear trends. Panel B corresponds to column (5) and includes census tract characteristics controls.

Table 1 House transactions summary statistics by treatment status

	(1) All transactions		(2) Treated		(3) Control	
VARIABLES	mean	std dev.	mean	std dev.	mean	std dev.
Panel A House prices and DID variables						
Real house prices (1000 real dollars)	165.63	152.21	166.31	150.84	165.51	152.46
Post	0.66	0.47	0.66	0.47	0.66	0.47
Treated	0.16	0.36	1.00	0.00	0.00	0.00
Treated × Post	0.10	0.30	0.66	0.47	0.00	0.00
Panel B Housing attributes						
Number of bedrooms	3.04	0.94	3.02	0.93	3.05	0.94
Number of bathrooms	1.88	1.00	1.88	1.01	1.88	1.00
House age	67.95	39.87	64.17	39.54	68.65	39.89
House age squared in 1000	6.21	5.67	5.68	5.45	6.30	5.71
House sq ft in 10000	0.19	0.10	0.18	0.10	0.19	0.10
Building sq ft in 10000	0.25	0.11	0.25	0.11	0.25	0.11
Land area sq ft in 10000	6.33	30.18	5.14	26.03	6.54	30.89
Fireplace (yes=1)	0.26	0.44	0.28	0.45	0.26	0.44
Panel C Census tract characteristics						
Total population	3805.86	1518.22	3889.79	1519.83	3790.38	1517.42
Total households	1527.83	577.61	1567.20	600.76	1520.56	572.94
Number of homeowners	1528.14	576.80	1568.52	599.00	1520.69	572.31
Total housing units	1677.77	610.06	1713.04	641.85	1671.26	603.79
Owner-occupied housing units (%)	76.06	9.13	75.33	10.20	76.19	8.92
College degree (%)	20.46	8.54	20.63	8.84	20.43	8.48
Age under 18 (%)	24.12	3.37	24.18	3.56	24.11	3.33
Age 18-35 (%)	18.98	4.59	19.85	5.05	18.83	4.48
Age 35-64 (%)	38.61	3.98	38.43	3.94	38.65	3.98
Age 65+ (%)	18.28	4.32	17.54	4.85	18.42	4.20
Minority (incl. Hispanic) (%)	8.08	9.93	8.91	11.34	7.93	9.64
Median household income (10000 real dollars)	7.08	1.54	6.96	1.47	7.10	1.56
Mean household income (10000 real dollars)	8.67	1.84	8.51	1.71	8.70	1.87
Labor force (%)	66.70	5.44	67.33	5.97	66.59	5.33
Employed (%)	64.06	5.61	64.52	6.20	63.97	5.49
Unemployment rate (%)	3.92	2.35	4.11	2.59	3.88	2.30
Poverty rate (%)	10.01	5.01	10.28	5.56	9.96	4.90
Population density (people per sq mile)	441.64	947.51	618.28	1219.75	409.05	884.38
N	1,206,614		187,909		1,018,705	

Notes: The data are CoreLogic universe of house transactions state of Iowa 1993-2023. The census tract characteristics pertain to the decennial Census and ACS in the decade the transaction occurred. Real house prices are measured in thousands of 2024 dollars. Post is an indicator for whether a housing transaction occurs after the opening year of the treated CAFO. Treated is an indicator for whether a housing transaction is located within 5 miles of the treated CAFO. Treated × Post is the interaction between these two indicators. The census tract characteristics pertain to the decennial Census and yearly ACS in which the transaction occurred. The table reports means and standard deviations for all transactions, treated transactions, and control transactions.

Table 2 House transactions balance table at t = -1

	Mean: Control Group	Mean: Treated Group	Diff.	Std. Error	N
Number of bedrooms	3.038	2.989	0.049***	0.006	155,413
Number of bathrooms	1.810	1.832	-0.022***	0.007	155,413
House age	67.775	61.966	5.809***	0.275	155,413
House age squared in 1000	6.163	5.387	0.776***	0.038	155,413
House sq ft in 10000	0.192	0.181	0.011***	0.001	155,413
Building sq ft in 10000	0.247	0.242	0.005***	0.001	155,413
Land area sq ft in 10000	6.256	5.006	1.250***	0.206	155,413
Fireplace (yes=1)	0.253	0.276	-0.023***	0.003	155,413

Notes: Data are CoreLogic housing attributes. This table reports balance in housing attributes by treatment status in the stacked DiD sample used for the house price analysis, restricted to event year $T = -1$, the year before the treated CAFO opening. The control-group and treated-group columns report group means. The difference column reports the control-group mean minus the treated-group mean. Standard errors are reported. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 3 House price baseline DiD

VARIABLES	(1)	(2)	(3)	(4)
Post	0.004	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.018**	-0.019*	-0.018*	-0.018*
	(0.008)	(0.010)	(0.010)	(0.010)
Number of bedrooms		0.053***	0.050***	0.050***
		(0.001)	(0.001)	(0.001)
Number of bathrooms		0.032***	0.032***	0.032***
		(0.003)	(0.003)	(0.003)
Fireplace (yes=1)		0.133***	0.119***	0.119***
		(0.004)	(0.004)	(0.004)
House age		-0.002***	-0.002***	-0.002***
		(2.98e-04)	(2.70e-04)	(2.70e-04)
House age squared in 1000		-0.017***	-0.018***	-0.018***
		(0.002)	(0.002)	(0.002)
House sq ft in 10000		0.725***	0.678***	0.678***
		(0.029)	(0.027)	(0.027)
Building sq ft in 10000		1.765***	1.785***	1.787***
		(0.028)	(0.027)	(0.027)
Land area sq ft in 10000		0.003***	0.003***	0.003***
		(1.94e-04)	(1.83e-04)	(1.82e-04)
Owner-occupied housing units (%)				3.57e-05
				(4.71e-04)
College degree (%)				3.12e-04
				(0.001)
Minority (incl. Hispanic) (%)				-0.001*
				(0.001)
Median household income (10000 real dollars)				0.019***
				(0.002)
Unemployment rate (%)				0.001
				(0.001)
Population density (people per sq mile)				-5.04e-05**
				(2.17e-05)
Poverty rate (%)				0.003***
				(0.001)
Constant	11.698***	11.096***	11.094***	10.953***
	(0.003)	(0.012)	(0.011)	(0.045)
Cohort by CAFO FE	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports baseline stacked DiD estimates for housing prices. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for houses in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.

Table 4 House price baseline DiD with wind intensity

VARIABLES	(1)	(2)	(3)	(5)	(6)	(7)	(8)	(10)
Post	0.004	0.002	0.002	0.001	0.004	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated x Post	-0.024**	-0.021*	-0.020*	-0.020*	-0.016**	-0.018*	-0.018*	-0.017*
	(0.010)	(0.011)	(0.011)	(0.010)	(0.008)	(0.009)	(0.009)	(0.009)
House->CAFO dir in NW	0.036**	0.021***	-0.008	-0.008				
	(0.014)	(0.007)	(0.005)	(0.005)				
Treated x Post x dir in NW	0.054*	0.012	0.017	0.017				
	(0.031)	(0.015)	(0.013)	(0.013)				
House->CAFO dir in SE					-0.070***	-0.019***	-0.018***	-0.018***
					(0.018)	(0.007)	(0.005)	(0.005)
Treated x Post x dir in SE					-0.022	-0.014	-0.004	-0.004
					(0.042)	(0.021)	(0.017)	(0.017)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.463	0.220	0.447	0.463	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444	1,206,452	1,206,452	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table augments the baseline house price stacked DiD specification by adding directional exposure indicators based on the house-to-CAFO angle from the near table. The dependent variable is *ln(Real House Prices*), measured in 2024 dollars. The House-to-CAFO direction in NW zone indicator equals one for transactions located downwind of the CAFO under NW prevailing winds (house-to-CAFO direction between 112.5 and 157.5 degrees). The House-to-CAFO direction in SE zone indicator equals one for transactions located downwind of the CAFO under SE prevailing winds (house-to-CAFO direction between -67.5 and -22.5 degrees). These directional indicators are defined for all transactions, including control observations, rather than being set to zero for controls. The triple interaction terms, such as Treated × Post × House-to-AFO direction in NW or SE zone, measure whether the post-opening treatment effect differs for houses located in the specified directional zone relative to houses outside that zone. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.

Table 5 House price DiD dynamics

VARIABLES	(1)	(2)	(3)	(4)
Post	0.003	4.31e-04	7.78e-05	-4.36e-04
	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Event Time T = -3	-0.001	-2.81e-04	-4.52e-05	-1.97e-04
	(0.010)	(0.013)	(0.013)	(0.012)
Treated × Event Time T = -2	-0.005	-0.007	-0.006	-0.006
	(0.008)	(0.007)	(0.007)	(0.007)
Treated × Event Time T = 0	-0.013	-0.015*	-0.013*	-0.012
	(0.009)	(0.008)	(0.008)	(0.008)
Treated × Event Time T = 1	-0.016	-0.020*	-0.019*	-0.019*
	(0.011)	(0.011)	(0.010)	(0.010)
Treated × Event Time T = 2	-0.022**	-0.024***	-0.023**	-0.022**
	(0.009)	(0.009)	(0.009)	(0.009)
Treated × Event Time T = 3	-0.026**	-0.027**	-0.026**	-0.025**
	(0.012)	(0.011)	(0.011)	(0.011)
Cohort by CAFO FE	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports dynamic difference-in-differences estimates by event time relative to CAFO openings. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. The omitted event time is $T = -1$, so each reported interaction coefficient measures the difference between treated and control houses in that event year relative to the year before the CAFO opening. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.

Table 6 House price DiD pre- and post-CWAA

	(I) 1996-2002 pre-2003 cohorts					(II) 2004-2020 post-2003 cohorts, no before 2004 observations				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
VARIABLES	ln Real House Prices									
Post	0.007	-0.001	0.003	-0.007	0.004	0.003	-5.74e-06	-1.89e-04	2.51e-04	-0.001
	(0.024)	(0.024)	(0.024)	(0.022)	(0.025)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.021	-0.024	-0.029	-0.002	-0.017	-0.017*	-0.018*	-0.018*	-0.019*	-0.017*
	(0.030)	(0.025)	(0.027)	(0.022)	(0.027)	(0.009)	(0.010)	(0.011)	(0.010)	(0.010)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.281	0.419	0.440	0.447	0.441	0.216	0.450	0.465	0.468	0.465
Observations	42,850	42,850	42,841	42,841	42,841	1,148,242	1,148,242	1,148,233	1,148,233	1,148,233

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates separately by the opening year of the treated CAFO in each cohort. Panel I restricts the sample to cohorts with treated CAFO openings from 1996 to 2002. Panel II restricts the sample to cohorts with treated CAFO openings from 2004 to 2020 and excludes observations before 2004. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.

Table 7 House price DiD exogenous policy treatment event

VARIABLES	(1) ln Real House Prices	(2)	(3)	(4)
Treated × Post	-0.065**	-0.060*	-0.061*	-0.079**
	(0.030)	(0.035)	(0.033)	(0.039)
Observations	42,490	42,490	42,477	42,477
R-squared	0.292	0.443	0.473	0.473
Cohort by CAFO FE	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates for enactment of the CWAA. Treated units are house transactions within a 5 mile radius of CAFOs operating continuously from 2000 to 2007; treatment is enactment of the CWAA in 2003. Control units are house transactions over the same calendar years but in locations where no CAFO exists until after 2012. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.

Table 8 Corn acreage (two-year continuous) 1-mile buffer DID

	(1)	(2)	(3)	(4)
VARIABLES	log of 2-yr continuous corn area in acres within a 1-mile radius			
Post	-0.095***	-0.028*	-0.028*	-0.029*
	(0.016)	(0.016)	(0.016)	(0.016)
Treated*post	0.104***	0.101***	0.101***	0.107***
	(0.027)	(0.027)	(0.027)	(0.027)
Cohort by CAFO FE	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES
R-squared	0.722	0.742	0.742	0.743
Observations	50,802	50,802	50,802	50,802

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked CAFO DiD estimates using two-year continuous corn acreage measured within a 1-mile radius around each CAFO. The dependent variable is *ln(2-yr continuous corn area in acres within a 1-mile radius)*, meaning the log of acreage planted with corn for two consecutive years within the 1-mile buffer around each CAFO. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Table 9 Corn acreage (two-year continuous) 3-mile buffer DID

	(1)	(2)	(3)	(4)	(5)
VARIABLES	log of 2-yr continuous corn area in acres within a 3-mile radius				
Post	-0.056***	-0.021**	-0.021**	-0.019*	-0.021**
	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Treated*post	0.027**	0.024**	0.024**	0.032***	0.027**
	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)
Cohort by CAFO FE	YES	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES
R-squared	0.855	0.890	0.890	0.909	0.890
Observations	50,804	50,804	50,804	50,804	50,804

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked CAFO DiD estimates using two-year continuous corn acreage measured within a 3-mile radius around each CAFO. The dependent variable is *ln(2-yr continuous corn area in acres within a 3-mile radius)*, meaning the log of acreage planted with corn for two consecutive years within the 3-mile buffer around each CAFO. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Table 10 Corn acreage (two-year continuous) 5-mile buffer DID

	(1)	(2)	(3)	(4)
VARIABLES	log of 2-yr continuous corn area in acres within a 5-mile radius			
Post	-0.054***	-0.016*	-0.016*	-0.016*
	(0.010)	(0.009)	(0.009)	(0.009)
Treated*post	0.011	0.008	0.008	0.011
	(0.010)	(0.009)	(0.009)	(0.009)
Cohort by CAFO FE	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES
Census tract FE	NO	NO	YES	YES
Census tract characteristics controls	NO	NO	NO	YES
R-squared	0.878	0.918	0.918	0.919
Observations	50,804	50,804	50,804	50,804

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked CAFO DiD estimates using two-year continuous corn acreage measured within a 5-mile radius around each CAFO. The dependent variable is *ln(2-yr continuous corn area in acres within a 5-mile radius)*, meaning the log of acreage planted with corn for two consecutive years within the 5-mile buffer around each CAFO. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects and census tract characteristics are included as indicated.

Table 11 EIF population DiD (5-mile band)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	log of EIF data 5-mile band area-weighted population				
Post	0.005***	-0.003**	-0.003**	-0.002**	-0.003**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Treated*post	0.006***	0.006***	0.006***	0.005***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Cohort by CAFO FE	YES	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES
R-squared	0.993	0.994	0.994	0.995	0.994
Observations	55,317	55,317	55,317	55,317	55,317

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates using EIF population data. The dependent variable is *ln(EIF data 5-mile band area-weighted population)*, meaning the log of the EIF-based area-weighted total population within the 5-mile band around each CAFO. Treated × Post is the interaction between an indicator for EIF observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Table 12 EIF DiD age shares (5-mile band)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	log of EIF data 5-mile band age under 18 population					log of EIF data 5-mile band age 18-65 population					log of EIF data 5-mile band age above 65 population				
Post	-0.022***	-0.006***	-0.006***	-0.005**	-0.006***	-0.007***	-0.003**	-0.003**	-0.002*	-0.003**	0.063***	-0.002	-0.002	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Treated*post	0.011***	0.011***	0.011***	0.009***	0.011***	0.007***	0.006***	0.006***	0.005***	0.006***	-0.001	-0.001	-0.001	0.001	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.988	0.989	0.989	0.989	0.989	0.993	0.994	0.994	0.994	0.994	0.989	0.991	0.991	0.992	0.991
Observations	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates using EIF population data by age group. The dependent variables are the log of the EIF-based area-weighted populations within the 5-mile band around each CAFO: columns (1)–(5) use the population under age 18, columns (6)–(10) use the population ages 18–65, and columns (11)–(15) use the population above age 65. Treated × Post is the interaction between an indicator for EIF observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Table 13 EIF income groups DiD (5-mile band)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	log of EIF data 5-mile band income lowest quintile population					log of EIF data 5-mile band income second quintile population				
Post	0.018***	-0.001	-0.001	-0.001	-0.001	-0.016***	-0.006**	-0.006**	-0.005*	-0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Treated*post	0.006	0.005	0.005	0.005	0.005	0.007**	0.007**	0.007**	0.005	0.007*
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.983	0.985	0.985	0.986	0.985	0.980	0.981	0.981	0.982	0.981
Observations	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317	55,317
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
VARIABLES	log of EIF data 5-mile band income middle quintile population					log of EIF data 5-mile band income fourth quintile population				
Post	7.13e-05	-0.001	-0.001	-0.001	-0.001	0.018***	-0.001	-0.001	-0.002	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Treated*post	0.008**	0.008**	0.008**	0.008**	0.008**	0.005	0.005	0.005	0.004	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.979	0.980	0.980	0.981	0.980	0.981	0.984	0.984	0.985	0.984
Observations	55,317	55,317	55,317	55,317	55,317	55,311	55,311	55,311	55,311	55,311
	(21)	(22)	(23)	(24)	(25)					
VARIABLES	log of EIF data 5-mile band income highest quintile population									
Post	0.009	-0.007	-0.007	-0.006	-0.007					
	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)					
Treated*post	0.002	0.003	0.003	0.003	0.001					
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)					
Cohort by CAFO FE	YES	YES	YES	YES	YES					
Calendar year FE	NO	YES	YES	YES	YES					
Census tract FE	NO	NO	YES	YES	YES					
Census tract-specific linear trends	NO	NO	NO	YES	NO					
Census tract characteristics controls	NO	NO	NO	NO	YES					
R-squared	0.954	0.967	0.967	0.968	0.967					

Observations	55,303	55,303	55,303	55,303	55,303

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates using EIF population data by income group. The dependent variables are the log of the EIF-based area-weighted populations within the 5-mile band around each CAFO: columns (1)–(5) use the population in the lowest income quintile, columns (6)–(10) use the population in the second income quintile, columns (11)–(15) use the population in the middle income quintile, columns (16)–(20) use the population in the fourth income quintile, and columns (21)–(25) use the population in the highest income quintile. Treated × Post is the interaction between an indicator for EIF observations in the treated group and an indicator for post-opening years. All specifications include cohort-by-CAFO fixed effects. Calendar-year fixed effects, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Online Appendix for "Housing value, sorting effects and point-source pollution: Did the Clean Water Act Amendments localize the disamenity?"

Appendix A1.

The 2003 Clean Water Act amendments (CWAA) were a regulatory turning point. While Iowa had established basic state-level manure guidelines in 1985, the 2003 federal rule expanded compliance to significantly more facilities and established core mandates (U.S. EPA, 2003). (i) NPDES Permitting Mandate: The 2003 rule designated large CAFOs as point sources under the National Pollutant Discharge Elimination System (NPDES), creating a universal "duty to apply" for permits and mandating enforceable Nutrient Management Plans (NMPs) overseen by the Iowa Department of Natural Resources (US EPA, 2003; Centner, 2004; Chen et al., 2025). All CAFOs were required to develop and implement a plan to manage manure and wastewater. (ii) Land Application Controls (LACs): Federalized land-application oversight by introducing the Phosphorus Index (P-Index) to calculate field-specific manure capacities and prevent discharge. (iii) Containment standards: Facilities exceeding size thresholds (e.g., 1,000 animal units) were required to eliminate unpermitted manure storage discharges and restrict land application rates of nitrogen and phosphorus to mitigate field runoff (US EPA, 2003).

In sum, the impact of the 2003 Clean Water Act (CWA) amendments in Iowa is a combination of new federal mandates and the strengthening of existing state laws. Below are the specific legal and regulatory references for Iowa for each of the five points previously discussed.

1. Mandatory Nutrient Management Plans (NMPs)
    - Specific Iowa Source: Iowa Administrative Code 567—65.16 and 40 CFR § 122.23.
    - The Specifics: While Iowa required Manure Management Plans (MMPs) for certain operations since 1985, the 2003 federal rule mandated that any CAFO defined as a "point source" must develop a plan that meets technical standards for nitrogen and phosphorus. This forced Iowa to align its state-level MMPs with federal "Nutrient Management Plan" requirements to ensure compliance for operations that might discharge.
2. Implementation of the Phosphorus Index (P-Index)
    - Specific Iowa Source: Iowa Code Section 459.312.
    - The Specifics: In 2002 and 2003, Iowa legally shifted from nitrogen-only planning to the Phosphorus Index. This was a direct response to federal pressure to better manage phosphorus runoff. For any operation submitting a plan after 2003, the P-Index became a mandatory calculation to determine exactly how much manure could be spread based on the specific risk of phosphorus moving into nearby waterbodies.
3. Regulation of "Land Application" as a Discharge
    - Specific Iowa Source: Iowa Admin. Code r. 567-65.101(6) and the 2013 EPA/DNR Work Plan Agreement.
    - The Specifics: Iowa law explicitly states that "all manure... shall be land-applied in a manner that will *not cause surface or groundwater pollution".* The 2003 CWA changes

clarified that if an Iowa producer applies manure in a way that leads to runoff (e.g., applying to frozen ground or during heavy rain without a plan), it is legally considered a discharge from a point source, even if it didn't come from a pipe.

4. Annual Reporting and Updates (The "Short Form")
    - Specific Iowa Source: Iowa DNR Form 542-8156 (MMP Annual Update).
    - The Specifics: To comply with the increased oversight from the 2003 amendments, Iowa established a system where CAFO owners must submit annual updates and pay a compliance fee.

Centner, T. J. (2004). *Empty pastures: Confined animals and the transformation of the rural landscape*. University of Illinois Press.

Chen, C.-T., Lade, G. E., Crespi, J. M., & Keiser, D. A. (2025). Size-based regulation and water quality: Evidence from the Iowa hog industry. *American Journal of Agricultural Economics*, *108*(3), 829–855. https://doi.org/10.1111/ajae.70006

U.S. Environmental Protection Agency. (2003). National Pollutant Discharge Elimination System permit regulation and effluent limitation guidelines and standards for concentrated animal feeding operations (CAFOs); Final rule. *Federal Register*, 68(29), 7175–7274.

Appendix A2.

A2.1 Wind direction

Prior studies suggest that the negative price effects of CAFOs are larger when houses are located downwind of the facility (Herringes et al., 2005; Isakson and Ecker, 2008). To test whether CAFO openings have stronger impacts on houses in downwind regions—and to test a potential wind-channel mechanism—we construct several variables of downward wind exposure.

We use historical daily wind direction and wind speed information from the Climatology Lab's gridMET product, which covers contiguous US with 4-km-resolution during our whole research period from 1993 to 2023. To decide whether one house is in the downwind region from the CAFO, we first find out the approach direction from the CAFO to the house, then we compare this direction with the prevailing wind direction using CAFO as the reference. If the angle between these two directions are less than 30°, we assign the downwind exposure variable for this house to be 1, as illustrated in Appendix Figure A2.

The wind data are daily. We aggregate using two time windows (the 2 months and the 3 months before the transaction) and four alternative definitions: (i) a wind speed-weighted vector mean direction, (ii) an unweighted arithmetic vector mean direction, (iii) the wind direction on the day with the maximum wind speed, and (iv) a modal wind direction based on 16 directional sectors. Together this yields eight prevailing-wind direction measures (2 windows × 4 definitions). In the literature, researchers used a uniform prevailing wind direction method to decide the downwind exposure. Namely, the prevailing wind direction is southeastern in summer and

northwestern in winter. e also constructed several downwind exposure variables with this method. With this method, we classify a house as downwind if the house is located within the prevailing-wind sectors from its nearest CAFO. In total, we construct 11 downwind exposure variables: eight based on rolling prevailing-wind measures and three based on prevailing-wind sectors.

We therefore construct several measures of downwind exposure. We first compute multiple prevailing-wind measures over rolling windows of the two months and three months prior to each housing transaction. Our measures include a speed-weighted vector-mean wind direction, which converts the 360-degree meteorological wind direction into *u* and *v* components, takes wind-speed-weighted averages of these components, and then converts the resulting mean vector back to a 360-degree direction. We also compute an unweighted (arithmetic) vector-mean direction, which averages the *u* and *v* components without speed weights and then converts back to a direction. In addition, we define a maximum wind speed direction as the wind direction on the day with the highest wind speed within the time window. Finally, we construct a modal wind direction based on 16 directional sectors, defined as the sector with the highest day count in the time window.

Next, for each prevailing-wind measure we calculate the angle between the prevailing-wind direction measure and the line connecting the CAFO to the housing transaction. We set the corresponding downwind exposure indicator equal to one if this angle is less than 30 degrees, and zero otherwise. Beyond these data-driven measures based on rolling wind direction and speed, we also follow the simpler approach used in the literature and define 8-sector-based exposure measures using Iowa's seasonal wind patterns (southeasterly winds in spring and summer and northwesterly winds in autumn and winter). Under this approach, a transaction is classified as southeast or northwest downwind if the CAFO lies to the southeast or northwest of the property.

A2.2 Local population, age and income data

To study how CAFO openings affect nearby economic outcomes, we use the Gridded Environmental Impacts Frame (EIF) data[9]. The Gridded EIF, produced by the U.S. Census Bureau, provides population counts on a 0.01-degree grid, including tabulations by "race × age × sex" and "race × income decile." We merge these gridded population measures into the stacked CAFO dataset to construct indicators of population size and demographic composition around CAFOs. Specifically, for each year from 1999 to 2023 at the grid-cell level, we aggregate race-by-age-by-sex and race-by-income tabulations into total population, population counts for three age groups (under 18, ages 19–65, and 65 and older), and population counts by income decile. We then construct a 5-mile buffer around each CAFO location and intersect it with the EIF grid. Using the intersection area as weights, we aggregate grid-cell population counts to 5-mile buffer

[9] https://www.census.gov/data/experimental-data-products/gridded-eif.html

counts. These variables are merged into the stacked CAFO dataset and used to form outcomes such as log total population, log of age-group population, and log population counts for income groups (5 quintiles) within the 5-mile buffer.

A2.3 Cropland data layer

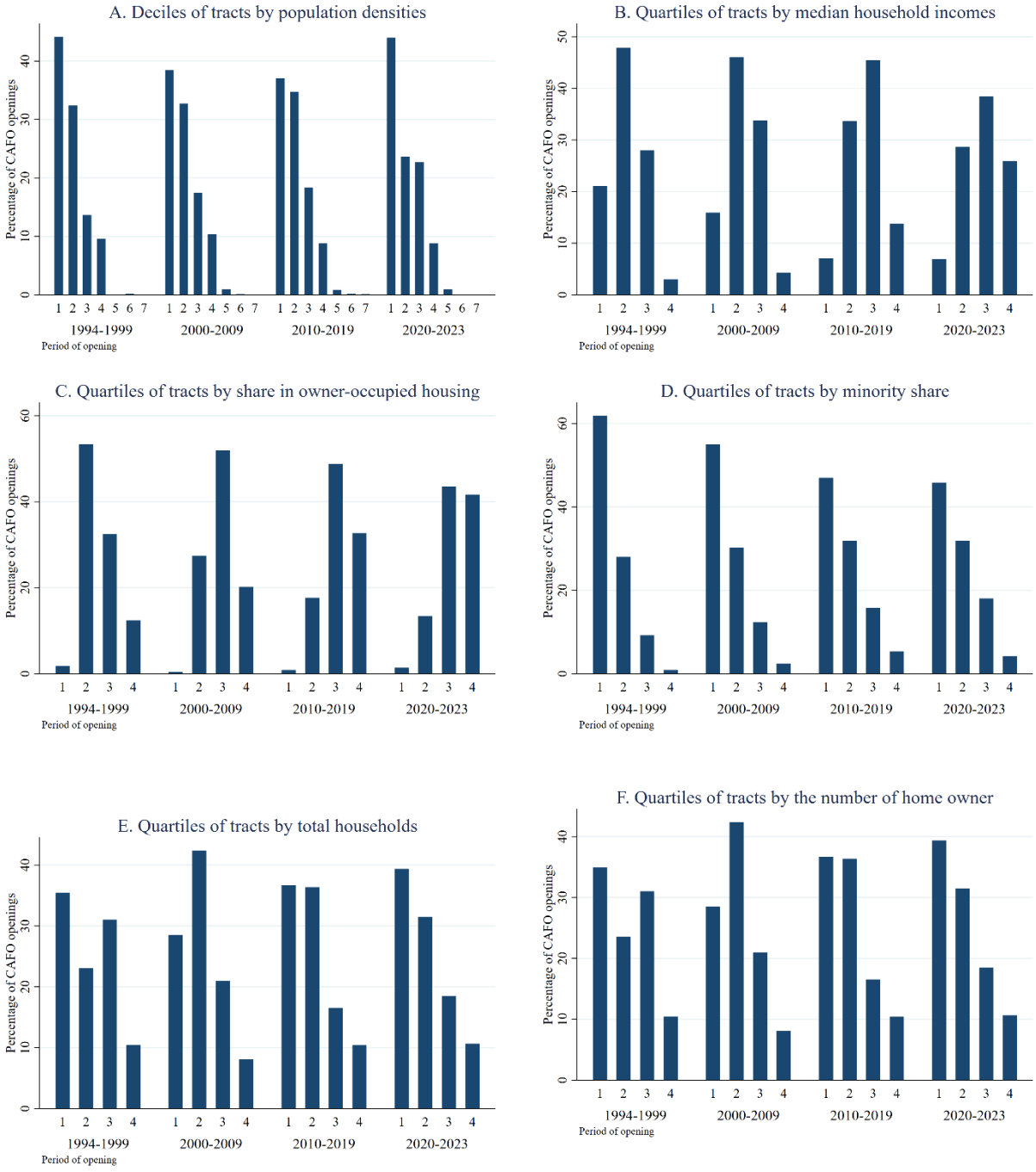
To examine whether CAFO openings change nearby crop types through local manure application—and thus provide indirect evidence of spatially concentrated impacts by odor under the Clean Water Act amendments—we study how CAFO openings affect the continuous corn acreage. Compared with soybeans, corn typically requires higher nutrient inputs and is more likely to benefit from manure produced at nearby CAFOs. At the same time, because crop rotation is common, corn acreage in a single year may not capture longer-run, CAFO-induced shifts in crop choice. We therefore use continuous corn acreage as an indirect proxy for sustained manure use and local crop type change around CAFOs. The Iowa Cropland Data Layer (CDL), a high-resolution, crop-specific land cover dataset produced annually by the USDA National Agricultural Statistics Service (NASS). It provides digital, geo-referenced raster maps showing exactly what was planted or grown across the state during a given growing season.

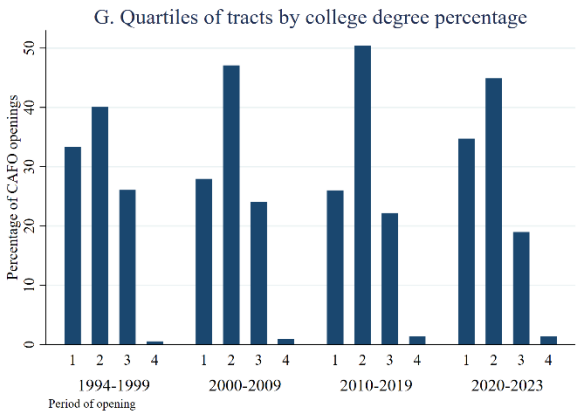
We use Iowa's Cropland Data Layer (CDL) rasters for 2001–2023 (we exclude 2000 because the raster data did not cover the whole state) to construct the land use variables.[10] For each CAFO, we first compute crop composition within 1-, 3-, and 5-mile buffers. In any calendar year, we define a continuous corn as the corn is the crop type in both the previous year and current year. Since there are lagged land use decisions, i.e., this year's continuous corn depends on last year's land use decision, we changed how we match the continuous corn to our stacked sample. Specially, for event years (t = -1, -2,-3), we match the continuous corn in the same calendar year to event years. For event years (t=0,1,2,3), we match them with the continuous corn at three years later. For example, for t = 0 we use CDL classifications in years t + 2 and t + 3 to identify two-year continuous corn; for t = 1 we use years t + 3 and t + 4, and so on. This procedure yields continuous corn acreage measures for 2002–2023 within 1/3/5-mile buffers, which we merge into the stacked CAFO dataset as key outcome variables for the subsequent analysis.

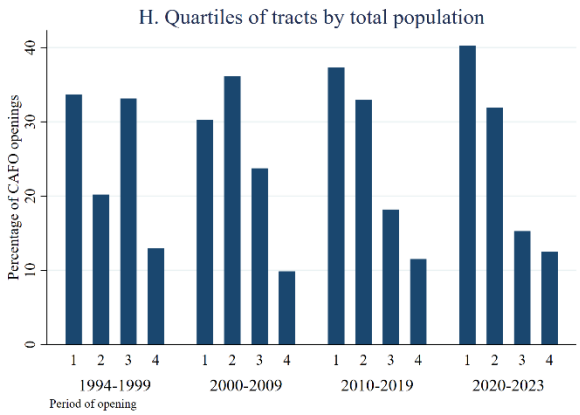
[10] https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

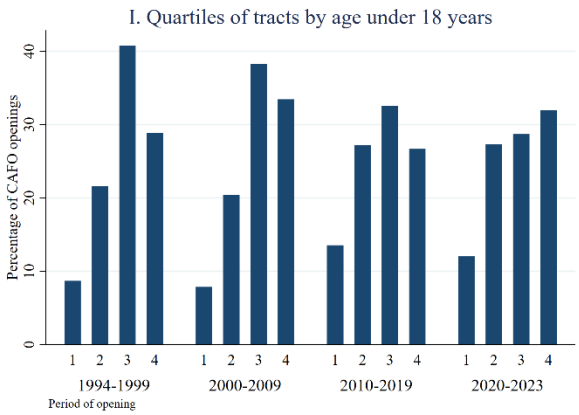
Appendix Figures and Tables

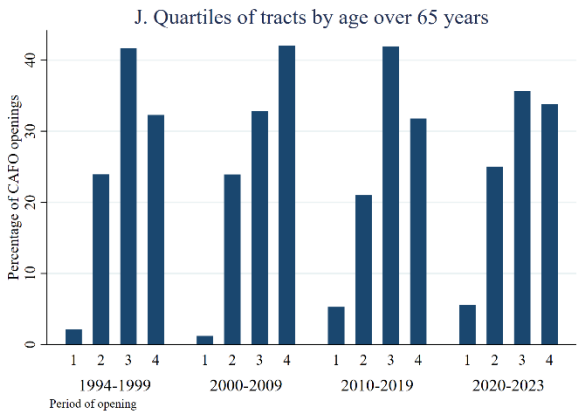
Appendix Figure A1 Census tract demographics of CAFO openings over time

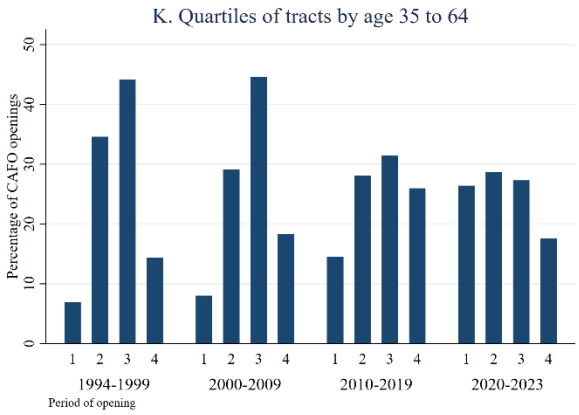


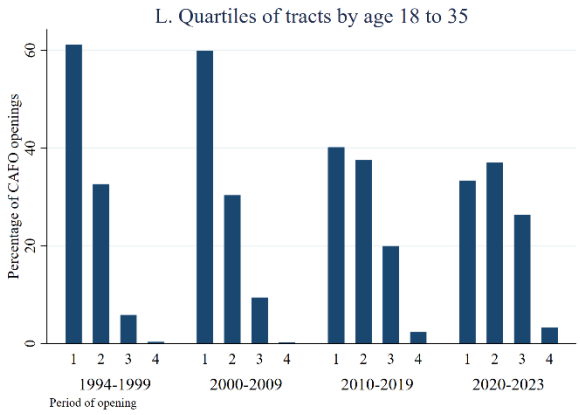

G. Quartiles of tracts by college degree percentage
Percentage of CAFO openings
0
10
20
30
40
50
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening

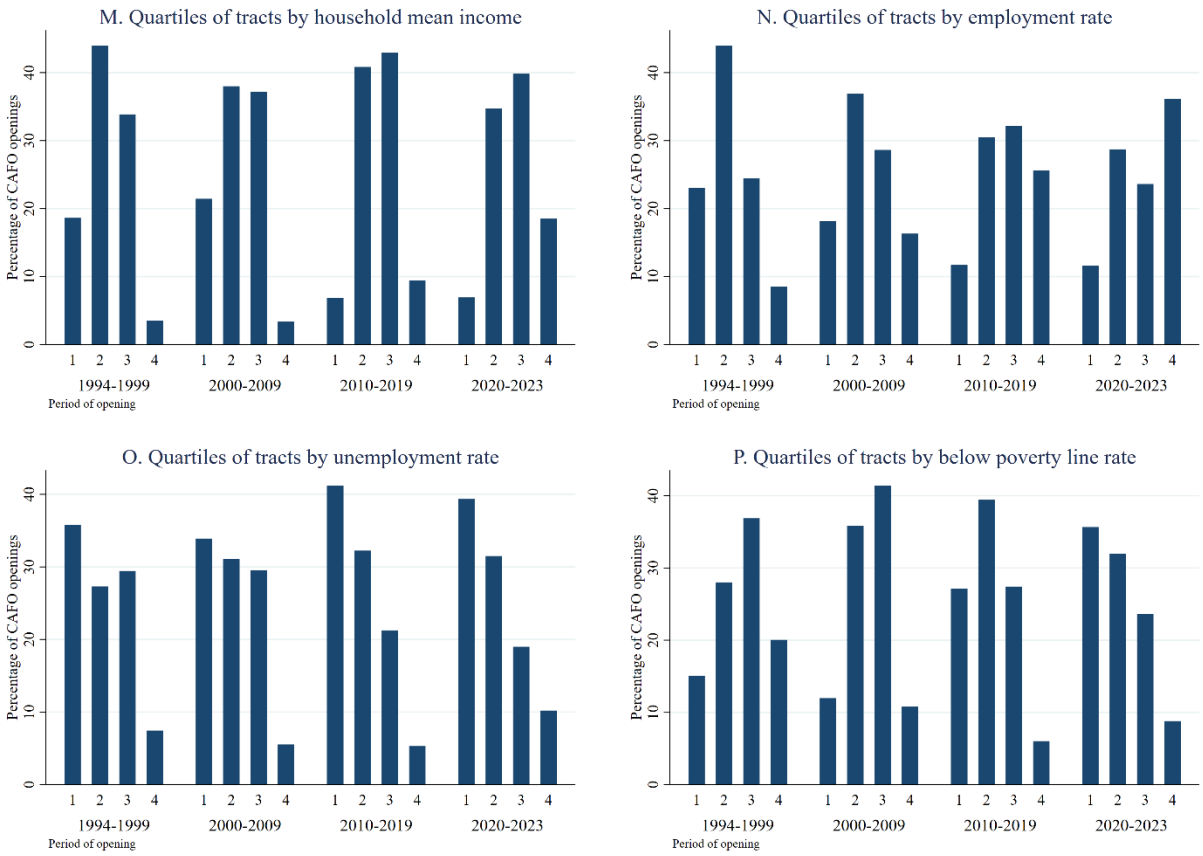

H. Quartiles of tracts by total population
Percentage of CAFO openings
0
10
20
30
40
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening


I. Quartiles of tracts by age under 18 years
Percentage of CAFO openings
0
10
20
30
40
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening


J. Quartiles of tracts by age over 65 years
Percentage of CAFO openings
0
10
20
30
40
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening

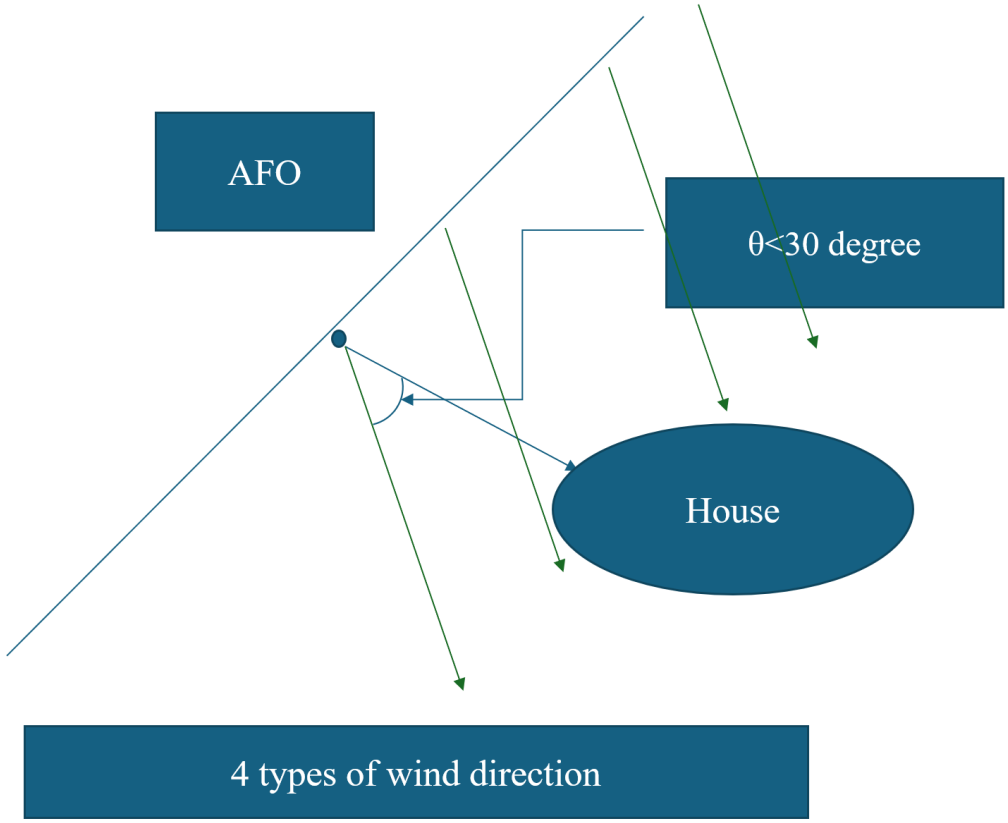

K. Quartiles of tracts by age 35 to 64
Percentage of CAFO openings
0
10
20
30
40
50
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening


L. Quartiles of tracts by age 18 to 35
Percentage of CAFO openings
0
20
40
60
1 2 3 4
1994-1999
2000-2009
2010-2019
2020-2023
Period of opening



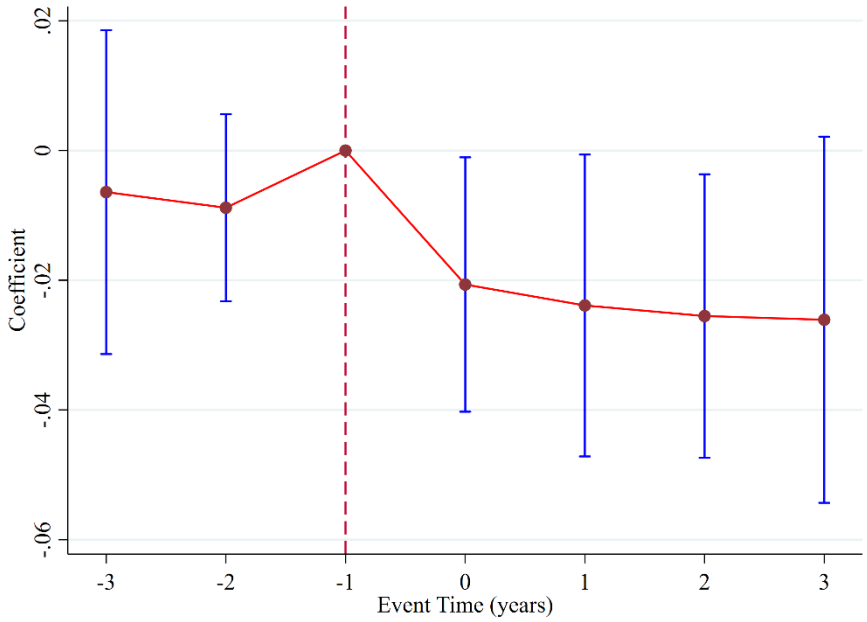
Notes: These graphs depict the percentage of CAFO openings within each opening period that are located in census tracts with different demographic and socioeconomic characteristics. Tracts are grouped by deciles of population density in Panel A and by quartiles of the corresponding tract characteristic in Panels B–P, with groups defined separately for each time period. For example, Panel A shows the share of CAFO openings in each opening period that occurred in tracts belonging to each population-density decile in that same period. The opening periods are 1994–1999, 2000–2009, 2010–2019, and 2020–2023. The figures are based on tract-level demographic and socioeconomic data merged to the census tract of each CAFO opening in the matched Iowa CAFO dataset.

Appendix Figure A2 The illustration of downward wind exposure designation



Notes: This figure illustrates the designation of downwind exposure for a house relative to its nearest CAFO. The blue line from the CAFO to the house represents the approach direction from the facility to the residence, while the green arrows denote alternative prevailing wind directions using the CAFO as the reference point. A house is classified as downwind when the angle θ between the AFO-to-house direction and the wind direction is smaller than the specified threshold (shown here as $\theta < 30^{\circ}$). In the empirical analysis, prevailing wind direction is constructed from daily gridMET wind direction and wind speed data using two rolling time windows (the 2 months and the 3 months before the housing transaction) and four types of wind directions: a wind speed-weighted vector mean direction, an unweighted arithmetic vector mean direction, the wind direction on the day with the maximum wind speed, and a modal wind direction based on 16 directional sectors. This illustration is schematic and is not drawn to scale.

Appendix Figure A3 Event study figures with only not-yet-treated controls



Notes: This figure reports a robustness version of the event-study estimates that retains only not-yet-treated controls and drops always-treated controls, corresponding to col. 4 Table 5 specification. In both panels, coefficients are normalized to the omitted pre-treatment period $t = -1$, so each estimate is interpreted relative to the year immediately before the CAFO opening. Vertical bars denote 95% confidence intervals, and the dashed vertical line marks the baseline event year. Panel A corresponds to Appendix Table 18 column (4) and includes census tract-specific linear trends. Panel B corresponds to Appendix Table 18 column (5) and includes census tract characteristics controls.

Appendix Table 1 Number of transactions per event year by cohort and groups

Treated transactions				
Event year	Min treated transactions	Max treated transactions	Avg treated transactions	Sum of treated transactions
-3	0	1,980	19.211	18,366
-2	0	1,233	21.127	20,768
-1	0	1,490	24.770	24,621
0	0	1,263	27.799	27,771
1	0	1,088	29.333	29,450
2	0	1,471	32.309	32,535
3	0	1,584	34.159	34,398
Treated Total	38	10,109	185.498	187,909
Control transactions				
Event year	Min control transactions	Max control transactions	Avg control transactions	Sum of control transactions
-3	0	2,565	102.835	98,310
-2	0	2,840	119.691	117,656
-1	0	2,641	131.581	130,792
0	0	2,404	146.233	146,087
1	0	2,742	162.663	163,314
2	0	2,946	175.748	176,978
3	0	2,818	184.278	185,568
Control Total	5	18,956	1005.632	1,018,705
Number of cohorts: 1,013				

Notes: This table summarizes the number of housing transactions in the stacked CAFO sample by event year, cohort, and treatment status. Event year is measured relative to the treated CAFO opening year, with event year 0 denoting the opening year. The treated panel reports transaction counts for treated observations, and the control panel reports transaction counts for control observations. For each event year, the table reports the minimum, maximum, average, and total number of transactions across cohort-by-event-year cells. The "Treated Total" and "Control Total" rows aggregate transaction counts across all event years from -3 to 3. The final analysis sample includes 1,013 cohorts.

Appendix Table 2 Baseline regression with downward wind exposure variables (speed-weighted direction; all; allow controls to have one value)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ln Real House Prices									
Post	0.004	0.002	0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.018**	-0.019*	-0.018*	-0.019**	-0.017*	-0.017*	-0.019*	-0.018*	-0.019**	-0.017*
	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
wind_wspw_2mprev	-0.018***	-0.011***	-0.006***	-0.006***	-0.006**					
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)					
wind_wspw_3mprev						-0.013***	-0.010***	-0.004	-0.004	-0.004
						(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Treated x Post x wind_wspw_2mprev	0.003	0.001	-0.002	-0.002	-0.002					
	(0.009)	(0.007)	(0.007)	(0.007)	(0.007)					
Treated x Post x wind_wspw_3mprev						-0.004	2.67e-04	-0.003	-0.003	-0.003
						(0.009)	(0.008)	(0.007)	(0.007)	(0.007)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.465	0.463	0.220	0.447	0.462	0.465	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates that augment the baseline specification with downwind exposure variables based on speed-weighted prevailing wind direction. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. wind_wspw_2mprev is a downwind exposure indicator constructed using the speed-weighted vector-mean prevailing wind direction over the two months before each housing transaction. wind_wspw_3mprev is defined analogously using the three months before each housing transaction. For each window, wind directions are first converted into wind-vector components, averaged within the corresponding time window using wind speed as weights, and then converted back into a 360-degree prevailing wind direction. The downwind exposure indicator

equals one if the angle between the prevailing wind direction and the line connecting the CAFO and the housing transaction is less than 30 degrees, and zero otherwise. These wind exposure variables are defined for all transactions, including control observations, rather than being set to zero for controls. The triple interaction terms, such as Treated × Post × wind_wspw_2mprev, measure whether the post-opening treatment effect differs for downwind-exposed transactions relative to non-downwind-exposed transactions. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Appendix Table 3 Baseline regression with downward wind exposure variables (arithmetic mean direction; all; allow controls to have one value)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ln Real House Prices									
Post	0.004	0.002	0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.017**	-0.019*	-0.018*	-0.019*	-0.017*	-0.018**	-0.019**	-0.018*	-0.019**	-0.017*
	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
wind_arith_2mprev	-0.019***	-0.013***	-0.007***	-0.007***	-0.007***					
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)					
wind_arith_3mprev						-0.019***	-0.013***	-0.006***	-0.006**	-0.006***
						(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Treated x Post x wind_arith_2mprev	-0.005	-0.003	-0.006	-0.005	-0.006					
	(0.010)	(0.008)	(0.007)	(0.007)	(0.007)					
Treated x Post x wind_arith_3mprev						-0.001	-0.001	-0.003	-0.003	-0.003
						(0.010)	(0.009)	(0.008)	(0.008)	(0.008)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.465	0.463	0.220	0.447	0.462	0.465	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates that augment the baseline specification with downwind exposure variables based on arithmetic-mean prevailing wind direction. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. wind_arith_2mprev is a downwind exposure indicator constructed using the arithmetic-mean prevailing wind direction over the two months before each housing transaction. wind_arith_3mprev is defined analogously using the three months before each housing transaction. For each window, wind directions are first converted into wind-vector components, averaged within the corresponding time window without wind-speed weights, and then converted back into a 360-degree prevailing wind direction. The downwind exposure indicator equals one if the angle between the prevailing downwind direction and the direction from the CAFO to the housing transaction is less than 30 degrees, and zero otherwise. These wind exposure variables are defined for all transactions, including control observations, rather than being set to zero for controls. The triple interaction terms, such as Treated × Post × wind_arith_2mprev, measure whether the post-opening treatment effect differs for downwind-exposed transactions relative to non-downwind-exposed transactions. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Appendix Table 4 Baseline regression with downward wind exposure variables (max mean direction; all; allow controls to have one value)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ln Real House Prices									
Post	0.004	0.002	0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.019**	-0.020*	-0.019*	-0.020**	-0.018*	-0.019**	-0.020*	-0.019*	-0.020**	-0.018*
	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)	(0.009)	(0.011)	(0.011)	(0.010)	(0.010)
wind_max_2mprev	-0.005	-0.004*	-0.001	-0.001	-0.001					
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)					
wind_max_3mprev						-0.004	-0.006**	-0.003	-0.004*	-0.003
						(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Treated x Post x wind_max_2mprev	0.009	0.005	0.002	0.002	0.001					
	(0.012)	(0.009)	(0.007)	(0.007)	(0.007)					
Treated x Post x wind_max_3mprev						0.009	0.007	0.003	0.004	0.002
						(0.011)	(0.008)	(0.007)	(0.006)	(0.006)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.465	0.463	0.220	0.447	0.462	0.465	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates that augment the baseline specification with downwind exposure variables based on the maximum wind-speed direction. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. wind_max_2mprev is a downwind exposure indicator constructed using the wind direction associated with the maximum wind speed over the two months before each housing transaction. wind_max_3mprev is defined analogously using the three months before each housing transaction. For each window, the prevailing wind direction is defined as the wind direction observed when wind speed reaches its maximum within the corresponding time window. The downwind exposure indicator equals one if the angle between the prevailing downwind

direction and the direction from the CAFO to the housing transaction is less than 30 degrees, and zero otherwise. These wind exposure variables are defined for all transactions, including control observations, rather than being set to zero for controls. The triple interaction terms, such as Treated × Post × wind_max_2mprev, measure whether the post-opening treatment effect differs for downwind-exposed transactions relative to non-downwind-exposed transactions. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Appendix Table 5 Baseline regression with downward wind exposure variables (modal mean direction; all; allow controls to have one value)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ln Real House Prices									
Post	0.004	0.002	0.002	0.002	0.001	0.004	0.002	0.002	0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Treated × Post	-0.018*	-0.020*	-0.018*	-0.019*	-0.017*	-0.019**	-0.020*	-0.018*	-0.020**	-0.017*
	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
wind_mode16zone_2mprev	-0.008**	-0.010***	-0.005*	-0.005**	-0.004*					
	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)					
wind_mode16zone_3mprev						-0.008**	-0.006**	-0.001	-0.002	-0.001
						(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Treated x Post x wind_mode16zone_2mprev	0.001	0.003	-0.002	-0.002	-0.002					
	(0.010)	(0.007)	(0.007)	(0.007)	(0.006)					
Treated x Post x wind_mode16zone_3mprev						0.009	0.003	-0.001	-4.53e-04	-0.002
						(0.012)	(0.009)	(0.007)	(0.008)	(0.007)
Cohort by CAFO FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES
R-squared	0.220	0.447	0.462	0.465	0.463	0.220	0.447	0.462	0.465	0.463
Observations	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444	1,206,452	1,206,452	1,206,444	1,206,444	1,206,444

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports stacked DiD estimates that augment the baseline specification with downwind exposure variables based on the modal daily wind-direction zone. The dependent variable is *ln(Real House Prices)*. Treated × Post is the interaction between an indicator for observations in the treated group and an indicator for post-opening years. wind_mode16zone_2mprev is a downwind exposure indicator constructed using the modal daily wind-direction zone over the two months before each housing transaction. wind_mode16zone_3mprev is defined analogously using the three months before each housing transaction. For each window, the prevailing wind direction is defined as the most frequently observed daily wind-direction zone within the corresponding time window. The downwind exposure indicator equals one if the angle between the prevailing downwind direction and the direction from the CAFO to the housing transaction is less than 30 degrees, and zero otherwise. These wind exposure variables are defined for all transactions, including control observations, rather than being set to zero for controls. The triple interaction terms, such as Treated × Post × wind_mode16zone_2mprev, measure whether the post-opening treatment effect differs for downwind-exposed transactions relative to non-downwind-exposed transactions. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects, Census tract-specific linear trends, and census tract characteristics are included as indicated.

Appendix Table 6 Dynamic regression with not-yet-treated controls

VARIABLES	(1)	(2)	(3)	(4)	(5)
	ln Real House Prices				
Post	0.013	0.007	0.009	0.009	0.009
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)
Treated × Event Time T = -3	0.002	-0.003	-0.006	-0.012	-0.006
	(0.011)	(0.013)	(0.013)	(0.010)	(0.013)
Treated × Event Time T = -2	-0.004	-0.009	-0.008	-0.011	-0.009
	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)
Treated × Event Time T = 0	-0.026**	-0.021**	-0.021**	-0.017*	-0.021**
	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)
Treated × Event Time T = 1	-0.031**	-0.025**	-0.025**	-0.018*	-0.024**
	(0.012)	(0.012)	(0.012)	(0.010)	(0.012)
Treated × Event Time T = 2	-0.040***	-0.028**	-0.027**	-0.016*	-0.026**
	(0.011)	(0.011)	(0.012)	(0.009)	(0.011)
Treated × Event Time T = 3	-0.045***	-0.030**	-0.028*	-0.016	-0.026*
	(0.014)	(0.014)	(0.015)	(0.011)	(0.014)
Cohort by CAFO FE	YES	YES	YES	YES	YES
Calendar year FE	YES	YES	YES	YES	YES
Housing attributes controls	NO	YES	YES	YES	YES
Census tract FE	NO	NO	YES	YES	YES
Census tract-specific linear trends	NO	NO	NO	YES	NO
Census tract characteristics controls	NO	NO	NO	NO	YES
R-squared	0.222	0.431	0.446	0.450	0.446
Observations	373,749	373,749	373,742	373,742	373,742

Notes: *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. Robust standard errors in parentheses are clustered at the cohort level. The table reports dynamic stacked DiD estimates for housing prices, keeping only not-yet-treated controls in the control group. The dependent variable is *ln(Real House Prices)*, measured in 2024 dollars. Event time is measured relative to the CAFO opening year, with event time T=−1 omitted as the reference period. Each Treated × Event Time coefficient measures the treatment-control difference in that event year relative to the year before the CAFO opening. All specifications include cohort-by-CAFO fixed effects and calendar-year fixed effects. Additional housing attributes, census tract fixed effects and census tract characteristics are included as indicated.