AJAE appendix for

"Hog barns and neighboring house prices: Anticipation and post-establishment impacts"

Chad Lawley

January 19, 2021

The material contained herein is supplementary to the article named in the title and published in the *American Journal of Agricultural Economics*

A. Study Area Background

Like other jurisdictions in North America, the southeastern region of Manitoba experienced substantial increases in the size of the hog sector beginning in the 1990s and continuing into the mid-2000s. Local conflict surrounding hog barns in Manitoba and other North American locations has often been the result of odour from barns, both real and perceived. This is not a new source of conflict in Manitoba. In 1971 the Manitoba Clean Environment Commission (CEC) responded to an odour related complaint by ordering a hog operation to reduce the size of its herd and to change its manure handling procedures (CEC 2007). A series of events tied to this complaint led to creation of Manitoba's *The Nuisance Act* in 1974, which limits the right to sue for nuisance due to odour (CEC 2007), similar to "right to farm" legislation in other jurisdictions. Concerns about odour have persisted. The primary complaint received by the Manitoba Farm Practices Review Board (FPRB) concerns odour from hog barns; in 2007 the CEC (2007) reported that 77% of all complaints received by the FPRB related to odour, and 87% of odour complaints were related to odour from hog barns. Odour-related concerns affected hog barn expansion in even the most intensive production regions in Manitoba, including the municipality of Hanover (Sanders 2001; Gilbey 2006). Casual inspection of recent public comments on new barn proposals posted to the Manitoba Livestock Technical Review Public Registry suggest that odour and its potential impact on property values continue to be among the top concerns expressed by local residents.[1]

Barn Approval Process

The approval process for a new livestock barn or expansion of an existing livestock barn in Manitoba has evolved over time and has generally involved the following three steps: 1) preparation of a report by the provincial Technical Review Committee (TRC); 2) a decision by the

[1] The Public Registry can be found at https://www.gov.mb.ca/mr/livestock/public_registries.html.

local municipal council about a conditional use application; and 3) a decision by the province about the manure storage facility permit (CEC 2007). The TRC report assesses the suitability of the proposed livestock facility as judged by risks to health, safety, and the environment, as well as compliance of the proposed facility with development plan policies, zoning bylaws, and the *Provincial Planning Regulation*. The report from the TRC is initiated by an application from a barn proponent to the local municipal council. The coordinator of the TRC solicits public comments through ads in local newspapers and letters sent directly to potentially affected residents (comments are collected over a period of 30 days). These comments are posted to the Manitoba Livestock Technical Review Public Registry. Public notice of the conditional use hearing is required 14 days prior to the hearing.

Conditional use orders are granted by local municipal councils, which places them at the centre of disputes about hog barn establishment. Proponents of livestock barns suggest that small, vocal groups of opponents have significant influence over local municipal councils, whereas opponents of hog barn development suggest that municipal councils are swayed by proponents and the provincial government despite local opposition to barn development (CEC 2007). Manitoba municipal councils have historically approved most conditional use applications; between 1998 and 2005, 86% of proposed barns or expansions reviewed by TRCs were approved by municipal councils (CEC 2007). In 2006, the Provincial government issued a province-wide moratorium on development and expansion of hog barns, primarily due to a concern about phosphorus pollution causing algal blooms in Lake Winnipeg. The moratorium was lifted across much of Manitoba in 2008 and then lifted across the entire province in 2017, restoring more control of the approval process with municipal councils.

Minimum Separation Distances and Public Notifications

Manitoba regulations address several of the issues that arise due to the potential negative consequences of barns on neighboring residents. First, an important component of the *Provincial Land Use Policies* relates to minimum separation distances between residences and manure storage or animal confinement facilities. Minimum separation distances vary by the size of barn, the type of manure storage, and land use designation; the minimum separation distance associated with a house in an area designated for agriculture is between 500 metres and 1 km for the largest hog barns, depending on the type of manure storage facilities, while the separation distance restrictions from designated residential areas range from 530 metres for the smallest barns to 4 kms for the largest barns (*Provincial Planning Regulation M.R. 80/2011*). As described in more detail later in the article, the minimum separation distance applicable to most barns in Manitoba in the late 1990s and early to mid-2000s was less than 2 kms.

Second, prior to the year 2000 *The Planning Act* required barn proponents to notify all residents within 100 metres of a proposed barn about the public conditional use hearing. Amendments to *The Planning Act* in 2000 required that residents within 2 km of a proposed hog barn be notified of public comment periods and conditional use hearings and in 2006 *The Planning Act* was further amended to require that residents within 3 km be notified. Both the minimum separation distances and public comment and hearing notification requirements are designed to mitigate negative externalities of hog barns that are less than 2 to 3 kms from a residence.

Odour Dispersion Models

Zhang et al. (2012) estimate the spatial extent of the impact of hog barn odour using a combination of odour dispersion estimates and odour acceptability levels or frequency of odour annoyance free periods. Their study is based off of data collected in 2000 and is applied to a hypothetical "average" hog operation with 675 animal units. Depending on the dispersion model used, Zhang et al (2012) suggest that an average separation distance (between a barn and house) of 2.9 to 3.8 kms will achieve a low annoyance standard of 88 hours annoyance over the course of a year (99% anoyance free). The average separation distance falls to 1.2 to 1.9 kms for an annoyance standard of 263 hours annoyance over the course of a year (97% anoyance free). Note that these annoyance measures provide estimates of the average number of hours but are not adjusted for the timing of the annoyance. Relaxing the annoyance standard to 438 hours annoyance (95% annoyance free) decreases the average minimum separation distance to 0.7 to 1.5 kms. Survey evidence suggests that fewer than half of residents find this level of annoyance "acceptable."[2] Comparing these estimates to the nuisance costs estimated in this article, it appears as though there is a price discount due to close barns that generate what most people consider to be an unacceptable level of annoyance. Based on Zhang et al. (2012), barns more than 2 km from a house appear to generate relatively low annoyance levels.

B. Summary Statistics

The basic research design compares house sales with at least one barn in the immediate proximity of the house to a comparable set of house sales that do not have a barn within their immediate proximity. Table B1 presents means and standard deviations for houses within 2 km of a barn (treated house sales) and for houses between 2 and 10 kms from a barn, as well as normalized differences in means between these two subsamples. On average, the raw data in table

[2] Odour acceptability levels are derived from the results of household surveys of people living close to barns and people living farther from barns. Zhang et al. (2012) do not address selection issues that may arise due to indifferent households (those more accepting of hog barns) locating closer to barns.

B1 indicates that houses within 2 km of a hog barn sell for higher prices than houses that are farther from a hog barn. Houses close to barns tend to be on higher capability soil and on larger land parcels than those farther from barns. Houses close to barns tend to be older; the average age of houses close to barns at the time of sale is 30.5 years while the average age for those farther from barns is 26.1 years. House parcels close to barns are more likely to have additional buildings such as non-species barns, machine sheds, and workshops. Houses close to barns tend to be closer to the community of Steinbach. Houses closer to barns were surrounded by more cropland in 1980, and the value of land and livestock within 8 km of the house parcel was higher on average. Houses closer to barns tended to be in more sparsely populated areas, with higher average incomes and house values in 1980. On average, houses within 2 kms of a barn have 15 hog barns and 13 poultry barns within 8 km, compared to houses 2 to 10 kms from a barn, which have 10 hog barns and 9.5 poultry barns within 8 km.

Examination of the raw data presented in table B1 indicates substantial differences between the two sale groups. Linear regression methods may be sensitive to model specifications (functional form of covariates) with a normalized difference that exceeds 0.25 (Imbens and Rubin 2015). As presented in table B1, several of the covariates in the raw data have normalized differences greater than 0.25, including high capability soil, parcel area, the presence of non-species barns, and five of the seven variables capturing the neighboring agricultural and economic landscape. Important for this study, the normalized differences in the number of hog and poultry barns within 8 kms between the treated and untreated groups are substantial. This suggests that, on average, the two subsamples are drawn from locations with substantially different features. As expected, the houses within 2 km of a hog barn are in intensive livestock production regions, whereas houses farther than 2 kms from a barn tend to be in less intensive livestock production regions.

As discussed in the data trimming section of the main text, the data trimming procedure improves covariate balance of several important control variables. Table B2 presents means for the treated and control house sales in the trimmed sample, the normalized differences in these means, and means for the discarded low propensity score and high propensity score observations. As noted in the main text, the normalized differences fall for 22 of the 35 covariates, suggesting an overall improvement in balance. Important for this study, the normalized differences for the number of hog and poultry barns within 8 kms improves substantially to the point where the intensity of neighboring livestock production is similar across treated and untreated house sales.

Table B3 presents the full set of means and standard deviations for the trimmed sample, broken out by treated and control house sales, for sales that occur before and after barn establishment, as well as sales of houses that are between 5 and 10 kms from a barn.

C. Trends in House Prices

In this section, I show the evolution of house prices over time, relative to the date of barn establishment. I also present the results from a simple hedonic analysis of house prices. The residuals from this hedonic model are presented graphically for the four groups used in the difference-in-differences analysis, treated and control, pre- and post-barn establishment. Figure C1 presents the yearly average log of house sale prices relative to the date of barn establishment. The figure indicates that house sale prices in the treated and control groups were approximately equal and tended to move together prior to barn establishment. Prices in the treated group are higher than in the control group after barn establishment. As outlined in the data section of the main article, this simple comparison of means before and after barn establishment does not control for changes in the composition of the sample of houses in the two groups. In the following, I present results from a basic hedonic model of house prices that controls for these important covariates, and I follow this with plots of the sale price residuals derived from this simple hedonic regression.

I present results from two hedonic regressions of the log of house sale price on house and land parcel characteristics and month and year fixed effects:

(C1) $$\ln(p_{ht}) = \beta X_h + \delta_t + u_{hjt}.$$

Table C1 presents results from two regressions based on equation (C1). The first presents results for the full trimmed sample, while the second presents results for a trimmed sample including only those houses that are within 5 kms of at least one hog barn. Slope, elevation, and soil capability of the land parcel appear to have little impact on house sale prices. The size of the parcel has a positive and statistically significant impact on house sale prices. Older houses tend to sell for lower prices and the quadratic term on the age of the house indicates that the effect of age diminishes with time; a 10-year-old house sells for approximately 5% less than a newly built house, while a 60-year-old house sells at a 2% discount relative to a 50-year-old house.

As expected, construction quality is among the most important determinants of house price. Houses in the highest quality construction category (good) sell for approximately a 75% premium over houses classified in the omitted lowest quality category (poor). The price premium associated with construction quality decreases with the lower quality categories; average-good houses sell for a 50% premium, average quality sells for a 38% premium, and fair quality houses sell for an 18% premium over poor quality houses. Multiple and split story houses sell for small premiums over single story houses. The square footage of the house commands a significant premium: a 1%

increase in square footage increases the sale price by 17 to 18%. Air conditioning, a brick exterior, fireplace, basement, garages, and other buildings all add value to the houses in this sample. On average, houses that are farther from Winnipeg sell at a discount relative to houses that are closer to the city. After controlling for distance to Winnipeg, houses for which Steinbach and Ste. Anne are the closest major centres sell for a higher price than houses for which Niverville is the closest centre.

The importance of the 1980 measures of the agricultural and economic landscape within 8 kms is mixed. Houses in regions with a greater share of surrounding grassland in 1980 sell at a discount, relative to the share of surrounding land in developed use or cropland. Houses in regions with lower agricultural land values in 1980 tend to sell for a higher price. Finally, houses in regions with higher average incomes in 1980 sell for a higher price during the study period. The variables included in the specifications reported in table C1 are included as controls in all the specifications reported in the article.

Residuals from the regression presented in column 2 of table C1 are plotted in figure C2. The mean house sale price residuals are plotted separately for houses within 2 kms of a barn and houses between 2 and 5 kms from a barn, for each year relative to barn establishment date. The weighted mean is then plotted for the pre- and post-establishment treated groups and the pre- and post-establishment control groups, allowing for a comparison of four means similar to that conducted in a standard 2x2 difference-in-differences. The yearly means bounce around substantially, but figure C2 indicates that on average the mean sale price residuals are approximately equal in the pre barn establishment period but diverge in the post establishment period such that the mean value of the sale price residuals falls by just under 5% relative to the pre barn period.

D. Spatial Difference in Differences: Additional Robustness

Alternative Samples

A general concern in hedonic property value models is adjustment in the quantity of the housing stock in response to changes in the amenity or disamenity being studied, and the impact that this market adjustment might have on property prices. Adjustments in the quantity of housing can potentially absorb some of the price impact. For example, the supply of housing might increase in regions farther from hog barns. All else equal, increased supply of housing farther from the barn will decrease the prices of houses farther from the barn, relative to prices of houses close to the barn. The market adjustment will therefore reduce the estimated impact of hog barns on local house prices. This adjustment will not take place immediately and and if it is important then estimates of the potential negative impact of hog barns on house prices will fall over time. In light of this potential concern, recent hedonic property value studies restrict their sample to house sales that occur within a relatively tight timeframe around the event being studied, ranging from one or two years (Congdon-Hohman 2013; Dealy, Horn, and Berrens 2017) to five years (Haninger, Ma, and Timmins 2017).

The results reported in the tables of the article are based on a sample of house sales that occur no more than five years before or after hog barn construction within 10 kms. As a robustness check, table D1 presents results from several regressions based on house sales that occur no more than i) three, ii) seven, or iii) nine years before or after the hog barn build date. The results from these three alternative samples are largely consistent with the results based on the five year sample. There is no evidence of pre-existing differences in house prices in the treated and control groups, and houses that are within 2 kms of a hog barn at the time of sale sell at a discount. It is interesting to note that the estimated price impact of a hog barn is highest in the sample restricted to sales within 3 years of a hog barn build and lowest in the sample restricted to sales within 9 years of the barn build date, ranging from 5.6% to 4.1%.

Role of Barn Size and Location

Several prior studies examining the impact of livestock barns on house prices have considered the roles of 1) being downwind of a barn and 2) the size of barn as measured by animal unit equivalents. Both characteristics are thought to influence the actual or perceived extent of odor problems. Table D2 presents the results of several specifications investigating the impact of being located downwind of the hog barn and the impact of barn size on house prices. Several previous studies have examined the role of prevailing winds. Herriges, Secchi, and Babcock (2005) find that houses located within the path of prevailing winds suffer the largest drop in house prices. Isakson and Ecker (2008) examine the role of prevailing wind combined with distance from the barn and find that the role of wind is limited to houses that are within 3 miles of a barn. Being downwind of a barn within 3 miles tends to substantially decrease house prices. Kim and Goldsmith (2009) find little evidence that prevailing winds matter; when prevailing wind does matter, the effect is contrary to expectations.

Prevailing wind appears to have little influence on the impact of neighboring hog barns on house prices in this region. The definition of prevailing wind is based on historical wind data that suggests prevailing winds in southern Manitoba (south of Winnipeg) come from the south for most of the year. Prevailing winds are defined as the region ranging from south southeast to the southwest.[3] Column (1) of table D2 includes a dummy variable equal to one if the nearest barn within 2 kms is located downwind within the prevailing wind path. The results suggest that there is no additional impact due to being downwind from the hog barn.

Past research has presented mixed results regarding barn size. Isakson and Ecker (2008) find that animal units are negatively correlated with house prices, suggesting that the largest barns have the largest negative impact on neighboring houses. Ready and Abdalla (2005) find mixed results on barn size, once again measured in animal units. Very large barns tended to have the largest negative impact, but the impact does not vary monotonically with size, such that medium barns had a larger negative impact than large barns. Ready and Abdalla (2005) also note that the estimated impacts of barn size are not statistically different from one another. Similarly, Herriges, Secchi, and Babcock (2005) find that moderate-sized hog operations tend to have a greater impact on house prices than large-scale operations, perhaps due to correlation between size and the management and age of the facility.

Animal unit equivalents are not available for this study. Distinctions between different sized barns are therefore based on square footage information included in assessment records. Square footage can only serve as a rough proxy for animal units due to square footage requirements that differ according to the type of pig. For example, the square footage requirement for a nursery differ from the square footage requirements for a finishing barn, leading to significant differences in the density of animals and animal unit equivalents. I divide square footage into quintiles and restrict the analysis to barns that are in the top three quintiles, which corresponds to hog barns larger than

[3] ArcGIS is used to calculate the angle between each sold house and the nearest hog barn within 2 kms. The angle is set to 0 for east, 180 (or -180) for west, 90 for north, and -90 for south. The dummy variable for prevailing wind is set to 1 if the angle is between -70 and -180.

14,000 square feet.[4] To further investigate the role of barn size, I classify barns in the fourth quintile as "medium" barns and barns in the fifth quintile as "large" barns. The results presented in column (2) of table D2 suggest that the impact of medium and large hog barns is not different from the overall impact of barns within the third quintile. Finally, the result in column (3) of table D2 indicates that the impact of the largest hog barns is no different than the impact of small and medium sized barns.[5]

E. Repeat Sales Analysis

I construct a repeat sales subsample comprised of 161 houses within 2 kms of a barn, with at least one sale pre-barn establishment and one sale post-barn establishment, and 271 houses 2 to 5 kms from a barn, once again with both pre- and post-barn establishment sales. I start with a sample selection model to assess if houses in the repeat sale subsample are representative of the full sample in the study region. Clapp and Giaccotto (1992) outline reasons that houses involved in repeat sales are not likely to be representative of the population of house sales: 1) poorly maintained houses may be purchased with the intent to repair and renovate prior to quick resale, 2) frequent transactions on the same house are more likely for less desirable houses that are not meeting buyers expectations, and 3) "starter homes" are more frequently resold. As reported in table E1, the houses involved in repeats sales in this region of Manitoba tend to be older, are of lower construction quality, are less likely to be multi-storey, are less likely to have valuable outbuildings such as a

[4] This is just below the *current* minimum size for a sustainable finishing barn in Manitoba (https://www.manitobapork.com/new-barn-development/starting-or-expanding-a-hog-barn).

[5] Results where medium and large barns are entered separately generate similar results, with weak evidence that the medium-sized barns have a smaller impact on house prices relative to the "small" and "large" barns.

garage and a machine shed, and are farther from Winnipeg. The simple hedonic results presented in table C1 suggest that these covariates are among the most important determinants of house prices in this region. Consistent with Clapp and Giaccotto (1992), each of these factors suggest that less desirable houses are more likely to be involved in repeat sales.

Table E2 presents the results of a repeat sales analysis. Note that a sale can be comprised of multiple roll parcels, which implies that the sales parcel characteristics associated with an individual house can change over time. Further, construction of additional buildings such as garages, workshops, and machine sheds can occur between sales. These observed changes are controlled for in the repeat sales regressions reported in table E2. Consistent with the main results I find that the presence of a barn within 2 kms of a house prior to the house sale reduces the price of the house by 5.4%. This estimate is less precisely estimated (statistically significant only at the 10% level), consistent with the smaller sample size. Once again, consistent with the main results, the presence of a barn within 2 to 5 kms prior to the sale appears have no impact on house prices.

F. Alternative Research Design Exploiting Timing of Barn Establishment

Rather than using variation in spatial proximity to hog barns, the results reported in this section are derived from temporal variation in the establishment of hog barns in close proximity to houses. This approach relies on random timing of hog barn establishment. The sample is restricted to house sales that are within 2 kms of a hog barn at some time during the study period. This set of treated house sales is divided into g subgroups according to the year the barn was established; each of these subgroups has sales that occur prior to barn establishment (the sale year is earlier than the year the barn was constructed) and sales that occur after the barn is established. The year of sale is normalized across subgroups such that the "event year" for each observation is the difference between the calendar year in which the sale occurs and the calendar year in which the barn is built.[6] These observations serve as treated observations for group g, where negative event years correspond to pre-treatment observations and positive event years correspond to post-treatment observations.

Control observations are drawn from the remaining subgroups that have had no new barn establishment within the five years preceding the date of establishment and five years after the date of establishment for group g. Each of the houses in the control group is within 2 kms of a hog barn at some time during the study period. Observations are excluded as controls according to the following criteria: 1) if the event year of the potential control observation is less than g, then all house sales that occur prior to construction of the local barn are dropped from the set of control observations; 2) if the event year of the potential control observation is greater than g, then all house sales that occur after construction of the local barn are dropped from the set of controls; and 3) if there are multiple barns within 2 kms of the house sale and the build date of the last hog barn is less than g, then all house sales that occur prior to construction of the local barn are dropped from the set of control observations.

Separate datasets comprised of treated and control observations are assembled for each subgroup g. These separate datasets are combined to construct a new dataset with g treated groups and their associated control observations. Note that an individual house sale might enter the dataset multiple times, at least once as a treated observation (pre- or post-treatment) and up to $g - 1$ times

[6] For example, houses that are within 2 kms of a barn constructed in 1998 are assigned to subgroup $g = 1998$. For this subgroup, a sale that occurs in 1996 is assigned to event year "-2" and a sale that occurs in 2001 is assigned to event year "3." Houses that are within 2 kms of a barn built in 2001 are assigned to subgroup $g = 2001$. For this subgroup, a sale that occurs in 1996 is assigned to event year "-5" and a sale that occurs in 2001 is assigned to event year "0."

as control observations. This approach is applied separately to the set of treated houses (within 2 kms of a barn) and to a set of placebo houses (2 to 5 kms from a barn). The results of this approach corroborate the results from the baseline approach if negative treatment effects are identified in the set of treated houses and no treatment effects are identified in the set of placebo houses.

There are several important trade-offs with this approach as compared to the baseline approach outlined in the empirical strategy section of the main article. First, the analysis is restricted to house sales that are eventually treated, which improves covariate balance between the treated and control observations. Whereas the baseline approach relied on a trimming procedure to improve balance of the treated and control observations, this approach simply limits the analysis to those houses that are eventually within 2 kms of a barn. Second, the set of control observations is restricted to those that have not had new barn establishment within a ten-year window around each treated event. Cengiz et al. (2019) follow a similar approach in an effort to reduce possible bias due to heterogeneous treatment effects.

A drawback of this approach is that it relies on the assumption that, conditional on treatment (i.e., eventually being within 2 kms of a hog barn), the year of hog barn establishment is random. In table F1, I estimate the impact of time-invariant house sale characteristics on the year that a hog barn is built within 2 kms of the house. In table F1, I estimate the impact of time-invariant house sale characteristics on the year that a hog barn is built within 2 kms of the house. Column (1) presents results for the 1,081 houses that are within 2 kms of a hog barn and are involved in a sale during the study period. The 1,081 houses neighbor 119 unique barns, which implies that several of these houses are within 2 kms of the same hog barn. Columns (2) and (3) present results for a smaller set of houses adjacent to barns built after 1995 and 2000, respectively.

Overall, focussing on the results presented in column (1), there appears to be correlation between house sale characteristics and the timing of hog barn construction. Several of the important determinants of house price, such as the quality of house construction and the number of stories, are not correlated with the timing of barn construction. However, barns constructed in earlier years tend to be located next to houses on smaller parcels, with more square footage, and that are farther from Winnipeg. Houses with fireplaces are more likely to be near a barn constructed later in the study period, whereas houses with attached garages are treated earlier. Variables documenting location and the characteristics of the surrounding landscape as measured in 1980 appear to be correlated with the timing of neighboring barn construction. Hog barns constructed in earlier years tend to be near houses in landscapes with high land values, lower livestock value, higher density of houses, and lower average income. Overall, these results suggest that some important physical characteristics of the house are related to neighboring barn establishment timing, and characteristics of the neighboring landscape appear to be strongly correlated with the timing of barn establishment. Thus, while the results presented in this section provide a useful robustness check of the main results, they should be interpreted with caution.

The house price impact of at least one hog barn within 2 kms is estimated in regression form using the following estimating equation:

(F1) $\ln(p_{hgt}) = \beta X_h + \alpha_g + \delta_t + \gamma \text{Treat}_{ht} + \sum_{s=-10}^{s=10} \varphi_s e_{ht} + \sum_{s=-10}^{s=10} \omega_s \text{Treat}_{ht} \times e_{ht} + \varepsilon_{hgt}$

where g indexes the event year subgroup, α_g is a set of fixed effects for each event year group, and ε_{hgt} is the error term. Treat_{ht} is an indicator equal to one if house h is in the treatment group in year t. As in the spatial difference in differences specification above, the individual normalized event years are denoted e_{ht} and range from the house sale occuring ten years or more prior to hog barn establishment to sales occuring ten years or more after hog barn establishment. In this specification the primary coefficients of interest are the ω_s, which estimate the difference in sales prices between the treated and control houses s years after hog barn establishment. As mentioned above, the parameters of equation (F1) are estimated separately for a sample of treated houses (within 2 kms of a hog barn) and a sample of placebo houses (within 2 to 5 kms of a barn).

Figure F1 plots the ω_t coeffcients, tracing out the evolution of differences in prices between house sales in the treated group and houses in the control group, for each normalized event year in the study period. The left panel presents results for the treated houses and the right panel presents results for the placebo set of houses. The results presented in the left panel of figure F1 are largely consistent with those presented in figure 1 of the main article. Once again, there is evidence of pre trends due to market anticipation of barn establishment, and the estimated coefficients plotted in figure F1 are always less than zero after the barn is established. The right panel in figure F1 plots coefficient estimates using a placebo dataset constructed from all houses that are within 2 to 5 kms of a hog barn. Visual inspection suggests that hog barn establishment within 2 to 5 kms does not impact house sale prices.

Tables F2 and F3 present results for the impact of hog barns on house prices, averaged over the entire post barn period, for treated houses within 0 to 2 kms of a barn and placebo houses within 2 to 5 kms of a barn. Estimates are derived from the following estimating equation:

$$\text{(F2)} \quad \ln(p_{hgt}) = \beta X_h + \alpha_g + \delta_t + \gamma \text{Treat}_{ht} + \vartheta \text{Post}_{ht} + \varphi \text{Treat}_{ht} \times \text{Post}_{ht} + \varepsilon_{hgt}.$$

which provides an estimate, φ, of the average causal impact of hog barns on the sale price of houses. This estimate is identified off of the timing of hog barn establishment and is not biased by unobserved spatial determinants of hog barn location since all houses are approximately the same distance from a barn.

The results presented in column (1) of tables F2 and F3 are based on specifications that ignore anticipation of barn establishment. These results indicate that a barn within 2 kms reduces house sale prices by 7.4%, while a barn within 2 to 5 kms has no impact on house prices. This result is largely consistent with the spatial difference in differences estimates presented in the previous section.

An advantage of this alternative specification is that it relies exclusively on house sales that are within 2 kms of a hog barn at some time during the study period. This eliminates potential issues associated with endogenous treatment as discussed in the spatial difference in differences estimates reported above. Columns (2) through (5) of tables F2 and F3 repeat the quasi-myopic specifications as conducted in Malani and Reif (2015). Similar to the graphical evidence presented in figure F1, the results are consistent with housing market anticipation of hog barn establishment. Allowing for potential anticipation increases the impact of a hog barn on house prices by as much as 2.3 percentage points to a maximum impact of 9.7%. Moreover, as reported in column (5), it appears as though the average decrease in house prices over the three years preceeding barn establishment is 6.9%. Note also that there is no evidence of treatment effects within the placebo group of houses, once again consistent with the notion that the impact of hog barns on house prices does not extend beyond 2 kms. Since endogenous treatment along the spatial dimension is not an issue in this approach, these results suggests that the pre-trend in house prices, as observed in figure 1 of the main article and figure F1, are likely the result of housing market anticipation as opposed to endogenous treatment.

G. Alternative Specifications Following Prior Studies

Much of the prior literature examining the impact of livestock barns on residential property prices has used a linear proximity index with a parametric form that estimates relatively large impacts close to houses and smaller impacts on houses that are farther from the barn. Most of these studies have used some variant of the inverse of distance between the house and the nearest barn (Ready and Abdalla 2005; Kim and Goldsmith 2009), the log of the distance between the house and the nearest barn (Herriges, Secchi, and Babcock 2005), or the distance between the house and nearest barn (Isakson and Ecker 2008; Kuethe and Keeney 2012). Herriges, Secchi, and Babcock (2005) and Kuethe and Keeney (2012) do not limit the spatial extent of barns on house prices, whereas Ready and Abdalla (2005), Isakson and Ecker (2008), and Kim and Goldsmith (2009) examine impacts within spatial buffers. In this section, I estimate the impacts of hog barns on house prices following these prior approaches.

Consistent with the prior literature, I restrict the analysis to sales of houses that occur after the barn is established. I construct a linear proximity index following Ready and Abdalla (2005):

(G1) $$LPI = \left\{ \begin{matrix} \frac{1}{Dist} - \frac{1}{Limit} & \text{if } Dist < Limit \\ 0 & \text{if } Dist \geq Limit \end{matrix} \right\}$$

where $Dist$ is the distance between the house and the nearest barn measured in metres and $Limit$ is the assumed outer limit of the impact of barns on house prices. The results reported in Ready and Abdalla (2005) enter the proximity index with an additional quadratic term:

(G2) $$QPI = \left\{ \begin{matrix} \frac{1}{Dist^2} - \frac{1}{Limit^2} & \text{if } Dist < Limit \\ 0 & \text{if } Dist \geq Limit \end{matrix} \right\}.$$

As in Ready and Abdalla (2015), I test for the appropriate value of the outer limit by including a second outer ring index:

(G3) $$ORI = \left\{ \begin{matrix} \frac{1}{Limit} - \frac{1}{K} & \text{if } Dist < Limit \\ \frac{1}{Dist} - \frac{1}{K} & \text{if } Limit \leq Dist \leq K \\ 0 & \text{if } Dist \geq K \end{matrix} \right\}.$$

The spatial limit of the disamenity can be tested by inclusion of the linear proximity index and the outer ring index, where the spatial extent of the disamenity, $Limit$, occurs when the outer ring index goes to zero. Like the results reported in the main article, I find that hog barns have no impact on houses beyond 2 kms. Consistent with this result, the results presented in this section assume that the outer limit is 2001 metres.

A couple of prior studies use the log of the distance to the nearest barn. Herriges, Secchi, and Babcock (2005) use log of distance with no limit on the spatial limit of the impact of hog barns beyond the extent of the study area. Their estimates of the house price discount due to a hog barn at a specific distance (½ mile, 1 mile, etc.) is calculated relative to a house with no barns within 3 miles. Ready and Abdalla (2005) construct a proximity index using the log of distance, but do not report results. Following Ready and Abdalla (2005), I construct the following spatial proximity index using log of distance to the nearest barn:

(G4)
$$LPI_{log} = \begin{cases} \ln(Dist) - \ln(Limit) & \text{if } Dist < Limit \\ 0 & \text{if } Dist \geq Limit \end{cases}$$

The linear, quadratic, and log of distance specifications are each estimated using two approaches. Both samples are restricted to house sales that have at least one hog barn within 5 kms at some point during the study period. The first approach is a cross-sectional analysis intended to mimic the type of sample available in prior studies; all sales that occur prior to establishment of the first barn within 5 kms are dropped. The second approach utilizes a difference-in-differences design using the same sample used in column (3) of table 2 in the main article. It is important to note that the approaches used in this appendix do not replicate the various attempts to correct for spatial correlation and endogeneity in the prior literature. Rather, the results reported in this section are used to explore the impact of alternative specifications and research designs on the house price discounts reported in the main article.

Results using these proximity indices are presented in table G1. I present both results for a cross-sectional linear proximity index and quadratic proximity index in columns (1) and (3), respectively. For comparison purposes I also present difference-in-difference results for the linear and quadratic proximity indices in columns (2) and (4). First, note that the cross-sectional estimates presented in columns (1) and (3) are 12% to 37% higher than the difference-in-differences estimates presented in columns (2) and (4). This suggests that, in this study region, the estimates based on the cross-sectional specifications used in prior studies will tend to overestimate the house price discount, relative to the difference-in-difference specifications used in this article.

Second, it appears as though the parametric form used in the prior studies tends to estimate relatively large impacts if the house is very close to a barn and that the impact falls off quickly. This result is independent of the research design and is apparent in both the cross-sectional and the difference-in-differences results presented in table G1. For example, the results suggest that a house that is within 634 metres of a barn (the average distance for houses that are within 1 km of at least one hog barn) declines by 4.1 to 7.1%. Houses that are 1,576 metres from a barn (the average distance for houses that are 1 to 2 kms from a barn) decline by 0.5 to 1%. Overall, a house that is 1,412 metres from a barn (the average distance for a house that is within 2 kms of a barn) declines in price by 0.8 and 1.5% due to the presence of the hog barn prior to the sale of the house. Like the results presented in this article, these results suggest that the impact of hog barns declines with distance. In contrast to the prior literature, the analysis used in the main article does not impose a specific functional form on the extent to which the impact of the disamenity declines with distance from the barn. In the Ready and Abdalla (2005) specification, the impact declines quickly with distance—the price impact due to the disamenity is quite large if the house is very close to a barn, but drops almost to zero just a little farther from the barn. Since houses within 1 km of a barn are rare, these results suggest that there is an economically significant house price discount for only a small number of houses across the entire study region.

The role of anticipation is a potentially important factor that has not been directly accounted for in the prior literature. Past research has used data where sales occur after barn establishment. However, this past research may be biased due to inclusion of “control” houses that are sold just prior to barn establishment. This is most likely in cases where the barn is established a few years after the end of the study period. If the market anticipates the future arrival of a barn by discounting the price today, then including these houses as controls will bias estimates downward. This is most likely to be a concern in studies that use sales data over a relatively short time period drawn from years where the hog industry is expanding and many new barns are being constructed.

To assess the potential role of anticipation I re-estimate the linear proximity index models on several subsets of the data, presented in table G2. First, I look at house sales that occur 1) between 1993 and 1998, a period coinciding with a significant expansion of the Manitoba hog sector and 2) between 2005 and 2010, a period just after the expansion of the hog sector and leading into the 2006 hog barn moratorium. Since there are fewer barns established after house sales in the 2005-2010 period, potential bias due to unobserved anticipation is expected to be lower in this period. I assess the potential role that anticipation played in previous studies by comparing results obtained from 1) a sample that drops all house sales where a barn is established near to the house three or fewer years post sale and 2) a sample that includes house sales that have occurred prior to barn establishment three or fewer years before the house sale.

During the expansionary period, the naïve estimates suggest that house prices decline by 4.6% at 634 metres from a barn, whereas the estimates accounting for anticipation (problematic observations dropped from the estimation sample) suggest a price discount of 7.3% at 634 metres from a barn. Note that the number of observations falls by 149 house sales when accounting for anticipation. The results from the post-expansionary study tell a similar story, although the difference between the results with the samples accounting for anticipation and those that do not is somewhat smaller; a hog barn at 634 metres is estimated to increase the house price discount from 5.6% without accounting for anticipation to 7.3% after accounting for anticipation. In this case, 9 observations are dropped in the sample accounting for anticipation, consistent with the low probability of future barn establishment in the 2005 to 2010 period.

References

Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer. 2019. "The effect of minimum wages on low-wage jobs." *The Quarterly Journal of Economics* 134(3):1405-1454.

Clapp, John M., and Carmelo Giaccotto. 1992. "Estimating price indices for residential property: a comparison of repeat sales and assessed value methods." *Journal of the American Statistical Association* 87(418):300-306.

Clean Environment Commission. 2007. "Environmental sustainability and hog production in Manitoba." https://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=19200&md=1

Congdon-Hohman, Joshua M. 2013. "The lasting effects of crime: The relationship of discovered methamphetamine laboratories and home values." *Regional Science and Urban Economics* 43(1):31-41.

Dealy, Bern C., Brady P. Horn, and Robert P. Berrens. 2017. "The impact of clandestine methamphetamine labs on property values: Discovery, decontamination and stigma." *Journal of Urban Economics* 99:161-172.

Gilbey, Robert. 2006. "Hanover council will soon decide on a hog barn expansion," Steinbach Online Last accessed on the World Wide Web December 13, 2019 https://www.steinbachonline.com/local/hanover-council-will-soon-decide-on-a-hog-barn-expansion

Haninger, Kevin, Lala Ma, and Christopher Timmins. 2017. "The value of brownfield remediation." *Journal of the Association of Environmental and Resource Economists* 4(1):197-241.

Herriges, Joseph A., Silvia Secchi, and Bruce A. Babcock. 2005. "Living with hogs in Iowa: the impact of livestock facilities on rural residential property values." *Land Economics* 81(4):530-545.

Imbens, Guido W., and Donald B. Rubin. 2015. *Causal inference in statistics, social, and biomedical sciences*. New York, Cambridge University Press.

Isakson, Hans R., and Mark D. Ecker. 2008. "An analysis of the impact of swine CAFOs on the value of nearby houses." *Agricultural Economics* 39(3):365-372.

Kim, Jungik, and Peter Goldsmith. 2009. "A spatial hedonic approach to assess the impact of swine production on residential property values." *Environmental and Resource Economics* 42(4):509-534.

Kuethe, Todd H., and Roman Keeney. 2012. "Environmental externalities and residential property values: externalized costs along the house price distribution." *Land Economics* 88(2):241-250.

Malani, Anup, and Julian Reif. 2015. "Interpreting pre-trends as anticipation: Impact on estimated treatment effects from tort reform." *Journal of Public Economics* 124:1-17.

Provincial Planning Regulation M.R. 81/2011, In *The Planning Act* C.C.S.M. 2011 c. P80, Appendix 1. Last accessed from the World Wide Web Nov 14, 2019: https://web2.gov.mb.ca/laws/regs/current/081.11.pdf

Ready, Richard C., and Charles W. Abdalla. 2005. "The amenity and disamenity impacts of agriculture: estimates from a hedonic pricing model." *American Journal of Agricultural Economics* 87(2):314-326.

Sanders, Carol. 2001. “Mitchell residents fighting hog barn,” Winnipeg Free Press, February 2, 2001 (page 9 (A7)).

Zhang, Q., Z. Gao, A. La, and H. Guo. 2012. “Development of dispersion-based setback distance guideline for Manitoba,” Final Report. Last accessed from the World Wide Web February 10, 2020 https://www.manitobapork.com/images/MLMMI/2009-11/Final%20Report%202009-11%20Zhang%20Dispersion-based%20setback%20distance.pdf

Table B1. Summary Statistics for Raw Data

	Within 2 km of hog barn		Between 2 and 10 km from a hog barn		Normalized differences
	Mean	Std. Dev.	Mean	Std. Dev.	
ln(Price)	11.96	0.62	11.89	0.71	0.11
Slope	0.52	0.33	0.45	0.56	0.14
Elevation (metres)	77.11	5.14	77.61	5.94	-0.09
High capability soil (%)	36.25	39.41	25.78	35.04	0.28
Medium capability soil (%)	62.94	39.44	71.64	36.43	-0.23
Parcel area (acres)	5.29	7.16	2.40	4.68	0.48
Age of house at sale date	30.48	23.63	26.14	23.03	0.19
Quality: good (Yes=1)	0.02	0.14	0.02	0.14	0.01
Quality: average-good (Yes=1)	0.17	0.37	0.18	0.38	-0.04
Quality: average (Yes=1)	0.55	0.50	0.59	0.49	-0.08
Quality: fair (Yes=1)	0.22	0.41	0.16	0.37	0.13
Stories: Multiple (Yes=1)	0.24	0.43	0.18	0.38	0.16
Stories: Split (Yes=1)	0.15	0.36	0.20	0.40	-0.13
Square footage (Yes=1)	1233.78	416.44	1200.87	415.90	0.08
Air conditioning (Yes=1)	0.40	0.49	0.47	0.50	-0.13
Brick exterior (Yes=1)	0.23	0.42	0.26	0.44	-0.07
Fireplace (Yes=1)	0.17	0.38	0.17	0.37	0.02
Basement (Yes=1)	0.80	0.40	0.79	0.41	0.05
Attached garages	0.57	0.50	0.56	0.50	0.01
Detached garages	0.39	0.56	0.33	0.52	0.11
Barns	0.17	0.59	0.04	0.32	0.26
Machine sheds	0.18	0.66	0.07	0.40	0.21
Workshops	0.06	0.34	0.02	0.22	0.13
Distance to Winnipeg	30382.47	12839.29	32077.68	16459.96	-0.12
Nearest centre: Steinbach	0.53	0.50	0.46	0.50	0.14
Nearest centre: Ste. Anne	0.14	0.35	0.15	0.36	-0.03
1980 cropland within 8 km (%)	44.94	18.38	36.45	18.19	0.46
1980 grassland within 8 km (%)	19.53	8.17	21.66	8.51	-0.26
1980 land value within 8 km ($)	855.36	117.84	788.45	141.93	0.51
1980 livestock value within 8 km ($)	121.75	52.88	108.29	48.69	0.27
1980 number of houses within 8 km	1650.32	614.96	3199.26	9815.66	-0.22
1980 average income within 8 km ($)	31179.72	3433.88	30544.71	3700.86	0.18
1980 avg. house value in 8 km ($)	65356.21	5285.06	63059.51	8489.02	0.33
Number of hog barns within 8 km	15.23	10.15	10.42	9.77	0.48
Number of poultry barns in 8 km	13.12	8.50	9.54	8.25	0.43
Observations	2,205		15,191		

Table B2. Means for Trimmed and Discarded Samples

	Trimmed sample			Discarded sample	
	Within 2 km of hog barn	Between 2 and 10 km from a hog barn	Normalized difference	Low propensity score $ps < 0.066$	High propensity score $ps > 0.934$
ln(Price)	11.98	11.95	0.05	11.85	11.79
Slope	0.52	0.47	0.11	0.44	0.52
Elevation (metres)	76.72	78.24	-0.32	77.28	71.90
High capability soil (%)	38.02	26.59	0.30	24.87	97.05
Medium capability soil (%)	61.79	72.66	-0.28	71.22	2.62
Parcel area (acres)	5.34	3.70	0.25	1.55	15.51
Age of house at sale date	30.66	26.61	0.18	25.82	52.44
Quality: good (Yes=1)	0.02	0.02	0.02	0.02	0.00
Quality: average-good (Yes=1)	0.17	0.16	0.03	0.19	0.00
Quality: average (Yes=1)	0.54	0.59	-0.11	0.58	0.38
Quality: fair (Yes=1)	0.21	0.18	0.07	0.15	0.63
Stories: Multiple (Yes=1)	0.25	0.19	0.15	0.17	0.38
Stories: Split (Yes=1)	0.15	0.18	-0.08	0.21	0.00
Square footage (Yes=1)	1236.40	1224.77	0.03	1185.08	1074.94
Air conditioning (Yes=1)	0.41	0.42	-0.02	0.49	0.63
Brick exterior (Yes=1)	0.24	0.23	0.02	0.28	0.13
Fireplace (Yes=1)	0.18	0.16	0.05	0.17	0.00
Basement (Yes=1)	0.83	0.78	0.12	0.78	0.81
Number of attached garages	0.58	0.58	0.01	0.54	0.56
Number of detached garages	0.38	0.36	0.03	0.31	0.25
Number of non-species barns	0.18	0.09	0.17	0.01	0.50
Number of machine sheds	0.19	0.11	0.14	0.05	0.38
Number of workshops	0.06	0.04	0.09	0.02	0.00
Distance to Winnipeg (metres)	29249.88	32951.54	-0.32	31754.81	17203.50
Nearest centre: Steinbach (Yes=1)	0.52	0.60	-0.15	0.37	0.00
Nearest centre: Ste. Anne (Yes=1)	0.14	0.19	-0.16	0.13	0.00
1980 cropland within 8 km (%)	46.11	45.89	0.01	30.06	24.55
1980 grassland within 8 km (%)	19.39	18.27	0.14	23.90	29.53
1980 land value within 8 km ($)	870.19	850.20	0.20	745.16	713.75
1980 livestock value within 8 km ($)	123.51	132.07	-0.18	92.41	33.11
1980 number of houses within 8 km	1680.56	1732.41	-0.10	4148.93	1122.49
1980 average income within 8 km ($)	31408.98	30187.92	0.39	30731.48	35336.55
1980 avg. house value in 8 km ($)	65937.67	63673.67	0.43	62543.54	68506.55
Number of hog barns within 8 km	15.63	15.28	0.03	7.18	3.44
Number of poultry barns in 8 km	13.76	13.59	0.02	6.77	0.56
Observations	2,065	6,121		9,194	16

Notes: The propensity score cut-offs used to discard observations are calculated based on the procedure outlined in Imbens and Rubin (2015).

Table B3. Summary Statistics for Estimation Sample

	Within 2 km of a hog barn				Between 2 and 5 km from a hog barn				Between 5 and 10 km from a hog barn	
	Sale before barn		Sale after barn		Sale before barn		Sale after barn			
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std Dev
ln(Price)	11.58	0.49	11.83	0.58	11.58	0.52	11.70	0.53	11.65	0.73
Slope	0.50	0.37	0.52	0.33	0.42	0.48	0.38	0.46	0.63	0.50
Elevation (metres)	76.29	4.69	77.01	4.78	77.93	4.58	77.52	4.41	80.26	5.07
High capability soil (%)	39.60	40.51	36.57	38.59	35.03	41.00	28.93	39.22	25.29	34.88
Medium capability soil (%)	60.06	40.57	63.16	38.67	64.42	41.20	70.82	39.35	73.11	35.38
Parcel area (acres)	5.53	7.26	5.47	7.71	4.45	6.28	3.28	5.45	5.55	5.99
Age of house at sale date	30.88	21.81	30.34	23.10	21.49	19.27	26.64	19.91	25.08	19.12
Quality: good (Yes=1)	0.02	0.14	0.02	0.14	0.03	0.16	0.01	0.11	0.01	0.10
Quality: average-good (Yes=1)	0.08	0.27	0.15	0.36	0.10	0.30	0.11	0.31	0.11	0.31
Quality: average (Yes=1)	0.56	0.50	0.56	0.50	0.61	0.49	0.62	0.49	0.61	0.49
Quality: fair (Yes=1)	0.30	0.46	0.20	0.40	0.21	0.41	0.21	0.41	0.21	0.41
Stories: Multiple (Yes=1)	0.27	0.44	0.26	0.44	0.22	0.41	0.18	0.39	0.24	0.43
Stories: Split (Yes=1)	0.10	0.31	0.11	0.31	0.13	0.34	0.17	0.38	0.11	0.32
Square footage (Yes=1)	1151.26	394.54	1252.40	410.18	1203.95	422.87	1178.87	399.02	1244.36	415.37
Air conditioning (Yes=1)	0.31	0.46	0.40	0.49	0.37	0.48	0.40	0.49	0.31	0.46
Brick exterior (Yes=1)	0.21	0.41	0.22	0.41	0.24	0.43	0.20	0.40	0.16	0.37
Fireplace (Yes=1)	0.15	0.36	0.20	0.40	0.18	0.38	0.15	0.36	0.16	0.37
Basement (Yes=1)	0.85	0.36	0.83	0.38	0.81	0.39	0.80	0.40	0.68	0.47
Number of attached garages	0.45	0.51	0.58	0.51	0.47	0.51	0.54	0.51	0.40	0.49
Number of detached garages	0.34	0.52	0.39	0.55	0.39	0.54	0.36	0.53	0.51	0.60
Number of non-species barns	0.19	0.60	0.21	0.69	0.11	0.50	0.08	0.43	0.11	0.50
Number of machine sheds	0.16	0.60	0.19	0.67	0.13	0.50	0.10	0.47	0.13	0.58
Number of workshops	0.04	0.32	0.06	0.35	0.02	0.20	0.03	0.25	0.02	0.22
Distance to Winnipeg (kms)	27.80	11.54	30.03	11.57	31.95	11.71	32.13	12.29	34.98	11.15
Nearest centre: Steinbach (Yes=1)	0.48	0.50	0.55	0.50	0.61	0.49	0.65	0.48	0.37	0.48
Nearest centre: Ste. Anne (Yes=1)	0.14	0.35	0.17	0.37	0.21	0.40	0.10	0.30	0.59	0.49
1980 cropland within 8 km (%)	45.24	19.43	46.81	17.73	46.18	19.13	47.56	18.06	34.13	12.35
1980 grassland within 8 km (%)	20.27	8.59	18.92	7.96	18.94	8.36	17.36	7.84	24.37	6.34
1980 land value within 8 km ($)	876.11	98.51	873.81	95.18	852.79	86.35	862.16	109.38	780.93	92.65
1980 livestock value within 8 km ($)	123.06	58.21	127.96	48.91	130.84	44.12	129.54	44.85	128.07	37.48
1980 number of houses within 8 km	1656.41	378.51	1695.48	360.94	1782.60	610.28	1865.68	780.06	1339.31	447.50
1980 average income within 8 km ($)	31826.61	3539.82	31070.37	3045.51	30658.64	3182.27	30320.85	3193.55	30233.60	2388.89
1980 avg. house value in 8 km ($)	66323.08	5228.74	65471.83	4416.83	64608.84	5716.57	64382.33	5874.29	60621.33	6922.87
Number of hog barns within 8 km	14.75	10.22	16.29	9.92	12.40	7.26	17.70	10.36	3.47	2.52
Number of poultry barns in 8 km	13.70	8.66	14.37	7.73	14.66	7.68	15.13	7.80	7.52	6.37
Observations	562		693		723		1,978		419	

Table C1. Impact of House and Parcel Characteristics on Sale Price

	Full estimation sample Houses within 10 km of hog barn			Limited sample Houses within 5 km of hog barn		
	Coefficient		Std. Err.	Coefficient		Std. Err.
Constant	8.357	***	0.380	8.689	***	0.465
Land parcel slope	0.007		0.026	-0.006		0.031
Land parcel elevation (metres)	0.018	**	0.008	0.015	**	0.007
High capability soil (%)	-0.001		0.001	-0.002		0.002
Medium capability soil (%)	0.000		0.001	-0.002		0.002
ln(Parcel acres)	0.054	***	0.006	0.055	***	0.007
Age of house at sale date (10 years)	-0.057	***	0.011	-0.060	***	0.011
(Age of house at sale date)^2	0.004	**	0.001	0.005	***	0.001
Quality: good (Yes=1)	0.584	***	0.057	0.584	***	0.056
Quality: average-good (Yes=1)	0.497	***	0.039	0.494	***	0.049
Quality: average (Yes=1)	0.377	***	0.035	0.380	***	0.040
Quality: fair (Yes=1)	0.176	***	0.042	0.174	***	0.043
Stories: Multiple (Yes=1)	0.063	**	0.024	0.050	*	0.025
Stories: Split (Yes=1)	0.062	***	0.014	0.059	***	0.012
ln(Square footage)	0.164	***	0.022	0.158	***	0.025
Air conditioning (Yes=1)	0.060	***	0.016	0.055	***	0.017
Brick exterior (Yes=1)	0.073	***	0.018	0.067	***	0.019
Fireplace (Yes=1)	0.044	**	0.017	0.056	***	0.012
Basement (Yes=1)	0.092	***	0.023	0.104	***	0.026
Attached garages	0.154	***	0.015	0.167	***	0.015
Detached garages	0.082	***	0.011	0.082	***	0.011
Barns	0.074	***	0.013	0.070	***	0.011
Machine sheds	0.046	***	0.012	0.047	***	0.014
Workshops	0.127	***	0.020	0.123	***	0.019
Distance to Winnipeg (kms)	-0.022	***	0.005	-0.019	***	0.005
Nearest centre: Steinbach (Yes=1)	0.088	**	0.040	0.060		0.044
Nearest centre: Ste. Anne (Yes=1)	0.106	***	0.028	0.082	**	0.035
1980 cropland within 8 km (%)	0.005		0.003	0.005		0.004
1980 grassland within 8 km (%)	-0.019	**	0.007	-0.017	**	0.007
1980 land value within 8 km ($1,000)	-1.654	***	0.365	-1.597	***	0.392
1980 livestock value within 8 km ($1,000)	1.635		1.479	1.836		1.731
1980 number of houses within 8 km (1,000)	-0.001		0.007	0.002		0.007
1980 average income within 8 km ($1,000)	0.083	***	0.029	0.080	**	0.031
1980 avg. house value in 8 km ($1,000)	-0.009		0.007	-0.008		0.010
Observations	4,375			3,956		
R^2	0.571			0.597		

Notes: All specifications include year, month, and municipality fixed effects. Standard errors are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table D1. Alternative Samples

	At least one barn built within 3 years of sale		At least one barn built within 7 years of sale		At least one barn built within 9 years of sale	
	(1)		(2)		(3)	
	Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)	
Hog barn within 2 km (D^2)	-0.006		0.008		0.007	
	(0.025)		(0.027)		(0.026)	
Hog barn within 5 km (D^5)	0.036		0.022		0.016	
	(0.053)		(0.031)		(0.029)	
Within 2 km × post barn $(D^2 * \tau)$	-0.056	**	-0.046	**	-0.041	*
	(0.026)		(0.023)		(0.021)	
Within 5 km × post barn $(D^5 * \tau)$	-0.019		-0.036	**	-0.037	**
	(0.018)		(0.017)		(0.017)	
Observations	3,435		5,151		5,829	
R^2	0.545		0.605		0.629	

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table D2. Location and Size of Hog Barn

	Prevailing wind		Medium and large hog barns		Large hog barns	
	(1)		(2)		(3)	
	Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)	
Hog barn within 2 km (D^2)	0.008		0.008		0.009	
	(0.026)		(0.026)		(0.026)	
Hog barn within 5 km (D^5)	0.032		0.033		0.032	
	(0.039)		(0.039)		(0.038)	
Within 2 km × post barn $(D^2 * \tau)$	-0.059	**	-0.064	**	-0.047	**
	(0.024)		(0.024)		(0.021)	
Barn in prevailing wind within 2 km × post barn	0.109					
	(0.097)					
Medium/large hog barn within 2 km × post barn			0.025			
			(0.044)			
Large hog barn within 2 km × post barn					-0.116	
					(0.104)	
Within 5 km × post barn $(D^5 * \tau)$	-0.031		-0.032		-0.034	
	(0.020)		(0.020)		(0.021)	
Observations	4,375		4,375		4,375	
R^2	0.573		0.573		0.573	

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table E1. Selection into Repeat Sale Subsample

	Coefficient		Std. Err.
Constant	-1.571	**	0.706
Land parcel slope	-0.031		0.022
Land parcel elevation (metres)	0.007		0.008
High capability soil (%)	-0.004	***	0.001
Medium capability soil (%)	-0.004	***	0.001
ln(Parcel acres)	0.000		0.008
Age of house at sale date (10 years)	0.010	*	0.005
Quality: good (Yes=1)	-0.134	*	0.066
Quality: average-good (Yes=1)	-0.117	*	0.062
Quality: average (Yes=1)	-0.037		0.055
Quality: fair (Yes=1)	-0.007		0.049
Stories: Multiple (Yes=1)	-0.062	**	0.027
Stories: Split (Yes=1)	-0.015		0.023
ln(Square footage)	-0.053		0.035
Air conditioning (Yes=1)	-0.025		0.019
Brick exterior (Yes=1)	0.042		0.028
Fireplace (Yes=1)	0.017		0.023
Basement (Yes=1)	-0.015		0.029
Attached garages	-0.038	**	0.017
Detached garages	0.012		0.016
Barns	0.000		0.018
Machine sheds	-0.020		0.013
Workshops	0.004		0.030
Distance to Winnipeg (kms)	0.007		0.005
Nearest centre: Steinbach (Yes=1)	-0.119	**	0.056
Nearest centre: Ste. Anne (Yes=1)	0.006		0.063
1980 cropland within 8 km (%)	0.001		0.004
1980 grassland within 8 km (%)	-0.018	*	0.010
1980 land value within 8 km ($1,000)	-2.031	***	0.478
1980 livestock value within 8 km ($1,000)	6.303	***	2.079
1980 number of houses within 8 km (1,000)	0.007		0.005
1980 average income within 8 km ($1,000)	0.121	***	0.031
1980 avg. house value in 8 km ($1,000)	-0.006		0.006
Observations	2,225		
R^2	0.056		

Notes: Dependent variable = 1 if house is involved in a repeat sale, zero otherwise (each house appears only once in this sample). Sample is restricted to houses that are within 5 kms of a hog barn at some time in the study period. Specifications includes municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table E2. Repeat Sale Analysis

	Coefficient		Std. Err.
Within 2 km × post barn ($D^2 \times \tau$)	-0.052	*	0.030
Within 5 km × post barn ($D^5 \times \tau$)	0.022		0.026
Observations	1,288		
Number of groups	432		
R^2 within	0.512		
R^2 between	0.001		
R^2 overall	0.027		

Notes: All specifications include year and month fixed effects, slope, elevation, high capability soil, medium capability soil, parcel acres, the age of the house, the presence of an attached garage, detached garage, barn, machine shed, and workshop. Standard errors are adjusted for 432 house groups. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table F1. Timing of Barn Establishment

	All			Post 1995			Post 2000		
	(1)			(2)			(3)		
	Coefficient		Std. Err.	Coefficient		Std. Err.	Coefficient		Std. Err.
Constant	1925	***	17.50	2012	***	12.62	2004	***	13.40
Land parcel slope	0.19		0.46	-0.20		0.25	-0.44		0.46
Land parcel elevation (metres)	-0.22		0.18	-0.12		0.32	0.17		0.25
High capability soil (%)	-0.08		0.06	-0.01		0.03	0.02		0.01
Medium capability soil (%)	-0.08		0.06	0.02		0.03	-		
ln(Parcel acres)	0.55	*	0.28	0.36	**	0.17	-0.47	*	0.26
Quality: good (Yes=1)	0.82		0.83	0.36		0.64	-0.18		1.04
Quality: average-good (Yes=1)	1.20		0.88	0.39		0.72	-0.44		1.08
Quality: average (Yes=1)	0.29		0.77	-0.29		0.69	-0.27		1.07
Quality: fair (Yes=1)	1.05		1.32	0.45		0.94	-0.33		1.31
Stories: Multiple (Yes=1)	0.04		0.45	-0.17		0.29	-0.74		0.56
Stories: Split (Yes=1)	0.06		0.52	-0.24		0.44	-0.51		0.39
ln(Square footage)	-1.30	**	0.55	-0.66		0.45	-0.15		0.53
Air conditioning (Yes=1)	-0.02		0.34	0.07		0.20	0.87	**	0.32
Brick exterior (Yes=1)	-0.26		0.49	0.26		0.22	-0.26		0.33
Fireplace (Yes=1)	0.79	**	0.36	0.47	*	0.24	0.57	*	0.30
Basement (Yes=1)	-0.28		0.47	-0.38		0.26	0.09		0.34
Attached garages	-0.72	**	0.34	-0.53	***	0.16	-0.51		0.38
Detached garages	0.02		0.24	-0.18		0.19	0.06		0.30
Barns	0.03		0.24	-0.04		0.15	0.02		0.26
Machine sheds	-0.39		0.27	-0.08		0.12	0.09		0.18
Workshops	0.43		0.39	-0.08		0.23	-0.17		0.40
Distance to Winnipeg (kms)	0.30	**	0.13	-0.02		0.21	-0.23		0.15
Nearest centre: Steinbach (Yes=1)	-1.25		1.38	-1.59		2.37	1.09		1.56
Nearest centre: Ste. Anne (Yes=1)	0.11		1.61	-2.67		2.29	1.43		1.94
1980 cropland within 8 km (%)	-0.16	*	0.08	-0.44	***	0.07	0.28	*	0.15
1980 grassland within 8 km (%)	-0.74		0.46	-0.21		0.37	0.17		0.29
1980 land value, 8 km ($1,000)	-89.60	***	18.75	1.77		12.17	-17.76		34.10
1980 livestock value, 8 km ($1,000)	318.1	***	59.72	145.5	***	45.83	-9.71		81.45
1980 no. of houses, 8 km (1,000)	-0.85	***	0.28	1.45		2.07	-5.04		4.01
1980 average income, 8 km ($1,000)	5.49	***	1.73	0.42		0.80	-0.29		1.40
1980 avg. house value, 8 km ($1,000)	0.03		0.31	-0.02		0.23	0.21		0.45
Observations	1,081			787			246		
R^2	0.409			0.535			0.514		

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table F2. Sample Constructed by Event Year: Treated Group (0 to 2 kms)

	(1)		(2)		(3)		(4)		(5)	
	Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)	
Treat	-0.012		0.0002		0.004		0.011		0.011	
	(0.020)		(0.021)		(0.022)		(0.024)		(0.024)	
Post	-0.013		-0.014		-0.015		-0.015		-0.015	
	(0.011)		(0.011)		(0.011)		(0.011)		(0.011)	
Treat × Post	-0.074	***	-0.087	***	-0.090	***	-0.097	***	-0.097	***
	(0.025)		(0.026)		(0.027)		(0.058)		(0.028)	
Within 2 km, sold same year as barn built	-0.026		-0.040		-0.044		-0.051		-0.050	
	(0.058)		(0.058)		(0.058)		(0.058)		(0.058)	
Within 2 km, sold 1 year before barn			-0.091	*	-0.095	*	-0.102	**		
			(0.049)		(0.050)		(0.050)			
Within 2 km, sold 2 years before barn					-0.044		-0.051			
					(0.063)		(0.063)			
Within 2 km, sold 3 years before barn							-0.048			
							(0.055)			
Within 2 km, sold 1 to 3 years before barn									-0.069	*
									(0.036)	
Observations	16,135		16,135		16,135		16,135		16,135	
R^2	0.568		0.569		0.569		0.570		0.570	

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table F3. Sample Constructed by Event Year: Placebo Group (2 to 5 kms)

	(1)		(2)		(3)		(4)		(5)	
	Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)	
Treated	0.009		0.008		0.001		0.004		0.004	
	(0.013)		(0.014)		(0.015)		(0.017)		(0.017)	
Post	-0.012	**	-0.012	**	-0.012	**	-0.012	**	-0.012	**
	(0.005)		(0.005)		(0.005)		(0.005)		(0.005)	
Treated × Post	-0.015		-0.014		-0.007		-0.010		-0.010	
	(0.015)		(0.016)		(0.017)		(0.019)		(0.019)	
Within 2 km, sold same year as barn built	-0.010		-0.009		-0.002		-0.005		-0.005	
	(0.028)		(0.029)		(0.030)		(0.030)		(0.030)	
Within 2 km, sold 1 year before barn			0.004		0.012		0.009			
			(0.030)		(0.031)		(0.031)			
Within 2 km, sold 2 years before barn					0.039		0.035			
					(0.034)		(0.035)			
Within 2 km, sold 3 years before barn							-0.016			
							(0.034)			
Within 2 km, sold 1 to 3 years before barn									0.010	
									(0.023)	
Observations	59,404		59,404		59,404		59,404		59,404	
R^2	0.569		0.569		0.571		0.570		0.570	

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors (in brackets) are adjusted for 27 Statistics Canada dissemination areas. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table G1. Spatial Proximity Indices

	Cross-section linear distance	DID linear distance	Cross-section quadratic distance	DID quadratic distance	Cross-section log proximity	DID log proximity
	(1)	(2)	(3)	(4)	(5)	(6)
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Inverse of linear distance × post barn within 2 km ($Dist^{-1} * D^2 * \tau$)	-43.02 **	-37.63 **	-83.85 **	-57.30		
	(16.18)	(16.26)	(31.98)	(34.62)		
Inverse of quadratic distance × post barn in 2 km ($(Dist^2)^{-1} * D^2 * \tau$)			8,546 *	4,359		
			(4,914)	(5,059)		
Inverse of linear distance × barn within 2 km ($Dist^{-1} * D^2$)		-8.13		58.06		
		(19.61)		(38.16)		
Inverse of quadratic distance × barn within 2 km ($(Dist^2)^{-1} * D^2$)				-14,258 **		
				(6,563)		
Ln(distance) × post barn within 2 km ($ln\ (Dist) * D^2 * \tau$)					0.075 ***	0.061 **
					(0.022)	(0.025)
Ln(distance) × barn within 2 km ($ln\ (Dist) * D^2$)						-0.007
						(0.025)
Within 5 km × post barn ($D^5 * \tau$)		-0.024		-0.023		-0.028
		(0.020)		(0.020)		(0.020)
			Impacts post-barn establishment			
Impact at 634 metres from barn	-0.046 ***	-0.041 **	-0.071 ***	-0.052 *	-0.086 ***	-0.070 **
	(0.017)	(0.018)	(0.025)	(0.027)	(0.025)	(0.029)
Impact at 1,412 meters from barn	-0.009 ***	-0.008 **	-0.015 ***	-0.011 *	-0.026 ***	-0.021 **
	(0.002)	(0.003)	(0.006)	(0.006)	(0.008)	(0.009)
Impact at 1,576 meters from barn	-0.006 ***	-0.005 **	-0.010 ***	-0.007 *	-0.018 ***	-0.014 **
	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)	(0.006)
			Impacts pre-barn establishment			
Impact at 634 metres from barn		-0.009		0.031		0.008
		(0.021)		(0.029)		(0.032)
Impact at 1,412 meters from barn		-0.002		0.009		0.002
		(0.004)		(0.007)		(0.010)
Impact at 1,576 meters from barn		-0.001		0.006		0.002
		(0.003)		(0.004)		(0.007)
Observations	2,671	3,956	2,671	3,956	2,671	3,956
R^2	0.633	0.602	0.631	0.608	0.632	0.601

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors are adjusted for 27 Statistics Canada dissemination areas. The mean distance to a barn for houses that are within 1 km of a barn is 634 metres, the mean distance for a house within 2 kms of a barn is 1,412 metres, and the mean distance for a house within 1 to 2 kms is 1,576 metres. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

Table G2. Anticipation in Expansionary and Post-Expansionary Periods

	Expansionary period accounting for anticipation (1993-1998)		Expansionary period without accounting for anticipation (1993-1998)		Post-expansionary period accounting for anticipation (2005-2010)		Post-expansionary period without accounting for anticipation (2005-2010)	
	(1)		(2)		(3)		(4)	
	Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)		Coefficient (Std. Err.)	
Inverse of linear distance × post barn within 2 km ($Dist^{-1} * D^2 * \tau$)	-42.88	*	-68.11	*	-52.28		-67.59	*
	(23.96)		(38.13)		(34.48)		(36.65)	
			Impacts post-barn establishment					
Impact at 634 metres from barn	-0.046	*	-0.073	*	-0.056	*	-0.073	*
	(0.026)		(0.041)		(0.034)		(0.039)	
Impact at 1,412 meters from barn	-0.009	*	-0.014	*	-0.011	*	-0.014	*
	(0.005)		(0.008)		(0.007)		(0.008)	
Impact at 1,576 meters from barn	-0.006	*	-0.009	*	-0.007	*	-0.009	*
	(0.003)		(0.005)		(0.004)		(0.005)	
Observations	855		706		605		596	
R^2	0.470		0.486		0.602		0.604	

Notes: All specifications include covariates included in specifications in appendix table C1, year, month, and municipality fixed effects. Standard errors are adjusted for 27 Statistics Canada dissemination areas. The mean distance to a barn for houses that are within 1 km of a barn is 634 metres, the mean distance for a house within 2 kms of a barn is 1,412 metres, and the mean distance for a house within 1 to 2 kms is 1,576 metres. Asterisks indicate the following: ***=statistical significance at the 1% level, **=statistical significance at the 5% level, and *=statistical significance at the 10% level.

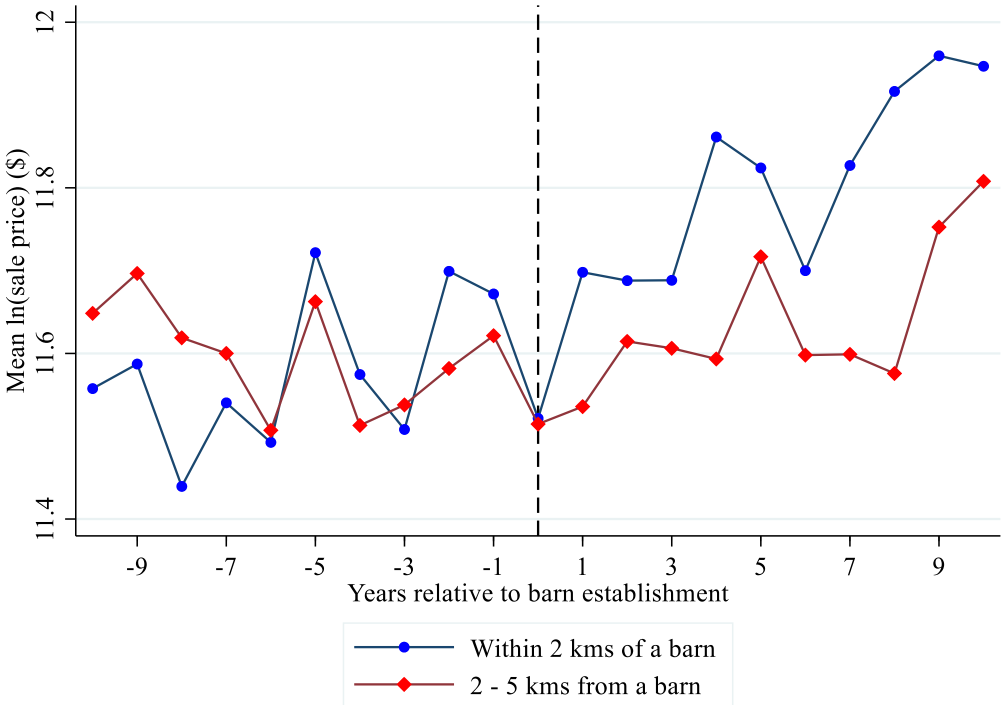

Figure C1. House sale prices

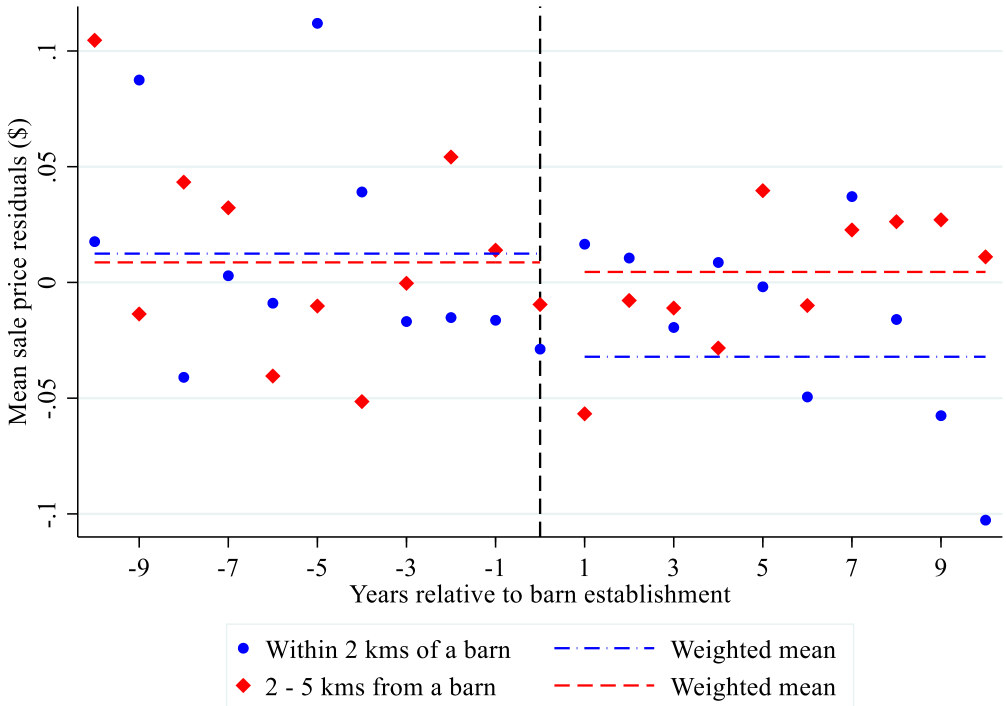

Figure C2. Mean sale price residuals

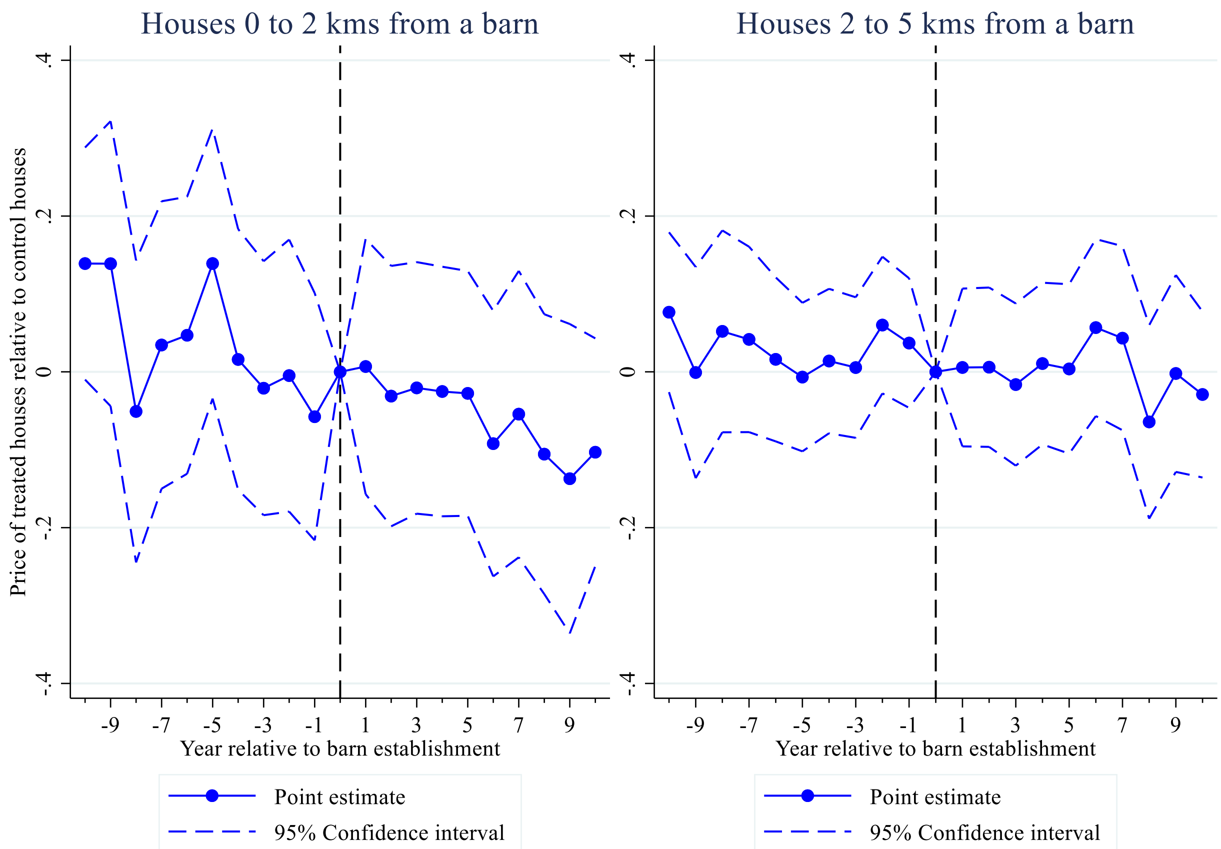

Figure F1. Prices of treated houses relative to control houses before and after barn establishment, event year samples

Note: This figure plots the coefficients ω_t from estimation of equation (F1), normalized to 0 in the year the barn is established. The left panel plots results for treated houses 0 to 2 kms from a barn. The right panel plots results for a placebo group of houses 2 to 5 kms from a barn. Annual leads and lags 10 or more years before to 10 or fewer years after barn establishment.