Supplemental Appendix To: The Cost of Unconventional Gas Extraction: A Hedonic Analysis

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Abstract

This appendix contains detailed results and discussion from all models estimated for this paper:

1. Additional details on the balance metrics used in the matching models;
2. Some additional descriptive statistics;
3. Log-linear regression estimates across a multitude of samples and specifications;
4. Propensity score and multivariate matching treatment effect estimates;
5. Quasi difference-in-differences results;
6. Discussion and conclusion of results (within each section).

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1 Empirical Model and Estimation Methods

1.1 Methods Used in this Appendix

The empirical models used to generate the results in this appendix are versions of the linear-in-parameters semi-log regression and the matching estimators. These estimators are described in the manuscript; please reference the manuscript for those details. Where relevant in this appendix, each section contains a brief discussion of the estimator being used.

Before presenting the additional results, we briefly provide a bit more details on several important issues related to the matching estimator.

1.2 Balance and Balance Assessment in Matching Models

When there is concern that treatment is not random, though the selection on observables assumption is assumed to hold, a critical means of assessing model reliability is via assessing whether the matched treated/control samples are statistically similar along observable dimensions. As is evident, matching methods rely critically on being able to 'balance' the covariates between the treated/untreated properties, post-match. If balancing fails, then the treatment parameter estimates may still be biased.

Assessment of balance can be done in different ways. A common approach is to use t-tests of the null hypothesis of equal sample means across treated and untreated properties in the matched sample. However, Imbens & Rubin (2015, p. 311) argue that this is not the ideal approach, because the t-test is sensitive to the sample size; further, the goal is not to test the null hypothesis of statistical parity in central tendencies, but rather to assess covariate balance. The goal is to ascertain the extent to which the sample will yield biased treatment effect estimates. In an ideal case, post-matching tests will reveal statistically indistinguishable sample means across treated/untreated units.

1.2.1 Methods for Pre-Match Assessment of Balance and Overlap

It is helpful to provide a sense of overall balance and overlap in the samples for both Bradford and Lycoming counties before any matching or estimation is done. The procedures here generally follow Imbens & Rubin (2015).

The Normalized Difference The first metric we consider for assessing balance is the *normalized difference* for each covariate, given by

$$\Delta_{ct} = \frac{\mu_t - \mu_c}{\sqrt{(\sigma_t^2 - \sigma_c^2)/2}} \tag{1}$$

in which μ denotes the mean, σ_2 denotes the variance, and the subscripts t and c indicate the treated and control samples, respectively. This normalized differences provides a measure of dispersion of the means of the two samples that is unit free. Further, in contrast to the standard t-test for equality of means, the normalized difference is invariant to changes in the sample size. Further, as stated by Imbens & Rubin (2015), the purpose of balance tests is not to directly test the null hypothesis that the two subsamples have the same central tendencies, but rather assess the feasibility of using adjustment methods (e.g., matching or regression) to eliminate biases associated with observable covariates that arise in treatment effect estimation. To estimate Δ_{ct}, one can use sample averages and sample variances.

The normalized difference is in standard deviations. The larger the normalized difference for each covariate, the more difficult it will be to deploy adjustment techniques to adjust for biases. To provide some perspective, normalized difference measures of approximately 0.1 are in line with "what one might expect in a completely randomized experiment" (Imbens & Rubin 2015, p. 352).

The Log Ratio of Standard Deviations While the normalized difference measures differences in the central tendencies of the covariate distributions across treated/control samples, the *log ratio of standard deviations* measures the difference in dispersions of the two distributions. This measure is given by

$$\Gamma_{ct} = \log(\sigma_t) - \log(\sigma_c) \tag{2}$$

where notation is as before. This measure can also be calculated from sample standard deviations, and the larger the value of Γ_{ct} for any particular covariate the larger the difference in distributional dispersion. For large values of Γ_{ct}, the more difficult it will be to adjust for biases.

The Fraction of Observations in the Tails of the Opposing Distribution One of the important requirements for different bias adjustment methods (e.g., regression or matching) is sufficient overlap in the distributions of covariates. One way to assess overlap is to determine the fraction of observations in the treated group that lie in the tails of the distribution for the control group. For instance, if we determine that 40% of the observations in the treated group for some covariate lie in the tails of the distribution of the covariate for the control group, then we know that it will be difficult to find corresponding observations in the control group to match to the treated units. The issue is that, given the *fundamental problem of causal inference* (Holland 1986), counterfactuals must be imputed. To reliably imput, there must be sufficient overlap in the distributions of covariates across treated/control samples. (The same measure can be calculated for the control group.)

Formally, we calculate this percentage via

$$\pi_t^{\alpha} = \left[1 - F_t\left(F_c^{-1}(1-\alpha/2)\right)\right] + F_t\left(F_c^{-1}(\alpha/2)\right) \tag{3}$$

for significance level α (such as $\alpha = 0.05$), and distribution functions $F(\cdot)$. We use the analogous measure for the control group

$$\pi_c^{\alpha} = \left[1 - F_c\left(F_t^{-1}(1-\alpha/2)\right)\right] + F_c\left(F_t^{-1}(\alpha/2)\right). \tag{4}$$

In practice, we can estimate the empirical distribution functions based on the samples of data and calculate π. If we choose $\alpha = 0.05$, we calculate $\hat{\pi}_t^{0.05}$ as

$$\hat{\pi}_t^{0.05} = \left[1 - \hat{F}_t\left(\hat{F}_c^{-1}(0.975)\right)\right] + \hat{F}_t\left(\hat{F}_c^{-1}(0.025)\right). \tag{5}$$

The Feasibility of Adjusting on the Propensity Score Another important metric of overlap is to look directly at overlap in the estimated propensity score across the sample, and ascertain the fraction of treated units with a corresponding unit in the control group with a close value of the propensity score. If we denote the estimated propensity score with $\hat{e}(X_i)$, for unit $i = 1, 2, \ldots, n$, then we are interested in calculating for each observation

$$\varsigma_i = \begin{cases} 1 & \text{if} \sum_{i':W_{i'} \neq W_i} \mathbb{1}_{|\hat{e}(X_{i'}) - \hat{e}(X_i)| \leq \psi} \geq 1 \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

in which W_i denotes treatment status for unit i, i' is another unit in the sample (from i), and ψ is some threshold of difference in propensity score (such as $\psi = 0.1$). We then calculate the fraction of observations in each treated/control sample with overlap in the propensity score

$$q_c = \frac{1}{n_c} \sum_{i:W_i=0} \varsigma_i \qquad\qquad q_t = \frac{1}{n_t} \sum_{i:W_i=1} \varsigma_i. \tag{7}$$

Ideally, these shares will be relatively high. If, for example, q_t is 0.90, then we conclude that 90 percent of the treated observations have a corresponding observation in the control group with a similar propensity score (within ψ). Given the theoretical importance of the propensity score, it is likely (in this example) that we will be able to reliable match on $\hat{e}(X_i)$ and reliable estimate a treatment effect parameter.

Looking at Distributional Differences In addition to these summary measures of balance and overlap, we can also explore distributional difference in key covariates and/or the estimated propensity score. Imbens & Rubin (2015) suggest using (non-smooth) histograms to assess general distributional differences. An alternative approach is to use a bootstrapped Kolmogorov-Smirnoff (KS) test of the null hypothesis of equivalent distributions of (continuous) covariates across the treated/untreated samples, post-match (Abadie 2002). The advantage of the KS test is that is tests the entire distribution of the covariates across matched samples, and the bootstrap testing procedure is shown to work well in small samples.

1.3 Bias of Matching Estimators and Bias Adjustment

When implementing matching methods, the researcher must specify whether matches should be exact or not, and whether matching is to be done with replacement or not. Typically, matching is allowed to be inexact – at least for continuous covariates – because the data is not sufficiently large to allow for exact matches, especially over multiple dimensions. Abadie & Imbens (2011) discuss the bias associated with matching estimators of the average treatment effect under inexact matching with replacement, and propose bias corrections. Simulation results indicate that standard unadjusted matching estimators are sensitive to the number of matches, particularly for $M > 4$.

This bias in matching estimators arises when the number of continuous covariates used to match exceeds one (Abadie & Imbens 2006). This means that if one matches only on the propensity score, the bias correction is not needed. Abadie & Imbens (2012) derive the variance of τ_{att} when matching is done on an estimated propensity score.[1]

In light of these issues, our strategy is to deploy the Abadie & Imbens (2012) bias corrected estimator when matching on multiple covariates, and to use the standard τ_{att} estimator when matching directly on the propensity score but assessing significance using the appropriate Abadie & Imbens (2012) variance estimator. We note that Muehlenbachs, Spiller & Timmins (2014) mention use of a bias-corrected estimator, though they are less explicit on details.

[1]The asymptotic variance of τ_{att} derived by Abadie & Imbens (2012) is somewhat tedious, so we do not re-derive it here. See Abadie & Imbens (2012) for details.

2 Discussion and Descriptive Statistics by City

2.1 Bradford County

There are two urban areas in Bradford County: Sayre and Towanda. Approximately 21 percent of the property sales in our dataset come from Sayre and 14 percent come from Towanda. The remaining 65 percent come from non-urban areas. From the 2010 census, the population in Sayre is 5582 and the population in Towanda is 2916. These details are important for two reasons.

First, there are not many city observations, and these two cities are very small. This means that there is less potential for "urban area" effects to impact property values. The most important factor that may influence our results is the fact that city properties are on city-regulated water. This factor will exist in any small cities, including Sayre and Towanda. What we can avoid, at least to a large extent, is nonlinear neighborhood effects that exist in proximity to large cities, such as Pittsburgh. Because of heterogeneous neighborhood characteristics that exist in (the fringes of) large cities – such as differences between upscale suburb areas compared to outlying areas with high poverty – it is not clear how best to control for urban proximity in a regression. One strategy is to follow Gopalakrishnan & Klaiber (2014) and include as a regressor "distance to city" (in their case, distance to Pittsburgh), though it is not clear to what extent this strategy adequately controls for nonlinear urban proximity effects that substantially impact property values.

Second, given the proportion of property transactions in these cities, we can comfortably include indicators for location in these cities in a regression. These cities are small enough that there are not likely to be nonlinear urban effects, so we can control for these cities via a standard indicator for location in a city. And, we have enough observations in the cities that these indicators will not be collinear with other variables (see the following regarding Lycoming County).

2.2 Lycoming County

Our data for Lycoming County contain property transactions from 29 cities in Pennsylvania. The table below reports the percentage of observations in our sample for each city, as well as the population in each city from the 2010 census. Two important notes:

1. Not every city has a recorded 2010 census population. For the purpose of this appendix, it does not matter much – it is clear that these cities are very small.

2. Cities listed with an asterisk are not located within Lycoming County (though they appear in our data as the location of a property transaction from Lycoming County).

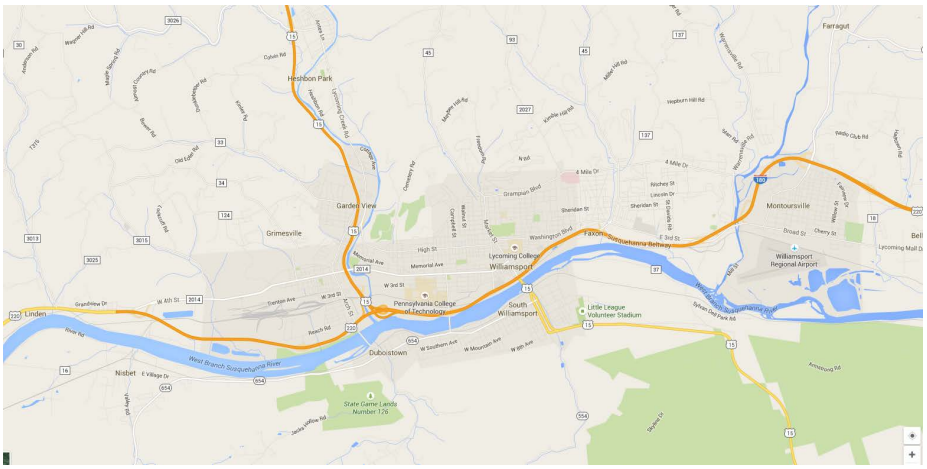
The following can be seen from Table 1. *First*, the majority of our city/urban property transactions come from 11 cities (Williamsport, Montoursville, South Williamsport, Muncy, Jersey Shore, Hughesville, Montgomery, Cogan Station, Linden, Trout Run, and Duboistown), with only the first 6 of these cities containing at least 5 percent of our observations. This is important when considering the use of city-level fixed effects in a regression – most of these cities do not contain enough observations to warrant inclusion of a fixed effect. In other words, we can include a city indicator, but for many of these cities there are not enough property transactions in these cities that such indicators will be reliable.

Second, these cities are very small. Williamsport is by far the largest, with a 2010 population of about 30,000. There are cluster of cities (Williamsport, South Williamsport, Duboistown and Montoursville) along the Susquehanna River that jointly contain about 63 percent of our observed property transactions. Figure 1 below shows a map of these cities along the Susquehanna River, and the corresponding clustering of property transactions in this area (the darkest cluster of properties on the second map). This is important from a regression modeling perspective

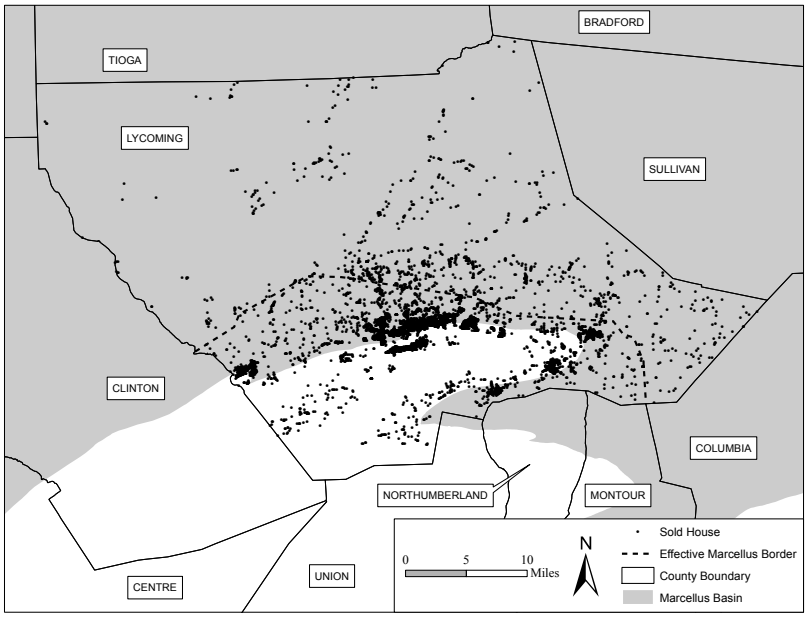
Table 1: Distribution of observations by city in Lycoming County

City	Percent of Obs.	2010 Population
Williamsport	0.3925	29386
Montoursville	0.1423	4615
South Williamsport	0.0831	6381
Muncy	0.0812	2477
Jersey Shore	0.0792	4363
Hughesville	0.0594	2128
Montgomery	0.0415	1579
Cogan Station	0.0386	
Linden	0.0213	3175
Trout Run	0.0184	
Duboistown	0.0109	1206
Allenwood*	0.0097	321
Unityville*	0.0058	
Pennsdale	0.0041	
Liberty*	0.0022	248
Salladasburg	0.0019	238
Muncy Valley*	0.0012	
Ralston	0.0012	
Roaring Branch	0.0012	1162
Lock Haven*	0.0010	9770
Morris*	0.0010	737
Waterville	0.0010	
Benton*	0.0005	824
Cammal	0.0002	
Canton*	0.0002	1971
Lairdsville	0.0002	993
Picture Rocks	0.0002	679
Antes Fort	0.0000	
Hillsgrove*	0.0000	287

because we need to make sure that we carefully account for differences that exist between properties located in this central "urban" area and properties that are rural. This is also important once we consider using the shale boundary in Lycoming County for identification, because many of these urban properties are clustered on the edge of the shale.



(a) Map of Lycoming County



(b) Location of Property Sales in Lycoming County

Figure 1: Cities and Property Sales in Lycoming Country.

3 Pre-Match Assessment

We consider each of our pre-match assessment measures for both Bradford and Lycoming counties. We consider each county in turn, and for each county, we define treatment as being within $\{1, 2, 3\}$ miles of a shale well.

3.1 Bradford County

3.1.1 Treatment at 1 Mile

We first consider treatment defined as shale activity within one mile of the property transaction. Pre-match balancing statistics are given in Table 2. We first look at the propensity score. It is clear that the mean of the propensity score across treated and control samples is substantially different. The normalized difference measure is 1.75, which indicates substantial difference in the normalized difference in means as well; the log difference in dispersion is 0.188 which is not particularly high. The final two columns give the share of each sample that lie within the tails of the opposing distributions: over 33 percent of the treated sample lies in the tails of the control distribution, and nearly 54 percent of the control sample lies in the tails of the estimated propensity score for the treated distribution. These metrics generally imply that there is a substantial lack of balance and overlap in the estimated propensity scores across treated and control samples.

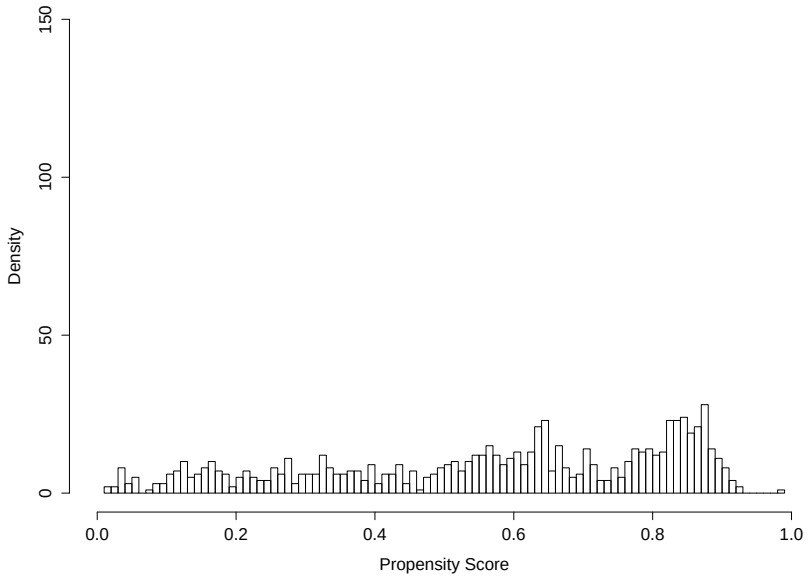
Looking at the other covariates, we see that age, bedrooms, bathrooms, square footage, distance to nearest highway, and distance to nearest road are all generally well balanced and have substantial overlap in distribution. Other covariates, such as the number of stories in the house, whether the property is on private water, and location in Sayre, are substantially out of balance, with little overlap. These variables will likely lead to substantial bias in the estimate of the treatment effect, if balance is not improved.

Table 2: Results for pre-matching statistics for Bradford County

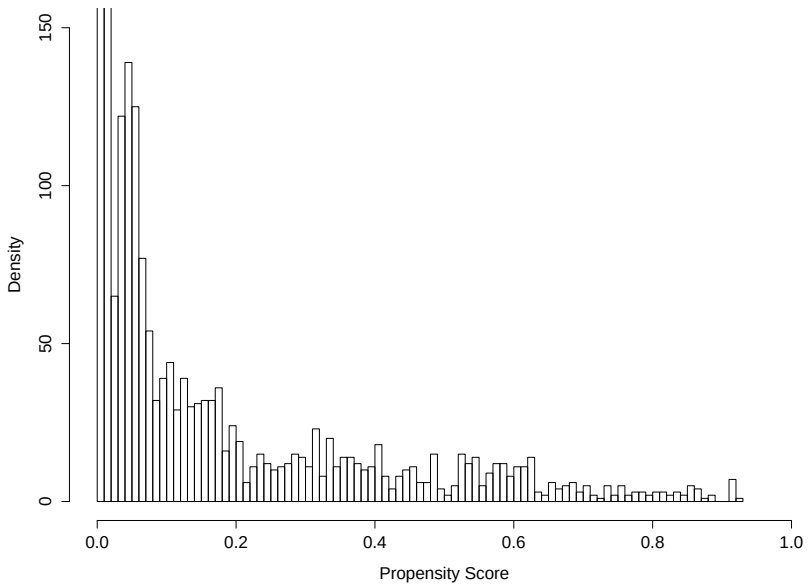
	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.569	0.251	0.165	0.208	1.750	0.188	0.335	0.539
Age	66.247	48.076	73.664	46.823	-0.156	0.026	0.049	0.077
Stories	1.417	0.451	1.547	0.468	-0.285	-0.037	0.503	0.390
Bedrooms	2.847	1.215	3.044	1.245	-0.160	-0.024	0.071	0.073
Bathrooms	1.438	0.765	1.484	0.765	-0.060	0.001	0.107	0.072
SQFT	15.404	7.256	16.283	7.446	-0.120	-0.026	0.078	0.078
Acres	10.413	39.993	6.504	22.746	0.120	0.564	0.045	0.097
Warm Air	0.426	0.495	0.502	0.500	-0.152	-0.011	0.574	0.498
Private Water	0.772	0.420	0.464	0.499	0.668	-0.173	0.228	0.536
Highway	6.218	5.665	5.136	5.859	0.188	-0.034	0.037	0.062
Major Road	0.279	0.522	0.219	0.501	0.118	0.042	0.073	0.037
Sayre	0.015	0.121	0.289	0.454	-0.826	-1.318	0.985	1.000
Towanda	0.187	0.390	0.131	0.337	0.154	0.146	0.813	0.869

Note: Treatment is defined as shale activity within 1 mile.

We plot in Figure 2 a histogram of the estimated propensity score for the treated (top) and control (bottom) samples. While the distributions are not symmetric, there does exist overlap across most of the distribution, which suggests that it might be feasible to match on the propensity score to restore balance.



(a) Estimated propensity score for treated units in Bradford County



(b) Estimated propensity score for control units in Bradford County

Figure 2: Histograms of the estimated propensity score for Bradford County for 1-mile treatment.

As a final measure of overlap, we calculate the fraction of the data with at least one unit in the opposing treatment group that has a similar propensity score value. This measure helps to assess overlap in the propensity score, and hence feasibility of matching on the propensity score. We find that 100 percent of the units in both the treated and control units have a corresponding unit in the opposing treatment group with a threshold level of 0.1 (or 10 percent). This indicates that it may be feasible to restore balance by matching on the propensity score.

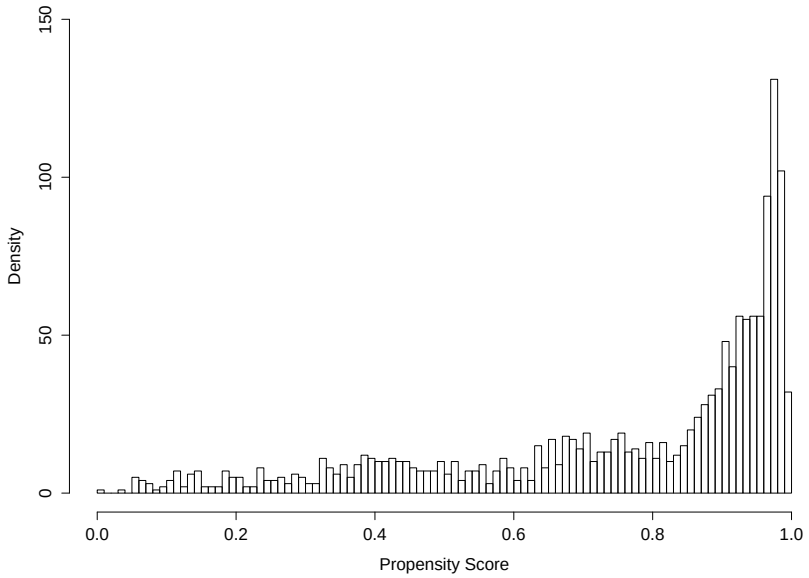
3.1.2 Treatment at 2 Miles

We repeat the balance and overlap pre-match assessment exercises for Bradford County, defining treatment to be shale activity within 2 miles. Results are reported in Table 3. The results are generally the same as before, when treatment was defined as shale activity within 1 mile – we find imbalance and lack of overlap in the propensity score, though Figure 3 indicates that this apparent lack of overlap comes from skewness of the distributions. Calculating the shares of units in treated/control groups with a corresponding unit in the opposing group within 10 percent tolerance, indicates that 100 percent of the units have a corresponding match. The results again indicate that it may be feasible to match based on the propensity score and restore balance.

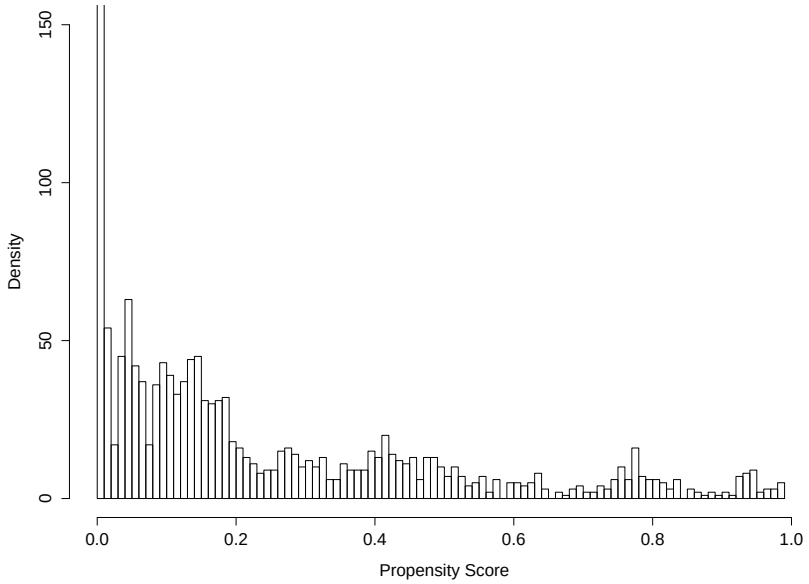
Table 3: Results for pre-matching statistics for Bradford County

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.762	0.248	0.247	0.251	2.069	-0.013	0.388	0.481
Age	73.439	48.211	69.707	46.241	0.079	0.042	0.060	0.073
Stories	1.485	0.465	1.538	0.467	-0.115	-0.004	0.444	0.398
Bedrooms	2.973	1.288	3.006	1.188	-0.027	0.081	0.082	0.052
Bathrooms	1.468	0.802	1.475	0.726	-0.009	0.099	0.090	0.073
SQFT	16.050	7.752	16.027	7.026	0.003	0.098	0.071	0.068
Acres	8.567	33.151	6.574	23.018	0.070	0.365	0.062	0.053
Warm Air	0.463	0.499	0.499	0.500	-0.072	-0.003	0.537	0.501
Private Water	0.633	0.482	0.463	0.499	0.347	-0.034	0.367	0.537
Highway	6.102	5.884	4.745	5.683	0.235	0.035	0.067	0.046
Major Road	0.234	0.461	0.237	0.551	-0.006	-0.178	0.058	0.050
Sayre	0.064	0.245	0.368	0.482	-0.795	-0.680	0.936	0.632
Towanda	0.195	0.396	0.096	0.294	0.284	0.297	0.805	0.904

Note: Treatment is defined as shale activity within 2 miles.



(a) Estimated propensity score for treated units in Bradford County



(b) Estimated propensity score for control units in Bradford County

Figure 3: Histograms of the estimated propensity score for Bradford County for 2-mile treatment.

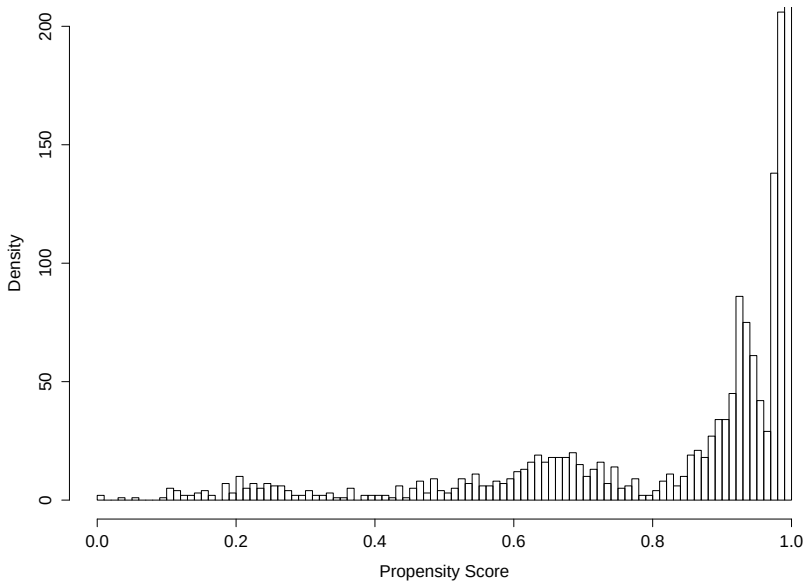
3.1.3 Treatment at 3 Miles

Our last set of pre-match assessment exercises is based on defining treatment to be shale activity within 3 miles of a property in Bradford County. Statistical results are reported in Table 4, and histograms for the propensity score for the treated (top) and control (bottom) groups are shown in Figure 4. The results are largely consistent with the previous pre-match assessments for Bradford County. The overlap assessment of feasibility to match on the propensity score indicates that 100 percent of units in both groups have a corresponding unit in the opposing group that is a potential match.

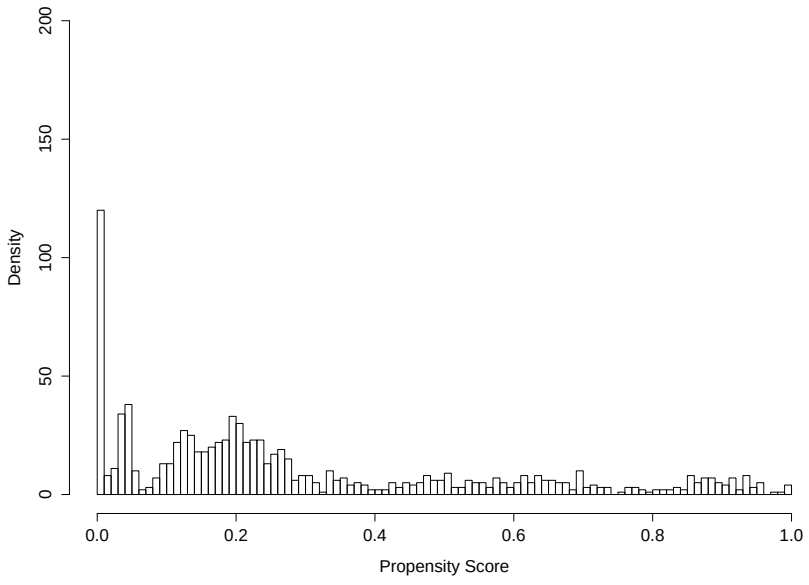
Table 4: Results for pre-matching statistics for Bradford County

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.859	0.211	0.289	0.268	2.362	-0.239	0.637	0.532
Age	74.494	47.678	65.707	45.927	0.188	0.037	0.056	0.077
Stories	1.510	0.466	1.514	0.468	-0.010	-0.004	0.421	0.422
Bedrooms	2.998	1.269	2.971	1.179	0.023	0.073	0.079	0.056
Bathrooms	1.471	0.777	1.471	0.741	0.001	0.047	0.081	0.083
SQFT	16.133	7.548	15.845	7.098	0.039	0.061	0.072	0.069
Acres	7.922	31.386	6.908	21.987	0.037	0.356	0.060	0.052
Warm Air	0.476	0.500	0.490	0.500	-0.028	-0.001	0.524	0.510
Private Water	0.580	0.494	0.488	0.500	0.185	-0.013	0.420	0.512
Highway	5.802	5.910	4.689	5.576	0.194	0.058	0.066	0.049
Major Road	0.248	0.549	0.210	0.408	0.079	0.297	0.067	0.037
Sayre	0.125	0.330	0.394	0.489	-0.647	-0.392	0.875	0.606
Towanda	0.171	0.377	0.095	0.293	0.227	0.252	0.829	0.905

Note: Treatment is defined as shale activity within 3 miles.



(a) Estimated propensity score for treated units in Bradford County



(b) Estimated propensity score for control units in Bradford County

Figure 4: Histograms of the estimated propensity score for Bradford County for 3-mile treatment.

3.2 Lycoming County

We now turn to the same pre-match assessment statistics for Lycoming County. Here, we do not discriminate between on/off-shale properties, and focus on treatment defined as shale activity within $\{1, 2, 3\}$ miles of a property.

3.2.1 Treatment at 1 Mile

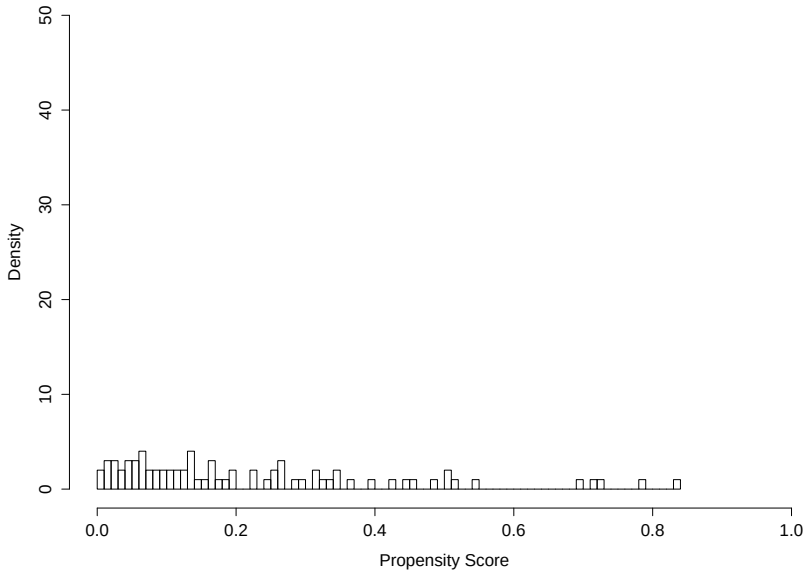
Table 5 contains pre-match statistics for Lycoming County with treatment defined as shale activity within 1 mile. As in Bradford County, we do not find balance and overlap in terms of the estimated propensity score. Many covariates, such as the number of bedrooms or bathrooms are generally well-balanced. Others, such as distance to nearest highway, are not well-balanced and will likely lead to bias in the treatment effect parameters if left unadjusted.

Figure 5 shows histograms of the estimated propensity score for the treated (top) and control (bottom) groups. Is it clear that the percent of the distribution in the opposing distribution tails (reported in the last columns of Table 5) is largely coming from skewness of the distributions. The share of observations in each treatment group that have at least one corresponding match (within 10 percent tolerance) in the opposing group is 98.7 percent and 100 percent, respectively for the treated and control groups.

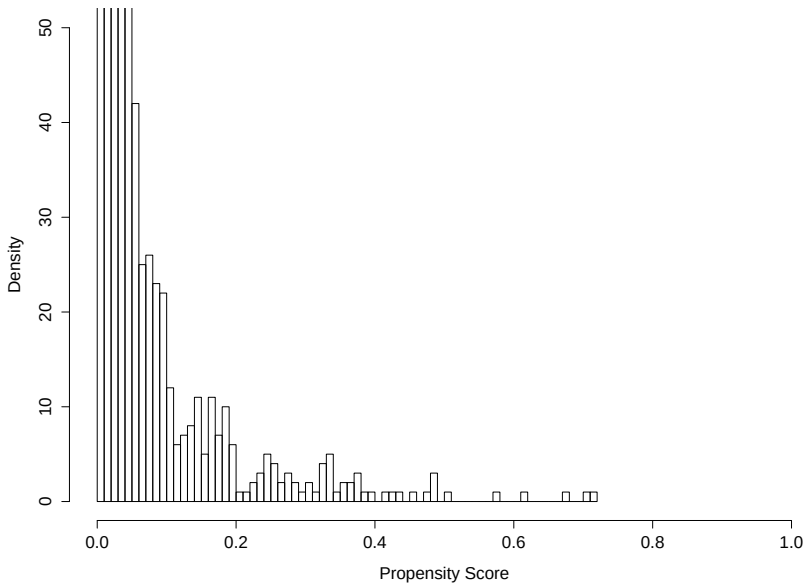
Table 5: Results for pre-matching statistics for Lycoming County

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.224	0.201	0.017	0.054	1.407	1.320	0.500	0.777
Age	49.342	40.121	64.233	35.788	-0.392	0.114	0.118	0.011
Stories	1.421	0.490	1.532	0.488	-0.228	0.005	0.461	0.406
Bedrooms	2.829	0.944	2.974	1.359	-0.124	-0.365	0.066	0.050
Bathrooms	1.533	0.763	1.527	0.695	0.008	0.094	0.079	0.049
SQFT	17.637	6.983	16.570	6.218	0.161	0.116	0.066	0.075
Acres	5.897	15.461	1.694	7.455	0.346	0.729	0.079	0.497
Basement	0.118	0.325	0.144	0.352	-0.077	-0.078	0.882	0.856
Garage	0.053	0.225	0.069	0.319	-0.061	-0.350	0.947	0.965
Air	0.171	0.379	0.247	0.431	-0.188	-0.130	0.829	0.753
Private Water	0.895	0.309	0.270	0.444	1.633	-0.363	0.105	0.730
Highway	8.601	5.677	2.256	3.025	1.395	0.630	0.368	0.276
Major Road	0.420	0.523	0.205	0.260	0.521	0.701	0.171	0.014
Hughesville	0.197	0.401	0.056	0.230	0.432	0.554	0.803	0.944
Jersey Shore	0.118	0.325	0.079	0.270	0.131	0.186	0.882	0.921
Montoursville	0.237	0.428	0.144	0.351	0.238	0.198	0.763	0.856
Muncy	0.066	0.250	0.082	0.275	-0.063	-0.097	0.934	0.918
South Williamsport	0.000	0.000	0.088	0.284	-0.440	-	1.000	1.000
Williamsport	0.000	0.000	0.394	0.489	-1.139	-	1.000	1.000

Note: Treatment is defined as shale activity within 1 mile.



(a) Estimated propensity score for treated units in Lycoming County



(b) Estimated propensity score for control units in Lycoming County

Figure 5: Histograms of the estimated propensity score for Lycoming County for 1-mile treatment.

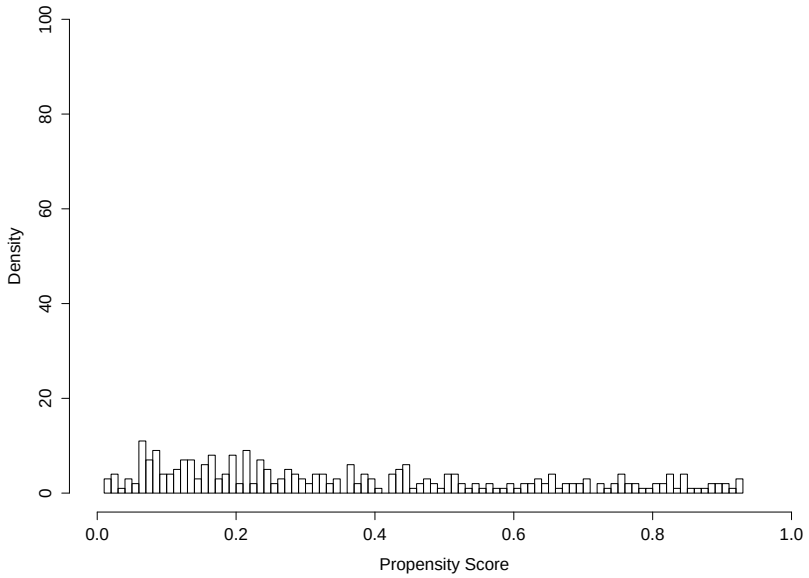
3.2.2 Treatment at 2 Miles

The results when defining treatment to be shale activity within 2 miles is largely the same, so we will not go into lengthy detail. The statistics are reported in Table 6, and the histograms are show in Figure 6. We find that the share of treated/control units that have at least one potential opposing match is 1 for each group.

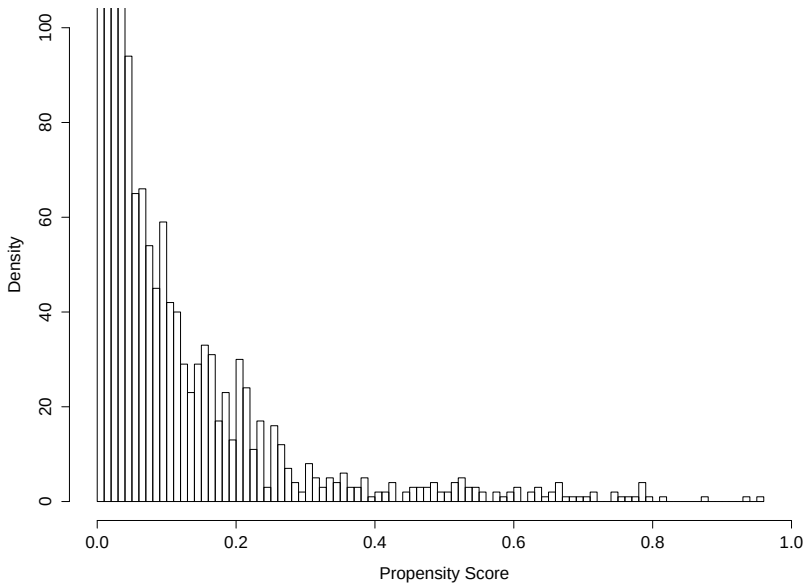
Table 6: Results for pre-matching statistics for Lycoming County

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.369	0.260	0.053	0.111	1.582	0.852	0.399	0.719
Age	47.064	33.409	65.334	35.791	-0.528	-0.069	0.046	0.021
Stories	1.391	0.470	1.542	0.488	-0.314	-0.036	0.512	0.430
Bedrooms	2.957	0.881	2.972	1.384	-0.013	-0.451	0.060	0.050
Bathrooms	1.621	0.740	1.519	0.692	0.142	0.068	0.060	0.049
SQFT	17.484	6.760	16.518	6.185	0.149	0.089	0.057	0.051
Acres	4.845	14.826	1.526	6.746	0.288	0.787	0.082	0.284
Basement	0.164	0.371	0.142	0.349	0.060	0.059	0.836	0.858
Garage	0.071	0.296	0.069	0.319	0.007	-0.074	0.950	0.966
Air	0.206	0.405	0.249	0.432	-0.102	-0.065	0.794	0.751
Private Water	0.712	0.454	0.247	0.431	1.049	0.050	0.288	0.753
Highway	6.537	5.395	2.041	2.707	1.053	0.690	0.281	0.068
Major Road	0.290	0.384	0.203	0.257	0.264	0.404	0.100	0.019
Hughesville	0.157	0.364	0.051	0.220	0.351	0.504	0.843	0.949
Jersey Shore	0.125	0.331	0.076	0.266	0.161	0.220	0.875	0.924
Montoursville	0.345	0.476	0.129	0.335	0.525	0.351	0.655	0.871
Muncy	0.057	0.232	0.084	0.278	-0.106	-0.179	0.943	0.916
South Williamsport	0.000	0.000	0.094	0.291	-0.454	-	1.000	1.000
Williamsport	0.032	0.176	0.415	0.493	-1.035	-1.027	0.968	0.585

Note: Treatment is defined as shale activity within 2 miles.



(a) Estimated propensity score for treated units in Lycoming County



(b) Estimated propensity score for control units in Lycoming County

Figure 6: Histograms of the estimated propensity score for Lycoming County for 2-mile treatment.

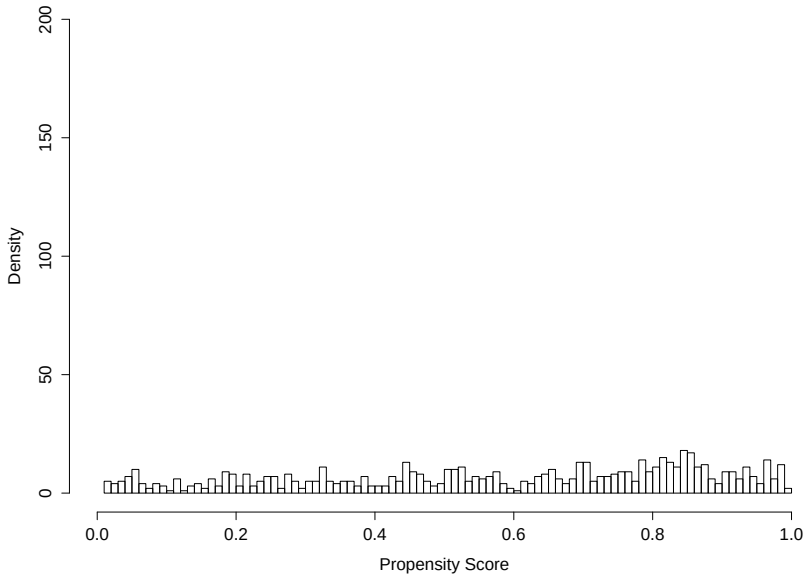
3.2.3 Treatment at 3 Miles

The results when defining treatment to be shale activity within 3 miles is largely the same, so we will not go into lengthy detail. The statistics are reported in Table 7, and the histograms are show in Figure 7. We find that the share of treated/control units that have at least one potential opposing match is 1 for each group.

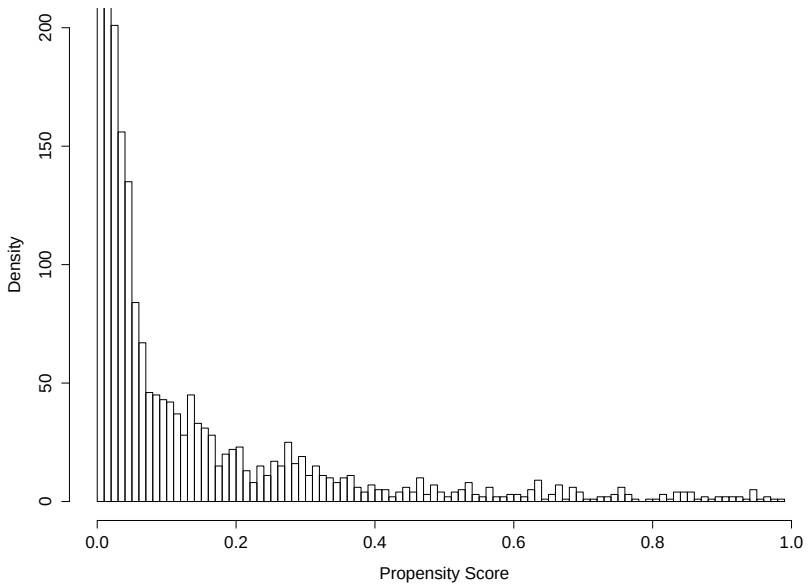
Table 7: Results for pre-matching statistics for Lycoming County

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score	0.579	0.278	0.095	0.169	2.103	0.498	0.465	0.626
Age	54.051	34.797	66.148	35.825	-0.343	-0.029	0.045	0.029
Stories	1.415	0.472	1.556	0.488	-0.295	-0.034	0.505	0.418
Bedrooms	2.970	0.894	2.971	1.435	-0.001	-0.474	0.057	0.049
Bathrooms	1.592	0.709	1.513	0.692	0.113	0.023	0.052	0.049
SQFT	16.988	6.305	16.503	6.218	0.078	0.014	0.046	0.058
Acres	3.713	12.762	1.347	5.955	0.238	0.762	0.084	0.176
Basement	0.160	0.367	0.140	0.347	0.055	0.055	0.840	0.860
Garage	0.069	0.326	0.069	0.315	-0.001	0.032	0.964	0.965
Air	0.239	0.427	0.247	0.431	-0.019	-0.011	0.761	0.753
Private Water	0.483	0.500	0.238	0.426	0.527	0.160	0.517	0.762
Highway	4.717	4.943	1.863	2.408	0.734	0.719	0.227	0.035
Major Road	0.261	0.330	0.198	0.252	0.212	0.270	0.090	0.024
Hughesville	0.178	0.383	0.032	0.177	0.488	0.771	0.822	0.968
Jersey Shore	0.081	0.273	0.080	0.271	0.003	0.005	0.919	0.920
Montoursville	0.444	0.497	0.079	0.269	0.914	0.614	0.556	0.921
Muncy	0.045	0.207	0.090	0.287	-0.182	-0.325	0.955	0.910
South Williamsport	0.000	0.000	0.106	0.308	-0.487	-	1.000	1.000
Williamsport	0.051	0.220	0.461	0.499	-1.064	-0.819	0.949	0.539

Note: Treatment is defined as shale activity within 3 miles.



(a) Estimated propensity score for treated units in Lycoming County



(b) Estimated propensity score for control units in Lycoming County

Figure 7: Histograms of the estimated propensity score for Lycoming County for 3-mile treatment.

3.3 Conclusion from this Section

These pre-match exercises have shed important light on the initial imbalance between treated and control units prior to any balance adjustment via matching or regression. We find that, while certain covariates are well-balanced, others are not. It is well-established that this imbalance, if unadjusted, will bias estimates of treatment effect parameters. The lack of overlap for certain covariates suggests possible sensitivity of regression estimates of the parameters. We find that there is overlap in the distributions of the estimated propensity scores for treated/control units, which suggests that it may be possible to match based on the propensity score to eliminate these biases.

4 Log-Linear Regression Models

4.1 Interaction with Acreage

In this model, we consider interaction of each of our shale proximity variables with acreage of the property. The idea is that properties with larger acreage may be better insulated from shale activity on/near the property if, for example, the shale activity can occur farther from the actual residence. The rest of the regression specification remains the same.

4.1.1 Bradford County

Results for Bradford County are reported in Table 8. We find a few instances of significance, but perhaps the most noteworthy is in Model 7, in which we find that the number of shale wells within 3 miles leads to a decrease in property values, but that this effect diminishes (gets closer to zero) as the property size increases in acreage. However, testing significance of the marginal impact of shale activity on property values, evaluated at the average acreage of 8.2 acres, indicates statistical insignificance of this marginal effect.

Table 8: Baseline regressions with acreage interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.006						
	(0.005)						
Acres × Dist. to Nearest Well	0.00003						
	(0.0001)						
Activity in 1 Mile		−0.035					
		(0.042)					
Acres × Activity in 1 Mile		−0.001					
		(0.001)					
Activity in 2 Miles			−0.065				
			(0.043)				
Acres × Activity in 2 Miles			−0.0002				
			(0.001)				
Activity in 3 Miles				−0.081*			
				(0.048)			
Acres × Activity in 3 Miles				−0.001			
				(0.001)			
Count in 1 Mile					−0.001		
					(0.004)		
Acres × Count in 1 Mile					0.0001		
					(0.0001)		
Count in 2 Miles						−0.002	
						(0.001)	
Acres × Count in 2 Miles						0.0001**	
						(0.00004)	
Count in 3 Miles							−0.001*
							(0.001)
Acres × Count in 3 Miles							0.0001***
							(0.00002)
Observations	3,317	3,317	3,317	3,317	3,317	3,317	3,317
Adjusted R^2	0.207	0.207	0.208	0.208	0.207	0.208	0.209
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.1.2 Lycoming County

Results for Lycoming County are reported in Table 9. Several parameters are statistically significant, but we do not find any strong significance that shale activity leads to a *decrease* in property values, nor do we find any significance of a differential effect across property acreage.

Table 9: Baseline regressions with acreage interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.00000						
	(0.003)						
Acres × Dist. to Nearest Well	0.001***						
	(0.0002)						
Activity in 1 Mile		−0.020					
		(0.057)					
Acres × Activity in 1 Mile		−0.001					
		(0.003)					
Activity in 2 Miles			0.066**				
			(0.033)				
Acres × Activity in 2 Miles			0.0001				
			(0.002)				
Activity in 3 Miles				0.039			
				(0.026)			
Acres × Activity in 3 Miles				−0.006***			
				(0.002)			
Count in 1 Mile					0.0004		
					(0.008)		
Acres × Count in 1 Mile					−0.0004		
					(0.001)		
Count in 2 Miles						0.003	
						(0.003)	
Acres × Count in 2 Miles						−0.0001	
						(0.0002)	
Count in 3 Miles							0.002*
							(0.001)
Acres × Count in 3 Miles							−0.0001
							(0.0001)
Observations	4,140	4,140	4,140	4,140	4,140	4,140	4,140
Adjusted R^2	0.414	0.412	0.413	0.414	0.412	0.412	0.413
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.2 Sales Within 60 Days of Permitting

One important conclusion reached by Gopalakrishnan & Klaiber (2014) is that negative shale activity effects are localized over time and space. These regressions assess whether our general lack of significance is because we have not specifically focused on temporally localized impacts. Indeed, the hydraulic fracturing process only lasts several weeks, after which time many of the potential negative effects are removed from the area (e.g., truck traffic, water use, chemical use, the drilling tower, noise/odors). Of course, some surface facilities remain, as do factors contributing to groundwater concerns. By focusing only on property transactions that occurred within 60 days of the permitting of a well, we can ascertain whether there is a stronger impact of shale activity on properties right around the actual time of drilling.

4.2.1 Bradford County

Tables 10 shows that when considering shale impacts only within 60 days of permitting of a shale well, we find that the number of shale wells within 2 and 3 miles is significantly associated with reduced housing values by about 2 percent.

Table 11 considers the same specification, but with interactions with water source included. These models reveal that shale activity within 3 miles, as well as the count of shale wells within 2 and 3 miles, are significantly associated with reductions in property values for homes that are not on private water. As before, we do not find that these effects are significant for properties that rely on well water.

Table 10: Regressions for sales within 60 days of permitting for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.001						
	(0.005)						
Activity in 1 Mile		0.015					
		(0.065)					
Activity in 2 Miles			−0.007				
			(0.040)				
Activity in 3 Miles				−0.046			
				(0.034)			
Count in 1 Mile					0.004		
					(0.019)		
Count in 2 Miles						−0.014*	
						(0.008)	
Count in 3 Miles							−0.020***
							(0.005)
Observations	2,948	2,948	2,948	2,948	2,948	2,948	2,948
Adjusted R^2	0.220	0.220	0.220	0.220	0.220	0.221	0.223
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.2.2 Lycoming County

Tables 12 and 13 report similar regressions for Lycoming County. Unlike in Bradford County, we do not find any statistical significance of temporally localized impacts of shale activity on property values. This conclusion does not depend on interaction with water source.

Table 11: Regressions for sales within 60 days of permitting with water source interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.003						
	(0.006)						
Private Water × Dist. to Nearest Well	−0.008						
	(0.007)						
Activity in 1 Mile		0.068					
		(0.148)					
Private Water × Activity in 1 Mile		−0.065					
		(0.165)					
Activity in 2 Miles			−0.057				
			(0.066)				
Private Water × Activity in 2 Miles			0.075				
			(0.080)				
Activity in 3 Miles				−0.146***			
				(0.051)			
Private Water × Activity in 3 Miles				0.166***			
				(0.064)			
Count in 1 Mile					−0.005		
					(0.047)		
Private Water × Count in 1 Mile					0.011		
					(0.052)		
Count in 2 Miles						−0.043**	
						(0.017)	
Private Water × Count in 2 Miles						0.037*	
						(0.019)	
Count in 3 Miles							−0.035***
							(0.010)
Private Water × Count in 3 Miles							0.021*
							(0.011)
Private Water	0.075	0.038	0.020	−0.027	0.033	0.014	0.005
	(0.057)	(0.046)	(0.049)	(0.052)	(0.046)	(0.048)	(0.050)
Observations	2,948	2,948	2,948	2,948	2,948	2,948	2,948
Adjusted R^2	0.220	0.220	0.220	0.222	0.220	0.221	0.224
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 12: Regressions for sales within 60 days of permitting for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.002						
	(0.003)						
Activity in 1 Mile		−0.029					
		(0.110)					
Activity in 2 Miles			−0.033				
			(0.058)				
Activity in 3 Miles				−0.015			
				(0.037)			
Count in 1 Mile					0.055		
					(0.044)		
Count in 2 Miles						0.012	
						(0.020)	
Count in 3 Miles							−0.004
							(0.011)
Observations	3,182	3,182	3,182	3,182	3,182	3,182	3,182
Adjusted R^2	0.438	0.438	0.438	0.438	0.438	0.438	0.438
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 13: Regressions for sales within 60 days of permitting with water source interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.004						
	(0.004)						
Private Water × Dist. to Nearest Well	0.004						
	(0.005)						
Activity in 1 Mile		0.325					
		(0.243)					
Private Water × Activity in 1 Mile		−0.442					
		(0.271)					
Activity in 2 Miles			0.085				
			(0.111)				
Private Water × Activity in 2 Miles			−0.160				
			(0.128)				
Activity in 3 Miles				0.034			
				(0.055)			
Private Water × Activity in 3 Miles				−0.088			
				(0.072)			
Count in 1 Mile					0.328		
					(0.243)		
Private Water × Count in 1 Mile					−0.282		
					(0.247)		
Count in 2 Miles						0.036	
						(0.067)	
Private Water × Count in 2 Miles						−0.027	
						(0.070)	
Count in 3 Miles							0.010
							(0.029)
Private Water × Count in 3 Miles							−0.017
							(0.031)
Private Water	−0.022	0.016	0.018	0.019	0.015	0.015	0.016
	(0.050)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Observations	3,182	3,182	3,182	3,182	3,182	3,182	3,182
Adjusted R^2	0.438	0.438	0.438	0.438	0.438	0.438	0.438
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.3 Sales in 2008

In these models, we restrict our sample only to properties that were sold in 2008, which is the first year of property transactions in our data nearby to shale activity. These regressions are important for two reasons. *First*, it is possible that the first year of shale extraction in the region was accompanied with increased uncertainty regarding the potential negative effects of shale activity. Such uncertainty might manifest in property values. Over time, in the absence of any major public announcements of damage stemming from shale activity, property markets might adjust so that property values no longer were significantly impacted by nearby shale activity (at least to an extent that we can statistically identify the effects). Hence, restricting our analysis to 2008 sales should allow us to detect shale activity impacts, if such impacts were particularly strong in the first year of shale activity in the region.

Second, it is possible that shale activity puts pressure on property values because of an increase in demand for housing in the area from workers brought in to work on various aspects of shale exploration and extraction. While these workers are likely to be temporarily residing in the area, their presence may put pressure on rental prices which ultimately may spill over into housing prices. Yet, these effects are not likely to be severe in the initial year of extraction, or are at least likely to be minimized in a restricted sample for 2008 property sales.

4.3.1 Bradford County

Tables 14 and 15 contain regression results for 2008 property transactions in Bradford County, without and with water source interactions. As can be seen, we do not find any statistical significance of any of the shale activity measures in our regressions.

Table 14: Regressions for 2008 property sales for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.010						
	(0.009)						
Activity in 1 Mile		−0.117					
		(0.302)					
Activity in 2 Miles			0.197				
			(0.149)				
Activity in 3 Miles				−0.013			
				(0.120)			
Count in 1 Mile					−0.045		
					(0.252)		
Count in 2 Miles						0.038	
						(0.089)	
Count in 3 Miles							−0.063
							(0.056)
Observations	591	591	591	591	591	591	591
Adjusted R^2	0.240	0.238	0.241	0.238	0.238	0.239	0.240
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.3.2 Lycoming County

Tables 16 and 17 contain analogous regression results for 2008 property transactions in Lycoming County, without and with interaction with water source. In these regressions, we find that shale activity within 1 mile of the property is associated with a significant reduction in property values, as is the number of shale wells within 1 mile. However, looking into the data, we find that this significance comes from too few observations in the indicator, and hence is spurious. There is only 1 property transaction picked up by this indicator. In addition, Table 17 shows that these effects do not differ across water source (as can be seen, there are no properties in

Table 15: Regressions for 2008 property sales with water source interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.023						
	(0.015)						
Private Water × Dist. to Nearest Well	0.018						
	(0.018)						
Activity in 1 Mile		−0.238					
		(0.793)					
Private Water × Activity in 1 Mile		0.141					
		(0.855)					
Activity in 2 Miles			0.307				
			(0.300)				
Private Water × Activity in 2 Miles			−0.143				
			(0.337)				
Activity in 3 Miles				0.192			
				(0.221)			
Private Water × Activity in 3 Miles				−0.272			
				(0.247)			
Count in 1 Mile					−0.236		
					(0.793)		
Private Water × Count in 1 Mile					0.213		
					(0.836)		
Count in 2 Miles						0.296	
						(0.300)	
Private Water × Count in 2 Miles						−0.281	
						(0.311)	
Count in 3 Miles							0.186
							(0.220)
Private Water × Count in 3 Miles							−0.262
							(0.224)
Private Water	−0.084	0.045	0.054	0.102	0.043	0.068	0.110
	(0.166)	(0.113)	(0.116)	(0.123)	(0.113)	(0.115)	(0.122)
Observations	591	591	591	591	591	591	591
Adjusted R^2	0.240	0.237	0.240	0.239	0.237	0.238	0.240
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

private water within 1 mile of shale activity). We also see significance of the count of shale wells within 3 miles for properties that are not on private water.

Table 16: Regressions for 2008 property sales for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.012						
	(0.017)						
Activity in 1 Mile		−1.093**					
		(0.482)					
Activity in 2 Miles			0.082				
			(0.204)				
Activity in 3 Miles				−0.038			
				(0.125)			
Count in 1 Mile					−0.547**		
					(0.241)		
Count in 2 Miles						−0.111	
						(0.095)	
Count in 3 Miles							−0.066
							(0.047)
Observations	661	661	661	661	661	661	661
Adjusted R^2	0.337	0.342	0.337	0.337	0.342	0.338	0.339
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 17: Regressions for 2008 property sales with water source interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.019						
	(0.021)						
Private Water × Dist. to Nearest Well	0.010						
	(0.017)						
Activity in 1 Mile		−1.093**					
		(0.482)					
Private Water × Activity in 1 Mile							
Activity in 2 Miles			−0.415				
			(0.466)				
Private Water × Activity in 2 Miles			0.602				
			(0.508)				
Activity in 3 Miles				−0.283			
				(0.227)			
Private Water × Activity in 3 Miles				0.313			
				(0.241)			
Count in 1 Mile					−0.547**		
					(0.241)		
Private Water × Count in 1 Mile							
Count in 2 Miles						−0.220	
						(0.233)	
Private Water × Count in 2 Miles						0.129	
						(0.253)	
Count in 3 Miles							−0.182*
							(0.099)
Private Water × Count in 3 Miles							0.135
							(0.103)
Private Water	−0.102	−0.012	−0.024	−0.035	−0.012	−0.018	−0.033
	(0.153)	(0.061)	(0.061)	(0.063)	(0.061)	(0.061)	(0.062)
Observations	661	661	661	661	661	661	661
Adjusted R^2	0.337	0.342	0.337	0.338	0.342	0.338	0.340
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

4.4 Removing City Properties

In these regressions we remove all property sales that occur in the cities mentioned previously in this document. In the event that there are differences in city properties that are not adequately captured by our regression design, these regressions should provide a clearer perspective on the impact of shale activity on rural properties.

4.4.1 Bradford County

Regression results for Bradford County without and with water source interactions are reported in Tables 18 and 19. In the first table, we do not find any statistical significance. In the second table, we find that shale activity negative impacts property values in Models 1, 3, 4, and 7. These effects are not significant for properties on well water (i.e., joint effect that includes the water source interaction), but is only significant for properties on public water.

Table 18: Regressions without city sales for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.006						
	(0.005)						
Activity in 1 Mile		−0.042					
		(0.051)					
Activity in 2 Miles			−0.045				
			(0.055)				
Activity in 3 Miles				−0.082			
				(0.062)			
Count in 1 Mile					0.002		
					(0.004)		
Count in 2 Miles						0.0005	
						(0.002)	
Count in 3 Miles							−0.0003
							(0.001)
Observations	2,144	2,144	2,144	2,144	2,144	2,144	2,144
Adjusted R^2	0.204	0.204	0.204	0.205	0.204	0.204	0.204
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.4.2 Lycoming County

The results for Lycoming County are reported in Tables 20 and 21. In both tables, we fail to find any statistical significance, except in Model 1 of the second table. In this model, we find evidence that properties that are located farther from shale activity transact at higher prices, but this effect is not significant for private water properties.

Table 19: Regressions without city properties with water source interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.021**						
	(0.010)						
Private Water × Dist. to Nearest Well	−0.017*						
	(0.009)						
Activity in 1 Mile		−0.126					
		(0.094)					
Private Water × Activity in 1 Mile		0.108					
		(0.101)					
Activity in 2 Miles			−0.174**				
			(0.087)				
Private Water × Activity in 2 Miles			0.169*				
			(0.088)				
Activity in 3 Miles				−0.195**			
				(0.090)			
Private Water × Activity in 3 Miles				0.154*			
				(0.088)			
Count in 1 Mile					−0.008		
					(0.010)		
Private Water × Count in 1 Mile					0.012		
					(0.011)		
Count in 2 Miles						−0.005	
						(0.004)	
Private Water × Count in 2 Miles						0.006*	
						(0.004)	
Count in 3 Miles							−0.003*
							(0.002)
Private Water × Count in 3 Miles							0.003**
							(0.001)
Private Water	0.081	−0.009	−0.091	−0.094	−0.010	−0.048	−0.074
	(0.063)	(0.065)	(0.080)	(0.085)	(0.061)	(0.067)	(0.071)
Observations	2,144	2,144	2,144	2,144	2,144	2,144	2,144
Adjusted R^2	0.205	0.204	0.205	0.205	0.204	0.205	0.205
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 20: Regressions without city sales for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.008						
	(0.008)						
Activity in 1 Mile		−0.133					
		(0.106)					
Activity in 2 Miles			0.069				
			(0.073)				
Activity in 3 Miles				0.046			
				(0.065)			
Count in 1 Mile					−0.014		
					(0.017)		
Count in 2 Miles						0.001	
						(0.006)	
Count in 3 Miles							0.001
							(0.003)
Observations	672	672	672	672	672	672	672
Adjusted R^2	0.362	0.362	0.362	0.361	0.361	0.361	0.361
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 21: Regressions without city properties with water source interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.023*						
	(0.013)						
Private Water × Dist. to Nearest Well	−0.017						
	(0.012)						
Activity in 1 Mile		0.013					
		(0.377)					
Private Water × Activity in 1 Mile		−0.155					
		(0.386)					
Activity in 2 Miles			−0.047				
			(0.190)				
Private Water × Activity in 2 Miles			0.130				
			(0.197)				
Activity in 3 Miles				−0.117			
				(0.153)			
Private Water × Activity in 3 Miles				0.184			
				(0.156)			
Count in 1 Mile					0.010		
					(0.037)		
Private Water × Count in 1 Mile					−0.030		
					(0.041)		
Count in 2 Miles						−0.003	
						(0.014)	
Private Water × Count in 2 Miles						0.005	
						(0.015)	
Count in 3 Miles							−0.001
							(0.007)
Private Water × Count in 3 Miles							0.002
							(0.007)
Private Water	0.208*	0.080	0.065	0.048	0.080	0.074	0.073
	(0.114)	(0.063)	(0.064)	(0.067)	(0.062)	(0.063)	(0.063)
Observations	672	672	672	672	672	672	672
Adjusted R^2	0.363	0.361	0.361	0.362	0.361	0.360	0.360
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

4.5 Shale Activity Measured by Well Pads Only

We now consider the incidence of shale activity by measuring only well pads, and not well bores. One of the features of unconventional drilling is that multiple well bores can be drilled from a single well pad. It is possible then that the manifestation of shale activity in property values comes from proximity to well pads – that is, given a well pad nearby, the marginal impact of another well bore on nearby properties from that pad is zero.

4.5.1 Bradford County

Bradford County results are reported in Tables 22 and 23. Without considering any water source interactions, we only find significance of well bores in Model 2. There are, however, only 7 observations picked out by that indicator, which makes this result unreliable (and also explains the really large coefficient estimate). In Table 23, we only find significance of distance to nearest well, and as before, our results do not reveal any meaningful interactions with water source.

Table 22: Regressions with shale activity measured by well pads for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.007						
	(0.005)						
Activity in 1 Mile		-0.772^{***}					
		(0.296)					
Activity in 2 Miles			0.005				
			(0.124)				
Activity in 3 Miles				-0.067			
				(0.091)			
Count in 1 Mile					0.013		
					(0.027)		
Count in 2 Miles						0.007	
						(0.006)	
Count in 3 Miles							-0.001
							(0.003)
Observations	3,317	3,317	3,317	3,317	3,317	3,317	3,317
Adjusted R^2	0.208	0.209	0.207	0.207	0.207	0.208	0.207
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.5.2 Lycoming County

Lycoming County results are reported in Tables 24 and 25. In the first table, we find a significant positive effect of shale activity within 2 miles, and for the count of shale wells within 3 miles. This result is difficult to explain, but does not appear in the following table in which we include interactions with water source. In Table 25, we find a significant interactive effect in Model 2 for the private water interaction term. The shale impact for these properties (i.e., the joint effect) is not statistically significant. The same is true of Model 5, though we find significance in the coefficient on the interactive term, the parameters are not jointly significant which means that the effect of shale activity on property values is not significant for properties on private (or public) water.

Table 23: Regressions with shale activity measured by well pads with water source interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.014**						
	(0.007)						
Private Water × Dist. to Nearest Well	−0.009						
	(0.006)						
Activity in 1 Mile		−0.330					
		(0.781)					
Private Water × Activity in 1 Mile		−0.517					
		(0.844)					
Activity in 2 Miles			0.090				
			(0.231)				
Private Water × Activity in 2 Miles			−0.120				
			(0.273)				
Activity in 3 Miles				0.123			
				(0.165)			
Private Water × Activity in 3 Miles				−0.273			
				(0.197)			
Count in 1 Mile					−0.326		
					(0.782)		
Private Water × Count in 1 Mile					0.340		
					(0.782)		
Count in 2 Miles						0.009	
						(0.022)	
Private Water × Count in 2 Miles						−0.003	
						(0.023)	
Count in 3 Miles							0.004
							(0.015)
Private Water × Count in 3 Miles							−0.005
							(0.015)
Private Water	0.050	0.017	0.019	0.026	0.016	0.017	0.019
	(0.050)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Observations	3,317	3,317	3,317	3,317	3,317	3,317	3,317
Adjusted R^2	0.208	0.209	0.207	0.208	0.207	0.207	0.207
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 24: Regressions with shale activity measured by well pads for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.002						
	(0.003)						
Activity in 1 Mile		−0.047					
		(0.059)					
Activity in 2 Miles			0.062*				
			(0.036)				
Activity in 3 Miles				0.029			
				(0.028)			
Count in 1 Mile					−0.024		
					(0.030)		
Count in 2 Miles						0.010	
						(0.009)	
Count in 3 Miles							0.009*
							(0.005)
Observations	4,140	4,140	4,140	4,140	4,140	4,140	4,140
Adjusted R^2	0.412	0.412	0.413	0.412	0.412	0.412	0.413
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 25: Regressions with shale activity measured by well pads with water source interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.005						
	(0.003)						
Private Water × Dist. to Nearest Well	−0.007*						
	(0.004)						
Activity in 1 Mile		0.233					
		(0.155)					
Private Water × Activity in 1 Mile		−0.321*					
		(0.164)					
Activity in 2 Miles			0.078				
			(0.061)				
Private Water × Activity in 2 Miles			−0.022				
			(0.070)				
Activity in 3 Miles				0.001			
				(0.038)			
Private Water × Activity in 3 Miles				0.053			
				(0.047)			
Count in 1 Mile					0.138		
					(0.086)		
Private Water × Count in 1 Mile					−0.180**		
					(0.090)		
Count in 2 Miles						0.029	
						(0.021)	
Private Water × Count in 2 Miles						−0.022	
						(0.023)	
Count in 3 Miles							0.018
							(0.012)
Private Water × Count in 3 Miles							−0.011
							(0.012)
Private Water	0.065*	0.021	0.017	0.009	0.021	0.020	0.020
	(0.034)	(0.023)	(0.023)	(0.024)	(0.023)	(0.023)	(0.024)
Observations	4,140	4,140	4,140	4,140	4,140	4,140	4,140
Adjusted R^2	0.413	0.413	0.412	0.412	0.413	0.412	0.413
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

4.6 Horizontal Wells Only

In this final set of analysis, we restrict our focus to the incidence of horizontal shale wells only. That is, we have removed all vertical shale wells from the regression. (As we show in the paper, there are relatively few vertical shale wells in this region. Nevertheless, we consider this set of regressions for robustness and completeness.)

4.6.1 Bradford County

Bradford County results are reported in Tables 26 and 27. In the first table, we find significance of distance to nearest well, and significance in Model 2 of activity of shale within 1 mile. However in Model 2, and as suggested by the magnitude of the coefficient, we find this result is not reliable since there are only 7 observations that have shale activity within 1 mile for this model. We do not find any statistical significance in Table 27 when considering interactions with water source.

Table 26: Regressions using only horizontal wells for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.005^{**}						
	(0.002)						
Activity in 1 Mile		-0.772^{***}					
		(0.296)					
Activity in 2 Miles			0.005				
			(0.124)				
Activity in 3 Miles				−0.067			
				(0.091)			
Count in 1 Mile					0.012		
					(0.023)		
Count in 2 Miles						0.006	
						(0.005)	
Count in 3 Miles							−0.001
							(0.002)
Observations	3,317	3,317	3,317	3,317	3,317	3,317	3,317
Adjusted R^2	0.208	0.209	0.207	0.207	0.207	0.208	0.207
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

4.6.2 Lycoming County

The Lycoming County regression results considering only horizontal wells are provided in Tables 28 and 29. The most noteworthy significance is on the interaction terms in the second table in Models 1 and 2. As in previous regressions, when considering the marginal effect of shale activity on property values for properties on private water, we do not find statistical significance.

Table 27: Regressions using only horizontal wells with water source interactions for Bradford County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.003						
	(0.004)						
Private Water × Dist. to Nearest Well	0.003						
	(0.004)						
Activity in 1 Mile		−0.330					
		(0.781)					
Private Water × Activity in 1 Mile		−0.517					
		(0.844)					
Activity in 2 Miles			0.090				
			(0.231)				
Private Water × Activity in 2 Miles			−0.120				
			(0.273)				
Activity in 3 Miles				0.123			
				(0.165)			
Private Water × Activity in 3 Miles				−0.273			
				(0.197)			
Count in 1 Mile					−0.326		
					(0.782)		
Private Water × Count in 1 Mile					0.338		
					(0.782)		
Count in 2 Miles						0.008	
						(0.019)	
Private Water × Count in 2 Miles						−0.002	
						(0.019)	
Count in 3 Miles							0.003
							(0.013)
Private Water × Count in 3 Miles							−0.004
							(0.013)
Private Water	−0.026	0.017	0.019	0.026	0.016	0.017	0.019
	(0.082)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Observations	3,317	3,317	3,317	3,317	3,317	3,317	3,317
Adjusted R^2	0.208	0.209	0.207	0.208	0.207	0.207	0.207
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 28: Regressions using only horizontal wells for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	−0.0001						
	(0.003)						
Activity in 1 Mile		−0.047					
		(0.059)					
Activity in 2 Miles			0.062*				
			(0.036)				
Activity in 3 Miles				0.029			
				(0.028)			
Count in 1 Mile					0.007		
					(0.009)		
Count in 2 Miles						0.002	
						(0.002)	
Count in 3 Miles							0.002
							(0.001)
Observations	4,140	4,140	4,140	4,140	4,140	4,140	4,140
Adjusted R^2	0.412	0.412	0.413	0.412	0.412	0.412	0.412
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 29: Regressions using only horizontal wells with water source interactions for Lycoming County

	Dependent variable:						
	log(Price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.002						
	(0.003)						
Private Water × Dist. to Nearest Well	−0.005*						
	(0.003)						
Activity in 1 Mile		0.233					
		(0.155)					
Private Water × Activity in 1 Mile		−0.321*					
		(0.164)					
Activity in 2 Miles			0.078				
			(0.061)				
Private Water × Activity in 2 Miles			−0.022				
			(0.070)				
Activity in 3 Miles				0.001			
				(0.038)			
Private Water × Activity in 3 Miles				0.053			
				(0.047)			
Count in 1 Mile					0.029		
					(0.020)		
Private Water × Count in 1 Mile					−0.027		
					(0.022)		
Count in 2 Miles						0.004	
						(0.006)	
Private Water × Count in 2 Miles						−0.003	
						(0.006)	
Count in 3 Miles							0.003
							(0.003)
Private Water × Count in 3 Miles							−0.002
							(0.004)
Private Water	0.062*	0.021	0.017	0.009	0.019	0.018	0.018
	(0.034)	(0.023)	(0.023)	(0.024)	(0.023)	(0.023)	(0.023)
Observations	4,140	4,140	4,140	4,140	4,140	4,140	4,140
Adjusted R^2	0.412	0.413	0.412	0.412	0.412	0.412	0.412
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

4.7 Conclusion from this Section

In this section, we present regression results from a variety of different regression models and subsamples for both Bradford and Lycoming Counties. The models are standard log-linear hedonic regressions, and are not without weakness. Nevertheless, it is noteworthy that despite the array of models we consider we do not find any strong patterns of statistical significance pertaining to impacts of shale activity on property values. In some specifications, we do find significant parameters; however, in the context of the wide array of models we consider, these instances of significance seem to be few. It is also noteworthy that these results are vastly different from previous research that has used similar models and found statistical significance.

We summarize these results as follows:

1. We consider three different measures of shale activity – continuous distance, indicator for any activity, and count of wells – in addition to variable distances to shale activity/counts. Despite this range of metrics, we do not find reliable patterns of significance.

2. We do not find any robust patterns of differential effects for properties that rely on private/public water.

3. We do not find that our results are sensitive to inclusion/exclusion of "city" properties (see our initial discussion in this appendix); consideration of all shale activity or just horizontal wells; incidence of well bores vs. well pads.

We offer, as a caveat to these results, the following. Imbens & Rubin (2015) discuss sensitivity of the regression approach to lack of overlap in the covariate distributions across the treated/control groups. To the extent that these types of effects persist in our data, the results in this appendix may be biased to an extent that significance is masked. Yet, in the context of the baseline log-linear model we present here, the finding that shale activity does not impact property values is quite robust, and different from results reported by previous authors.

5 Adding the Shale Boundary to Lycoming County Regressions

5.1 Removing City Properties

In the results appendix, we have shown that many of the urban area properties in Lycoming County are located in a few clustered cities along the Shale boundary. Here, we attempt to ascertain the impact of potential differences between urban/rural properties in our sample.

5.1.1 Differences in Sample Means

We first consider differences in sample means between on/off shale properties. Table 30 considers our full sample for Lycoming County, and tests the null hypothesis of equality of sample means for housing characteristics between on/off-shale properties. It is important to remember that many of these off-shale properties are located in small cities clustered near the shale boundary (on the off-shale side).

From the t-tests, we can see many significant differences between on/off-shale properties. It is possible to control for these differences in hedonic regressions, but the extent of differences between on/off-shale properties provides some indication that there are substantial differences that may be difficult to control for.

Table 30: Test of equality of sample means for full Lycoming County sample

	On Shale	Off Shale	p-value
Age	62.462	68.188	0.000
Stories	1.536	1.515	0.242
Bedrooms	2.993	2.906	0.037
Bathrooms	1.552	1.452	0.000
SQFT	16.787	15.957	0.000
Basement	0.144	0.135	0.490
Garage	0.067	0.073	0.609
Air Cond.	0.255	0.215	0.010
Acre	1.948	1.595	0.232
Private Water	0.307	0.233	0.000
Dist. to Highway	2.704	1.478	0.000
Dist. to Major Road	0.211	0.218	0.530

Next, we conduct the same tests for rural properties on/off-shale. That is, we remove all properties that are located in Duboistown, Hughesville, Jersey Shore, Montgomery, Montoursville, Muncy, South Williamsport, and Williamsport. This restricts our sample to 455 properties, with 410 located above shale and 45 located off-shale. Table 31 shows that there are far fewer statistically significant differences in mean values of these variables for the restricted sample. We find significant differences in the number of stories for each property, with off-shale properties having slightly more stories; and significant differences in distance to nearest highway and major road, with off-shale properties being closer to highways but farther from major roads. Overall, these properties seem much more homogenous in the restricted sample, which makes it more likely that our regression will be able to control for any differences in properties across the shale boundary.

5.1.2 Regressions with the Restricted Rural Sample

We now consider log-linear regressions using only the rural properties, exploring in each case differences across the shale boundary. Results are shown in Table 32. It is clear that, with

Table 31: Test of equality of sample means for rural properties in Lycoming County

	On Shale	Off Shale	p-value
Age	49.517	49.667	0.979
Stories	1.355	1.511	0.043
Bedrooms	2.827	2.822	0.976
Bathrooms	1.521	1.389	0.190
SQFT	16.657	17.974	0.220
Basement	0.090	0.133	0.421
Garage	0.095	0.089	0.913
Air Cond.	0.141	0.133	0.881
Acre	5.964	10.436	0.238
Private Water	0.929	0.933	0.919
Dist. to Highway	5.407	4.568	0.078
Dist. to Major Road	0.313	0.632	0.000

the exception of Models 2 and 4, there is no statistical difference in property values on/off the shale. Further, with the exception of Models 1 and 2, in addition to exploring differences between on/off-shale properties, we also explore the impact of both distance to nearest well and our count of shale wells within 1, 2, and 3 miles. None of these variables show any statistical significance.

A few important notes:

1. In Models 2 and 4, in which we find some significance: variance inflation factors indicate the shale measures are highly collinear, indicating that the statistical significance of the shale indicator in these models is driven by multicollinearity, and not actual significance.

2. The effect of the sample restriction is clear in the lack of significance in many of the standard housing variables.

3. We do not include interactions with the count variables and the shale indicator because there are no properties that we over the shale and within 1, 2, and 3 miles of a well.

Table 32: Regression results for Lycoming County using only rural property sales

	Dependent variable:						
	log(price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Shale Indicator	0.167	0.594*	0.172	0.538*	0.176	0.171	0.170
	(0.129)	(0.336)	(0.131)	(0.303)	(0.130)	(0.130)	(0.130)
Private Water × Shale Indicator		−0.466					
		(0.338)					
Dist. to Nearest Well			0.003	0.046			
			(0.010)	(0.033)			
Dist. to Nearest Well × Shale Indicator				−0.042			
				(0.032)			
Count in 1 Mile					−0.021		
					(0.018)		
Count in 2 Miles						−0.003	
						(0.006)	
Count in 3 Miles							−0.001
							(0.003)
Private Water	0.113	0.531*	0.110	0.110	0.104	0.109	0.111
	(0.103)	(0.320)	(0.104)	(0.104)	(0.104)	(0.104)	(0.104)
Age	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age^2	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Stories	−0.101	−0.100	−0.102	−0.098	−0.103	−0.102	−0.102
	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)	(0.065)
Bedrooms	0.006	0.004	0.005	0.005	0.004	0.005	0.006
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
Bathrooms	0.122**	0.128**	0.123**	0.124**	0.120**	0.121**	0.122**
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
SQFT	0.028***	0.028***	0.028***	0.028***	0.028***	0.028***	0.028***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Basement	0.188**	0.180**	0.188**	0.184**	0.195**	0.189**	0.190**
	(0.088)	(0.088)	(0.088)	(0.088)	(0.088)	(0.088)	(0.088)
Garage	−0.034	−0.028	−0.033	−0.028	−0.035	−0.035	−0.035
	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)
Air Cond.	0.192**	0.185**	0.190**	0.194**	0.188**	0.190**	0.190**
	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)	(0.076)
Acres	0.013***	0.014***	0.013***	0.013***	0.013***	0.013***	0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
$Acres^2$	−0.00005*	−0.0001*	−0.00005*	−0.0001*	−0.00005	−0.00005	−0.00005*
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Dist. to Highway	0.003	0.002	0.003	0.002	0.003	0.002	0.002
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Dist. to Major Road	0.206***	0.200***	0.206***	0.203***	0.221***	0.207***	0.206***
	(0.063)	(0.063)	(0.063)	(0.063)	(0.065)	(0.064)	(0.063)
Constant	10.475***	10.093***	10.446***	10.071***	10.486***	10.487***	10.482***
	(0.237)	(0.365)	(0.253)	(0.377)	(0.237)	(0.239)	(0.238)
Observations	455	455	455	455	455	455	455
Adjusted R^2	0.381	0.383	0.380	0.381	0.382	0.380	0.380
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *p<0.1; **p<0.05; ***p<0.01

5.1.3 Regression Using Only On-Shale Properties

Before exploring further the relationship between the shale boundary, property sales, and shale activity, we first consider regressions using a full sample of observations that are on-shale (that is, we do not restrict to rural observations only). As can be seen in Tables 33 and 34, regardless of whether or not we include water source interactions, there is no statistical significance.

Table 33: Regression results for Lycoming County using only on-shale property sales

	Dependent variable:						
	log(price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.001						
	(0.003)						
Activity in 1 Mile		−0.014					
		(0.053)					
Activity in 2 Miles			0.070**				
			(0.032)				
Activity in 3 Miles				0.038			
				(0.026)			
Count in 1 Mile					−0.002		
					(0.008)		
Count in 2 Miles						0.002	
						(0.002)	
Count in 3 Miles							0.002
							(0.001)
Observations	455	455	455	455	455	455	455
Adjusted R^2	0.381	0.383	0.380	0.381	0.382	0.380	0.380
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 34: Regression results with water source interactions for Lycoming County using only on-shale property sales

	Dependent variable:						
	log(price)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dist. to Nearest Well	0.004						
	(0.004)						
Private Water × Dist. to Nearest Well	−0.006						
	(0.004)						
Activity in 1 Mile		0.221					
		(0.153)					
Private Water × Activity in 1 Mile		−0.264					
		(0.160)					
Activity in 2 Miles			0.091*				
			(0.052)				
Private Water × Activity in 2 Miles			−0.032				
			(0.062)				
Activity in 3 Miles				0.015			
				(0.034)			
Private Water × Activity in 3 Miles				0.046			
				(0.044)			
Count in 1 Mile					0.026		
					(0.020)		
Private Water × Count in 1 Mile					−0.032		
					(0.021)		
Count in 2 Miles						0.007	
						(0.006)	
Private Water × Count in 2 Miles						−0.005	
						(0.007)	
Count in 3 Miles							0.003
							(0.004)
Private Water × Count in 3 Miles							−0.001
							(0.004)
Private Water	0.039	0.005	0.001	−0.011	0.003	0.003	0.001
	(0.036)	(0.026)	(0.027)	(0.027)	(0.026)	(0.026)	(0.026)
Observations	3,192	3,192	3,192	3,192	3,192	3,192	3,192
Adjusted R^2	0.441	0.441	0.441	0.441	0.440	0.440	0.441
Hedonic Controls?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Note:							*p<0.1; **p<0.05; ***p<0.01

5.2 Conclusion from this Section

We have considered additional specifications of our log-linear regression model for Lycoming County by incorporating additional differences based on location on/off-shale. It is clear that, despite these additional sample restrictions, we do not find any statistical significance of shale activity on property values. Hereafter, we turn towards development of matching and differencing strategies for identifying any negative effects of shale activity.

6 Matching in Bradford and Lycoming County

We now turn to treatment effect estimates using matching techniques for both Bradford and Lycoming Counties. For both counties, we consider the following:

1. We estimate the Average Effect of Treatment on the Treated (ATT).
2. We deploy both propensity score matching and multivariate covariate matching techniques.
3. For the multivariate matching models, we report bias adjusted estimates and the corresponding standard errors. For the propensity score matching models, we report the standard estimates with the corrected standard errors. See Abadie & Imbens (2006, 2011, 2012) for details.
4. We define treatment to be a binary indicator for shale activity within 1, 2, and 3 miles of a property.
5. In all cases, we report post-match balancing statistics and describe improvements in balancing pre-/post-match.
6. For all models, we consider one-to-one matching and one-to-four matching. Muehlenbachs et al. (2014) use one-to-four matching; it is not clear from Imbens & Rubin (2015) whether one-to-four matching is generally superior to one-to-one matching, so we report both.

In addition, specifically for Lycoming County, we consider:

1. Inclusion of the indicator for being on the shale.
2. Restricting the control units to be drawn from off-shale properties.

6.1 One-to-One Matching

For our first set of matching estimates, we allow only a single control unit for each treated unit. We deploy both PSM and MM *without* imposing any restrictions on the match. The first table for each county reports the *ATT* estimates – bias adjusted for the MM estimates, and unadjusted with Abadie & Imbens (2012) standard errors for PSM. The following tables report the post-match balancing statistics.

6.1.1 Bradford County

Table 35: ATT estimates for propensity score and multivariate matching models for Bradford County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.1515**		-0.0511		-0.4752**	
	0.0782		0.0956		0.2219	
Bias Adjusted		-0.0733		-0.0087		-0.4092***
		0.0720		0.0825		0.0978

Note: Standard errors reported below each ATT estimate.

Table 35 shows that there is statistical significance using the bias adjusted *ATT* for the PSM model when treatment is defined via 1 or 3 miles, and using MM when treatment is at 3 miles. Both estimates at 3 miles is really large.

Tables 36, 37 and 38 show post-match balancing statistics for the Treatment 1, Treatment 2, and Treatment 3 models, respectively. Starting with Table 36, we can see that both the PSM and MM procedures have balanced the covariates to a great extent when comparing the balancing statistics to Table 2. After matching, the normalized differences and log differences in dispersion is close to zero for nearly all covariates. The propensity score is better balanced in the PSM model than in the MM model, but both models have greatly reduced the imbalance compared to pre-match.

The same general improvements in post-match balance can be observed in Tables 37 and 38, relative to Tables 3 4.

Table 36: Results for post-matching statistics for Bradford County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.571	0.233	0.570	0.233	0.001	0.001	0.070	0.046
Age	66.247	48.066	65.177	46.704	0.023	0.029	0.054	0.064
Stories	1.417	0.451	1.421	0.454	-0.009	-0.008	0.503	0.501
Bedrooms	2.847	1.215	2.896	1.365	-0.038	-0.117	0.071	0.115
Bathrooms	1.438	0.765	1.467	0.820	-0.037	-0.069	0.107	0.124
SQFT	15.404	7.254	15.618	8.667	-0.027	-0.178	0.071	0.144
Acres	10.413	39.985	9.413	28.278	0.029	0.346	0.042	0.059
Warm Air	0.426	0.495	0.388	0.487	0.078	0.015	0.574	0.612
Private Water	0.772	0.420	0.783	0.413	-0.026	0.017	0.228	0.217
Highway	6.218	5.664	5.755	6.469	0.076	-0.133	0.027	0.106
Major Road	0.279	0.522	0.303	0.588	-0.042	-0.119	0.045	0.076
Sayre	0.015	0.121	0.017	0.131	-0.019	-0.074	1.000	1.000
Towanda	0.187	0.390	0.166	0.372	0.054	0.046	0.813	0.834
Multivariate Matching								
Propensity Score	0.571	0.233	0.565	0.236	0.025	-0.011	0.031	0.066
Age	66.247	48.076	68.445	45.478	-0.047	0.056	0.056	0.050
Stories	1.417	0.451	1.433	0.455	-0.037	-0.008	0.503	0.488
Bedrooms	2.847	1.215	2.859	1.083	-0.011	0.115	0.085	0.082
Bathrooms	1.438	0.765	1.412	0.677	0.035	0.122	0.128	0.086
SQFT	15.404	7.256	15.090	6.688	0.045	0.081	0.082	0.092
Acres	10.413	39.993	7.487	26.287	0.086	0.420	0.061	0.047
Warm Air	0.426	0.495	0.421	0.494	0.010	0.002	0.574	0.579
Private Water	0.772	0.420	0.773	0.419	-0.003	0.002	0.228	0.227
Highway	6.218	5.665	5.809	6.066	0.070	-0.068	0.036	0.081
Major Road	0.279	0.522	0.210	0.457	0.142	0.134	0.061	0.045
Sayre	0.015	0.121	0.014	0.116	0.010	0.043	1.000	1.000
Towanda	0.187	0.390	0.184	0.388	0.006	0.005	0.813	0.816

Note: Treatment is defined as shale activity within 1 mile.

Table 37: Results for post-matching statistics for Bradford County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.766	0.238	0.766	0.238	0.002	0.001	0.085	0.025
Age	73.439	48.207	83.010	57.419	-0.181	-0.175	0.034	0.125
Stories	1.485	0.465	1.480	0.451	0.010	0.031	0.444	0.426
Bedrooms	2.973	1.288	2.905	1.179	0.055	0.088	0.082	0.074
Bathrooms	1.468	0.801	1.421	0.736	0.061	0.085	0.113	0.101
SQFT	16.050	7.751	15.401	7.244	0.086	0.068	0.094	0.083
Acres	8.567	33.148	9.630	35.693	-0.031	-0.074	0.064	0.046
Warm Air	0.463	0.499	0.442	0.497	0.043	0.004	0.537	0.558
Private Water	0.633	0.482	0.631	0.483	0.005	-0.001	0.367	0.369
Highway	6.102	5.884	6.780	7.253	-0.103	-0.209	0.082	0.110
Major Road	0.234	0.461	0.316	0.729	-0.135	-0.458	0.088	0.077
Sayre	0.064	0.244	0.068	0.252	-0.016	-0.029	0.936	0.932
Towanda	0.195	0.396	0.105	0.307	0.252	0.254	0.805	0.895
Multivariate Matching								
Propensity Score	0.766	0.238	0.683	0.287	0.315	-0.187	0.069	0.073
Age	73.439	48.211	72.506	45.705	0.020	0.053	0.062	0.033
Stories	1.485	0.465	1.520	0.456	-0.077	0.020	0.444	0.396
Bedrooms	2.973	1.288	2.942	1.122	0.026	0.138	0.082	0.070
Bathrooms	1.468	0.802	1.457	0.664	0.015	0.188	0.113	0.076
SQFT	16.050	7.752	15.458	6.652	0.082	0.153	0.090	0.084
Acres	8.567	33.151	5.916	22.491	0.094	0.388	0.116	0.027
Warm Air	0.463	0.499	0.465	0.499	-0.004	-0.000	0.537	0.535
Private Water	0.633	0.482	0.647	0.478	-0.028	0.008	0.367	0.353
Highway	6.102	5.884	5.856	6.345	0.040	-0.075	0.099	0.036
Major Road	0.234	0.461	0.209	0.418	0.057	0.098	0.087	0.038
Sayre	0.064	0.245	0.071	0.256	-0.027	-0.047	0.936	0.929
Towanda	0.195	0.396	0.146	0.353	0.130	0.115	0.805	0.854

Note: Treatment is defined as shale activity within 2 miles.

Table 38: Results for post-matching statistics for Bradford County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.862	0.205	0.862	0.206	-0.001	-0.001	0.115	0.025
Age	74.494	47.676	81.772	41.023	-0.164	0.150	0.076	0.034
Stories	1.510	0.466	1.603	0.396	-0.217	0.162	0.421	0.232
Bedrooms	2.998	1.268	2.929	0.889	0.064	0.356	0.079	0.042
Bathrooms	1.471	0.777	1.626	0.656	-0.215	0.170	0.104	0.066
SQFT	16.133	7.547	16.233	6.888	-0.014	0.091	0.074	0.065
Acres	7.922	31.384	35.492	88.183	-0.417	-1.033	0.078	0.124
Warm Air	0.476	0.500	0.518	0.500	-0.083	-0.001	0.524	0.482
Private Water	0.580	0.494	0.682	0.466	-0.213	0.058	0.420	0.318
Highway	5.802	5.910	6.871	5.951	-0.180	-0.007	0.157	0.066
Major Road	0.248	0.549	0.195	0.450	0.105	0.198	0.056	0.039
Sayre	0.125	0.330	0.118	0.323	0.020	0.024	0.875	0.882
Towanda	0.171	0.377	0.018	0.134	0.541	1.033	1.000	0.982
Multivariate Matching								
Propensity Score	0.862	0.205	0.650	0.304	0.815	-0.390	0.096	0.144
Age	74.494	47.678	71.054	45.345	0.074	0.050	0.062	0.057
Stories	1.510	0.466	1.537	0.453	-0.059	0.029	0.421	0.376
Bedrooms	2.998	1.269	2.994	1.090	0.004	0.152	0.079	0.059
Bathrooms	1.471	0.777	1.475	0.666	-0.005	0.153	0.104	0.070
SQFT	16.133	7.548	15.368	6.459	0.109	0.156	0.087	0.069
Acres	7.922	31.386	6.498	22.255	0.052	0.344	0.098	0.029
Warm Air	0.476	0.500	0.477	0.500	-0.001	-0.000	0.524	0.523
Private Water	0.580	0.494	0.593	0.491	-0.027	0.005	0.420	0.407
Highway	5.802	5.910	5.178	5.834	0.106	0.013	0.070	0.051
Major Road	0.248	0.549	0.192	0.440	0.112	0.221	0.067	0.042
Sayre	0.125	0.330	0.240	0.427	-0.303	-0.258	0.875	0.760
Towanda	0.171	0.377	0.119	0.324	0.149	0.152	0.829	0.881

Note: Treatment is defined as shale activity within 3 miles.

6.1.2 Lycoming County

Table 39: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.0693		0.0221		0.0028	
	0.0842		0.0520		0.0491	
Bias Adjusted		-0.1491*		0.0191		-0.0242
		0.0894		0.0442		0.0413

Note: Standard errors reported below each ATT estimate.

Table 39 reports the one-to-one matching ATT estimates for Lycoming County. We find a significantly negative effect of shale activity within 1 mile of the property using the MM estimator. Otherwise, we do not find any statistical significance of the ATT using either type of matching.

Post-match balancing metrics are reported in Tables 40, 41, and 42. The relevant pre-match statistics are reported in Tables 5, 6, and 7. As was the case in Bradford County with one-to-one matching, both the PSM and MM methods substantially improve balance in the sample. For instance, for all covariates, the normalized differences and log differences in dispersion measurements substantially decrease. It is worth noting that while the MM balance greatly improves post-matching, several covariates (age and highway) are still relatively different in normalized mean, and distance to nearest road has a relatively large dispersion. While we find statistical significance of ATT from this model, some covariates remain slightly out of balance.

Table 40: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.218	0.206	0.217	0.203	0.006	0.016	0.053	0.026
Age	49.342	40.047	45.825	35.893	0.092	0.110	0.132	0.014
Stories	1.421	0.489	1.378	0.493	0.088	-0.007	0.500	0.543
Bedrooms	2.829	0.942	2.914	0.848	-0.095	0.105	0.066	0.046
Bathrooms	1.533	0.762	1.515	0.673	0.024	0.124	0.079	0.049
SQFT	17.637	6.970	17.186	6.904	0.065	0.010	0.066	0.037
Acres	5.897	15.432	5.377	15.460	0.034	-0.002	0.013	0.094
Basement	0.118	0.325	0.072	0.260	0.156	0.221	0.882	0.928
Garage	0.053	0.224	0.035	0.220	0.079	0.022	0.947	0.978
Air	0.171	0.378	0.125	0.332	0.131	0.131	0.829	0.875
Private Water	0.895	0.308	0.926	0.263	-0.110	0.161	0.105	0.074
Highway	8.601	5.666	8.632	6.201	-0.005	-0.090	0.039	0.121
Major Road	0.420	0.522	0.468	0.853	-0.068	-0.490	0.026	0.089
Hughesville	0.197	0.400	0.277	0.450	-0.187	-0.117	0.803	0.723
Jersey Shore	0.118	0.325	0.053	0.225	0.234	0.366	0.882	0.947
Montoursville	0.237	0.427	0.224	0.419	0.031	0.020	0.763	0.776
Muncy	0.066	0.249	0.047	0.213	0.081	0.158	0.934	0.953
South Williamsport	0.000	0.000	0.012	0.109	-0.155	-Inf	1.000	1.000
Williamsport	0.000	0.000	0.084	0.279	-0.426	-Inf	1.000	1.000
Multivariate Matching								
Propensity Score	0.218	0.207	0.128	0.139	0.509	0.395	0.092	0.118
Age	49.342	40.121	40.974	32.870	0.228	0.199	0.079	0.026
Stories	1.421	0.490	1.388	0.459	0.069	0.066	0.500	0.539
Bedrooms	2.829	0.944	2.921	0.669	-0.113	0.345	0.066	0.013
Bathrooms	1.533	0.763	1.645	0.642	-0.159	0.173	0.513	0.026
SQFT	17.637	6.983	17.239	4.600	0.067	0.417	0.158	0.000
Acres	5.897	15.461	5.137	14.971	0.050	0.032	0.013	0.118
Basement	0.118	0.325	0.105	0.309	0.041	0.051	0.882	0.895
Garage	0.053	0.225	0.053	0.278	0.000	-0.212	0.947	0.974
Air	0.171	0.379	0.171	0.379	0.000	0.000	0.829	0.829
Private Water	0.895	0.309	0.842	0.367	0.155	-0.172	0.105	0.158
Highway	8.601	5.677	6.732	5.236	0.342	0.081	0.079	0.132
Major Road	0.420	0.523	0.359	0.382	0.135	0.314	0.145	0.013
Hughesville	0.197	0.401	0.197	0.401	0.000	0.000	0.803	0.803
Jersey Shore	0.118	0.325	0.118	0.325	0.000	0.000	0.882	0.882
Montoursville	0.237	0.428	0.224	0.419	0.031	0.020	0.763	0.776
Muncy	0.066	0.250	0.066	0.250	0.000	0.000	0.934	0.934
South Williamsport	0.000	0.000	0.013	0.115	-0.162	-Inf	1.000	1.000
Williamsport	0.000	0.000	0.092	0.291	-0.447	-Inf	1.000	1.000

Note: Treatment is defined as shale activity within 1 mile.

Table 41: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.373	0.272	0.373	0.272	-0.001	-0.002	0.053	0.077
Age	47.064	33.391	46.316	34.591	0.022	-0.035	0.039	0.024
Stories	1.391	0.470	1.423	0.493	-0.066	-0.048	0.512	0.568
Bedrooms	2.957	0.881	3.090	0.887	-0.150	-0.007	0.060	0.050
Bathrooms	1.621	0.740	1.695	0.776	-0.098	-0.048	0.053	0.068
SQFT	17.484	6.756	18.143	6.875	-0.097	-0.017	0.075	0.050
Acres	4.845	14.818	4.784	15.653	0.004	-0.055	0.043	0.068
Basement	0.164	0.370	0.217	0.413	-0.137	-0.109	0.836	0.783
Garage	0.071	0.296	0.065	0.321	0.020	-0.082	0.950	0.970
Air	0.206	0.405	0.212	0.409	-0.014	-0.010	0.794	0.788
Private Water	0.712	0.454	0.701	0.458	0.023	-0.010	0.288	0.299
Highway	6.537	5.393	6.170	5.041	0.070	0.067	0.053	0.051
Major Road	0.290	0.384	0.316	0.332	-0.075	0.147	0.093	0.010
Hughesville	0.157	0.364	0.145	0.353	0.031	0.031	0.843	0.855
Jersey Shore	0.125	0.331	0.157	0.364	-0.093	-0.096	0.875	0.843
Montoursville	0.345	0.476	0.371	0.484	-0.054	-0.016	0.655	0.629
Muncy	0.057	0.232	0.053	0.224	0.019	0.037	0.943	0.947
South Williamsport	0.000	0.000	0.016	0.126	-0.181	-Inf	1.000	1.000
Williamsport	0.032	0.176	0.076	0.266	-0.196	-0.411	0.968	0.924
Multivariate Matching								
Propensity Score	0.373	0.272	0.283	0.251	0.345	0.079	0.068	0.121
Age	47.064	33.409	46.317	31.798	0.023	0.049	0.032	0.028
Stories	1.391	0.470	1.397	0.467	-0.011	0.008	0.537	0.559
Bedrooms	2.957	0.881	2.940	0.697	0.022	0.235	0.060	0.025
Bathrooms	1.621	0.740	1.591	0.656	0.043	0.121	0.406	0.036
SQFT	17.484	6.760	16.739	5.551	0.120	0.197	0.082	0.028
Acres	4.845	14.826	3.752	13.092	0.078	0.124	0.064	0.057
Basement	0.164	0.371	0.164	0.371	0.000	0.000	0.836	0.836
Garage	0.071	0.296	0.057	0.274	0.050	0.077	0.950	0.964
Air	0.206	0.405	0.181	0.386	0.063	0.049	0.794	0.819
Private Water	0.712	0.454	0.630	0.484	0.175	-0.064	0.288	0.370
Highway	6.537	5.395	5.266	4.884	0.247	0.100	0.064	0.060
Major Road	0.290	0.384	0.290	0.328	-0.000	0.158	0.093	0.021
Hughesville	0.157	0.364	0.149	0.357	0.020	0.019	0.843	0.851
Jersey Shore	0.125	0.331	0.128	0.335	-0.011	-0.012	0.875	0.872
Montoursville	0.345	0.476	0.331	0.471	0.030	0.010	0.655	0.669
Muncy	0.057	0.232	0.057	0.232	0.000	0.000	0.943	0.943
South Williamsport	0.000	0.000	0.025	0.156	-0.226	-Inf	1.000	1.000
Williamsport	0.032	0.176	0.085	0.280	-0.228	-0.462	0.968	0.915

Note: Treatment is defined as shale activity within 2 miles.

Table 42: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.588	0.289	0.588	0.289	0.000	0.000	0.052	0.055
Age	54.051	34.791	43.353	33.404	0.314	0.041	0.027	0.069
Stories	1.415	0.472	1.395	0.488	0.042	-0.035	0.505	0.601
Bedrooms	2.970	0.893	3.076	1.223	-0.099	-0.314	0.057	0.049
Bathrooms	1.592	0.709	1.701	0.706	-0.154	0.004	0.052	0.051
SQFT	16.988	6.304	17.083	6.617	-0.015	-0.048	0.072	0.051
Acres	3.713	12.760	3.749	13.869	-0.003	-0.083	0.021	0.106
Basement	0.160	0.367	0.124	0.330	0.103	0.106	0.840	0.876
Garage	0.069	0.326	0.046	0.228	0.081	0.354	0.964	0.962
Air	0.239	0.427	0.202	0.401	0.091	0.062	0.761	0.798
Private Water	0.483	0.500	0.587	0.493	-0.210	0.015	0.517	0.413
Highway	4.717	4.942	5.401	5.978	-0.125	-0.190	0.012	0.103
Major Road	0.261	0.330	0.340	0.459	-0.199	-0.328	0.061	0.036
Hughesville	0.178	0.383	0.129	0.335	0.137	0.133	0.822	0.871
Jersey Shore	0.081	0.273	0.111	0.314	-0.102	-0.141	0.919	0.889
Montoursville	0.444	0.497	0.487	0.500	-0.087	-0.006	0.556	0.513
Muncy	0.045	0.207	0.026	0.160	0.100	0.256	0.955	0.974
South Williamsport	0.000	0.000	0.022	0.148	-0.214	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.067	0.251	-0.070	-0.132	0.949	0.933
Multivariate Matching								
Propensity Score	0.588	0.289	0.427	0.299	0.547	-0.033	0.075	0.081
Age	54.051	34.797	48.172	33.623	0.172	0.034	0.027	0.076
Stories	1.415	0.472	1.349	0.461	0.141	0.024	0.529	0.620
Bedrooms	2.970	0.894	2.991	0.722	-0.026	0.214	0.057	0.037
Bathrooms	1.592	0.709	1.626	0.649	-0.050	0.089	0.052	0.042
SQFT	16.988	6.305	16.458	5.605	0.089	0.118	0.072	0.061
Acres	3.713	12.762	2.672	11.453	0.086	0.108	0.049	0.082
Basement	0.160	0.367	0.161	0.368	-0.004	-0.004	0.840	0.839
Garage	0.069	0.326	0.060	0.313	0.028	0.038	0.964	0.973
Air	0.239	0.427	0.214	0.410	0.061	0.040	0.761	0.786
Private Water	0.483	0.500	0.416	0.493	0.135	0.014	0.517	0.584
Highway	4.717	4.943	3.556	3.902	0.261	0.236	0.069	0.073
Major Road	0.261	0.330	0.257	0.291	0.011	0.129	0.060	0.039
Hughesville	0.178	0.383	0.173	0.379	0.012	0.010	0.822	0.827
Jersey Shore	0.081	0.273	0.076	0.266	0.017	0.026	0.919	0.924
Montoursville	0.444	0.497	0.345	0.476	0.203	0.044	0.556	0.655
Muncy	0.045	0.207	0.043	0.204	0.007	0.016	0.955	0.957
South Williamsport	0.000	0.000	0.052	0.223	-0.332	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.149	0.357	-0.333	-0.485	0.949	0.851

Note: Treatment is defined as shale activity within 3 miles.

6.2 One-to-Four Matching

For our second set of matching estimates, we allow for four control units for each treated unit. Otherwise, these results are the same as those just reported.

6.2.1 Bradford County

Table 43: ATT estimates for propensity score and multivariate matching models for Bradford County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.1618**		0.0829		-0.4237**	
	0.0627		0.0916		0.1846	
Bias Adjusted		-0.0693		-0.0823		-0.3267***
		0.0583		0.0530		0.0569

Note: Standard errors reported below each ATT estimate.

Table 43 indicates that the *ATT* is significant for the 1 and 3 mile models when using PSM, and at 3 miles when using MM.

Post-matching results are reported in Tables 44, 45, and 46. The relevant pre-match tables are Tables 2, 3, and 4. To avoid a lengthy discussion, we summarize these results by noting that, as in the one-to-one matching models, both the PSM and MM procedures improve covariate balance to a substantial degree.

Table 44: Results for post-matching statistics for Bradford County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.571	0.233	0.570	0.233	0.001	0.001	0.070	0.049
Age	66.247	48.052	68.608	46.585	-0.050	0.031	0.055	0.056
Stories	1.417	0.450	1.431	0.465	-0.032	-0.031	0.503	0.507
Bedrooms	2.847	1.215	2.930	1.292	-0.066	-0.062	0.085	0.090
Bathrooms	1.438	0.765	1.462	0.798	-0.031	-0.042	0.107	0.111
SQFT	15.404	7.252	16.042	8.473	-0.081	-0.156	0.071	0.125
Acres	10.413	39.974	12.615	35.393	-0.058	0.122	0.037	0.067
Warm Air	0.426	0.495	0.380	0.485	0.094	0.019	0.574	0.620
Private Water	0.772	0.420	0.781	0.413	-0.022	0.015	0.228	0.219
Highway	6.218	5.662	5.839	6.397	0.063	-0.122	0.026	0.105
Major Road	0.279	0.522	0.321	0.699	-0.067	-0.293	0.041	0.084
Sayre	0.015	0.121	0.015	0.123	-0.003	-0.013	1.000	1.000
Towanda	0.187	0.390	0.183	0.387	0.009	0.007	0.813	0.817
Multivariate Matching								
Propensity Score	0.571	0.233	0.534	0.244	0.153	-0.046	0.016	0.087
Age	66.247	48.053	67.014	45.052	-0.016	0.064	0.056	0.050
Stories	1.417	0.450	1.435	0.458	-0.040	-0.017	0.503	0.494
Bedrooms	2.847	1.215	2.866	1.061	-0.016	0.135	0.085	0.073
Bathrooms	1.438	0.765	1.402	0.649	0.050	0.165	0.128	0.081
SQFT	15.404	7.252	14.845	6.276	0.082	0.145	0.103	0.073
Acres	10.413	39.974	6.616	23.015	0.116	0.552	0.068	0.052
Warm Air	0.426	0.495	0.419	0.493	0.014	0.002	0.574	0.581
Private Water	0.772	0.420	0.743	0.437	0.068	-0.041	0.228	0.257
Highway	6.218	5.662	5.981	6.060	0.040	-0.068	0.039	0.069
Major Road	0.279	0.522	0.226	0.466	0.108	0.114	0.070	0.037
Sayre	0.015	0.121	0.017	0.130	-0.017	-0.067	1.000	1.000
Towanda	0.187	0.390	0.181	0.385	0.014	0.012	0.813	0.819

Note: Treatment is defined as shale activity within 1 mile.

Table 45: Results for post-matching statistics for Bradford County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.766	0.238	0.766	0.238	0.002	0.001	0.086	0.025
Age	73.439	48.199	78.293	56.139	-0.093	-0.153	0.024	0.126
Stories	1.485	0.465	1.485	0.463	-0.000	0.004	0.444	0.444
Bedrooms	2.973	1.288	2.895	1.265	0.061	0.018	0.082	0.097
Bathrooms	1.468	0.801	1.421	0.753	0.060	0.062	0.113	0.114
SQFT	16.050	7.750	15.468	7.553	0.076	0.026	0.092	0.110
Acres	8.567	33.142	11.896	41.323	-0.089	-0.221	0.058	0.058
Warm Air	0.463	0.499	0.430	0.495	0.066	0.007	0.537	0.570
Private Water	0.633	0.482	0.631	0.483	0.006	-0.002	0.367	0.369
Highway	6.102	5.883	6.994	7.361	-0.134	-0.224	0.081	0.109
Major Road	0.234	0.461	0.318	0.740	-0.135	-0.473	0.081	0.073
Sayre	0.064	0.244	0.063	0.243	0.003	0.005	0.936	0.937
Towanda	0.195	0.396	0.116	0.320	0.218	0.212	0.805	0.884
Multivariate Matching								
Propensity Score	0.766	0.238	0.605	0.303	0.592	-0.240	0.082	0.127
Age	73.439	48.199	71.699	45.024	0.037	0.068	0.063	0.041
Stories	1.485	0.465	1.512	0.467	-0.059	-0.004	0.444	0.423
Bedrooms	2.973	1.288	2.945	1.081	0.024	0.176	0.082	0.061
Bathrooms	1.468	0.801	1.429	0.644	0.053	0.219	0.113	0.068
SQFT	16.050	7.750	15.214	6.409	0.117	0.190	0.096	0.072
Acres	8.567	33.142	5.231	20.169	0.122	0.497	0.109	0.026
Warm Air	0.463	0.499	0.492	0.500	-0.058	-0.003	0.537	0.508
Private Water	0.633	0.482	0.588	0.492	0.092	-0.021	0.367	0.412
Highway	6.102	5.883	5.502	6.203	0.099	-0.053	0.082	0.037
Major Road	0.234	0.461	0.205	0.424	0.065	0.083	0.073	0.039
Sayre	0.064	0.244	0.082	0.274	-0.070	-0.115	0.936	0.918
Towanda	0.195	0.396	0.121	0.326	0.203	0.194	0.805	0.879

Note: Treatment is defined as shale activity within 2 miles.

Table 46: Results for post-matching statistics for Bradford County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.862	0.205	0.861	0.205	0.001	0.001	0.115	0.025
Age	74.494	47.669	78.921	41.676	-0.099	0.134	0.075	0.036
Stories	1.510	0.466	1.656	0.398	-0.337	0.157	0.421	0.210
Bedrooms	2.998	1.268	2.984	0.876	0.013	0.369	0.079	0.037
Bathrooms	1.471	0.777	1.539	0.651	-0.094	0.177	0.104	0.063
SQFT	16.133	7.546	15.928	6.479	0.029	0.153	0.080	0.059
Acres	7.922	31.380	20.301	61.956	-0.252	-0.680	0.078	0.076
Warm Air	0.476	0.499	0.444	0.497	0.065	0.005	0.524	0.556
Private Water	0.580	0.494	0.563	0.496	0.034	-0.005	0.420	0.437
Highway	5.802	5.909	5.416	6.141	0.064	-0.039	0.140	0.068
Major Road	0.248	0.549	0.221	0.411	0.056	0.290	0.072	0.037
Sayre	0.125	0.330	0.104	0.305	0.066	0.080	0.875	0.896
Towanda	0.171	0.377	0.027	0.163	0.496	0.836	0.829	0.973
Multivariate Matching								
Propensity Score	0.862	0.205	0.580	0.313	1.064	-0.420	0.291	0.203
Age	74.494	47.669	69.486	45.221	0.108	0.053	0.060	0.055
Stories	1.510	0.466	1.518	0.457	-0.019	0.020	0.421	0.400
Bedrooms	2.998	1.268	2.966	1.033	0.028	0.205	0.079	0.054
Bathrooms	1.471	0.777	1.422	0.646	0.069	0.185	0.104	0.068
SQFT	16.133	7.546	15.190	6.336	0.135	0.175	0.091	0.061
Acres	7.922	31.380	5.632	19.266	0.088	0.488	0.107	0.033
Warm Air	0.476	0.499	0.484	0.500	-0.016	-0.001	0.524	0.516
Private Water	0.580	0.494	0.577	0.494	0.005	-0.001	0.420	0.423
Highway	5.802	5.909	5.106	5.790	0.119	0.020	0.070	0.048
Major Road	0.248	0.549	0.189	0.414	0.122	0.281	0.068	0.040
Sayre	0.125	0.330	0.249	0.433	-0.324	-0.270	0.875	0.751
Towanda	0.171	0.377	0.109	0.312	0.179	0.188	0.829	0.891

Note: Treatment is defined as shale activity within 3 miles.

6.2.2 Lycoming County

Table 47: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.0946		0.0355		-0.0386	
	0.0705		0.0393		0.0391	
Bias Adjusted		-0.0843		0.0450		-0.0650**
		0.0724		0.0342		0.0287

Note: Standard errors reported below each ATT estimate.

Table 47 shows that the *ATT* is insignificant using both PSM and MM, except for 3 mile treatment with MM. Tables 48, 49, and 50 report post-match statistics for the covariates in the sample; the relevant pre-match balancing statistics are in Tables 5, 6, and 7. In general, the post-matched sample is well-balanced; the post-match balance is substantially better than the pre-match balance. However, Table 54 shows that several covariates remain slightly out of balance, post-match.

Table 48: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.218	0.206	0.210	0.188	0.039	0.092	0.092	0.026
Age	49.342	39.914	48.100	36.226	0.033	0.097	0.132	0.012
Stories	1.421	0.488	1.416	0.467	0.011	0.043	0.500	0.485
Bedrooms	2.829	0.939	2.852	0.788	-0.026	0.175	0.066	0.037
Bathrooms	1.533	0.759	1.545	0.681	-0.017	0.109	0.079	0.049
SQFT	17.637	6.947	17.385	7.414	0.035	-0.065	0.066	0.051
Acres	5.897	15.381	4.926	12.772	0.069	0.186	0.053	0.082
Basement	0.118	0.324	0.122	0.327	-0.010	-0.012	0.882	0.878
Garage	0.053	0.224	0.045	0.230	0.032	-0.029	0.947	0.963
Air	0.171	0.377	0.148	0.356	0.062	0.058	0.829	0.852
Private Water	0.895	0.307	0.919	0.273	-0.085	0.120	0.105	0.081
Highway	8.601	5.647	8.663	6.470	-0.010	-0.136	0.026	0.147
Major Road	0.420	0.521	0.390	0.542	0.058	-0.040	0.092	0.032
Hughesville	0.197	0.399	0.174	0.380	0.060	0.049	0.803	0.826
Jersey Shore	0.118	0.324	0.085	0.280	0.110	0.146	0.882	0.915
Montoursville	0.237	0.426	0.257	0.438	-0.048	-0.028	0.763	0.743
Muncy	0.066	0.248	0.048	0.215	0.075	0.144	0.934	0.952
South Williamsport	0.000	0.000	0.015	0.123	-0.177	-Inf	1.000	1.000
Williamsport	0.000	0.000	0.104	0.306	-0.481	-Inf	1.000	1.000
Multivariate Matching								
Propensity Score	0.218	0.206	0.122	0.137	0.548	0.405	0.079	0.148
Age	49.342	39.922	46.046	34.044	0.089	0.159	0.092	0.016
Stories	1.421	0.488	1.400	0.462	0.045	0.054	0.500	0.533
Bedrooms	2.829	0.939	2.944	0.713	-0.138	0.275	0.066	0.023
Bathrooms	1.533	0.759	1.581	0.625	-0.069	0.195	0.513	0.026
SQFT	17.637	6.949	16.834	5.300	0.130	0.271	0.132	0.013
Acres	5.897	15.384	4.615	14.797	0.085	0.039	0.053	0.148
Basement	0.118	0.324	0.102	0.303	0.052	0.066	0.882	0.898
Garage	0.053	0.224	0.036	0.204	0.077	0.092	0.947	0.970
Air	0.171	0.377	0.151	0.359	0.054	0.050	0.829	0.849
Private Water	0.895	0.307	0.793	0.406	0.283	-0.278	0.105	0.207
Highway	8.601	5.648	6.382	5.001	0.416	0.122	0.066	0.138
Major Road	0.420	0.521	0.339	0.382	0.178	0.311	0.145	0.007
Hughesville	0.197	0.399	0.201	0.401	-0.008	-0.006	0.803	0.799
Jersey Shore	0.118	0.324	0.118	0.324	0.000	0.000	0.882	0.882
Montoursville	0.237	0.426	0.220	0.415	0.039	0.025	0.763	0.780
Muncy	0.066	0.248	0.069	0.254	-0.013	-0.023	0.934	0.931
South Williamsport	0.000	0.000	0.023	0.150	-0.217	-Inf	1.000	1.000
Williamsport	0.000	0.000	0.105	0.307	-0.484	-Inf	1.000	1.000

Note: Treatment is defined as shale activity within 1 mile.

Table 49: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.373	0.271	0.372	0.270	0.003	0.005	0.053	0.057
Age	47.064	33.362	45.306	33.461	0.053	-0.003	0.032	0.039
Stories	1.391	0.470	1.416	0.482	-0.052	-0.026	0.512	0.553
Bedrooms	2.957	0.880	3.022	0.892	-0.073	-0.014	0.060	0.052
Bathrooms	1.621	0.739	1.666	0.745	-0.060	-0.009	0.053	0.063
SQFT	17.484	6.750	17.929	7.206	-0.064	-0.065	0.068	0.048
Acres	4.845	14.805	4.915	15.425	-0.005	-0.041	0.050	0.067
Basement	0.164	0.370	0.192	0.394	-0.075	-0.063	0.836	0.808
Garage	0.071	0.296	0.086	0.380	-0.045	-0.250	0.950	0.961
Air	0.206	0.405	0.191	0.393	0.040	0.030	0.794	0.809
Private Water	0.712	0.453	0.726	0.446	-0.031	0.015	0.288	0.274
Highway	6.537	5.388	6.328	5.418	0.039	-0.006	0.036	0.064
Major Road	0.290	0.384	0.300	0.365	-0.027	0.049	0.085	0.017
Hughesville	0.157	0.364	0.128	0.334	0.081	0.083	0.843	0.872
Jersey Shore	0.125	0.330	0.140	0.347	-0.044	-0.048	0.875	0.860
Montoursville	0.345	0.476	0.375	0.484	-0.062	-0.018	0.655	0.625
Muncy	0.057	0.232	0.048	0.213	0.042	0.084	0.943	0.952
South Williamsport	0.000	0.000	0.013	0.112	-0.161	-Inf	1.000	1.000
Williamsport	0.032	0.176	0.084	0.278	-0.225	-0.457	0.968	0.916
Multivariate Matching								
Propensity Score	0.373	0.271	0.224	0.220	0.601	0.208	0.121	0.130
Age	47.064	33.364	46.822	31.887	0.007	0.045	0.032	0.034
Stories	1.391	0.470	1.395	0.458	-0.008	0.026	0.537	0.545
Bedrooms	2.957	0.880	2.975	0.714	-0.022	0.209	0.214	0.024
Bathrooms	1.621	0.739	1.598	0.650	0.033	0.128	0.406	0.028
SQFT	17.484	6.751	16.691	5.585	0.128	0.190	0.078	0.027
Acres	4.845	14.806	3.302	12.498	0.113	0.169	0.050	0.090
Basement	0.164	0.370	0.147	0.354	0.047	0.044	0.836	0.853
Garage	0.071	0.296	0.052	0.272	0.069	0.085	0.950	0.973
Air	0.206	0.405	0.190	0.393	0.040	0.030	0.794	0.810
Private Water	0.712	0.453	0.545	0.498	0.349	-0.095	0.288	0.455
Highway	6.537	5.388	4.622	4.528	0.385	0.174	0.071	0.048
Major Road	0.290	0.384	0.271	0.302	0.054	0.240	0.093	0.022
Hughesville	0.157	0.364	0.146	0.353	0.030	0.029	0.843	0.854
Jersey Shore	0.125	0.330	0.116	0.320	0.027	0.032	0.875	0.884
Montoursville	0.345	0.476	0.321	0.467	0.051	0.018	0.655	0.679
Muncy	0.057	0.232	0.056	0.230	0.004	0.007	0.943	0.944
South Williamsport	0.000	0.000	0.025	0.156	-0.226	-Inf	1.000	1.000
Williamsport	0.032	0.176	0.110	0.313	-0.308	-0.576	0.968	0.890

Note: Treatment is defined as shale activity within 2 miles.

Table 50: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.588	0.289	0.588	0.289	-0.000	-0.000	0.060	0.043
Age	54.051	34.777	44.405	33.658	0.282	0.033	0.027	0.065
Stories	1.415	0.471	1.382	0.490	0.067	-0.039	0.505	0.620
Bedrooms	2.970	0.893	3.052	1.190	-0.078	-0.287	0.057	0.050
Bathrooms	1.592	0.708	1.689	0.709	-0.137	-0.001	0.052	0.054
SQFT	16.988	6.301	17.699	6.703	-0.109	-0.062	0.060	0.050
Acres	3.713	12.755	3.194	11.198	0.043	0.130	0.036	0.088
Basement	0.160	0.367	0.145	0.353	0.040	0.039	0.840	0.855
Garage	0.069	0.325	0.055	0.303	0.043	0.071	0.964	0.971
Air	0.239	0.427	0.236	0.425	0.007	0.004	0.761	0.764
Private Water	0.483	0.500	0.571	0.495	-0.177	0.009	0.517	0.429
Highway	4.717	4.940	5.008	5.183	-0.057	-0.048	0.025	0.073
Major Road	0.261	0.330	0.299	0.377	-0.107	-0.131	0.058	0.041
Hughesville	0.178	0.382	0.162	0.369	0.042	0.037	0.822	0.838
Jersey Shore	0.081	0.272	0.099	0.299	-0.066	-0.094	0.919	0.901
Montoursville	0.444	0.497	0.485	0.500	-0.083	-0.006	0.556	0.515
Muncy	0.045	0.207	0.031	0.172	0.074	0.182	0.955	0.969
South Williamsport	0.000	0.000	0.019	0.136	-0.196	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.077	0.266	-0.106	-0.192	0.949	0.923
Multivariate Matching								
Propensity Score	0.588	0.289	0.351	0.287	0.822	0.006	0.079	0.098
Age	54.051	34.777	47.171	33.441	0.202	0.039	0.027	0.068
Stories	1.415	0.471	1.359	0.462	0.120	0.020	0.529	0.607
Bedrooms	2.970	0.893	2.945	0.744	0.030	0.183	0.057	0.037
Bathrooms	1.592	0.708	1.609	0.659	-0.024	0.073	0.078	0.039
SQFT	16.988	6.301	16.622	5.487	0.062	0.138	0.073	0.041
Acres	3.713	12.755	2.399	10.378	0.113	0.206	0.048	0.106
Basement	0.160	0.367	0.141	0.348	0.053	0.052	0.840	0.859
Garage	0.069	0.325	0.052	0.287	0.054	0.125	0.964	0.977
Air	0.239	0.427	0.234	0.423	0.013	0.008	0.761	0.766
Private Water	0.483	0.500	0.390	0.488	0.188	0.024	0.517	0.610
Highway	4.717	4.940	3.328	3.725	0.318	0.282	0.085	0.054
Major Road	0.261	0.330	0.254	0.269	0.022	0.204	0.082	0.031
Hughesville	0.178	0.382	0.168	0.374	0.026	0.022	0.822	0.832
Jersey Shore	0.081	0.272	0.074	0.262	0.025	0.040	0.919	0.926
Montoursville	0.444	0.497	0.277	0.448	0.353	0.105	0.556	0.723
Muncy	0.045	0.207	0.041	0.198	0.020	0.046	0.955	0.959
South Williamsport	0.000	0.000	0.061	0.239	-0.360	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.187	0.390	-0.431	-0.574	0.949	0.813

Note: Treatment is defined as shale activity within 3 miles.

6.3 Lycoming Matching Including Shale Boundary

The following two models include the indicator for being on/off the shale in Lycoming County.

6.3.1 One-to-One Matching

Table 51: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.1522**		0.0707		-0.0180	
	0.0850		0.0533		0.0491	
Bias Adjusted		-0.1856**		0.0252		-0.0343
		0.0895		0.0415		0.0389

Note: Standard errors reported below each ATT estimate.

Table 51 shows that the *ATT* is significant with 1 mile treatment in both of the models, but is otherwise insignificant. Post-match statistics are reported in Tables 52, 53, and 54. Relative to the pre-match statistics, balance is substantially improved; however several covariates remain more out of balance than in previous matching models.

Table 52: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.236	0.213	0.235	0.214	0.000	-0.004	0.053	0.079
On Shale	1.000	0.000	1.000	0.000			1.000	1.000
Age	49.342	40.065	40.147	31.560	0.255	0.239	0.145	0.009
Stories	1.421	0.490	1.464	0.458	-0.091	0.066	0.500	0.434
Bedrooms	2.829	0.942	2.934	0.807	-0.120	0.155	0.276	0.046
Bathrooms	1.533	0.762	1.719	0.724	-0.250	0.051	0.487	0.060
SQFT	17.637	6.973	18.130	7.735	-0.067	-0.104	0.013	0.118
Acres	5.897	15.439	3.052	4.458	0.250	1.242	0.066	0.053
Basement	0.118	0.325	0.159	0.368	-0.118	-0.125	0.882	0.841
Garage	0.053	0.224	0.059	0.254	-0.026	-0.125	0.947	0.950
Air	0.171	0.379	0.213	0.411	-0.105	-0.083	0.829	0.787
Private Water	0.895	0.308	0.914	0.281	-0.066	0.092	0.105	0.086
Highway	8.601	5.669	8.367	6.940	0.037	-0.202	0.026	0.172
Major Road	0.420	0.523	0.571	0.827	-0.218	-0.458	0.039	0.059
Hughesville	0.197	0.400	0.110	0.314	0.244	0.242	0.803	0.890
Jersey Shore	0.118	0.325	0.126	0.334	-0.024	-0.028	0.882	0.874
Montoursville	0.237	0.427	0.336	0.475	-0.219	-0.105	0.763	0.664
Muncy	0.066	0.249	0.042	0.202	0.104	0.209	0.934	0.958
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.000	0.000	0.117	0.323	-0.512	-Inf	1.000	1.000
Multivariate Matching								
Propensity Score	0.236	0.214	0.130	0.137	0.587	0.443	0.145	0.171
On Shale	1.000	0.000	0.987	0.115	0.162	-Inf	1.000	1.000
Age	49.342	40.121	42.500	32.239	0.188	0.219	0.092	0.013
Stories	1.421	0.490	1.408	0.452	0.028	0.080	0.500	0.500
Bedrooms	2.829	0.944	2.895	0.685	-0.080	0.321	0.066	0.013
Bathrooms	1.533	0.763	1.651	0.648	-0.167	0.163	0.513	0.026
SQFT	17.637	6.983	17.086	4.631	0.093	0.411	0.092	0.026
Acres	5.897	15.461	5.069	14.975	0.054	0.032	0.013	0.132
Basement	0.118	0.325	0.105	0.309	0.041	0.051	0.882	0.895
Garage	0.053	0.225	0.053	0.278	0.000	-0.212	0.947	0.974
Air	0.171	0.379	0.171	0.379	0.000	0.000	0.829	0.829
Private Water	0.895	0.309	0.842	0.367	0.155	-0.172	0.105	0.158
Highway	8.601	5.677	6.797	5.240	0.330	0.080	0.079	0.118
Major Road	0.420	0.523	0.338	0.382	0.180	0.315	0.145	0.013
Hughesville	0.197	0.401	0.197	0.401	0.000	0.000	0.803	0.803
Jersey Shore	0.118	0.325	0.105	0.309	0.041	0.051	0.882	0.895
Montoursville	0.237	0.428	0.224	0.419	0.031	0.020	0.763	0.776
Muncy	0.066	0.250	0.066	0.250	0.000	0.000	0.934	0.934
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.000	0.000	0.118	0.325	-0.515	-Inf	1.000	1.000

Note: Treatment is defined as shale activity within 1 mile.

Table 53: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.410	0.270	0.410	0.271	-0.000	-0.001	0.036	0.054
On Shale	1.000	0.000	1.000	0.000			1.000	1.000
Age	47.064	33.395	47.427	36.087	-0.010	-0.078	0.032	0.052
Stories	1.391	0.470	1.465	0.492	-0.153	-0.045	0.512	0.510
Bedrooms	2.957	0.881	2.904	0.973	0.057	-0.100	0.060	0.069
Bathrooms	1.621	0.740	1.631	0.809	-0.013	-0.089	0.053	0.086
SQFT	17.484	6.757	17.366	5.904	0.019	0.135	0.064	0.048
Acres	4.845	14.820	4.119	12.221	0.053	0.193	0.050	0.056
Basement	0.164	0.371	0.139	0.347	0.068	0.066	0.836	0.861
Garage	0.071	0.296	0.080	0.398	-0.024	-0.296	0.950	0.966
Air	0.206	0.405	0.183	0.387	0.060	0.046	0.794	0.817
Private Water	0.712	0.454	0.737	0.441	-0.056	0.028	0.288	0.263
Highway	6.537	5.393	6.222	5.393	0.059	0.000	0.046	0.058
Major Road	0.290	0.384	0.281	0.288	0.025	0.287	0.100	0.007
Hughesville	0.157	0.364	0.140	0.347	0.047	0.047	0.843	0.860
Jersey Shore	0.125	0.331	0.109	0.312	0.048	0.058	0.875	0.891
Montoursville	0.345	0.476	0.416	0.494	-0.145	-0.036	0.655	0.584
Muncy	0.057	0.232	0.057	0.233	-0.001	-0.002	0.943	0.943
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.032	0.176	0.072	0.258	-0.179	-0.381	0.968	0.928
Multivariate Matching								
Propensity Score	0.410	0.270	0.304	0.256	0.402	0.053	0.050	0.114
On Shale	1.000	0.000	0.975	0.156	0.226	-Inf	1.000	1.000
Age	47.064	33.409	47.189	31.316	-0.004	0.065	0.039	0.021
Stories	1.391	0.470	1.393	0.460	-0.004	0.022	0.537	0.552
Bedrooms	2.957	0.881	2.940	0.671	0.023	0.273	0.060	0.021
Bathrooms	1.621	0.740	1.582	0.666	0.056	0.106	0.406	0.032
SQFT	17.484	6.760	16.544	5.601	0.151	0.188	0.071	0.025
Acres	4.845	14.826	3.779	13.104	0.076	0.123	0.064	0.064
Basement	0.164	0.371	0.153	0.361	0.029	0.027	0.836	0.847
Garage	0.071	0.296	0.057	0.274	0.050	0.077	0.950	0.964
Air	0.206	0.405	0.185	0.389	0.054	0.041	0.794	0.815
Private Water	0.712	0.454	0.630	0.484	0.175	-0.064	0.288	0.370
Highway	6.537	5.395	5.162	4.886	0.267	0.099	0.064	0.046
Major Road	0.290	0.384	0.275	0.316	0.041	0.196	0.100	0.018
Hughesville	0.157	0.364	0.149	0.357	0.020	0.019	0.843	0.851
Jersey Shore	0.125	0.331	0.110	0.314	0.044	0.053	0.875	0.890
Montoursville	0.345	0.476	0.335	0.473	0.023	0.008	0.655	0.665
Muncy	0.057	0.232	0.057	0.232	0.000	0.000	0.943	0.943
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.032	0.176	0.114	0.318	-0.318	-0.590	0.968	0.886

Note: Treatment is defined as shale activity within 2 miles.

Table 54: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.600	0.291	0.600	0.291	0.000	-0.000	0.054	0.046
On Shale	0.897	0.304	0.905	0.293	-0.028	0.037	0.103	0.095
Age	54.051	34.791	48.273	36.452	0.162	-0.047	0.027	0.060
Stories	1.415	0.472	1.411	0.483	0.008	-0.024	0.505	0.554
Bedrooms	2.970	0.893	3.093	1.034	-0.127	-0.146	0.057	0.045
Bathrooms	1.592	0.709	1.678	0.726	-0.121	-0.024	0.042	0.055
SQFT	16.988	6.304	17.496	6.638	-0.078	-0.052	0.075	0.038
Acres	3.713	12.760	4.128	14.229	-0.031	-0.109	0.027	0.100
Basement	0.160	0.367	0.119	0.324	0.119	0.124	0.840	0.881
Garage	0.069	0.326	0.082	0.399	-0.036	-0.204	0.964	0.975
Air	0.239	0.427	0.220	0.415	0.045	0.029	0.761	0.780
Private Water	0.483	0.500	0.609	0.488	-0.255	0.024	0.517	0.391
Highway	4.717	4.942	5.516	4.928	-0.162	0.003	0.067	0.055
Major Road	0.261	0.330	0.286	0.349	-0.074	-0.054	0.064	0.048
Hughesville	0.178	0.383	0.160	0.367	0.048	0.043	0.822	0.840
Jersey Shore	0.081	0.273	0.067	0.250	0.053	0.086	0.919	0.933
Montoursville	0.444	0.497	0.484	0.500	-0.081	-0.006	0.556	0.516
Muncy	0.045	0.207	0.026	0.160	0.101	0.259	0.955	0.974
South Williamsport	0.000	0.000	0.007	0.086	-0.122	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.087	0.283	-0.145	-0.252	0.949	0.913
Multivariate Matching								
Propensity Score	0.600	0.291	0.403	0.294	0.671	-0.010	0.061	0.118
On Shale	0.897	0.304	0.827	0.379	0.204	-0.219	0.103	0.173
Age	54.051	34.797	49.383	32.652	0.138	0.064	0.027	0.061
Stories	1.415	0.472	1.360	0.467	0.116	0.010	0.529	0.614
Bedrooms	2.970	0.894	2.963	0.716	0.009	0.222	0.057	0.037
Bathrooms	1.592	0.709	1.612	0.648	-0.030	0.090	0.052	0.039
SQFT	16.988	6.305	16.385	5.366	0.103	0.161	0.073	0.051
Acres	3.713	12.762	2.634	11.611	0.088	0.095	0.066	0.088
Basement	0.160	0.367	0.157	0.364	0.008	0.008	0.840	0.843
Garage	0.069	0.326	0.063	0.318	0.019	0.025	0.964	0.970
Air	0.239	0.427	0.230	0.421	0.021	0.013	0.761	0.770
Private Water	0.483	0.500	0.405	0.491	0.157	0.018	0.517	0.595
Highway	4.717	4.943	3.584	3.978	0.253	0.217	0.067	0.075
Major Road	0.261	0.330	0.241	0.266	0.067	0.219	0.084	0.033
Hughesville	0.178	0.383	0.173	0.379	0.012	0.010	0.822	0.827
Jersey Shore	0.081	0.273	0.073	0.261	0.028	0.045	0.919	0.927
Montoursville	0.444	0.497	0.321	0.467	0.254	0.062	0.556	0.679
Muncy	0.045	0.207	0.043	0.204	0.007	0.016	0.955	0.957
South Williamsport	0.000	0.000	0.016	0.127	-0.183	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.187	0.390	-0.430	-0.574	0.949	0.813

Note: Treatment is defined as shale activity within 3 miles.

6.3.2 One-to-Four Matching

Table 55: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.1418**		0.0500		0.0008	
	0.0607		0.0404		0.0397	
Bias Adjusted		-0.0958		0.0438		-0.0643**
		0.0749		0.0354		0.0275

Note: Standard errors reported below each ATT estimate.

Table 55 shows that the *ATT* is significant at 1 mile using PSM and at 3 miles using MM. The post-match statistics are shown in Tables 56, 57, and 58, and indicate that both PSM and MM substantially improve covariate balance relative to pre-match statistics. However, some covariates in each model remain slightly out of balance, which makes it difficult to conclude that there is no bias coming from these covariates.

Table 56: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.236	0.213	0.226	0.192	0.048	0.103	0.092	0.043
On Shale	1.000	0.000	1.000	0.000			1.000	1.000
Age	49.342	39.915	42.791	32.814	0.179	0.196	0.132	0.010
Stories	1.421	0.488	1.452	0.453	-0.065	0.075	0.500	0.439
Bedrooms	2.829	0.939	2.933	0.857	-0.115	0.091	0.066	0.051
Bathrooms	1.533	0.759	1.658	0.713	-0.170	0.062	0.079	0.055
SQFT	17.637	6.947	18.457	8.334	-0.107	-0.182	0.039	0.070
Acres	5.897	15.381	4.466	11.898	0.104	0.257	0.066	0.070
Basement	0.118	0.324	0.146	0.353	-0.080	-0.088	0.882	0.854
Garage	0.053	0.224	0.059	0.249	-0.027	-0.108	0.947	0.948
Air	0.171	0.377	0.224	0.417	-0.133	-0.102	0.829	0.776
Private Water	0.895	0.307	0.903	0.296	-0.029	0.038	0.105	0.097
Highway	8.601	5.647	8.587	6.784	0.002	-0.183	0.026	0.168
Major Road	0.420	0.521	0.435	0.566	-0.027	-0.083	0.079	0.028
Hughesville	0.197	0.399	0.132	0.339	0.178	0.163	0.803	0.868
Jersey Shore	0.118	0.324	0.092	0.290	0.084	0.109	0.882	0.908
Montoursville	0.237	0.426	0.329	0.471	-0.206	-0.100	0.763	0.671
Muncy	0.066	0.248	0.079	0.270	-0.050	-0.084	0.934	0.921
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.000	0.000	0.085	0.279	-0.429	-Inf	1.000	1.000
Multivariate Matching								
Propensity Score	0.236	0.213	0.129	0.140	0.591	0.421	0.132	0.214
On Shale	1.000	0.000	0.980	0.139	0.200	-Inf	1.000	1.000
Age	49.342	39.922	47.319	33.340	0.055	0.180	0.132	0.010
Stories	1.421	0.488	1.403	0.463	0.038	0.053	0.500	0.530
Bedrooms	2.829	0.939	2.967	0.708	-0.166	0.283	0.276	0.020
Bathrooms	1.533	0.759	1.571	0.615	-0.055	0.210	0.513	0.020
SQFT	17.637	6.949	16.874	5.303	0.124	0.270	0.079	0.023
Acres	5.897	15.384	4.651	15.384	0.081	0.000	0.053	0.145
Basement	0.118	0.324	0.095	0.294	0.074	0.095	0.882	0.905
Garage	0.053	0.224	0.036	0.204	0.077	0.092	0.947	0.970
Air	0.171	0.377	0.148	0.356	0.063	0.059	0.829	0.852
Private Water	0.895	0.307	0.783	0.413	0.307	-0.295	0.105	0.217
Highway	8.601	5.648	6.475	5.159	0.393	0.091	0.066	0.138
Major Road	0.420	0.521	0.314	0.359	0.237	0.373	0.184	0.007
Hughesville	0.197	0.399	0.201	0.401	-0.008	-0.006	0.803	0.799
Jersey Shore	0.118	0.324	0.102	0.303	0.052	0.066	0.882	0.898
Montoursville	0.237	0.426	0.227	0.420	0.023	0.015	0.763	0.773
Muncy	0.066	0.248	0.069	0.254	-0.013	-0.023	0.934	0.931
South Williamsport	0.000	0.000	0.003	0.057	-0.081	-Inf	1.000	1.000
Williamsport	0.000	0.000	0.115	0.320	-0.509	-Inf	1.000	1.000

Note: Treatment is defined as shale activity within 1 mile.

Table 57: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.410	0.270	0.410	0.270	-0.000	0.001	0.071	0.051
On Shale	1.000	0.000	1.000	0.000			1.000	1.000
Age	47.064	33.363	45.663	33.448	0.042	-0.003	0.032	0.044
Stories	1.391	0.470	1.400	0.470	-0.018	0.000	0.537	0.554
Bedrooms	2.957	0.880	2.949	0.874	0.010	0.007	0.060	0.054
Bathrooms	1.621	0.739	1.644	0.782	-0.030	-0.057	0.053	0.073
SQFT	17.484	6.750	17.471	6.788	0.002	-0.005	0.064	0.051
Acres	4.845	14.805	4.369	12.930	0.034	0.135	0.043	0.062
Basement	0.164	0.370	0.154	0.361	0.028	0.026	0.836	0.846
Garage	0.071	0.296	0.082	0.381	-0.031	-0.254	0.950	0.961
Air	0.206	0.405	0.224	0.417	-0.043	-0.030	0.794	0.776
Private Water	0.712	0.453	0.718	0.450	-0.015	0.007	0.288	0.282
Highway	6.537	5.388	6.205	5.322	0.062	0.012	0.039	0.051
Major Road	0.290	0.384	0.293	0.372	-0.010	0.031	0.100	0.014
Hughesville	0.157	0.364	0.124	0.330	0.094	0.098	0.843	0.876
Jersey Shore	0.125	0.330	0.118	0.323	0.019	0.022	0.875	0.882
Montoursville	0.345	0.476	0.401	0.490	-0.116	-0.031	0.655	0.599
Muncy	0.057	0.232	0.068	0.251	-0.044	-0.080	0.943	0.932
South Williamsport	0.000	0.000	0.000	0.000			1.000	1.000
Williamsport	0.032	0.176	0.096	0.295	-0.263	-0.514	0.968	0.904
Multivariate Matching								
Propensity Score	0.410	0.270	0.244	0.228	0.665	0.168	0.114	0.149
On Shale	1.000	0.000	0.961	0.194	0.285	-Inf	0.000	1.000
Age	47.064	33.364	47.587	31.422	-0.016	0.060	0.039	0.028
Stories	1.391	0.470	1.394	0.459	-0.006	0.023	0.537	0.549
Bedrooms	2.957	0.880	2.977	0.701	-0.025	0.228	0.214	0.021
Bathrooms	1.621	0.739	1.593	0.654	0.040	0.123	0.406	0.027
SQFT	17.484	6.751	16.626	5.613	0.138	0.185	0.078	0.029
Acres	4.845	14.806	3.285	12.372	0.114	0.180	0.057	0.091
Basement	0.164	0.370	0.144	0.351	0.054	0.052	0.836	0.856
Garage	0.071	0.296	0.049	0.267	0.079	0.101	0.950	0.976
Air	0.206	0.405	0.188	0.391	0.047	0.036	0.794	0.812
Private Water	0.712	0.453	0.551	0.498	0.338	-0.094	0.288	0.449
Highway	6.537	5.388	4.658	4.574	0.376	0.164	0.071	0.026
Major Road	0.290	0.384	0.260	0.290	0.087	0.280	0.110	0.014
Hughesville	0.157	0.364	0.147	0.354	0.027	0.027	0.843	0.853
Jersey Shore	0.125	0.330	0.107	0.309	0.056	0.067	0.875	0.893
Montoursville	0.345	0.476	0.315	0.465	0.064	0.023	0.655	0.685
Muncy	0.057	0.232	0.056	0.230	0.004	0.007	0.943	0.944
South Williamsport	0.000	0.000	0.004	0.060	-0.084	-Inf	1.000	1.000
Williamsport	0.032	0.176	0.128	0.334	-0.360	-0.641	0.968	0.872

Note: Treatment is defined as shale activity within 2 miles.

Table 58: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.600	0.291	0.600	0.291	-0.001	-0.001	0.058	0.032
On Shale	0.897	0.304	0.892	0.310	0.015	-0.019	0.103	0.108
Age	54.051	34.777	45.463	34.084	0.249	0.020	0.027	0.069
Stories	1.415	0.471	1.404	0.489	0.022	-0.037	0.505	0.585
Bedrooms	2.970	0.893	3.062	1.037	-0.095	-0.149	0.057	0.044
Bathrooms	1.592	0.708	1.673	0.714	-0.114	-0.007	0.052	0.049
SQFT	16.988	6.301	17.435	6.556	-0.069	-0.040	0.075	0.038
Acres	3.713	12.755	3.501	11.733	0.017	0.084	0.033	0.088
Basement	0.160	0.367	0.124	0.330	0.103	0.106	0.840	0.876
Garage	0.069	0.325	0.065	0.335	0.011	-0.030	0.964	0.971
Air	0.239	0.427	0.238	0.426	0.004	0.002	0.761	0.762
Private Water	0.483	0.500	0.616	0.486	-0.271	0.027	0.517	0.384
Highway	4.717	4.940	5.267	4.755	-0.113	0.038	0.079	0.052
Major Road	0.261	0.330	0.269	0.348	-0.026	-0.052	0.058	0.032
Hughesville	0.178	0.382	0.146	0.353	0.087	0.080	0.822	0.854
Jersey Shore	0.081	0.272	0.073	0.260	0.031	0.049	0.919	0.927
Montoursville	0.444	0.497	0.523	0.500	-0.159	-0.005	0.556	0.477
Muncy	0.045	0.207	0.025	0.155	0.111	0.291	1.000	0.975
South Williamsport	0.000	0.000	0.008	0.087	-0.124	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.081	0.273	-0.122	-0.217	0.949	0.919
Multivariate Matching								
Propensity Score	0.600	0.291	0.318	0.281	0.985	0.036	0.072	0.169
On Shale	0.897	0.304	0.849	0.358	0.145	-0.164	0.103	0.151
Age	54.051	34.777	48.984	33.030	0.149	0.052	0.027	0.061
Stories	1.415	0.471	1.376	0.464	0.082	0.017	0.529	0.582
Bedrooms	2.970	0.893	2.945	0.742	0.031	0.185	0.057	0.036
Bathrooms	1.592	0.708	1.598	0.660	-0.009	0.071	0.055	0.037
SQFT	16.988	6.301	16.549	5.430	0.075	0.149	0.076	0.032
Acres	3.713	12.755	2.397	10.384	0.113	0.206	0.048	0.092
Basement	0.160	0.367	0.142	0.350	0.049	0.048	0.840	0.858
Garage	0.069	0.325	0.050	0.284	0.060	0.135	0.964	0.979
Air	0.239	0.427	0.237	0.426	0.004	0.003	0.761	0.763
Private Water	0.483	0.500	0.376	0.484	0.217	0.031	0.517	0.624
Highway	4.717	4.940	3.348	3.706	0.314	0.287	0.073	0.049
Major Road	0.261	0.330	0.241	0.258	0.068	0.246	0.084	0.030
Hughesville	0.178	0.382	0.169	0.374	0.025	0.021	0.822	0.831
Jersey Shore	0.081	0.272	0.068	0.252	0.048	0.079	0.919	0.932
Montoursville	0.444	0.497	0.228	0.420	0.469	0.169	0.556	0.772
Muncy	0.045	0.207	0.041	0.198	0.020	0.046	0.955	0.959
South Williamsport	0.000	0.000	0.038	0.192	-0.283	-Inf	1.000	1.000
Williamsport	0.051	0.220	0.252	0.434	-0.584	-0.681	0.949	0.748

Note: Treatment is defined as shale activity within 3 miles.

6.4 Control Group Off Shale Lycoming County

Here, we explore the shale boundary model directly. We restrict our control units to come from the sample of off-shale properties. This allows us to match properties on the shale and near shale activity to units that are observationally identical but are off the shale.

6.4.1 One-to-One Matching

Table 59: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.0834		-0.0551		-0.0260	
	0.2934		0.1960		0.1313	
Bias Adjusted		-0.0418		-0.0551		-0.0952**
		0.1105		0.0518		0.0395

Note: Standard errors reported below each ATT estimate.

Table 59 reveals that the MM approach in Model 3 shows some significance. However, it is clear in these models that there is a lack of covariate balance (Tables 60, 61, and 62). This indicates that observables differences may contribute to bias in our estimate of the ATT.

This finding of imbalance is important, because Muehlenbachs et al. (2014) attempt to use off-shale properties as a control group as part of their identification strategy. Their balancing statistics are not reported.

Table 60: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.642	0.359	0.570	0.295	0.220	0.196	0.513	0.030
Age	49.342	40.090	40.460	18.267	0.285	0.786	0.132	0.013
Stories	1.421	0.490	1.201	0.381	0.502	0.250	0.500	0.759
Bedrooms	2.829	0.943	2.926	0.467	-0.130	0.704	0.276	0.011
Bathrooms	1.533	0.762	1.349	0.561	0.274	0.306	0.513	0.022
SQFT	17.637	6.978	15.226	5.697	0.379	0.203	0.079	0.009
Acres	5.897	15.448	2.400	4.746	0.306	1.180	0.132	0.034
Basement	0.118	0.325	0.020	0.142	0.391	0.829	1.000	0.980
Garage	0.053	0.225	0.037	0.266	0.065	-0.168	1.000	0.998
Air	0.171	0.379	0.045	0.209	0.412	0.595	0.829	0.955
Private Water	0.895	0.309	0.947	0.226	-0.192	0.311	0.105	0.053
Highway	8.601	5.672	7.096	2.738	0.338	0.728	0.461	0.071
Major Road	0.420	0.523	0.790	0.541	-0.695	-0.033	0.132	0.001
Jersey Shore	0.118	0.325	0.550	0.500	-1.024	-0.432	0.882	0.450
Montoursville	0.237	0.428	0.057	0.234	0.521	0.603	0.763	0.943
Muncy	0.066	0.249	0.037	0.191	0.127	0.266	0.934	0.963
Multivariate Matching								
Propensity Score	0.642	0.359	0.207	0.198	1.499	0.595	0.579	0.105
Age	49.342	40.121	45.697	29.940	0.103	0.293	0.039	0.053
Stories	1.421	0.490	1.362	0.452	0.126	0.082	0.500	0.579
Bedrooms	2.829	0.944	2.987	0.721	-0.188	0.269	0.066	0.026
Bathrooms	1.533	0.763	1.513	0.605	0.029	0.231	0.092	0.026
SQFT	17.637	6.983	16.365	5.886	0.197	0.171	0.079	0.013
Acres	5.897	15.461	4.016	11.363	0.139	0.308	0.066	0.105
Basement	0.118	0.325	0.105	0.309	0.041	0.051	0.882	0.895
Garage	0.053	0.225	0.039	0.196	0.062	0.137	0.947	0.961
Air	0.171	0.379	0.145	0.354	0.072	0.068	0.829	0.855
Private Water	0.895	0.309	0.763	0.428	0.353	-0.326	0.105	0.237
Highway	8.601	5.677	4.239	2.882	0.969	0.678	0.461	0.224
Major Road	0.420	0.523	0.415	0.432	0.011	0.191	0.118	0.000
Jersey Shore	0.118	0.325	0.118	0.325	0.000	0.000	0.882	0.882
Montoursville	0.237	0.428	0.211	0.410	0.063	0.042	0.763	0.789
Muncy	0.066	0.250	0.039	0.196	0.117	0.242	0.934	0.961

Note: Treatment is defined as shale activity within 1 mile.

Table 61: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.647	0.310	0.621	0.283	0.087	0.090	0.374	0.027
Age	47.064	33.402	39.461	24.596	0.259	0.306	0.046	0.031
Stories	1.391	0.470	1.541	0.488	-0.313	-0.036	0.537	0.427
Bedrooms	2.957	0.881	3.047	0.551	-0.122	0.469	0.214	0.023
Bathrooms	1.621	0.740	1.662	0.642	-0.059	0.142	0.399	0.040
SQFT	17.484	6.758	15.728	4.699	0.302	0.363	0.157	0.013
Acres	4.845	14.823	2.971	9.335	0.151	0.462	0.075	0.043
Basement	0.164	0.371	0.105	0.307	0.172	0.187	0.836	0.895
Garage	0.071	0.296	0.112	0.449	-0.106	-0.416	0.940	0.990
Air	0.206	0.405	0.122	0.328	0.229	0.212	0.794	0.878
Private Water	0.712	0.454	0.739	0.440	-0.061	0.031	0.288	0.261
Highway	6.537	5.394	5.404	3.501	0.249	0.432	0.270	0.073
Major Road	0.290	0.384	0.217	0.342	0.200	0.116	0.096	0.016
Jersey Shore	0.125	0.331	0.151	0.358	-0.076	-0.080	0.875	0.849
Montoursville	0.345	0.476	0.241	0.428	0.230	0.106	0.655	0.759
Muncy	0.057	0.232	0.027	0.161	0.152	0.366	0.943	0.973
Multivariate Matching								
Propensity Score	0.647	0.310	0.375	0.255	0.959	0.194	0.367	0.203
Age	47.064	33.409	44.872	30.197	0.069	0.101	0.032	0.043
Stories	1.391	0.470	1.363	0.459	0.061	0.025	0.537	0.577
Bedrooms	2.957	0.881	2.947	0.737	0.013	0.178	0.060	0.032
Bathrooms	1.621	0.740	1.541	0.625	0.117	0.170	0.082	0.028
SQFT	17.484	6.760	16.603	5.450	0.144	0.215	0.085	0.018
Acres	4.845	14.826	2.964	11.175	0.143	0.283	0.057	0.089
Basement	0.164	0.371	0.139	0.346	0.069	0.068	0.836	0.861
Garage	0.071	0.296	0.053	0.269	0.063	0.098	0.950	0.968
Air	0.206	0.405	0.181	0.386	0.063	0.049	0.794	0.819
Private Water	0.712	0.454	0.573	0.496	0.292	-0.088	0.288	0.427
Highway	6.537	5.395	3.117	2.926	0.788	0.612	0.317	0.093
Major Road	0.290	0.384	0.292	0.317	-0.007	0.192	0.057	0.053
Jersey Shore	0.125	0.331	0.125	0.331	0.000	0.000	0.875	0.875
Montoursville	0.345	0.476	0.295	0.457	0.107	0.041	0.655	0.705
Muncy	0.057	0.232	0.032	0.176	0.121	0.275	0.943	0.968

Note: Treatment is defined as shale activity within 2 miles.

Table 62: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.758	0.253	0.751	0.246	0.029	0.026	0.256	0.026
Age	54.051	34.793	44.906	30.079	0.281	0.146	0.027	0.039
Stories	1.415	0.472	1.265	0.438	0.329	0.074	0.529	0.714
Bedrooms	2.970	0.893	2.922	0.682	0.061	0.270	0.215	0.032
Bathrooms	1.592	0.709	1.437	0.649	0.228	0.088	0.411	0.039
SQFT	16.988	6.304	15.682	5.957	0.213	0.057	0.073	0.038
Acres	3.713	12.761	2.824	9.777	0.078	0.266	0.037	0.067
Basement	0.160	0.367	0.070	0.255	0.286	0.365	0.840	0.930
Garage	0.069	0.326	0.133	0.473	-0.158	-0.374	0.952	0.976
Air	0.239	0.427	0.356	0.479	-0.258	-0.116	0.761	0.644
Private Water	0.483	0.500	0.684	0.465	-0.416	0.072	0.517	0.316
Highway	4.717	4.942	3.307	3.430	0.331	0.365	0.181	0.037
Major Road	0.261	0.330	0.365	0.370	-0.296	-0.113	0.066	0.046
Jersey Shore	0.081	0.273	0.143	0.350	-0.198	-0.250	0.919	0.857
Montoursville	0.444	0.497	0.455	0.498	-0.021	-0.002	0.556	0.545
Muncy	0.045	0.207	0.009	0.094	0.224	0.794	1.000	0.991
Multivariate Matching								
Propensity Score	0.758	0.253	0.492	0.314	0.933	-0.216	0.342	0.191
Age	54.051	34.797	49.843	33.569	0.123	0.036	0.027	0.045
Stories	1.415	0.472	1.365	0.465	0.105	0.015	0.529	0.595
Bedrooms	2.970	0.894	2.922	0.738	0.058	0.191	0.057	0.034
Bathrooms	1.592	0.709	1.567	0.657	0.036	0.076	0.078	0.042
SQFT	16.988	6.305	16.336	5.578	0.110	0.122	0.072	0.054
Acres	3.713	12.762	2.400	9.916	0.115	0.252	0.048	0.117
Basement	0.160	0.367	0.143	0.351	0.046	0.045	0.840	0.857
Garage	0.069	0.326	0.057	0.289	0.039	0.119	0.964	0.973
Air	0.239	0.427	0.217	0.412	0.053	0.035	0.761	0.783
Private Water	0.483	0.500	0.436	0.496	0.093	0.008	0.517	0.564
Highway	4.717	4.943	2.331	2.632	0.603	0.630	0.226	0.070
Major Road	0.261	0.330	0.262	0.283	-0.004	0.157	0.096	0.031
Jersey Shore	0.081	0.273	0.078	0.268	0.011	0.017	0.919	0.922
Montoursville	0.444	0.497	0.272	0.445	0.364	0.110	0.556	0.728
Muncy	0.045	0.207	0.034	0.182	0.054	0.127	0.955	0.966

Note: Treatment is defined as shale activity within 3 miles.

6.4.2 One-to-Four Matching

Table 63: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Standard	-0.2060		0.0530		-0.0093	
	0.2219		0.1396		0.0862	
Bias Adjusted		-0.2018**		-0.0840*		-0.0835**
		0.0841		0.0429		0.0313

Note: Standard errors reported below each ATT estimate.

Table 63 reveals that the MM approach shows some significance in all three treatment models. However, it is clear in these models that there is a lack of covariate balance (Tables 64, 65, and 66), which indicates that observables differences may contribute to bias in our estimate of the *ATT*.

Table 64: Results for post-matching statistics for Lycoming County: Treatment 1

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.642	0.357	0.515	0.260	0.405	0.317	0.513	0.030
Age	49.342	39.919	40.367	22.549	0.277	0.571	0.132	0.013
Stories	1.421	0.488	1.330	0.459	0.192	0.062	0.500	0.640
Bedrooms	2.829	0.939	3.064	0.683	-0.287	0.317	0.276	0.022
Bathrooms	1.533	0.759	1.608	0.615	-0.108	0.211	0.513	0.024
SQFT	17.637	6.948	16.600	7.317	0.145	-0.052	0.079	0.013
Acres	5.897	15.383	3.378	7.819	0.206	0.677	0.105	0.038
Basement	0.118	0.324	0.026	0.160	0.362	0.706	1.000	0.974
Garage	0.053	0.224	0.017	0.177	0.176	0.232	1.000	0.998
Air	0.171	0.377	0.211	0.409	-0.102	-0.080	0.829	0.789
Private Water	0.895	0.307	0.944	0.230	-0.182	0.289	0.105	0.056
Highway	8.601	5.648	5.583	3.519	0.642	0.473	0.461	0.247
Major Road	0.420	0.521	0.544	0.573	-0.225	-0.096	0.132	0.008
Jersey Shore	0.118	0.324	0.229	0.421	-0.294	-0.262	0.882	0.771
Montoursville	0.237	0.426	0.237	0.426	-0.000	-0.000	0.763	0.763
Muncy	0.066	0.248	0.036	0.186	0.138	0.291	0.934	0.964
Multivariate Matching								
Propensity Score	0.642	0.357	0.169	0.189	1.655	0.637	0.579	0.138
Age	49.342	39.922	45.961	32.189	0.093	0.215	0.039	0.033
Stories	1.421	0.488	1.378	0.461	0.090	0.056	0.500	0.559
Bedrooms	2.829	0.939	2.964	0.759	-0.158	0.213	0.066	0.030
Bathrooms	1.533	0.759	1.475	0.614	0.083	0.213	0.092	0.033
SQFT	17.637	6.949	16.448	5.775	0.186	0.185	0.079	0.033
Acres	5.897	15.384	3.616	10.123	0.175	0.419	0.066	0.148
Basement	0.118	0.324	0.102	0.303	0.052	0.066	0.882	0.898
Garage	0.053	0.224	0.036	0.187	0.080	0.179	0.947	0.964
Air	0.171	0.377	0.158	0.365	0.035	0.032	0.829	0.842
Private Water	0.895	0.307	0.697	0.460	0.504	-0.403	0.105	0.303
Highway	8.601	5.648	4.006	2.944	1.020	0.651	0.461	0.234
Major Road	0.420	0.521	0.393	0.430	0.057	0.192	0.092	0.033
Jersey Shore	0.118	0.324	0.122	0.327	-0.010	-0.012	0.882	0.878
Montoursville	0.237	0.426	0.197	0.399	0.096	0.066	0.763	0.803
Muncy	0.066	0.248	0.043	0.203	0.102	0.203	0.934	0.957

Note: Treatment is defined as shale activity within 1 mile.

Table 65: Results for post-matching statistics for Lycoming County: Treatment 2

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.647	0.309	0.618	0.279	0.100	0.102	0.374	0.027
Age	47.064	33.364	40.281	24.944	0.230	0.291	0.046	0.028
Stories	1.391	0.470	1.358	0.476	0.070	-0.012	0.537	0.607
Bedrooms	2.957	0.880	2.967	0.610	-0.012	0.367	0.214	0.025
Bathrooms	1.621	0.739	1.498	0.617	0.180	0.181	0.406	0.030
SQFT	17.484	6.751	15.190	5.062	0.384	0.288	0.114	0.009
Acres	4.845	14.806	2.782	8.338	0.172	0.574	0.075	0.050
Basement	0.164	0.370	0.116	0.320	0.139	0.146	0.836	0.884
Garage	0.071	0.296	0.073	0.364	-0.007	-0.207	0.940	0.991
Air	0.206	0.405	0.131	0.337	0.202	0.182	0.794	0.869
Private Water	0.712	0.453	0.743	0.437	-0.070	0.036	0.288	0.257
Highway	6.537	5.388	5.356	3.386	0.263	0.464	0.292	0.062
Major Road	0.290	0.384	0.317	0.429	-0.067	-0.112	0.085	0.024
Jersey Shore	0.125	0.330	0.416	0.493	-0.695	-0.401	0.875	0.584
Montoursville	0.345	0.476	0.227	0.419	0.264	0.127	0.655	0.773
Muncy	0.057	0.232	0.025	0.156	0.163	0.398	1.000	0.975
Multivariate Matching								
Propensity Score	0.647	0.309	0.339	0.250	1.096	0.212	0.359	0.246
Age	47.064	33.364	46.763	30.454	0.009	0.091	0.032	0.036
Stories	1.391	0.470	1.344	0.443	0.104	0.057	0.537	0.589
Bedrooms	2.957	0.880	2.942	0.764	0.018	0.142	0.060	0.034
Bathrooms	1.621	0.739	1.528	0.630	0.135	0.160	0.427	0.032
SQFT	17.484	6.751	16.280	5.575	0.195	0.191	0.093	0.020
Acres	4.845	14.806	2.653	9.611	0.176	0.432	0.057	0.110
Basement	0.164	0.370	0.132	0.338	0.090	0.090	0.836	0.868
Garage	0.071	0.296	0.053	0.265	0.063	0.111	0.950	0.966
Air	0.206	0.405	0.182	0.386	0.061	0.047	0.794	0.818
Private Water	0.712	0.453	0.516	0.500	0.410	-0.098	0.288	0.484
Highway	6.537	5.388	2.931	2.856	0.836	0.635	0.306	0.079
Major Road	0.290	0.384	0.301	0.331	-0.032	0.148	0.057	0.051
Jersey Shore	0.125	0.330	0.119	0.324	0.016	0.019	0.875	0.881
Montoursville	0.345	0.476	0.281	0.450	0.138	0.056	0.655	0.719
Muncy	0.057	0.232	0.029	0.169	0.136	0.317	0.943	0.971

Note: Treatment is defined as shale activity within 2 miles.

Table 66: Results for post-matching statistics for Lycoming County: Treatment 3

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.758	0.253	0.749	0.245	0.037	0.032	0.256	0.026
Age	54.051	34.777	43.869	29.446	0.316	0.166	0.027	0.035
Stories	1.415	0.471	1.315	0.463	0.214	0.019	0.529	0.659
Bedrooms	2.970	0.893	2.932	0.739	0.046	0.189	0.057	0.037
Bathrooms	1.592	0.708	1.488	0.661	0.151	0.070	0.411	0.042
SQFT	16.988	6.301	16.286	6.287	0.111	0.002	0.073	0.045
Acres	3.713	12.755	2.628	8.091	0.102	0.455	0.043	0.051
Basement	0.160	0.367	0.083	0.275	0.238	0.286	0.840	0.917
Garage	0.069	0.325	0.087	0.382	-0.052	-0.159	0.952	0.979
Air	0.239	0.427	0.211	0.408	0.067	0.044	0.761	0.789
Private Water	0.483	0.500	0.687	0.464	-0.423	0.074	0.517	0.313
Highway	4.717	4.940	4.465	3.573	0.059	0.324	0.193	0.065
Major Road	0.261	0.330	0.366	0.427	-0.275	-0.256	0.057	0.059
Jersey Shore	0.081	0.272	0.250	0.433	-0.468	-0.464	0.919	0.750
Montoursville	0.444	0.497	0.309	0.462	0.280	0.072	0.556	0.691
Muncy	0.045	0.207	0.010	0.098	0.217	0.747	1.000	0.990
Multivariate Matching								
Propensity Score	0.758	0.253	0.420	0.316	1.180	-0.225	0.357	0.255
Age	54.051	34.777	51.709	33.323	0.069	0.043	0.027	0.037
Stories	1.415	0.471	1.360	0.457	0.118	0.031	0.529	0.593
Bedrooms	2.970	0.893	2.905	0.726	0.080	0.208	0.063	0.028
Bathrooms	1.592	0.708	1.538	0.636	0.081	0.107	0.436	0.031
SQFT	16.988	6.301	16.027	5.441	0.163	0.147	0.082	0.043
Acres	3.713	12.755	2.122	8.552	0.146	0.400	0.048	0.105
Basement	0.160	0.367	0.132	0.338	0.081	0.081	0.840	0.868
Garage	0.069	0.325	0.052	0.269	0.056	0.190	0.964	0.971
Air	0.239	0.427	0.201	0.401	0.091	0.062	0.761	0.799
Private Water	0.483	0.500	0.396	0.489	0.176	0.022	0.517	0.604
Highway	4.717	4.940	2.221	2.560	0.634	0.657	0.224	0.060
Major Road	0.261	0.330	0.264	0.294	-0.009	0.117	0.066	0.038
Jersey Shore	0.081	0.272	0.076	0.265	0.017	0.026	0.919	0.924
Montoursville	0.444	0.497	0.201	0.401	0.537	0.214	0.556	0.799
Muncy	0.045	0.207	0.033	0.179	0.060	0.143	0.955	0.967

Note: Treatment is defined as shale activity within 3 miles.

6.5 Conclusion from this Section

Here, we have explored a matching approach to estimating the ATT. We have deployed both propensity score matching and multivariate matching. We use bias-corrected estimates for the multivariate matching models, and standard ATT estimates with corrected standard errors for the propensity score matching models. We consider treatment defined as shale activity within 1, 2, or 3 miles of a property, and for each model we report post-match balancing statistics. In all cases, PSM and MM substantially improve the covariate balance, and in some cases to a degree that is largely acceptable for eliminating bias induced by imbalance across covariates.

We generally find a lack of significance of the estimated ATT. We find a few instances of significance in Bradford County, at both 1 mile and 3 miles, but we note that the estimates at 3 miles are really large and so unlikely to be reliable. Consistent with our regression models, we find very little significance in Lycoming County. It is noteworthy that often the PSM and MM models do not agree when one or the other finds significance.

One final note and potential caveat of our results, compared specifically to Muehlenbachs et al. (2014). They do not report balancing statistics. Our models are generally well-balanced, and we might suspect that in general their models are well-balanced too. However, it is important to recognize that they match on year, census tract, lot size, square footage, bedrooms, bathrooms, and year built (notes to their Table 2, p. 25). We also match on these exact same covariates, but in addition we match on a richer set of covariates. Indeed, distance to nearest major road or highway, city effects, and other housing attributes are important factors of housing prices, and are often largely out of balance in our sample pre-match. In addition, despite the large sample size, Muehlenbachs et al. (2014) restrict their sample heavily to a small 6km buffer around a well-pad. This makes it even more important to present balancing statistics, given that their choice of sample restriction greatly reduces the flexibility of the nonparametric matching procedure.

7 Quasi Triple Difference-in-Differences Models

7.1 Model Setup

For both counties, shale activity began in 2008; our housing price data begins in 2006 and 2004 for Bradford and Lycoming Counties respectively. This allows us to attempt a quasi triple difference-in-differences strategy, by including pre-shale activity transactions in our sample. We focus on the 1 mile distance around the wells as the potential proximity at which we might expect to see a significant impact; this expectation comes from previous work, and the mixed results in our cross sectional analysis that suggests that if there is an effect it occurs at a short distance. We call this group "1 Mile Group", which is the group of interest as it describes the group of properties before and after treatment of adjacency to shale gas development. We establish a control group with properties that are between 2 and 3 miles from a well. Using this control group reduces the potential for unobservable or omitted variables to bias the estimates. Lastly, we recognize that there may be different effects of shale gas development on homes reliant on private water versus municipal water, so we include that variable as our third difference.

The model specification is

$$\begin{aligned} \ln(P_i) \quad = \quad & \beta_1 1MileGroup_i + \beta_2 Treatment_i + \beta_3 PrivateWater_i + \\ & \beta_4(1MileGroup_i \times Treatment_i) + \\ & \beta_5(1MileGroup_i \times PrivateWater_i) + \\ & \beta_6(Treatment_i \times PrivateWater_i) + \\ & \beta_7(1MileGroup_i \times Treatment_i \times PrivateWater_i) + \\ & X_i\beta_8 + \epsilon_i \end{aligned} \tag{8}$$

where $Treatment$ is defined as the property being sold after a well is permitted, $PrivateWater$ indicates that the property relies on private well water rather than municipal water, and X_i is a set of control variables that are equivalent to the controls used throughout the cross sectional analysis in the paper. The primary coefficient of interest is β_7, which we expect to be negative if private well water properties are subject to negative externalities within proximity of 1 mile to shale gas development.

We caveat the results of these models because it need not be the case that the pre-shale property transactions are unconfounded by shale activity. In our data it may be that the pre-treatment control properties have some speculative values based on the beginning of shale activity or land men exploring and leasing land pre-development. An earlier pre-treatment trend and control may be a more robust differencing strategy which we are not able to undertake in this paper.

7.2 Bradford County

Table 67 reports results for the triple difference-in-differences regressions for Bradford County. In column (1) we use the band of mile 1 to mile 3 as the control group. In column (2) we eliminate properties between the bands and use the properties between 2 and 3 miles as the control group. In both models, we exclude any observations that are farther than 3 miles from a well location.

Table 67: Quasi triple difference-in-differences regressions for Bradford County

	Dependent variable:	
	log(Price)	
	(1)	(2)
1 Mile Group	-0.008	0.042
	(0.12)	(0.29)
Private Water	0.049	0.201
	(0.66)	(1.28)
Private Water × 1 Mile Group	0.104	0.143
	(1.67)	(1.09)
Treatment	-0.116	-0.196
	(1.73)	(1.07)
Treatment × Private Water	0.076	0.118
	(0.85)	(0.60)
Treatment × 1 Mile Group	-0.167	-0.157
	(1.82)	(0.99)
Treatment × 1 Mile Group × Private Water	-0.043	-0.030
	(0.53)	(0.20)
Observations	3,616	2,387
R^2	0.25	0.26
Census Indicators?	Yes	Yes
City Indicators?	Yes	Yes
Year Indicators?	Yes	Yes
Note:		*p<0.1; **p<0.05; ***p<0.01

7.3 Lycoming County

Table 68 shows results that interact shale treatment with the shale boundary, and also with property water source. The results in this table do not indicate any additional insights from previous regressions. In column (1) we use the band of mile 1 to mile 3 as the control group. In column (2) we eliminate properties between the bands and use the properties between 2 and 3 miles as the control group. We exclude any observations that are farther than 3 miles from a well location. In column (3) we exclude off-shale properties, with the aim of reducing further the potential for unobservable differences.

Table 68: Quasi triple difference-in-differences regressions for Lycoming County

	Dependent variable:		
	log(Price)		
	(1)	(2)	(3)
1 Mile Group	0.355**	0.442**	0.447**
	(3.00)	(3.65)	(3.56)
Private Water	-0.030	-0.064	-0.065
	(0.78)	(1.23)	(1.19)
Private Water × 1 Mile Group	-0.096	-0.033	-0.029
	(1.81)	(0.52)	(0.45)
Treatment	-0.150**	-0.195**	-0.225**
	(2.88)	(3.06)	(3.21)
Treatment × 1 Mile Group	0.263	0.303	0.288
	(1.38)	(1.55)	(1.42)
Treatment × Private Water	-0.011	0.006	-0.014
	(0.20)	(0.07)	(0.15)
Treatment × 1 Mile Group × Private Water	-0.124	-0.081	-0.103
	(1.57)	(0.92)	(1.12)
Observations	1,873	1,238	1,113
Adjusted R^2	0.29	0.30	0.30
Census Indicators?	Yes	Yes	Yes
City Indicators?	Yes	Yes	Yes
Year Indicators?	Yes	Yes	Yes
Note:			*p<0.1; **p<0.05; ***p<0.01

7.4 Conclusion from this Section

These regressions are designed as a triple difference-in-differences approach which may reduce the potential for omitted variable bias. The results are not substantially different than in the cross sectional analysis. Though the point estimates are generally similar to other papers, we again do not recover significance across both counties.

8 Matching Diff-in-Diff in Bradford and Lycoming County

These models are similar to some models used by Muehlenbachs et al. (2014). We estimate the *ATT* using matching for public and private water properties separately, and then difference these estimates to obtain a matched diff-in-diff estimate.

8.0.1 Bradford County

Table 69 reports results for Bradford County. We do not find much significance. We find significance in the public water sample using multivariate matching for treatment defined as shale activity within 1 and 2 miles, but we see in Tables 70 and 71 that several covariates are not well-balanced post-match. Further, the differenced *ATT* estimate is not significant in these models, nor is the PSM version of these models significant.

We find more significance of treatment at 3 miles using PSM. The effects are very large, and marginally significant (at a 10 percent level for the differenced estimate). The magnitude of this effect is difficult to explain; note that Table 75 indicates that the covariates are poorly balanced post-match. From these metrics, this finding does not appear to be credibly unbiased.

Table 69: ATT estimates for propensity score and multivariate matching models for Bradford County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Groundwater	-0.1264		0.3302		-0.9534**	
	0.1018		0.2197		0.4236	
Public Water	-0.0953		-0.1082		-0.0100	
	0.1068		0.1874		0.2467	
Difference	-0.0310		0.4383		-0.9434*	
	0.1475		0.2888		0.4902	
Groundwater		-0.0586		-0.0196		-0.3070**
		0.0910		0.1272		0.1534
Public Water		-0.1795**		-0.2325***		-0.0079
		0.0923		0.0744		0.1172
Difference		0.1208		0.2129		-0.2991
		0.1296		0.1473		0.1931

Note: Standard errors reported below each ATT estimate.

Table 70: Results for post-matching statistics for Bradford County: Treatment 1, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.433	0.226	0.428	0.215	0.023	0.047	0.087	0.027
Age	83.727	42.821	88.902	40.894	-0.124	0.046	0.066	0.040
Stories	1.609	0.465	1.680	0.443	-0.155	0.048	0.344	0.263
Bedrooms	3.180	0.969	3.240	1.337	-0.051	-0.322	0.169	0.060
Bathrooms	1.566	0.749	1.624	0.882	-0.071	-0.163	0.410	0.028
SQFT	16.354	6.172	16.638	7.528	-0.041	-0.199	0.055	0.042
Acres	0.823	2.050	0.472	0.857	0.223	0.872	0.126	0.036
Warm Air	0.437	0.497	0.367	0.483	0.143	0.029	0.563	0.633
Highway	3.237	5.519	2.551	4.795	0.133	0.141	0.175	0.020
Major Road	0.157	0.173	0.158	0.142	-0.008	0.200	0.142	0.009
Sayre	0.005	0.074	0.015	0.120	-0.092	-0.487	1.000	1.000
Towanda	0.344	0.476	0.371	0.484	-0.056	-0.017	0.656	0.629
Multivariate Matching								
Propensity Score	0.433	0.226	0.334	0.198	0.464	0.129	0.131	0.109
Age	83.727	42.837	85.492	41.146	-0.042	0.040	0.060	0.060
Stories	1.609	0.465	1.620	0.468	-0.023	-0.007	0.344	0.344
Bedrooms	3.180	0.969	3.137	0.824	0.049	0.163	0.180	0.027
Bathrooms	1.566	0.749	1.505	0.675	0.084	0.104	0.410	0.022
SQFT	16.354	6.174	16.158	5.614	0.033	0.095	0.066	0.049
Acres	0.823	2.051	0.449	1.147	0.225	0.581	0.126	0.027
Warm Air	0.437	0.497	0.464	0.500	-0.055	-0.005	0.563	0.536
Highway	3.237	5.521	2.782	4.970	0.087	0.105	0.175	0.022
Major Road	0.157	0.174	0.129	0.153	0.174	0.124	0.131	0.016
Sayre	0.005	0.074	0.060	0.238	-0.310	-1.171	0.995	1.000
Towanda	0.344	0.476	0.344	0.476	0.000	0.000	0.656	0.656

Note: Treatment is defined as shale activity within 1 mile.

Table 71: Results for post-matching statistics for Bradford County: Treatment 2, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.760	0.257	0.761	0.258	-0.003	-0.003	0.120	0.026
Age	95.104	40.129	112.789	39.425	-0.445	0.018	0.048	0.081
Stories	1.692	0.442	1.799	0.381	-0.259	0.148	0.261	0.170
Bedrooms	3.326	1.238	3.240	1.080	0.074	0.137	0.185	0.147
Bathrooms	1.583	0.863	1.693	0.768	-0.134	0.117	0.033	0.284
SQFT	17.516	7.729	17.929	7.520	-0.054	0.028	0.033	0.101
Acres	0.814	4.339	0.667	4.183	0.034	0.037	0.174	0.013
Warm Air	0.528	0.500	0.342	0.475	0.382	0.051	0.472	0.658
Highway	4.384	5.984	1.753	3.846	0.523	0.442	0.309	0.004
Major Road	0.110	0.135	0.134	0.111	-0.195	0.198	0.159	0.020
Sayre	0.130	0.336	0.092	0.289	0.121	0.152	0.870	0.908
Towanda	0.291	0.454	0.353	0.478	-0.133	-0.051	0.709	0.647
Multivariate Matching								
Propensity Score	0.760	0.257	0.516	0.279	0.910	-0.082	0.104	0.096
Age	95.104	40.133	92.278	37.069	0.073	0.079	0.087	0.026
Stories	1.692	0.442	1.719	0.433	-0.061	0.020	0.261	0.252
Bedrooms	3.326	1.238	3.335	1.038	-0.008	0.177	0.185	0.091
Bathrooms	1.583	0.863	1.551	0.657	0.042	0.274	0.467	0.419
SQFT	17.516	7.730	16.840	6.307	0.096	0.203	0.050	0.052
Acres	0.814	4.340	0.515	2.562	0.084	0.527	0.148	0.024
Warm Air	0.528	0.500	0.511	0.500	0.033	-0.001	0.472	0.489
Highway	4.384	5.985	2.589	4.583	0.337	0.267	0.178	0.015
Major Road	0.110	0.135	0.116	0.119	-0.045	0.123	0.076	0.022
Sayre	0.130	0.336	0.172	0.378	-0.119	-0.117	0.870	0.828
Towanda	0.291	0.455	0.126	0.332	0.414	0.314	0.709	0.874

Note: Treatment is defined as shale activity within 2 miles.

Table 72: Results for post-matching statistics for Bradford County: Treatment 3, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.887	0.193	0.590	0.336	1.082	-0.554	0.276	0.228
Age	94.123	39.696	89.970	34.036	0.112	0.154	0.115	0.055
Stories	1.701	0.435	1.807	0.370	-0.263	0.163	0.249	0.154
Bedrooms	3.316	1.211	3.244	0.837	0.070	0.370	0.196	0.126
Bathrooms	1.557	0.811	1.536	0.504	0.031	0.475	0.501	0.332
SQFT	17.305	7.300	15.896	5.171	0.223	0.345	0.086	0.016
Acres	0.651	3.545	0.565	2.661	0.028	0.287	0.121	0.038
Warm Air	0.536	0.499	0.461	0.499	0.150	0.001	0.464	0.539
Highway	3.635	5.414	1.146	2.097	0.606	0.949	0.244	0.016
Major Road	0.111	0.136	0.140	0.129	-0.220	0.048	0.074	0.025
Sayre	0.255	0.436	0.199	0.399	0.135	0.088	0.745	0.801
Towanda	0.233	0.423	0.039	0.194	0.589	0.780	0.767	0.961
Multivariate Matching								
Propensity Score	0.887	0.193	0.643	0.297	0.974	-0.429	0.279	0.156
Age	94.123	39.703	89.591	39.611	0.114	0.002	0.053	0.050
Stories	1.701	0.435	1.741	0.422	-0.093	0.030	0.249	0.232
Bedrooms	3.316	1.212	3.268	1.030	0.043	0.163	0.196	0.099
Bathrooms	1.557	0.811	1.515	0.617	0.058	0.273	0.466	0.377
SQFT	17.305	7.302	16.618	6.257	0.101	0.154	0.047	0.042
Acres	0.651	3.546	0.536	2.144	0.039	0.503	0.138	0.037
Warm Air	0.536	0.499	0.555	0.497	-0.039	0.004	0.464	0.445
Highway	3.635	5.415	2.655	4.562	0.196	0.171	0.083	0.006
Major Road	0.111	0.136	0.106	0.117	0.035	0.153	0.072	0.026
Sayre	0.255	0.436	0.474	0.500	-0.468	-0.136	0.745	0.526
Towanda	0.233	0.423	0.069	0.253	0.471	0.514	0.767	0.931

Note: Treatment is defined as shale activity within 3 miles.

Table 73: Results for post-matching statistics for Bradford County: Treatment 1, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.641	0.226	0.640	0.226	0.001	0.001	0.052	0.051
Age	61.087	48.344	63.466	46.652	-0.050	0.036	0.063	0.041
Stories	1.360	0.431	1.396	0.443	-0.082	-0.029	0.550	0.519
Bedrooms	2.748	1.262	2.959	1.169	-0.173	0.077	0.100	0.083
Bathrooms	1.400	0.766	1.410	0.649	-0.014	0.167	0.135	0.082
SQFT	15.123	7.526	15.590	7.122	-0.064	0.055	0.098	0.076
Acres	13.243	45.112	10.259	22.776	0.084	0.683	0.066	0.051
Warm Air	0.423	0.494	0.439	0.497	-0.034	-0.005	0.577	0.561
Highway	7.097	5.404	7.454	6.457	-0.060	-0.178	0.018	0.104
Major Road	0.315	0.582	0.324	0.629	-0.014	-0.078	0.065	0.047
Sayre	0.018	0.132	0.025	0.155	-0.047	-0.159	1.000	1.000
Towanda	0.140	0.348	0.110	0.314	0.090	0.103	0.860	0.890
Multivariate Matching								
Propensity Score	0.641	0.226	0.631	0.237	0.042	-0.048	0.026	0.077
Age	61.087	48.353	62.989	45.936	-0.040	0.051	0.065	0.058
Stories	1.360	0.431	1.373	0.438	-0.032	-0.017	0.550	0.542
Bedrooms	2.748	1.263	2.777	1.131	-0.024	0.110	0.100	0.097
Bathrooms	1.400	0.767	1.390	0.681	0.014	0.118	0.135	0.105
SQFT	15.123	7.527	14.761	6.992	0.050	0.074	0.092	0.108
Acres	13.243	45.121	8.865	27.982	0.117	0.478	0.066	0.060
Warm Air	0.423	0.494	0.415	0.493	0.016	0.003	0.577	0.585
Highway	7.097	5.405	6.706	5.983	0.069	-0.102	0.045	0.077
Major Road	0.315	0.582	0.240	0.507	0.139	0.139	0.066	0.040
Sayre	0.018	0.132	0.018	0.132	0.000	0.000	1.000	1.000
Towanda	0.140	0.348	0.139	0.346	0.005	0.005	0.860	0.861

Note: Treatment is defined as shale activity within 1 mile.

Table 74: Results for post-matching statistics for Bradford County: Treatment 2, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.800	0.235	0.799	0.235	0.001	0.000	0.057	0.026
Age	60.899	48.061	61.130	43.689	-0.005	0.095	0.080	0.011
Stories	1.365	0.435	1.400	0.434	-0.080	0.003	0.550	0.497
Bedrooms	2.768	1.273	2.723	1.442	0.033	-0.125	0.103	0.162
Bathrooms	1.401	0.756	1.279	0.743	0.163	0.018	0.133	0.174
SQFT	15.201	7.640	14.102	7.591	0.144	0.006	0.137	0.165
Acres	13.055	40.861	27.853	68.946	-0.261	-0.523	0.020	0.220
Warm Air	0.426	0.495	0.561	0.496	-0.274	-0.004	0.574	0.439
Highway	7.096	5.591	8.561	6.426	-0.243	-0.139	0.092	0.039
Major Road	0.306	0.558	0.317	0.604	-0.019	-0.079	0.089	0.032
Sayre	0.026	0.158	0.038	0.192	-0.071	-0.192	0.974	1.000
Towanda	0.139	0.346	0.033	0.177	0.388	0.669	0.861	0.967
Multivariate Matching								
Propensity Score	0.800	0.235	0.685	0.312	0.416	-0.282	0.159	0.070
Age	60.899	48.064	58.013	43.867	0.063	0.091	0.075	0.013
Stories	1.365	0.435	1.415	0.426	-0.117	0.021	0.550	0.462
Bedrooms	2.768	1.273	2.735	1.130	0.028	0.119	0.137	0.107
Bathrooms	1.401	0.756	1.417	0.678	-0.023	0.109	0.133	0.113
SQFT	15.201	7.641	14.843	6.715	0.050	0.129	0.116	0.108
Acres	13.055	40.864	8.305	25.127	0.140	0.486	0.056	0.117
Warm Air	0.426	0.495	0.449	0.498	-0.048	-0.006	0.574	0.551
Highway	7.096	5.592	7.581	6.289	-0.081	-0.118	0.084	0.035
Major Road	0.306	0.558	0.265	0.511	0.077	0.087	0.090	0.032
Sayre	0.026	0.158	0.026	0.158	0.000	0.000	1.000	1.000
Towanda	0.139	0.346	0.121	0.326	0.054	0.060	0.861	0.879

Note: Treatment is defined as shale activity within 2 miles.

Table 75: Results for post-matching statistics for Bradford County: Treatment 3, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.864	0.212	0.865	0.212	-0.003	-0.002	0.140	0.026
Age	60.281	47.937	75.830	41.102	-0.348	0.154	0.088	0.011
Stories	1.371	0.438	1.623	0.411	-0.594	0.063	0.546	0.245
Bedrooms	2.768	1.260	2.923	0.751	-0.149	0.517	0.136	0.032
Bathrooms	1.409	0.746	1.747	0.579	-0.506	0.253	0.129	0.049
SQFT	15.285	7.612	18.675	6.824	-0.469	0.109	0.102	0.051
Acres	13.185	40.294	107.517	133.886	-0.954	-1.201	0.021	0.513
Warm Air	0.433	0.496	0.656	0.475	-0.459	0.042	0.567	0.344
Highway	7.370	5.757	8.227	4.860	-0.161	0.170	0.146	0.034
Major Road	0.348	0.695	0.197	0.476	0.254	0.379	0.073	0.019
Sayre	0.030	0.171	0.039	0.195	-0.051	-0.130	0.970	0.961
Towanda	0.127	0.333	0.020	0.141	0.417	0.858	1.000	0.980
Multivariate Matching								
Propensity Score	0.864	0.212	0.613	0.348	0.870	-0.497	0.120	0.203
Age	60.281	47.940	57.978	44.586	0.050	0.073	0.075	0.032
Stories	1.371	0.438	1.395	0.404	-0.058	0.081	0.546	0.453
Bedrooms	2.768	1.260	2.782	1.092	-0.011	0.143	0.102	0.091
Bathrooms	1.409	0.746	1.473	0.693	-0.088	0.074	0.129	0.110
SQFT	15.285	7.613	14.528	6.363	0.108	0.179	0.114	0.091
Acres	13.185	40.297	10.947	27.168	0.065	0.394	0.053	0.158
Warm Air	0.433	0.496	0.429	0.495	0.007	0.001	0.567	0.571
Highway	7.370	5.758	7.237	5.743	0.023	0.003	0.084	0.028
Major Road	0.348	0.695	0.281	0.550	0.106	0.233	0.073	0.035
Sayre	0.030	0.171	0.030	0.171	0.000	0.000	0.970	0.970
Towanda	0.127	0.333	0.102	0.303	0.078	0.095	0.873	0.898

Note: Treatment is defined as shale activity within 3 miles.

8.0.2 Lycoming County

Results for Lycoming County are reported in Table 76. In some of these models, we find significance of shale impacts. For the significant differences at 1 and 2 miles for the multivariate matching models, we report that these point estimates are similar to those reported by previous studies. The following covariate balance tables report some remaining imbalance in both groundwater and public water samples, particularly with respect to distance to nearest highway. It is not clear the extent to which these differences induce bias; we know that the matching procedure has substantially reduced the covariate difference.

Table 76: ATT estimates for propensity score and multivariate matching models for Lycoming County

	Treatment 1		Treatment 2		Treatment 3	
Estimate	PSM	MM	PSM	MM	PSM	MM
Groundwater	-0.1079		-0.0480		-0.1504**	
	0.1065		0.0754		0.0703	
Public Water	0.8765		-0.0179		-0.0748	
			0.0339		0.0697	
Difference	-0.9844		-0.0301		-0.0756	
			0.0827		0.0990	
Groundwater		-0.1273		-0.0945		0.0193
		0.0970		0.0576		0.0557
Public Water		0.2670		0.0883		-0.1301**
		0.1970		0.0538		0.0564
Difference		-0.3943*		-0.1829**		0.1494*
		0.2196		0.0788		0.0792

Note: Standard errors reported below each ATT estimate.

Table 77: Results for post-matching statistics for Lycoming County: Treatment 1, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.335	0.396	0.258	0.273	0.227	0.372	0.375	0.125
Age	43.625	37.527	34.000	41.682	0.243	-0.105	0.125	0.625
Stories	1.438	0.496	1.562	0.496	-0.252	0.000	0.500	0.375
Bedrooms	3.000	0.535	2.875	0.991	0.157	-0.617	0.000	0.500
Bathrooms	1.688	0.651	1.875	0.518	-0.319	0.230	0.375	0.125
SQFT	18.090	5.242	18.386	5.537	-0.055	-0.055	0.125	0.125
Acres	1.926	1.847	1.432	1.997	0.257	-0.078	0.125	0.500
Air	0.375	0.518	0.625	0.518	-0.483	0.000	0.625	0.375
Highway	9.353	7.272	5.382	2.885	0.718	0.924	0.625	0.250
Major Road	0.393	0.250	0.329	0.365	0.204	-0.377	0.000	0.375
Jersey Shore	0.125	0.354	0.125	0.354	0.000	0.000	1.000	1.000
Montoursville	0.375	0.518	0.625	0.518	-0.483	0.000	0.625	0.375
Muncy	0.250	0.463	0.250	0.463	0.000	0.000	0.750	0.750
Multivariate Matching								
Propensity Score	0.335	0.396	0.116	0.212	0.689	0.624	0.250	0.500
Age	43.625	37.527	56.750	48.281	-0.304	-0.252	0.000	0.625
Stories	1.438	0.496	1.562	0.496	-0.252	0.000	0.500	0.375
Bedrooms	3.000	0.535	3.125	0.641	-0.212	-0.181	0.125	0.375
Bathrooms	1.688	0.651	1.688	0.753	0.000	-0.145	0.375	0.500
SQFT	18.090	5.242	19.420	6.666	-0.222	-0.240	0.000	0.375
Acres	1.926	1.847	1.527	1.566	0.233	0.165	0.125	0.625
Air	0.375	0.518	0.375	0.518	0.000	0.000	0.625	0.625
Highway	9.353	7.272	7.860	7.603	0.201	-0.045	0.125	0.375
Major Road	0.393	0.250	0.280	0.208	0.493	0.186	0.375	0.250
Jersey Shore	0.125	0.354	0.125	0.354	0.000	0.000	1.000	1.000
Montoursville	0.375	0.518	0.375	0.518	0.000	0.000	0.625	0.625
Muncy	0.250	0.463	0.125	0.354	0.303	0.269	1.000	0.875

Note: Treatment is defined as shale activity within 1 mile.

8.0.3 Conclusion from this Section

We find some evidence of significant shale effects in both counties using the matching diff-in-diff technique. We find evidence in Bradford County that covariate imbalance may be driving the result. This is less true for Lycoming County; in particular, we find that the covariate that is least well-balanced is distance to nearest highway. It is not clear the extent to which the remaining imbalance leads to bias. If the bias is small, then this is the first design that finds significant shale impacts in Lycoming County. If the imbalance induces bias, then the result is likely driven by this bias. Further, note that the PSM models did not identify this same effect.

Table 78: Results for post-matching statistics for Lycoming County: Treatment 2, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.279	0.199	0.279	0.201	-0.002	-0.009	0.062	0.082
Age	48.407	28.154	40.992	29.606	0.257	-0.050	0.000	0.208
Stories	1.364	0.467	1.417	0.487	-0.110	-0.041	0.580	0.566
Bedrooms	2.975	0.948	3.068	0.874	-0.102	0.081	0.173	0.029
Bathrooms	1.642	0.763	1.808	0.671	-0.231	0.128	0.383	0.029
SQFT	16.936	6.210	18.097	6.060	-0.189	0.024	0.074	0.070
Acres	1.083	3.187	0.660	3.014	0.136	0.056	0.037	0.086
Air	0.296	0.459	0.339	0.476	-0.091	-0.036	0.704	0.661
Highway	3.759	4.021	3.015	4.140	0.182	-0.029	0.062	0.086
Major Road	0.192	0.189	0.201	0.183	-0.045	0.036	0.185	0.029
Jersey Shore	0.148	0.357	0.126	0.334	0.064	0.069	0.852	0.874
Montoursville	0.593	0.494	0.722	0.450	-0.274	0.093	0.407	0.278
Muncy	0.025	0.156	0.008	0.091	0.129	0.542	1.000	1.000
Multivariate Matching								
Propensity Score	0.279	0.199	0.171	0.158	0.599	0.232	0.099	0.111
Age	48.407	28.174	50.111	29.352	-0.059	-0.041	0.000	0.123
Stories	1.364	0.468	1.315	0.436	0.109	0.070	0.605	0.630
Bedrooms	2.975	0.948	2.975	0.724	0.000	0.270	0.086	0.025
Bathrooms	1.642	0.763	1.685	0.700	-0.059	0.086	0.383	0.049
SQFT	16.936	6.214	16.753	5.672	0.031	0.091	0.049	0.074
Acres	1.083	3.189	0.945	2.601	0.048	0.204	0.037	0.086
Air	0.296	0.459	0.272	0.448	0.054	0.026	0.704	0.728
Highway	3.759	4.024	2.692	3.550	0.281	0.125	0.062	0.136
Major Road	0.192	0.189	0.190	0.169	0.015	0.112	0.136	0.025
Jersey Shore	0.148	0.357	0.136	0.345	0.035	0.036	0.852	0.864
Montoursville	0.593	0.494	0.568	0.498	0.050	-0.008	0.407	0.432
Muncy	0.025	0.156	0.012	0.111	0.091	0.340	1.000	1.000

Note: Treatment is defined as shale activity within 2 miles.

Table 79: Results for post-matching statistics for Lycoming County: Treatment 3, Public Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.716	0.277	0.715	0.277	0.001	-0.000	0.038	0.062
Age	60.136	32.066	46.356	31.130	0.436	0.030	0.012	0.144
Stories	1.397	0.465	1.276	0.424	0.274	0.091	0.555	0.684
Bedrooms	2.971	0.935	3.091	0.624	-0.150	0.405	0.217	0.006
Bathrooms	1.569	0.705	1.609	0.625	-0.059	0.120	0.436	0.024
SQFT	16.550	5.960	16.770	6.196	-0.036	-0.039	0.020	0.093
Acres	0.820	3.039	1.746	7.083	-0.170	-0.846	0.055	0.092
Air	0.289	0.454	0.330	0.471	-0.089	-0.037	0.711	0.670
Highway	2.421	3.157	3.543	4.050	-0.309	-0.249	0.043	0.148
Major Road	0.177	0.162	0.166	0.162	0.068	-0.002	0.055	0.050
Jersey Shore	0.061	0.239	0.080	0.272	-0.077	-0.130	0.939	0.920
Montoursville	0.662	0.474	0.611	0.488	0.105	-0.030	0.338	0.389
Muncy	0.006	0.076	0.002	0.044	0.062	0.548	1.000	1.000
Multivariate Matching								
Propensity Score	0.716	0.277	0.480	0.364	0.727	-0.270	0.283	0.214
Age	60.136	32.070	51.540	32.978	0.264	-0.028	0.017	0.104
Stories	1.397	0.465	1.293	0.442	0.229	0.050	0.555	0.682
Bedrooms	2.971	0.935	2.997	0.716	-0.031	0.267	0.078	0.026
Bathrooms	1.569	0.705	1.616	0.622	-0.070	0.125	0.058	0.038
SQFT	16.550	5.961	15.961	5.387	0.104	0.101	0.078	0.095
Acres	0.820	3.040	0.541	1.609	0.115	0.636	0.092	0.055
Air	0.289	0.454	0.275	0.447	0.032	0.016	0.711	0.725
Highway	2.421	3.158	1.846	2.283	0.208	0.324	0.078	0.023
Major Road	0.177	0.162	0.184	0.152	-0.045	0.061	0.064	0.049
Jersey Shore	0.061	0.239	0.058	0.234	0.012	0.023	0.939	0.942
Montoursville	0.662	0.474	0.503	0.501	0.326	-0.055	0.338	0.497
Muncy	0.006	0.076	0.006	0.076	0.000	0.000	1.000	1.000

Note: Treatment is defined as shale activity within 3 miles.

Table 80: Results for post-matching statistics for Lycoming County: Treatment 1, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.126	0.091	0.126	0.090	0.001	0.010	0.059	0.059
Age	50.015	40.529	49.192	38.373	0.021	0.055	0.074	0.043
Stories	1.419	0.492	1.500	0.485	-0.166	0.015	0.456	0.423
Bedrooms	2.809	0.979	2.963	0.748	-0.177	0.270	0.294	0.023
Bathrooms	1.515	0.775	1.716	0.723	-0.268	0.071	0.515	0.036
SQFT	17.584	7.173	19.818	9.896	-0.259	-0.322	0.103	0.072
Acres	6.364	16.244	8.061	19.949	-0.093	-0.205	0.059	0.064
Air	0.147	0.356	0.159	0.367	-0.032	-0.031	0.853	0.841
Highway	8.513	5.507	8.095	5.238	0.078	0.050	0.059	0.084
Major Road	0.424	0.546	0.385	0.340	0.086	0.475	0.206	0.007
Jersey Shore	0.118	0.324	0.124	0.331	-0.019	-0.022	0.882	0.876
Montoursville	0.221	0.417	0.286	0.454	-0.149	-0.086	0.779	0.714
Muncy	0.044	0.206	0.022	0.149	0.121	0.329	1.000	0.978
Multivariate Matching								
Propensity Score	0.126	0.091	0.103	0.068	0.293	0.283	0.162	0.029
Age	50.015	40.625	52.397	36.589	-0.062	0.105	0.162	0.000
Stories	1.419	0.493	1.397	0.428	0.048	0.142	0.500	0.485
Bedrooms	2.809	0.981	2.853	0.902	-0.047	0.084	0.074	0.059
Bathrooms	1.515	0.777	1.493	0.704	0.030	0.098	0.088	0.074
SQFT	17.584	7.190	15.963	5.419	0.255	0.283	0.088	0.059
Acres	6.364	16.282	5.959	15.704	0.025	0.036	0.059	0.044
Air	0.147	0.357	0.132	0.341	0.042	0.044	0.853	0.868
Highway	8.513	5.520	7.362	5.200	0.215	0.060	0.044	0.074
Major Road	0.424	0.548	0.371	0.438	0.106	0.224	0.132	0.000
Jersey Shore	0.118	0.325	0.118	0.325	0.000	0.000	0.882	0.882
Montoursville	0.221	0.418	0.221	0.418	0.000	0.000	0.779	0.779
Muncy	0.044	0.207	0.044	0.207	0.000	0.000	0.956	0.956

Note: Treatment is defined as shale activity within 1 mile.

Table 81: Results for post-matching statistics for Lycoming County: Treatment 2, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.433	0.245	0.433	0.244	0.003	0.003	0.040	0.062
Age	46.520	35.343	40.615	31.932	0.175	0.101	0.045	0.032
Stories	1.403	0.472	1.418	0.479	-0.033	-0.015	0.510	0.538
Bedrooms	2.950	0.855	3.010	0.752	-0.075	0.127	0.215	0.027
Bathrooms	1.612	0.732	1.587	0.722	0.035	0.014	0.415	0.041
SQFT	17.706	6.968	17.509	6.473	0.029	0.074	0.080	0.026
Acres	6.369	17.228	7.457	19.157	-0.060	-0.106	0.055	0.048
Air	0.170	0.376	0.186	0.390	-0.041	-0.035	0.830	0.814
Highway	7.663	5.478	7.489	6.486	0.029	-0.169	0.040	0.122
Major Road	0.329	0.433	0.367	0.444	-0.087	-0.023	0.105	0.022
Jersey Shore	0.115	0.320	0.166	0.373	-0.147	-0.154	0.885	0.834
Montoursville	0.245	0.431	0.299	0.459	-0.122	-0.063	0.755	0.701
Muncy	0.070	0.256	0.061	0.240	0.036	0.063	0.930	0.939
Multivariate Matching								
Propensity Score	0.433	0.245	0.358	0.232	0.315	0.054	0.180	0.050
Age	46.520	35.360	41.340	29.974	0.158	0.165	0.045	0.030
Stories	1.403	0.472	1.397	0.457	0.011	0.031	0.510	0.540
Bedrooms	2.950	0.855	2.975	0.638	-0.033	0.294	0.215	0.015
Bathrooms	1.612	0.732	1.622	0.683	-0.014	0.070	0.415	0.035
SQFT	17.706	6.971	16.704	5.272	0.162	0.279	0.090	0.005
Acres	6.369	17.236	4.533	14.367	0.116	0.182	0.080	0.045
Air	0.170	0.377	0.130	0.337	0.112	0.111	0.830	0.870
Highway	7.663	5.481	6.395	4.572	0.251	0.181	0.060	0.055
Major Road	0.329	0.434	0.342	0.365	-0.032	0.173	0.100	0.025
Jersey Shore	0.115	0.320	0.110	0.314	0.016	0.019	0.885	0.890
Montoursville	0.245	0.431	0.210	0.408	0.083	0.054	0.755	0.790
Muncy	0.070	0.256	0.065	0.247	0.020	0.034	0.930	0.935

Note: Treatment is defined as shale activity within 2 miles.

Table 82: Results for post-matching statistics for Lycoming County: Treatment 3, Private Water

	$\hat{\mu}_t$	$\hat{\sigma}_t$	$\hat{\mu}_c$	$\hat{\sigma}_c$	$\hat{\Delta}_{ct}$	$\hat{\Gamma}_{ct}$	$\hat{\pi}_t^{0.05}$	$\hat{\pi}_c^{0.05}$
Propensity Score Matching								
Propensity Score	0.557	0.278	0.556	0.276	0.003	0.006	0.087	0.027
Age	47.533	36.425	43.049	33.812	0.128	0.074	0.065	0.019
Stories	1.433	0.479	1.517	0.478	-0.174	0.002	0.502	0.438
Bedrooms	2.969	0.848	3.043	0.752	-0.092	0.120	0.214	0.025
Bathrooms	1.616	0.713	1.672	0.732	-0.077	-0.026	0.418	0.042
SQFT	17.457	6.629	18.308	7.486	-0.120	-0.122	0.071	0.056
Acres	6.813	17.583	5.862	14.416	0.059	0.199	0.062	0.057
Air	0.186	0.389	0.202	0.402	-0.042	-0.033	0.814	0.798
Highway	7.177	5.315	7.910	6.716	-0.121	-0.234	0.046	0.134
Major Road	0.350	0.428	0.381	0.521	-0.064	-0.197	0.046	0.035
Jersey Shore	0.102	0.303	0.195	0.397	-0.262	-0.268	0.898	0.805
Montoursville	0.211	0.408	0.210	0.408	0.001	0.001	0.789	0.790
Muncy	0.087	0.282	0.055	0.228	0.123	0.210	0.913	0.945
Multivariate Matching								
Propensity Score	0.557	0.278	0.430	0.246	0.484	0.123	0.180	0.062
Age	47.533	36.435	45.025	33.282	0.072	0.091	0.037	0.037
Stories	1.433	0.479	1.416	0.474	0.036	0.011	0.502	0.545
Bedrooms	2.969	0.848	3.009	0.689	-0.052	0.208	0.043	0.028
Bathrooms	1.616	0.713	1.611	0.674	0.007	0.056	0.068	0.043
SQFT	17.457	6.631	17.112	5.685	0.056	0.154	0.111	0.019
Acres	6.813	17.588	4.648	14.526	0.134	0.191	0.059	0.084
Air	0.186	0.390	0.195	0.397	-0.024	-0.019	0.814	0.805
Highway	7.177	5.316	5.361	3.613	0.400	0.386	0.093	0.037
Major Road	0.350	0.428	0.341	0.367	0.022	0.152	0.068	0.040
Jersey Shore	0.102	0.303	0.096	0.295	0.021	0.028	0.898	0.904
Montoursville	0.211	0.408	0.161	0.368	0.127	0.104	0.789	0.839
Muncy	0.087	0.282	0.080	0.272	0.022	0.034	0.913	0.920

Note: Treatment is defined as shale activity within 3 miles.

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