Fracking and Land Productivity: The Effects of Hydraulic Fracturing on Agriculture

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UNIVERSITY OF CALGARY

Introduction

- Can unconventional oil and gas drilling (UOGD)/ hydraulic fracturing harm other sectors?

Research Question

Can hydraulic fracturing harm agriculture?

Evidence from Alberta

Why Agriculture?

- Agriculture- shares many inputs.
- Agriculture - major water user in many jurisdictions.

Hydraulic Fracturing

Why this Question is Important?

Which ways hydraulic fracturing can affect agriculture?

- Water use
- Effects on soil/ agricultural land from sediment run-off
- Labor movement

Externalities of hydraulic fracturing -

- Economic effects (property value, employment, crime), Groundwater & Surface Water contamination, Health effects

Neglected: Externalities on other sectors through input competition, absence of price/ market

Contribution:

- First study to empirically examine the effects of unconventional oil & gas drilling (UGD) on agricultural productivity, in the context of Western Canada/ Alberta
  - Uses a novel dataset

Methodology and Summary

- Difference-in-differences: time series variation in the count of wells, cross-sectional variation in the water-dependency of crops.

Summary of Findings:

- One well within 11-20 km of the township, drilled during farming months, April-September: $\downarrow$ irrigated crop's productivity by 5.7%.
- No effect is observed $>$30 km.
- Alberta lost approximately \$14.8 million in 2014, 11% of the average revenue earned from irrigated crop production.

Background

Why Alberta?

Province with both unconventional oil and gas and agriculture

- Alberta: second largest shale gas producer, after BC. 41% of the total shale gas in-place reserve of Canada.
- Second highest agricultural producer province, after ON.
- Two irrigation methods: irrigation and dryland.
- Alberta's current water allocation system: Prior appropriation. License holders pay for water access not on volume.

Alberta's Water Allocation

Hydraulic Fracturing in Alberta

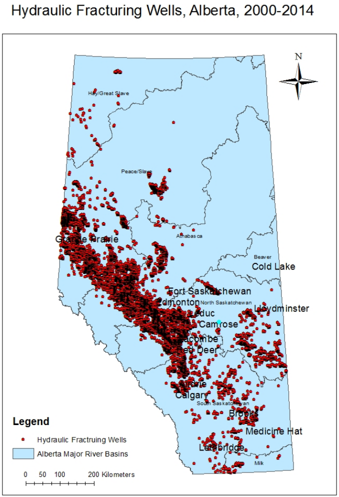
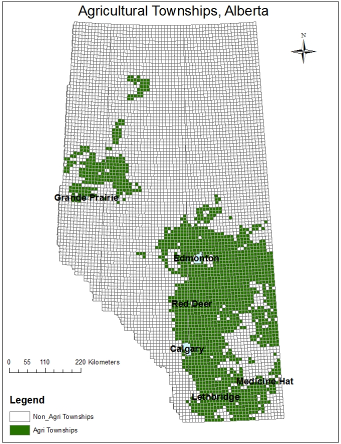


Figure 1: HF Well Locations, 2000-2014

Hydraulic Fracturing in Alberta



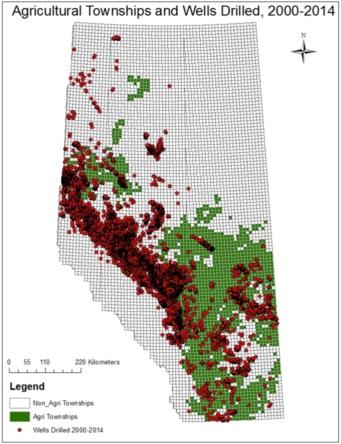
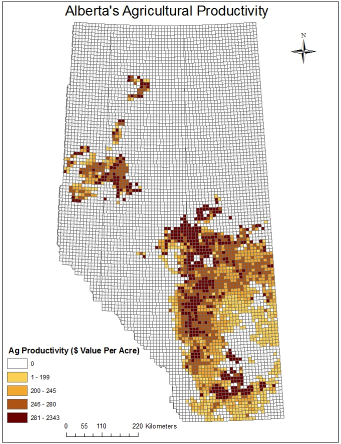


Figure 2: Hydraulic Fractruing Wells and Agricultural Townships

Irrigation Districts | Oil Sands

Hydraulic Fracturing in Alberta



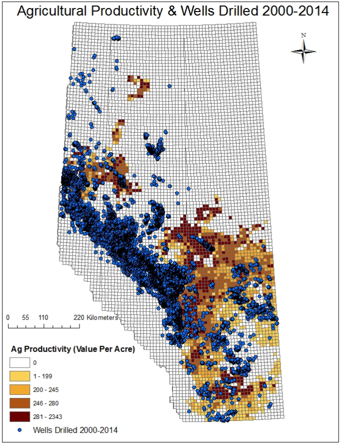


Figure 3: Agricultural Productivity and Well Locations

Hydraulic Fracturing and Agriculture

Hydraulic fracturing water usage

- Per well water use (2014): 4000 m^3.
- Per well daily water: 1800 m^3.
- Average fracking days: 3 to 4.

Irrigation water use

- Per farm yearly water use (2010): approximately 216,000 m^3.
- Per farm daily water use (2010): approximately 1200 m^3

Hydraulic Fracturing in Alberta

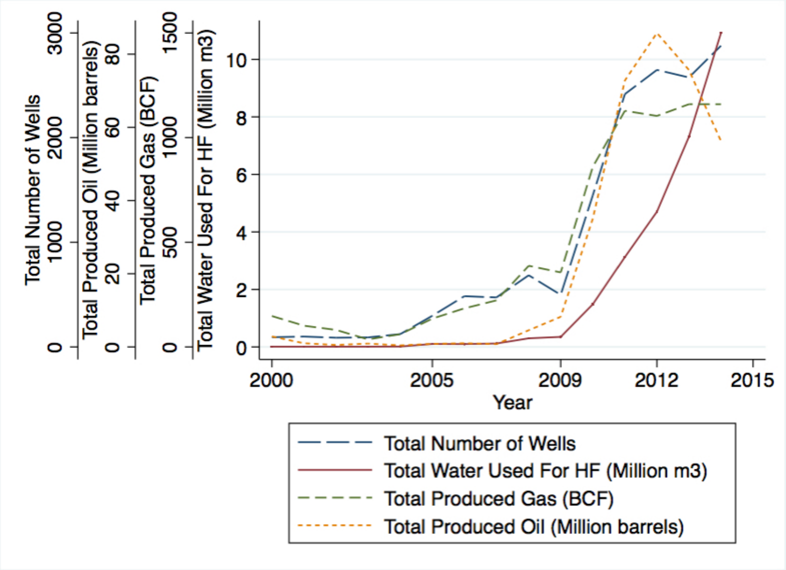


Figure 4: Number of Wells, Water Use and Production, 2000-2014

Hydraulic Fracturing in Alberta

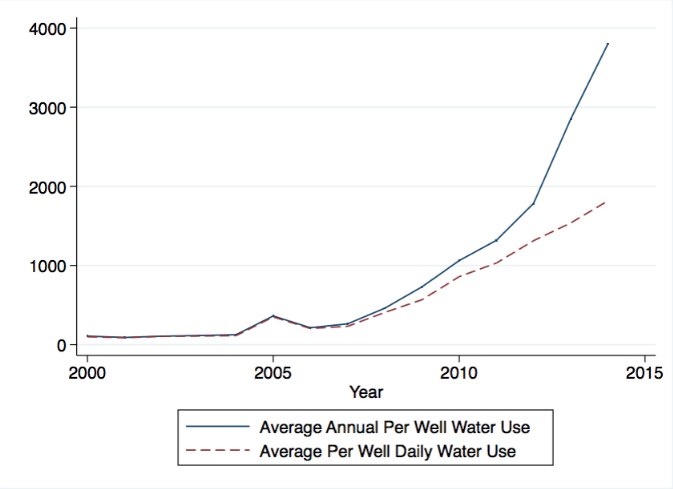


Figure 5: Per Well Water Use, Alberta, 2000-2014

Hydraulic Fracturing and Crop Yield

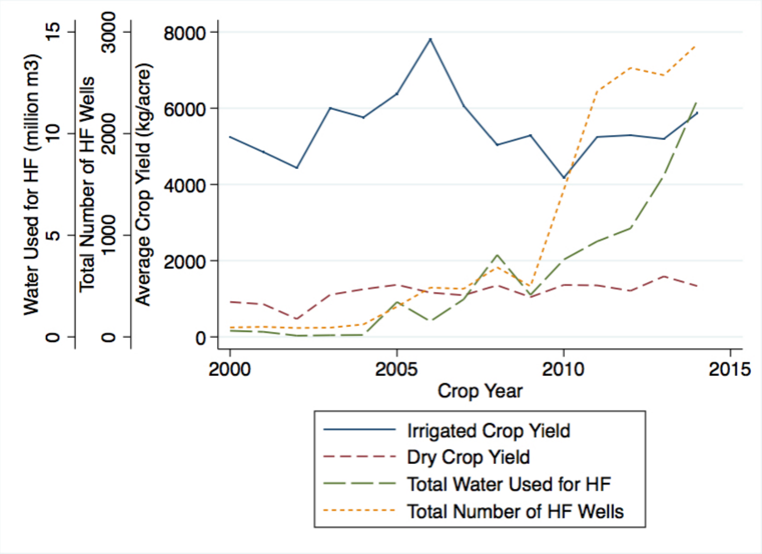


Figure 6: Average Crop Yield, Irrigated vs. Dry and HF Wells

Model

$$
\begin{aligned}
log\,(\text{Crop Yield})_{ict} = \alpha_0 + \sum_{d\,\epsilon\,B} \alpha_d(\text{Count of Wells in year t}_d) \\
+ \alpha_1(\text{Global Climate Index}_{it}) + \mu_{ic} + q_{ct} + \epsilon_{it}, \\
B = \{\text{0-10 km, 11-20 km}, \ldots, \text{40-50 km}\}, \\
> \text{50km} = \text{Omitted Category} \qquad t = (2000, 2001, \ldots\ 2014)
\end{aligned}
\tag{1}
$$

Where, i = township, c= crop, t = year

Also, (Total Water Used by the Wells in year t) used, instead of (Count of Wells in year t), to test the water competition channel.

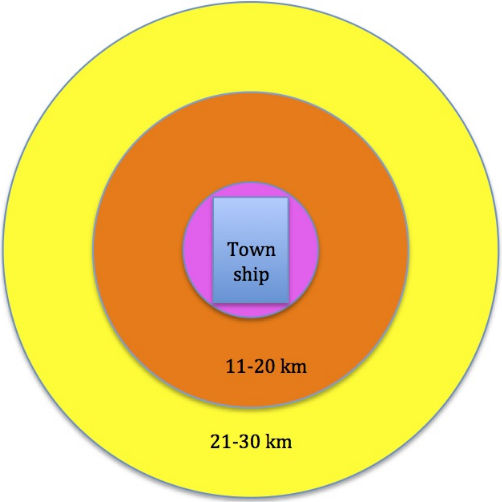


Figure 7: Sample Township

Data

- Agricultural crop yield, crop price, acres cultivated: Agricultural Financial Services Corp. (AFSC)
- Hydraulic Fracturing Well details of Alberta: Canadian Discovery's Well Completion and Frac Database (WCFD)
- Township level data, panel, years: 2000-2014.
- 25 types of crops: 12 irrigated, 13 dryland

Summary Statistics

Results

Table 1: Effect of Hydraulic Fracturing Proximity on log(Crop Yield)*100

	Panel A: Wells Drilled Any Month	Panel B: Wells Drilled April- September
	(1)	(2)
	Irrigated	Irrigated
Count of Hydraulic Fracturing Wells		
0- 10 km (Within Township)	0.735	1.736
	(0.783)	(1.625)
11-20 km	***-1.735	***-5.729
	(0.520)	(2.085)
21-30 km	***-1.021	-0.292
	(0.388)	(0.782)
31-40 km	0.154	0.374
	(0.275)	(0.735)
41-50 km	0.0108	-0.0664
	(0.257)	(0.572)
Observations	2015	2015
R^2	0.31	0.31

Notes: Dependent variable: log (Crop Yield)*100. Crop yield is measured as kg per acre. All specifications include Township-Crop FE, Crop-Year FE, and Global Climate Index. Standard Errors (in parentheses) are clustered by township. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Dryland

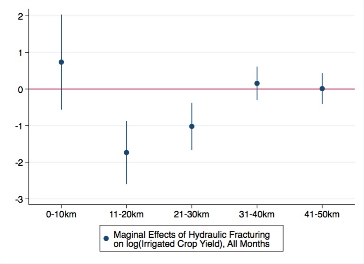
Results

Table 2: Effect of Hydraulic Fracturing Water Use on log(Crop Yield)

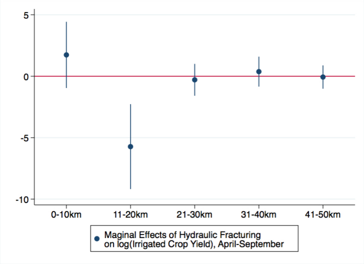
	Panel A: Wells Drilled Any Month	Panel B: Wells Drilled April- September
	(1)	(2)
	Irrigated	Irrigated
Total HF Water Use (1000 m^3)		
0- 10 km or Within Township	-0.0260	***-1.148
	(0.507)	(0.430)
11-20 km	**-1.282	*-1.763
	(0.559)	(0.969)
21-30 km	*-0.236	*-0.492
	(0.120)	(0.257)
31-40 km	-0.0610	-0.346
	(0.0961)	(0.226)
41-50 km	**-0.261	**-0.565
	(0.111)	(0.225)
Observations	2015	2015
R^2	0.308	0.286

Notes: Dependent variable: log (crop yield)*100. Crop yield is measured as kg per acre. All specifications include Township-Crop FE, Crop-Year FE, and Global Climate Index. Standard Errors (in parentheses) are clustered by township. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

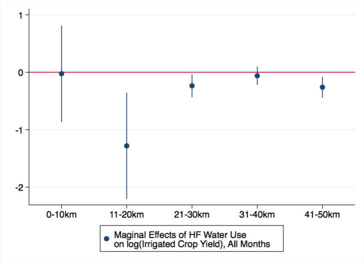
Dryland Crop Switch Dry Results Figure



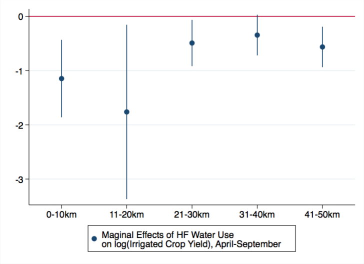
(a) All Months



(b) April-September



(c) All Months



(d) April-September

Figure 8: UOGD Effects on Irrigated Crops

Results

1 well drilled within 11-20 km:

- April-September: $\downarrow$ irrigated crop's productivity by 5.7%.
- Any month: $\downarrow$ irrigated crop's productivity by 1.7%.
- Effects disappear $>$30 km
- Within township: direct positive spillover effects counterbalance indirect negative effect

1000 m^3 water use $\uparrow$

- April-September: $\downarrow$ irrigated crop's productivity by 1.1% within 0-10 km. $\downarrow$ irrigated crop's productivity by 1.7% within 11-20 km.
- Any month: $\downarrow$ irrigated crop's productivity by 1.3% within 11-20 km.

Implication of the Results

Aggregating the effects of wells drilled during irrigation months April-September (Table 1, Column 2)

- In 2014, total loss of revenue due to irrigated crops' productivity ↓: \$14.8 million.
- Alberta lost approximately 11% of the average revenue earned from irrigated crop production only in 2014.

- Land use compensation paid to farmers (entry fee 500\$ per acre) for within farmland/ within township drilling.
- No compensation for distant indirect negative spillover effects.

Conclusion

- Close proximity to hydraulic fracturing wells can reduce irrigated crops' land productivity.
- Compensation to the farmers (possible water tax)

Thank you
Questions/ Comments?

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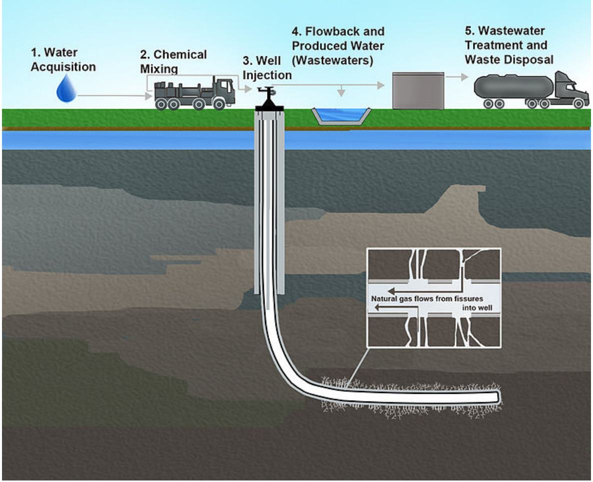
Hydraulic Fracturing



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Alberta's Water Allocation System: Summary

- Prior appropriation
  - Older licensees- more priority than recent licensees.
  - During scarcity, older license holders have first right.
- Use of fresh water (both surface and ground water) requires a license issued by either Alberta Environment or Alberta Energy Regulator (AER).
- Licenses can be issued as temporary diversion licenses (maximum duration: 1 year, no priority) or term licenses (example: 5 years term).
- Different water basins: different features. For example: water scarcity in South Saskatchewan river basin, no water scarcity in Peace river basin.

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Data

Table 3: Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Crop Yield (kg/acre)	46,608	1351.5	1933.4	0	32380
Irrigated Crop Yield (kg/acre)	2,015	5484.5	7703.9	42	32380
Dry Crop Yield (kg/acre)	44,593	1164.7	647.8	0	11578
Price per Kg	46608	0.25	0.13	0.03	1.1
Acres Cultivated	46,608	2611.3	1771.8	53	13373
Irrigated Acres Cultivated	2,015	1250.1	840.03	133	6303
Dry Acres Cultivated	44,593	2672.8	1778.1	53	13373
Hydraulic Fracturing Days	14740	3.5	25.2	1	1827
Per Well Total Water Used for Hydraulic Fracturing (m^3)	14631	1952.01	4094.9	0.8	84405.6
Per Well Daily Water Use (m^3)	14474	1171	1557.7	0.16	58740
Count of Hydraulic Fracturing Wells in township (0-10 km)	46608	0.39	2.6	0	65
Count of Hydraulic Fracturing Wells in township (11-20 km)	46608	1.4	5.5	0	96
Count of Hydraulic Fracturing Wells in township (21-30 km)	46608	2.3	7.5	0	108
Count of Hydraulic Fracturing Wells in township (31-40 km)	46608	3.2	9.4	0	130
Count of Hydraulic Fracturing Wells in township (41-50 km)	46608	4.2	11.3	0	135
Global Climate Index (Precipitation (millimeter))	46,591	421.1	41.7	308	566.5

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Results

Table 4: Effect of Hydraulic Fracturing Proximity on log(Crop Yield)

	Panel A: Wells Drilled Any Month	Panel B: Wells Drilled April- September
	(1)	(2)
	Dryland	Dryland
Count of Hydraulic Fracturing Wells		
0- 10 km or Within Township	0.118	-0.0500
	(0.116)	(0.358)
11-20 km	0.0810	0.111
	(0.0580)	(0.175)
21-30 km	0.00901	-0.218
	(0.0459)	(0.148)
31-40 km	-0.0215	-0.160
	(0.0408)	(0.124)
41-50 km	***-0.110	***-0.368
	(0.0302)	(0.0837)
Observations	44523	44523
R^2	0.507	0.508

Notes: Dependent variable: log (Crop Yield)*100. Crop yield is measured as kg per acre. All specifications include Township-Crop FE, Year FE, Crop-Year FE. Standard Errors (in parentheses) are clustered by township. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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Results

Table 5: Effect of Hydraulic Fracturing Water Use on log(Crop Yield)

	Panel A: Wells Drilled Any Month	Panel B: Wells Drilled April- September
	(1)	(2)
	Dryland	Dryland
Total Water Use (1000 m^3)		
0- 10 km or Within Township	*0.0546	0.0474
	(0.0322)	(0.0563)
11-20 km	0.00470	-0.0262
	(0.0232)	(0.0383)
21-30 km	-0.0249	-0.0815
	(0.0250)	(0.0529)
31-40 km	0.00164	-0.0121
	(0.0172)	(0.0252)
41-50 km	**-0.0286	**-0.0439
	(0.0125)	(0.0218)
Observations	44523	44523
R^2	0.507	0.485

Notes: Dependent variable: log (crop yield)*100. Crop yield is measured as kg per acre. All specifications include Township-Crop FE, Year FE, Crop-Year FE. Standard Errors (in parentheses) are clustered by township. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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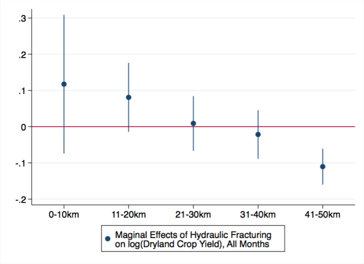
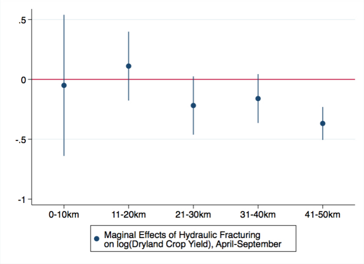
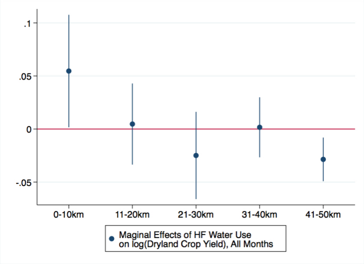


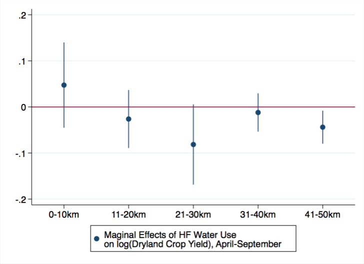
(a) All Months



(b) April-September



(c) All Months



(d) April-September

Figure 9: UOGD Effects on Dryland Crops Back

Results

Crop Composition

Table 6: Effect of Proximity to Wells on Fraction of Acres Irrigated

	Fraction Irrigated
Count of Hydraulic Fracturing Wells	
0-10km (Within Township)	-0.00824
	(0.0117)
11-20km	0.00675
	(0.0115)
21-30km	0.00274
	(0.00632)
31-40km	0.00407
	(0.00632)
41-50km	0.000143
	(0.00454)
Observations	2015
R^2	0.290

Notes: Dependent variable: Fraction of Acres Planted. All specifications include Township-Crop FE, Crop-Year FE, and Global Climate Index. Standard Errors (in parentheses) are clustered by township. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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