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# The Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution: Comment

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# Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution: Comment*

Alexander James[†] Brock Smith[‡]

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**Abstract**

In the mid 2000s, shale-energy-rich U.S. counties experienced a sudden and significant economic shock resulting from energy extraction. While the resulting localized economic effects are relatively well understood, less is known about the geographic dispersion of the effects. We build upon an existing literature, most notably Feyrer, Mansur, and Sacerdote (2017), by examining the conditional economic effects of nearby energy production. Because energy-producing counties tend to be located near each other, producing counties experience inward economic spillovers from other nearby producing counties and this inflates the estimated effect of own-county production. Accounting for this, we identify smaller income effects of hydrocarbon production than Feyrer, Mansur, and Sacerdote (2017), limited to counties within 60-80 miles of the source of production. The proposed estimation strategy can be applied more generally to estimate the dispersion of multiple, simultaneously occurring economic shocks.

*Keywords:* Economic Shocks; Regional Development; Economic Propagation

*JEL Classification:* L14, L81, Q33

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# 1 Introduction

Understanding the spatial dispersion of economic shocks is of obvious importance for policy evaluation and impact analysis. At the sub-national level, where transportation costs and migration frictions are relatively small, accounting for economic spillovers may be especially important. In a paper published in this *Review*, Feyrer, Mansur, Sacerdote (2017) (hereafter FMS) exploit the large and localized shale-energy booms of the mid and late 2000s and, using an innovative instrumentation strategy, identify significant and far-reaching economic propagation to nearby counties. This important result has implications for understanding economic shocks generally, and specifically highlights the importance of considering spatial spillovers in the context of resource booms.

In a baseline, county-level specification, FMS regress the year-on-year change in wage income and sector employment on oil and natural gas production.[1] Acknowledging that there may be important economic spatial spillovers, they draw concentric circles around all U.S. counties and aggregate up in 20 mile intervals to a radius of 200 miles.[2] For each aggregation level, they re-estimate the relationship between hydrocarbon production and changes in income and employment. Aggregation increases the estimated effect of oil and gas production and they interpret this as evidence of economic propagation.

FMS's methodology is intuitive in a specific context. Consider, for example, an oil-producing county that experiences an isolated production shock, with no other nearby counties

[1]There is a large existing literature that examines the regional impact of the U.S. shale boom and energy booms more generally. For just a few examples see Weber (2012, 2014); Munasib and Rickman (2015), Alcott and Keniston (2017), Maniloff and Mastromonaco (2017).

[2]Distances are measured from county centroids.

experiencing any shock. In the presence of spatial spillovers, the shock may increase wage income within that county and also in neighboring counties. Spatial aggregation captures these spillovers and the estimated effect of a unit of energy production increases as a result. But this scenario is, in reality, an exception to what is otherwise a rule: oil-producing counties are spatially correlated with each other and this has important implications for the estimating economic propagation.

Because major energy-producing counties tend to be located near each other (above major oil fields), producing counties typically experience inward economic spillovers from neighboring energy-producing counties. If these spillovers are not accounted for, they induce a positive correlation between the error term and own-county production that causes upward bias in the estimated effect of own-county production on own-county income. Spatial aggregation does not alleviate or account for this issue as clusters of oil-rich counties are also likely to be located near additional oil production. Even large producing geographic areas are likely to generate outward economic spillovers to—and experience inward spillovers from—neighboring energy-producing counties. Figure 1[3] shows that the majority of new oil production occurs in a nearly continuous band stretching from the Gulf Coast to the Canadian border. Clearly, even clusters of counties 200 miles wide (the maximum aggregation distance used by FMS) are likely to experience inward economic spillovers from nearby production.

We build upon FMS and propose an alternative estimation strategy that conditions the effect of own-county production on neighboring production.[4] We estimate the model using

[3]Figure 1 depicts oil and gas production per million people in 2014 using FMS's replication data. This map is slightly different than Figure 2 of FMS which describes aggregate production from 2004 to 2012.

[4]Spatial lags are commonly used to estimate propagation effects, see for example Anselin (2013).

FMS's replication data accessed through the American Economic Review's website and document significantly reduced propagation effects. Whereas FMS estimate that one million dollars of energy production generates \$98,051 of own-county income, and \$446,155 of income within 100 miles, we estimate these numbers as \$73,536 and \$277,422, respectively.[5] Additionally, FMS estimate that "wage income" and "IRS other income"[6] disperse up to 100 miles, and 200 miles away from production, respectively. We document more modest propagation effects within the range of 60-80 miles for both types of income. Constraining our analysis to non-oil-producing counties suggests that the dispersion effects are even more limited, and largely constrained to contiguous counties.

## 2 Feyrer, Mansur and Sacerdote (2017)

Before turning to our identification strategy and results, this section describes FMS's strategy and results in more detail. Contrasting our results from theirs helps to highlight the importance of conditioning the effect of own-county production on nearby production. FMS start by estimating the effect of own-county energy production on own-county income and employment for the years 2005-2012 by estimating equation (1) below:

$$\Delta Y_{i,t} = \beta_1 \times NewValue_{i,t} + \beta_2 \times NewValue_{i,t-1} + \alpha_i + \omega_t + \epsilon_{i,t}, \tag{1}$$

[5]These estimates are from OLS. FMS address the concern of endogenous energy production by instrumenting oil and gas production with geologic formations. However, instrumentation does not change their broad conclusions, and the extension of their analysis offered here applies to both OLS and IV estimation strategies. We therefore focus our attention at FMS's baseline, OLS results.

[6]"IRS other income" is the difference between adjusted gross income (AGI) and other categories including dividends, interest, and capital gains. FMS posit that this measure of income captures oil and gas royalties to landholders.

where $\Delta Y_{i,t}$ is the one-year change in annual income or employment in county $i$ in year $t$, and $NewValue_{i,t}$ is the value of oil and natural gas produced by wells that started producing in year $t$. Both dependent and independent variables are scaled by the one-year lag of employment. Assuming that the error term, $\epsilon_{i,t}$ is independently distributed, $\beta_1$ is an unbiased estimate of the effect of new oil and gas production.

To gauge the extent of spatial spillovers, FMS incrementally aggregate to larger geographic areas around each county. Spatial aggregation involves summing additional wage income, employment, and energy production. The estimated effect of a unit of energy production increases in response to spatial aggregation, and according to FMS, this "shows the geographic propagation of income and employment as we get farther from the sources of the new production" (pg. 1321).

Panels (a) and (b) of Figure 2 give FMS's baseline OLS results for wage and IRS other income. The aggregation level is measured on the horizontal axis, and the effect of one million dollars of energy production per capita is measured on the vertical axis. These results indicate that one million dollars of own-county energy production generates \$33,956 of wage income and \$64,093 of IRS other income. Up to a radius of forty miles from the county centroid, spatial aggregation leaves the treatment effect for both types of income unchanged. Further aggregation causes treatment effects for both types of income to rise considerably. Whereas the treatment effect for wage income plateaus at a one-hundred mile radius, that for IRS other income continues to rise monotonically out to 200 miles. Spatially aggregating to 100 miles, the treatment effects for wage and IRS other income are \$221,153 and \$225,001, respectively. Following FMS's interpretation, this implies that just (\$33,956+\$64,093)/(\$221,153+\$225,001)≈

22% of the income generated within one-hundred miles remains in the county of production, which highlights the importance of considering spatial spillovers when estimating the economic impact of energy production.

Interestingly, aggregation does not immediately cause the treatment effects to rise. FMS hypothesize that this is because “Between 0 and 50 miles, very few adjacent counties are being included. As we move from 50 to 100 miles, production in adjacent counties becomes significant and the coefficients rise”. (page 1325) While this is true at a 20-mile radius, aggregating to a forty-mile radius captures 7 neighboring counties on average. This is shown in Figure 1, which depicts 20 to 200 mile radii drawn around Montague County, Texas. It is therefore surprising that aggregating to a 40-mile radius leaves FMS's estimated treatment effect unchanged, as one would expect counties adjacent to energy-production to capture the majority of any spillovers.

FMS's results further suggest that some distant economic shocks are more effective at raising local income than are local shocks. This point is highlighted by examining the change in FMS's baseline estimated treatment effects (panels (c) and (d) of Figure 2). The wage effect of energy production 80-100 miles away is estimated to be more than two times *larger* than the effect of own-county production. There is no obvious explanation for why dispersion effects 60 and 80 miles away are so much larger than other distance bands, in particular for 40 miles away. Growth in the treatment effect for IRS other income is similarly erratic, peaking at both a radius of 80 miles and 200 miles.

FMS conclude from their results that the dispersion of wage income is limited to within 100 miles of production, and that IRS other income (which includes royalty payments) is more dispersed.[7] But as FMS point out, spatial aggregation captures additional energy production. The fact that hydrocarbon-producing counties tend to be clustered together (as shown in Figure 1) induces a positive correlation between the production variable of interest and the error term in Equation (1) in the presence of spatial income spillovers from surrounding counties. As mentioned earlier, even clusters of counties face both inward and outward spillovers, and the relative magnitude of each naturally varies in response to spatial aggregation, and variation in the estimated treatment effects in response to aggregation reflects this. In the next section we discuss an alternative estimation strategy that conditions on inward spillovers and allows for a more precise estimate of the dispersion of economic shocks.

# 3 Identification Strategy & Results

## 3.1 Identification Strategy

To estimate the conditional effects of distant energy production, we start by using FMS's replication data to find production and income in concentric 20-mile wide doughnuts around all U.S. counties. We then estimate the effect of own-county production, conditional on energy

[7]Absentee resource ownership dilutes the distribution of royalty payments and one may expect, then, that the economic effects of royalty payments are relatively dispersed as well (Brown, Fitzgerald, Weber, 2016).

production within each doughnut.[8] We specifically estimate the following:

$$\Delta Y_{i,t} = \sum_{d=1}^{d=10} [\gamma_d \times \Delta NewValue_{d,i,t} + \lambda_d \Delta NewValue_{d,i,t-1}] + \alpha_i + \omega_t + \epsilon_{i,t}, \tag{2}$$

where $\Delta Y_{i,t}$ is the one-year change in annual income or employment in county $i$ in year $t$, $NewValue_{d,i,t}$ is new hydrocarbon production in distance band $d$ away from county $i$, $\alpha_i$ are county fixed effects, and $\omega_t$ are year fixed effects. Similar to FMS, all dependent and independent variables are scaled by the one-year lag of employment in county $i$.[9] $d = 1$ corresponds to county $i$ production, $d = 2$ corresponds to a doughnut with an exterior radius of 40 miles (but not including county i),[10] $d = 3$ corresponds to a doughnut with an interior radius of 40 miles and an exterior one of 60 miles, and so on in 20 mile increments up to an exterior radius of 200 miles. Controlling for neighboring energy production, and hence inward spillovers, the effect of own-county production is captured by $\gamma_1$. The income effect of production within a 40 mile radius is given by $\gamma_2$, the income effect of production between 40 and 60 miles away is given by $\gamma_3$, and so on. Similar to FMS, the one-year lag of oil production within each doughnut is added as a control, and standard errors are two-way

[8] This strategy is similar to that used by Richter, Salanguit, and James (2018) who examine propagation effects of the Bakken oil boom. Weinstein, Partridge, and Alexandra (2017) also include a spatial lag for contiguous counties in their analysis of the fracking boom and identify significant spillovers. Other papers examining energy booms have acknowledged that spatial spillovers may exist, and address this by dropping contiguous counties from their set of controls (e.g., Black, McKinnish, Sanders (2005); Weber (2012); Michaels (2011)).

[9] Scaling the dependent variable by own-county employment while scaling doughnut energy production by doughnut employment raises concerns of scaling bias. Consider, for example, if the effect of distant oil production did not depend on distant population levels. In this case, the estimated effect of distant oil production per capita would be biased upward for doughnuts with a large population. We also estimate equation (2) without any scaling. These results are sensitive to outliers created by especially high-population counties, but after removing a small number of outliers we find similar results to those found when scaling by employment. These results are available upon request.

[10] We start with a radius of 40 miles because very few counties are included in doughnuts of only 20 miles. For the majority of observations zero counties would be included.

clustered by county and year.[11]

### 3.2 Results

The results from the estimation of equation (2) are given in panels (a) and (b) of Figure 3. Conditional on nearby energy production, one million dollars of own-county production per capita is estimated to generate \$24,875 of wage income and \$48,661 of IRS other income per capita. These respective effects are roughly 27% and and 24% smaller than those estimated by FMS.

Turning to propagation effects, the coefficient for the 40-mile distance implies that one million dollars of energy production occurring between 0 and 40 miles away (not including own-county production) causes an additional \$5,561 of wage income per capita in a given county. This drops to \$1,158 for production 40-60 miles away. Effects from further distances are statistically insignificant (though the effect at 80 miles is significant at the 10% level). For IRS other income, which is a higher variance outcome variable, propagation effects drop precipitously and are only statistically significant for the 40-60 mile distance band.

However, these results are not directly comparable to FMS's results from Figure 2. Whereas FMS purport to measure total outward spillovers to multiple counties within a given distance of a producing county, our specification captures inward spillovers to a single county from multiple producing counties at a given distance. For example, suppose there are $N$ counties making up an $n \times n$ county grid. The center county, county $i$, is the only energy producer and

[11] FMS also estimate Conley (1999) spatially adjusted standard errors. However, because this adjustment is only available for OLS, and because it generally yields smaller standard errors, FMS estimate two-way clustered standard errors throughout their analysis.

the immediately adjacent eight counties comprise region $j$. For expositional purposes, suppose that each county has a population of one. Further suppose that county $i$ produces one unit of energy, and that this generates one additional dollar of income for county $i$, and one additional dollar of income to region $j$ (one eighth of a dollar goes to each county). In this particular scenario, FMS's methodology yields unbiased estimates. A county-level analysis would reveal that a unit of own-county production generates one dollar of additional own-county income. Aggregating to include the eight surrounding counties captures the spillovers and the total estimated effect of a unit of oil production increases to two dollars. Note that the change in the estimated effect of county $i$ production when aggregating to include the eight surrounding counties reveals the income generated in region $j$ by energy produced in county $i$.

Now consider our methodology. We propose estimating the effect of energy produced in multi-county region $j$ on income earned in county $i$. Suppose now that a single county in region $j$ produces a unit of oil, and that all other counties are non producers. Continue to assume that the population of each county is one and that the pattern of spatial spillovers is the same as before. Our specification would indicate that one unit of energy produced in region $j$ (the doughnut around county $i$) generates 1/8 of an additional dollar of income in county $i$. But this effect is experienced by all eight counties surrounding the producing county. Therefore, to estimate total outward spillovers from a unit of production in a given county in a way that is directly comparable to FMS, we multiply our spillover effect estimates from equation (2) by the average sample population of each respective doughnut relative to the average U.S. county population (this is roughly equivalent to simply multiplying our estimated effects by the average number of counties in a given doughnut). This yields an estimate of total propagation from one million dollars of production to a given distance bin, which can then be compared to the FMS estimates shown in Figure 2.

The resulting estimates for total propagation within each distance band resulting from one million dollars of energy production are given in panels (c) and (d) of Figure 3 (note that the own-county effects are the same as those shown in panels (a) and (b)). Starting with the results for wage income, the estimated total propagation between 0-40 miles is $40,350. It may appear surprising that the propagation between 0-40 miles is higher than own-county effects. But recall that this is total wage income generated in a much larger area (7 counties on average) that is still close to the source of production. The per capita effect between 0-40 miles is still almost five times smaller than own-county production (from panel (a)). Total propagation falls consistently after 40 miles until fluctuating close to zero after 80 miles (and recall that per-capita effects are statistically insignificant after 60 miles). Panel (e) of Figure 3 gives the cumulative effects of those depicted in panel (c) of the same figure. Note that this cumulative effect increases immediately due to aggregation and is concave, implying that production occurring farther away has smaller effects on wage income than local production. We estimate that, within a one-hundred mile radius of extraction, one million dollars of energy production per capita generates $93,698 of wage income per capita (compared to FMS's estimate of $221,153).

Turning to the results for IRS other income, the total propagation estimates are given in panel (d) of Figure 3. Up to a distance of 140 miles, propagation falls monotonically. Propagation appears to spike at a distance of 140 miles. This occurs because the per-capita regression estimate at this distance does see a slight jump, as seen in panel (b), and this estimate is then multiplied by the average population in the 140-160 distance band, which covers a very large area. However, the per capita estimate is not statistically different from zero. Additionally, the IRS other income variable is considerably more volatile than the wage variable and includes much larger extreme values, making this result sensitive to the inclusion of these outliers. For example, omitting observations with new IRS other income per capita absolute values of less than $100,000, which drops only 12 observations, causes the estimated total propagation between 140-160 miles to drop from $47,330 to $22,158. Examining panel (f) shows that, consistent with the findings of FMS, the cumulative effect on IRS other income non-monotonically increases to a distance of 200 miles (but again, the treatment effects at large distances are sensitive to the inclusion of outliers). At a distance of 100 miles, cumulative propagation is $183,724 (compared to FMS's estimate of $225,002).

Perhaps the starkest contrast is for total propagation effects from 60-80 miles from production. Whereas FMS find that total wage propagation 60-80 miles from production is roughly 2.4 times larger than that for own-county production ($83,833 relative to $33,956), our results suggest the opposite is true. Namely, the estimated wage effect of production 60-80 miles away ($11,607) is less than half as large as that for own county production ($24,875). A similar but smaller contrast holds for IRS other income at 60-80 miles. More generally, dispersion of the economic effects of energy production depicted in Figure 3 largely fits with the intuition that the effects of an economic shock are systematically reduced with distance.

Taken together, we estimate reduced income effects of both local and distant energy production. We specifically estimate that one million dollars of energy production generates $24,875+$48,661 = $73,536 of total income per capita in the producing county, which is just

75% of FMS's estimate of \$98,051. This suggests that conditioning own-county production on neighboring production reduces estimated treatment effects for income by roughly 25%. One million dollars of energy production is also estimated to generate \$93,698 + \$183,724 = \$277,422 of total income per capita within 100 miles, which is just 62% of FMS's estimate of \$446,155. Similar to FMS, we document significant propagation effects, but only up to a distance of 60-80 miles, compared to FMS's estimates of up to 100 (wage) or 200 miles (IRS other income).

# 4 Additional Findings

## 4.1 Oil & Gas Specific Results

Considering that the production and transportation process for gas differs from that for oil (oil tends to be shipped by pipeline and gas tends to be shipped by truck or rail, for example), FMS estimate the unique wage income effect of oil and natural gas production separately. Their oil-specific OLS results are given in panel (a) of Figure 4 and are quite similar to their baseline set of results. Aggregation initially leaves the estimated treatment effect for oil unchanged. Beyond a radius of 40 miles, the treatment effect rises and peaks at a distance of one-hundred miles. But propagation effects from natural gas production are quite different from those for oil. The treatment effect nearly consistently rises in response to aggregation up to a radius of 200 miles. By FMS's interpretation, this implies that wage income resulting from natural-gas production reaches counties up to 200 miles away, and perhaps beyond.

Panels (a) and (b) of Figure 5 give our baseline hydrocarbon-type-specific set of results for wage income. Panels (c) and (d) give the estimated total propagation by distance bin, and panels (e) and (f) give the cumulative results. Starting with the oil-specific results in panel (a), the standard errors are larger than in the baseline estimation, rendering even the own-county results insignificant. The results are nonetheless consistent with some limited spatial propagation. As for the results for natural gas in panel (b), the effect of own-county production is positive and significant, and there is evidence of minimal (statistically insignificant) wage propagation.

Turning to panels (c) and (d), relative to FMS, we identify significantly smaller total dispersion effects for both types of production. Whereas FMS estimate that one million dollars of oil (gas) production generates $29,000 ($39,000) dollars of local income, we estimate that it produces $22,000 ($31,000) of own-county wage income. Within 100 miles, FMS find that one million dollars of oil (gas) production generates $240,000 ($218,000) dollars of wage income whereas we find it produces just $100,000 ($106,000) of wage income, respectively. In starker contrast, we find no extra wage income propagated beyond 100 miles, whereas FMS finds significant dispersion effects all the way out to 200 miles (for natural gas), totaling $518,000 in added wage income altogether.

## 4.2 Non-Oil Producing Counties

The fact that most energy-producing counties are close to other producing counties poses a further difficulty in estimating propagation effects. To isolate the effect of propagation, it is required that own-production is correctly controlled for. The assumption in our main specification (and in FMS) is that per capita income growth is a linear function of new production per capita, which is reasonable but still imposes fairly strong assumptions on the functional form. If the effect of own-county production is misspecified, this will impact the propagation estimates as well, and propagation estimates could simply reflect effects of own production not correctly captured by the specification, even in the absence of any true propagation effects. Therefore a "purer" test of propagation is to estimate equation (1) while restricting the sample to observations with no new own-county oil or gas production.

The results of this analysis are shown in Figure 6 in panels (a) and (b). There is no coefficient for own-county production in this case, so results begin with the effects of production 0-40 miles away. For easy comparison with our baseline results, in panels (c) and (d) we show the same results from Figure 3, but with the own-county effect estimates removed. The wage propagation effects are broadly similar when excluding producing counties, with nearly identical estimates for 0-40 miles. However, effects decrease with distance more rapidly and are insignificant after 40 miles for the non-producing sample. IRS other income propagation estimates, while also broadly similar, are insignificant for all distances for the non-producing sample.

# 5 Conclusion

The localized economic effect of the recent shale-energy boom has been well studied. Feyrer, Mansur and Sacerdote (2017) (FMS) filled a key gap in this literature by considering the spatial dispersion of these economic shocks. Their identification strategy consists of drawing concentric circles around oil and gas-producing counties, and aggregating up in 20 mile intervals to a radius of 200 miles. Spatial aggregation causes the estimated effect of oil production on income to grow, which is interpreted as evidence of spatial propagation. However, because energy-producing counties tend to be located near each other, producing counties experience inward economic spillovers from their producing neighbors. By not controlling for nearby production, the estimated effect of local production on local income is overestimated. Spatial aggregation does not solve this problem as even clusters of energy-producing counties tend to be located near additional energy production.

We propose an alternative estimation strategy that conditions the effect of own-county energy production on distant production. This effectively controls for inward spillovers and allows us to more precisely gauge the spatial dispersion of economic shocks originating from energy extraction. Whereas FMS find that one million dollars of energy production generates $446,155 of additional income within one-hundred miles, we estimate this number as $277,422. We also identify smaller propagation effects that are systematically diminished by distance from the point of extraction. FMS find that wage and IRS other income disperses up to 100 and 200 miles away, respectively. In contrast, we find that the dispersion of both types of income is limited to a distance of 60-80 miles. Constraining our analysis to non-energy-producing counties suggests that the dispersion of economic shocks is even more limited, and largely constrained to counties immediately adjacent to economic shocks. More generally, our analysis and methodology help to inform proper identification of the effects of multiple, simultaneously occurring economic shocks in the presence of spatial spillovers.

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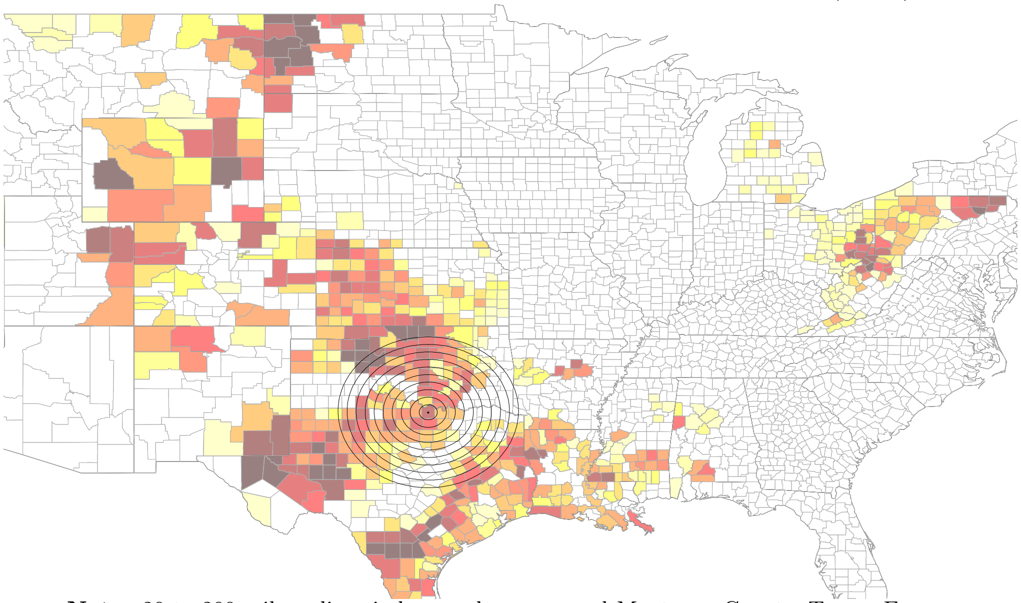
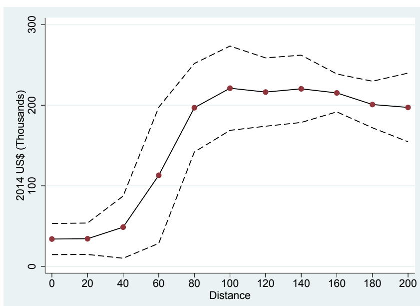
# 7 Tables and Figures

Figure 1: Spatial Distribution of Energy Production (2014)

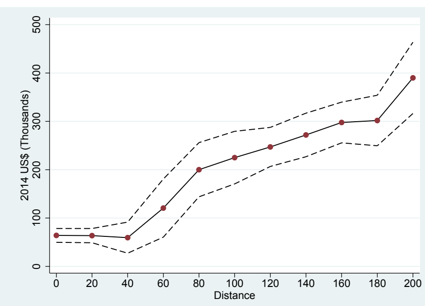


**Note.** 20 to 200 mile radius circles are drawn around Montague County, Texas. Energy production data was taken directly from FMS and reflect production in the year 2014 only. The value of production is measured per million people.

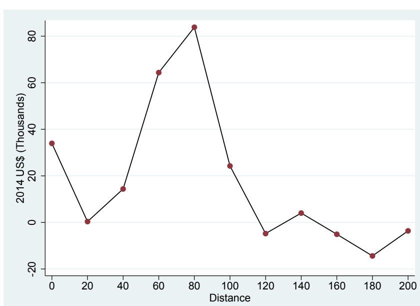
Figure 2: FMS OLS Propagation Estimates



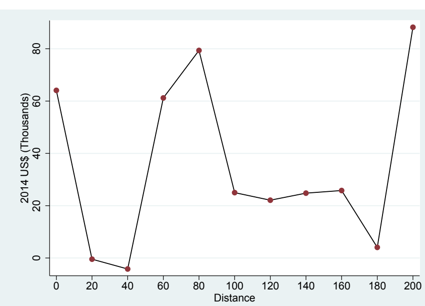

(a) Wage Income




(b) IRS Other Income



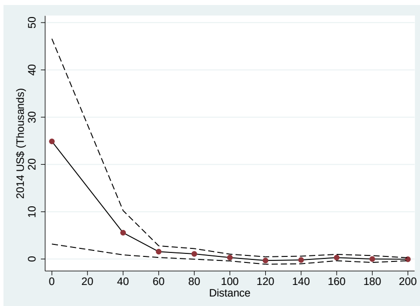

(c) Wage Income (Differenced)



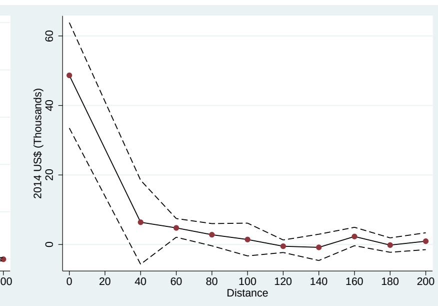

(d) IRS Other Income (Differenced)

**Note:** Panels (a) and (b) gives FMS's estimates of the effect of one million dollars of energy production per capita on either wage income, or IRS other income, respectively. Panels (c) and (d) describe the change in the estimated treatment effect resulting from aggregation. 5% confidence intervals are given.

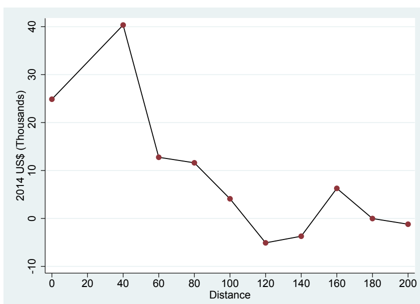
Figure 3: New Estimated Propagation Effects



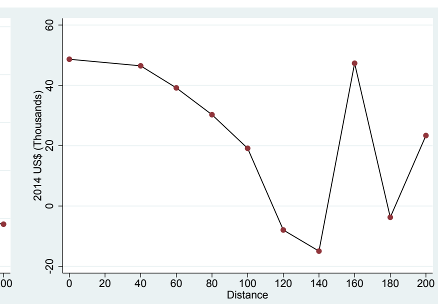

(a) Wage Income



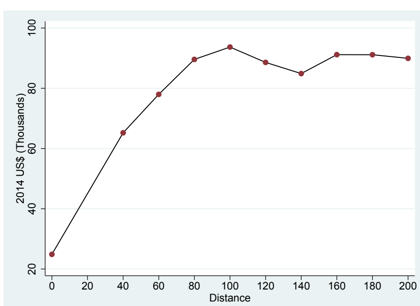

(b) IRS Other Income



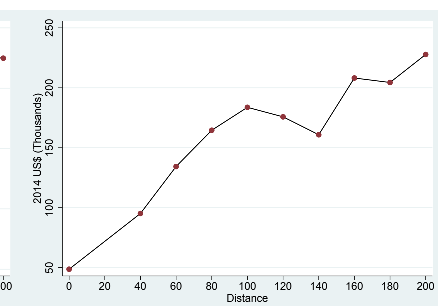

(c) Wage Income (Re-scaled)




(d) IRS Other Income (Re-scaled)



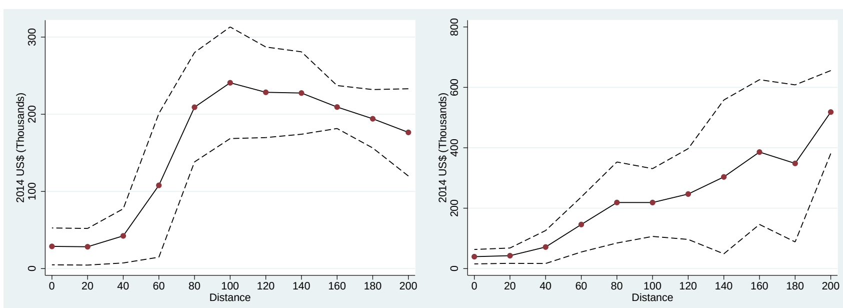

(e) Wage Income (Cumulative)




(f) IRS Other Income (Cumulative)

**Note:** Panels (a) and (b) give the baseline estimated treatment effects from equation (2). For panel (a) the corresponding sample size is 21,546 and the associated $R^2 = .309$. For panel (b), the corresponding sample size is 21,546, and the associated $R^2 = .138$. 5% confidence intervals are given. Panels (c) and (d) gives these treatment effects after being re-scaled by the ratio of average doughnut employment to average county employment. Panels (e) and (f) give the cumulative re-scaled treatment effects.

Figure 4: FMS Wage Income: Oil & Gas-Specific Results

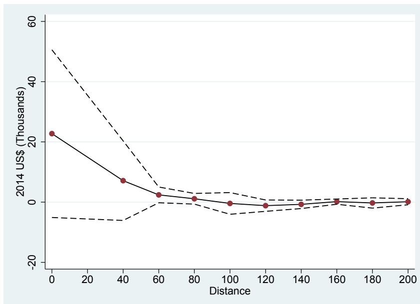



(a) Oil

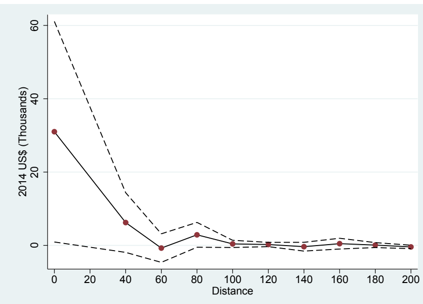
(b) Gas

**Note:** Panel (a) gives FMS's estimated results for oil production only. Panel (b) gives those for natural gas production only.

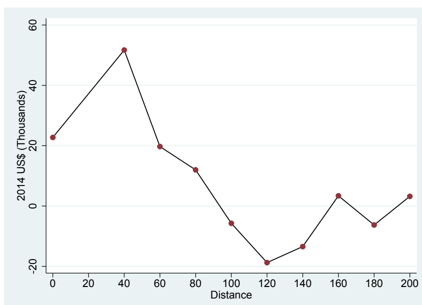
Figure 5: Wage Income: Oil & Gas-Specific Results



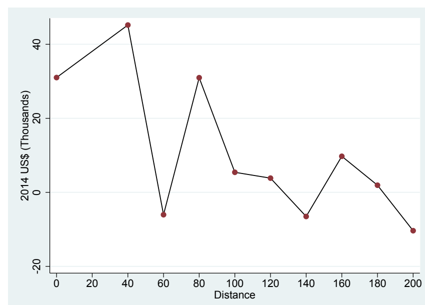

(a) Baseline Results: Oil



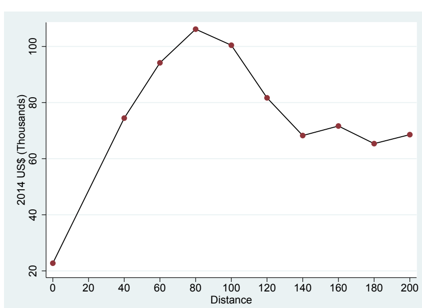

(b) Baseline Results: Gas



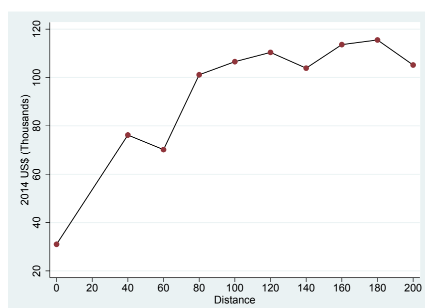

(c) Baseline (Scaled): Oil




(d) Baseline (Scaled): Gas




(e) Cumulative: Oil




(f) Cumulative: Gas

**Note:** Panels (a) and (b) give the results of estimating equation (2) for oil and gas production separately. For panel (a), the corresponding sample size is 21,546 and the associated $R^2 = .305$. For panel (b), the corresponding sample size is 21,546, and the associated $R^2 = .278$. Panels (e) and (f) give the cumulative scaled results. 5% confidence intervals are given. Panels (c) and (d) give the baseline results, scaled by the average population of each respective doughnut relative to the average county population size.

Figure 6: Propagation, Non-Producing Counties


(a) Wage Income

(b) IRS Other Income

(c) Wage Income (Baseline)

(d) IRS Other Income (Baseline)

**Note:** Panels (a) and (b) give the results of estimating equation (2) for non-energy producing counties only. For panel (a) the corresponding sample size is 16,031 and the associated $R^2 = .214$. For panel (b), the corresponding sample size is 16,031, and the associated $R^2 = .107$. For comparison purposes, panels (c) and (d) give the baseline set of results omitting the treatment effect for own county production. 5% confidence intervals are given.