An Economic Impact Analysis of Oil and Natural Gas Development in the Permian Basin

Wang, Haoying

New Mexico Tech

25 September 2018

An Economic Impact Analysis of Oil and Natural Gas Development in the Permian Basin

Haoying Wang

Department of Business and Technology Management
New Mexico Tech

Abstract:

This study analyzes the economic impact of oil and natural gas development in the Permian Basin with a focus on the NM part of the Basin. The analysis looks at the impacts on state revenue, local employment and income levels. Several existing economic impact reports from other states have been criticized by the peer-review literature that the impact estimates are very likely overstated due to questionable methodologies. In this analysis, a panel data regression model with county fixed effects and year effects is deployed to identify the impact of oil and natural gas production on employment and per job annual income at the county level. The analysis covers 62 counties (12 counties in NM and 50 counties in TX) for the time period of 1998 – 2016. The main findings of the analysis can be summarized as:

1. Over the last decade, according to different estimates the state revenue generated by the oil and natural gas industries in NM has been consistently exceeding one billion dollars per year. In the meantime, a large amount of intensive direct investment has been capitalized into the southeast NM.
2. In aggregate, per job annual income (in the real term) and the number of jobs have both experienced significant growth in the last two decades of active oil and natural gas development in the region. It is reasonable to speculate that much of the growth can be attributed to the ongoing energy development.
3. It is estimated that on average additional one million BBLs of oil equivalent production brings 54 jobs and about $170 (2015 dollar) extra annual income per job (or a 0.5% increase) in the county of production.
4. The intensive oil and natural gas production around the center of the basin (Lea County and Eddy County in NM) have had significant spatial spillover effects to the surrounding counties. Depending on the distance from the given county to the center of the Basin and for additional one million BBLs of oil equivalent production, the employment effect ranges from 35 to 10 jobs and the income effect ranges from $170 to $90 (2015 dollar) extra annual income per job.

The paper also provides details on methodology and guidelines on how to interpret estimation results. The estimated economic impact coefficients can be used for prediction purpose with available future production scenarios. The paper includes instructions and suggestions on how the prediction may proceed.

Keywords: Oil and Natural Gas, Permian Basin, Economic Impact, New Mexico

1. Overview

The oil and natural gas industries have been important to the state and local economies in New Mexico, both historically and contemporarily. The energy development in the San Juan Basin and the Permian Basin can be traced back to the 1930s (Graeser, 2002). According to the New Mexico State Oil Conservation Division, the natural gas production in the San Juan Basin peaked in the late 1990s. Since then, the production in the San Juan Basin has been declining. The oil production in the Permian Basin started growing quickly after 2007. In 2011, the oil production capacity in the Permian Basin reached one million BBLs per day. The production has been steadily increasing since then. Currently, the Permian Basin is one of the most productive areas in the US. Based on a recent update from the state land commissioner, New Mexico's Permian Basin has an estimated 50-year oil supply (Schneider, 2018).

Given such an unconventional shock to the regional economy, a thorough understanding of its economic impacts is important to state and local policymakers whose goal is often to promote long-term economic prosperity by taking the advantage of the energy 'boom' in the Permian Basin. According to the most recent ranking by the US Energy Information Administration (EIA) in 2018, New Mexico crude oil production ranked the third in the country. New Mexico natural gas production ranked the ninth in the country. The oil and natural gas industries account for nearly one-third of all state funding, most of which is used to support public education and health care (Flynn, 2017). The economic impact of the oil and natural gas industries in New Mexico is not limited to enhancing the state funding. The impact on local employment and income is also very significant.

This analysis focuses on three aspects of the economic impact: state revenue, employment (number of jobs), and income level. The analysis of state revenue impact is mostly based on compiling other existing estimates as the relevant data is very scattered. The analysis of employment and income impacts is rigorously based on a panel data regression model with county fixed effects and year effects. Towards the end, this paper also discusses how one may use the estimated impact coefficients to predict economic impacts based on projections on future production scenarios.

2. State Revenue Impact

In general, when the oil and natural gas industries are active, the state and its governments where the activities occur collect a significant amount of revenue through different channels. According to RegionTrack (2018) who did an estimate on the total tax payments for 16 major energy states in the US, the total oil and natural gas related tax payments was $1,146.3 million in New Mexico for FY2016. More recently, according to Robinson-Avila (2018) from the Albuquerque Journal, the online auction of oil and natural gas lease sale administered by the US BLM (Bureau of Land Management) generated $972.8 million in bonus bids for 142 parcels in Eddy, Lea and Chaves counties in early September 2018, which sets a historical high for all BLM lease sales across the nation. About $467 million from the lease sale goes to the state fund because 48 percent of the revenue from such lease auctions goes to the state where the oil and natural gas activity occurs under current practice (Robinson-Avila, 2018).

The revenue to the state of New Mexico in general consists of severance taxes, rents, bonuses, and royalty payments. The revenue is distributed among the following entities and funds: oil and gas reclamation fund, other state land beneficiaries, local governments, land grant permanent fund, severance tax bonding/permanent fund, and general fund (Iglesias, 2018). As pointed out by Iglesias (2018), who is an economist for the state Legislative Finance Committee (LFC), the accurate tax revenue data for the New Mexico oil and natural gas industries is difficult to compile. One of the main reasons is that the effective tax rate that applies to the value of production tends to be difficult to estimate.

Based on the statistical data provided in Iglesias (2018), from FY2007 to FY2017, the annual state revenue from the oil and natural gas industries has always been around or above $1.5 billion. In 2014, the revenue reached a record high of $2.6 billion. In the most recent fiscal year 2017, the total revenue is about $1.9 billion. According to Iglesias (2018), most of this revenue comes from three major sources: school taxes, severance taxes, and state land office rents, bonuses & royalties. At the same time, the oil and natural gas industries also generate a considerable amount of revenue for the federal government. On average, about one-third of the total government revenue generated goes to the federal government through federal land rents, bonuses, and royalties. For example, in the recent auction sale of oil and natural gas leases, the rest 52% (or about $500 million) goes to the US Treasury Department.

Another important aspect related to the impact on state revenue is the amount of direct investment. The direct investment essentially determines the level of potential state revenue in the future, assuming that other factors such as market conditions and taxation policy are stable. In this context, direct investment can be defined as the investment originated from other states (e.g. TX, OK, and WY), as well as from other countries (e.g. Canada). These investments get capitalized into equity in the state of New Mexico, which can generate tax revenue directly through the oil and natural gas industries and further indirectly through other related industries due to spillover effects. Compared to other revenues that are estimated based on the value of production, the direct investment is much more difficult to estimate. One way to estimate is through decomposing the cost of drilling and completing an oil or natural gas well. In the Permian Basin (the Wolfcamp Shale in particular), a relatively conservative estimate of the cost is somewhere between three to five million dollars[1]. According to a recent report by the US EIA (2016), the total onshore capital costs per well range from $4.9 million to $8.3 million, which usually covers land acquisition, capitalized drilling, completion and facilities costs, lease operating expenses, and gathering processing and transport costs. The completion cost generally ranges from $2.9 million to 5.6 million. Merva (2017) gives a slightly higher estimate of the total cost, ranging from $5.0 million to $9.3 million.

By breaking down the total cost, casing and cement costs in the drilling stage and most of the completion and facilities costs can be considered as the direct investment, which is roughly half of the total cost in a typical Permian Basin well spending breakdown (US EIA, 2016). Therefore, the direct investment related to an oil well in the Permian Basin is somewhere in the range of $2.5 to $4 million. Note that here equipment related costs (i.e. rig related costs, hydraulic fracture pump related costs) are not counted. According to the US EIA data from the Drilling Productivity Reports[2], 3971 wells were completed in the Permian Basin in 2017. Even with a conservative estimate, the associated direct investment is around $10 billion. From 2014 to 2016, 2702, 4026, 7203 wells were completed according to the same data, respectively. As stated in a market forecast report by IHS Markit, the Permian Basin will drill another 41,000 new wells and invest $308 billion through 2023[3].

To see how an investment at this scale could benefit the state of New Mexico, we proceed with the following back-of-the-envelope calculation. According to the well statistics database from the New Mexico Oil Conservation Division[4], 1283 wells were completed in the New Mexico part of the Permian Basin in 2014. With a direct investment ranging between $2.5 to $4 million per well, this translates to a total new investment in the range of $3.2 to $5.1 billion. Considering that most of the production activities concentrate within two counties (Lea and Eddy), this is a highly intensive direct investment. By 2017, the drilling activities slowed down with 532 wells completed according to the same data source, which translates to a total new direct investment in the range of $1.3 to $2.1 billion. Because of the cumulative effect of investments over time, the revenue impact of the direct investments over time can be considerably large. In the next section, the local employment and income impacts of the oil and natural gas development in the Permian Basin will be analyzed.

---

[1] The estimate is based on personal communications with NMT PRRC staff who have rich field experiences.

[2] https://www.eia.gov/petroleum/drilling/, accessed Sep 12, 2018.

[3] https://www.cnbc.com/2018/06/13/permian-will-soon-pump-enough-oil-to-be-opecs-2nd-biggest-producer.html, accessed Sep 12, 2018.

[4] http://www.emnrd.state.nm.us/OCD/statistics.html, accessed Sep 12, 2018.

3. Employment and Income Impact

Two of the most important regional economic performance measures are employment and income levels. It is expected that the oil and natural gas development in the Permian Basin should bring a significant positive impact onto the local economies – high growth in jobs and income. Though it is often a different question whether the growth is sustainable or will just be short-lived, the initial economic impact that the energy development can bring at least provides an important opportunity for the local economies to revitalize. Such a growth opportunity is very important to regions like south and southeast New Mexico which have solely relied on irrigated agriculture traditionally. In this analysis, a long historical panel data is deployed to measure how large the long-term economic impacts can be through extrapolating the historical trend. We look into both the temporal trend and the spatial spillover effects. First, it is necessary to look at the direct employment impact of drilling activities. It is the stage where an intensive labor demand occurs.

According to Flynn (2017), every drilling rig accounts for between 50 and 75 high-paying direct jobs in the Permian Basin, on the top of other indirect and induced jobs. Flynn (2017)'s estimate is consistent with Agerton et al. (2017) which suggest that an additional rig count on average can create 31 jobs immediately and 315 jobs in the long run with a national dataset. As of February 2018, it was reported that there were 87 rigs operating in New Mexico, which is a significant increase from 48 rigs reported in early 2017 (Hedden, 2018). The numbers suggest that there are around 5,000 high-paying drilling jobs currently active in southeast New Mexico. The rig counts peaked in late 2014 according to both Hedden (2018) and EnergyEconomist.com[5], with over 500 rigs operating in the entire Permian Basin (New Mexico and Texas). Considering the low population density in the area, such a direct labor demand would certainly spill further over to other sectors and the neighboring areas. In the following sections, instead of focusing on the oil and natural gas industries only, we use panel data regression models to examine the overall economic impact of oil and natural gas industries to the region and its surrounding areas. The analysis focuses on counties in New Mexico and southwest Texas during the time period 1998 – 2016. The study period is chosen based on data availability.

The data used in the analysis is compiled from three sources: (1) county-level employment and payroll income data from US Census County Business Pattern database; (2) Texas county-level oil and natural gas production data from the Railroad Commission of Texas; (3) New Mexico county-level oil and natural gas production data from the Petroleum Recovery

[5] http://www.energyeconomist.com/a6257783p/exploration/detail/permian/Permian_Basin_Overview.html, accessed Sep 14, 2018.

Research Center (PRRC) at New Mexico Tech. In the production data, crude oil and natural gas are reported separately. Note that oil production volume includes crude oil and condensate; natural gas production volume includes natural gas and casinghead gas if not explicitly specified. In some cases, it is necessary to convert natural gas volume into oil equivalent barrels. This analysis uses the standard unit conversion factor recommended by the Society of Petroleum Engineers (SPE): one MCF natural gas = 0.1767 BBL oil[6]. All the variables that are measured in dollar amount have been converted to constant dollars (in 2015 USD) using the standard GDP deflator (from the US BEA) throughout the analysis.

The regression model being deployed can be simply represented in the following way:

$$economic\_measure_{it} = oil_{it} + basin\_oil_{it} + basin\_oil_{it} * distance_i^2 + county\_effect\ (\alpha_i) + year\_effect\ (\gamma_t) + \varepsilon_{it}$$

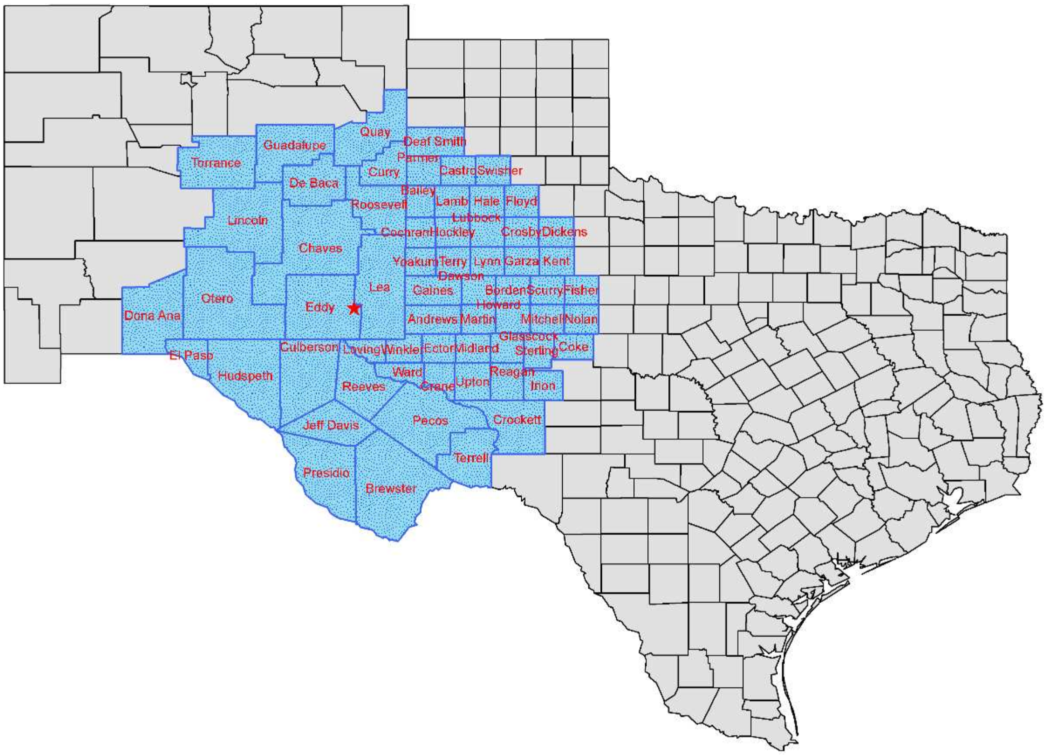
where $economic\_measure_{it}$ represents either number of jobs or per job annual income, with i indexing county and t indexing year. oil_{it} represents oil or oil equivalent production volume in the given county and year. $basin\_oil_{it}$ represents oil or oil equivalent production volume in the center of the Basin. In this analysis, the center of the Basin is defined as the area covering Lea County and Eddy County in New Mexico. It is the most productive and active area in the entire Basin currently. $distance_i$ is defined as the distance from the center of the Basin to the center of any given county. When computing the distance, coordinates [32.46403, -103.80788] are being used as the actual center of the Basin (see Figure 1), which is located somewhere between Lea County and Eddy County. $county\_effect\ (\alpha_i)$ represents time-invariant county fixed effects. $year\_effect\ (\gamma_t)$ represents time-varying temporal effects, which captures anything that is unique to a particular year (e.g. a shock to the whole regional economy). ε_{it} represents some unobserved random effects to the economic measure. The model can be estimated with many of the standard statistical packages (e.g. SAS, R, or STATA). The estimation details are available upon request.

One of the main features of the analysis is that the model allows for an interacting effect ($basin\_oil_{it} * distance_i^2$) between the oil production at the center of the Basin and the distance from the center of the Basin to counties. The interacting term helps to capture the spatial spillover effects which will be elaborated on later. In the following analysis, we consider a neighborhood of 200 miles from the center of the Basin. Figure 1 illustrates all the counties within the neighborhood in shaded blue. The study area consists of 62 counties. For counties beyond 200 miles, we believe that the spillover effects become very small. Another

---

[6] https://www.spe.org/industry/unit-conversion-factors.php, accessed Sep 14, 2018.

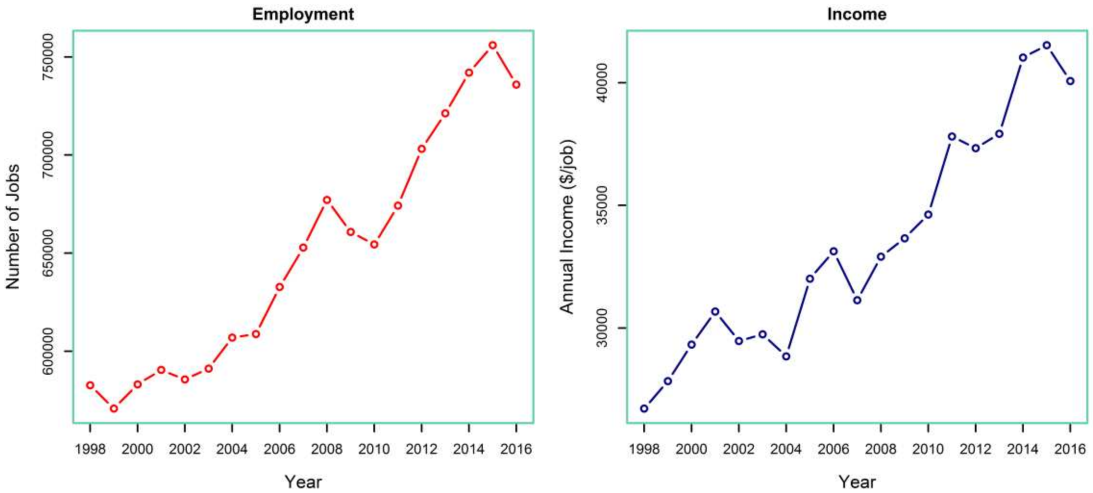
thing to note about the analysis is that we look at the overall county employment and income per job only. During an energy development boom, what usually happens is that employment tends to shift from other sectors (e.g. agriculture and services) to the energy production sector. Such an employment replacement effect can lead to false conclusions if the economic impact analysis focuses only on the direct employment effect occurred in the energy sector. The same thing applies when analyzing the income effect.



Note: (red) star indicates the center of the Basin as defined in this analysis.

Figure 1: County map of the study area

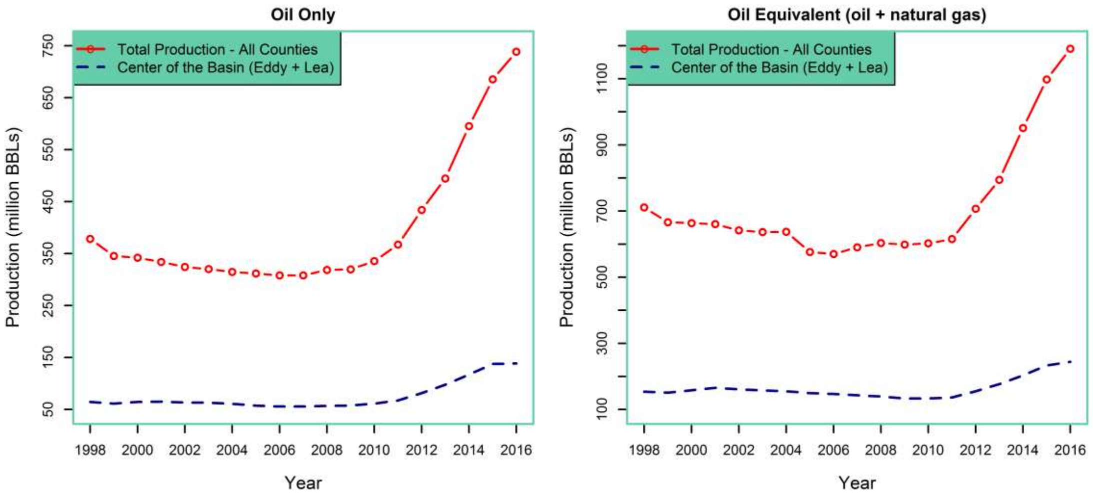
Figure 2 shows the increase in total employment and average annual income in the study area between 1998 and 2016. It indicates that the energy development in the region has been strongly associated with both the employment level trend and the income level trend. However, how much of the increases can be attributed to the oil and natural gas industries is an empirical question that warrants the analysis with the regression models. Figure 3 shows the total oil (and oil equivalent) production level in the region during the same time period. By comparing two sets of the graphs, it is very clear that there is a strong temporal association between the trends of the economic measures and the trends of the energy development. The production levels at the center of the Basin follow a similar trend as the total production in all counties. It is reasonable to expect that the energy production in the most productive area of the Basin has a significant spillover effect onto the surrounding economies (Feyrer et al., 2017).



Data source: computed from the US Census county business pattern database.

Note: income is measured in 2015 dollar.

Figure 2: Employment and income levels in the study area (1998 - 2016)

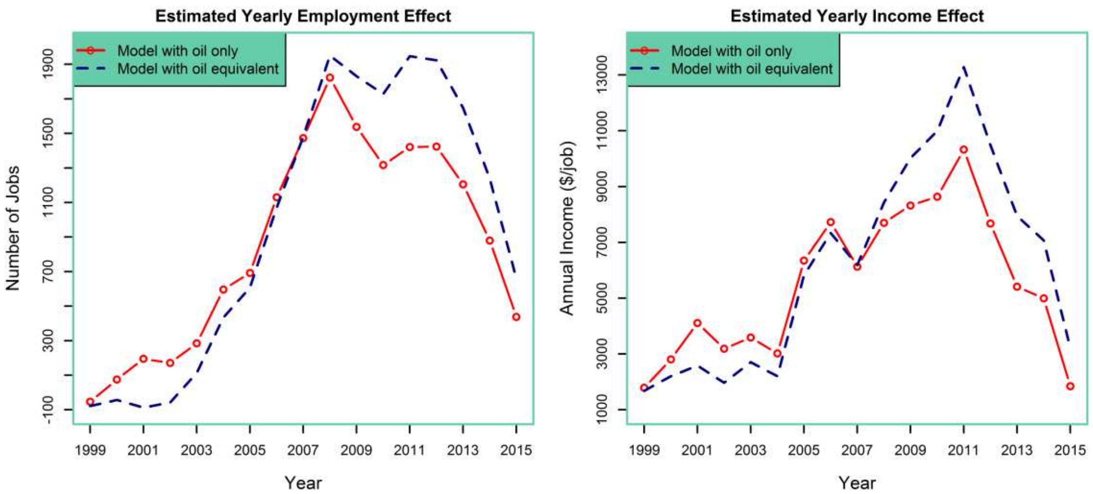


Data source: the Railroad Commission of Texas and PRRC at New Mexico Tech.

Figure 3: Total oil (and oil equivalent) production in the study area (1998 - 2016)

A simple correlation analysis between trends cannot give a concrete answer to the economic impact question that we are going after. We then rely on the regression model to decompose the impact while controlling for any spatial heterogeneities and macro-level temporal effects (uncorrelated with the energy development in the Basin). The coefficient estimates of the regression model are attached in the Appendix Table A1 for interested readers. First, we look at the temporal effects (estimates on the year effects) that give us an overall sense of how the employment and income levels change over time during the study period. All the year effects are relative to the 1998 level (the benchmark year) which is implicitly set to zero. In other words, the change of employment and income levels in the following years is considered as changes from the employment and income levels in 1998.

Figure 4 plots the estimated year effects from models for two different economic measures: employment (left) and income (right). For each model, two different oil measures are used: oil only and oil equivalent (including converted natural gas). The year effect estimates tell two things: (1) the change of employment and income levels due to macro-level changes in the economic environment (e.g. national policy change or exogenous shocks to the economic system); (2) any local impact on employment and income levels that is time-varying and not captured directly by the oil production related variables in the model. This uncaptured effect may include some indirect impacts through the oil and natural gas development that the regression model does not catch directly. Also, note that the model controls for county-specific time-invariant effects simultaneously. In other words, the model allows each county to have its own benchmark levels for employment and income. The year effects depicted here represent common impacts on employment and income in all counties and such impacts are at least region-wide.



Note: the income effect is measured in 2015 dollar.

Figure 4: Estimated average year effects of employment and income in the study area

Looking at Figure 4 and comparing with Figure 2 suggest that factors other than energy development in the region have been driving employment and income levels up first and then down, relative to the 1998 levels. The trends between employment and income are very similar to each other. Nevertheless, it should be pointed out that the employment effect peaked around 2008 while the income effect peaked later around 2011. The delay in income effect change suggests that income as an economic measure is less responsive to changes in economic conditions compared to the number of jobs.

While the model takes care of overall year effects and county specific fixed effects, the focus of the analysis should be identifying and interpreting the impacts of energy development on employment and income. As the results in Table A1 suggest, both models (with oil only and with oil equivalent) fit the historical data well. For the sake of completeness, we focus on the models with oil equivalent measures. In all models, the estimates of particular interest are the coefficients on variables *oil*, *basin oil*, and *basin oil*distance*^{2}. They are all statistically significant (at either 1% level or 5% level). In the employment model, an estimate of 0.0540 on *oil* indicates that on average every additional 1000 BBLs of oil equivalent production increases the total employment (across all sectors) by 0.0540 counts in a given county. In other words, every additional 18,519 BBLs of oil equivalent production can create one new job or every one million BBLs of oil equivalent production generates 54 jobs[7]. Note that this is an average impact across all years from 1998 to 2016 and for all counties. To get the impact for a particular county, the associated year effect and county fixed effect need to be taken into account. In the income model, an estimate of 0.1694 on *oil* indicates that on average every additional 1000 BBLs of oil equivalent production increases the average annual income (across all jobs) by $0.1694 (2015 dollar) in a given county. In other words, every additional one million BBLs of oil equivalent production can bump the average annual income by $169.4 (2015 dollar, or 0.5% of the average annual income level between 1998 and 2016). Similarly, this is an average impact across all years from 1998 to 2016 and for all counties. The associated year effect and county fixed effect need to be taken into account when analyzing a particular county.

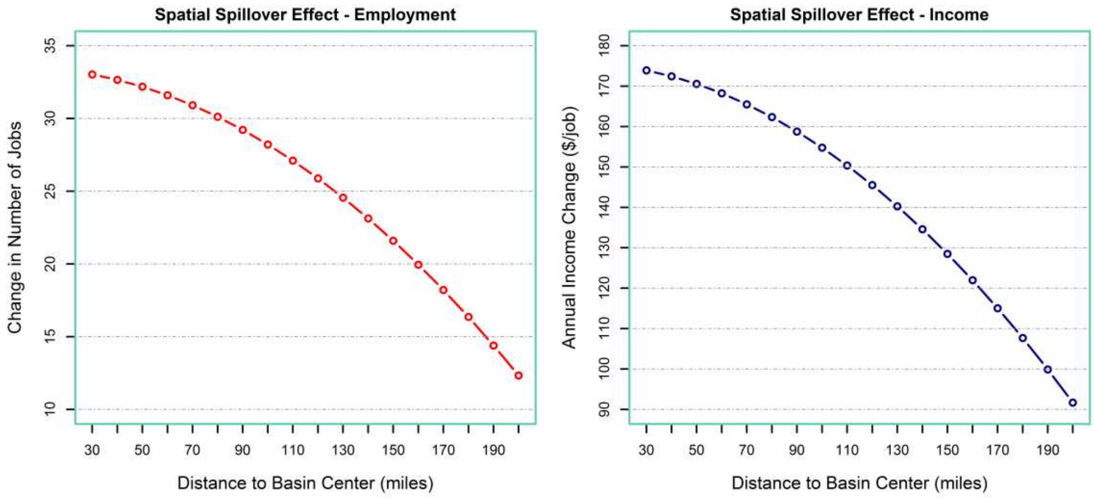
The extraction activities are not evenly distributed across the Basin. Some areas tend to have much more intensive extraction than other areas. In the recent years, one of the most intensively developed areas in the Basin is the area in Lea County and Eddy County (i.e. Bone Spring Play, Delaware Play, and Wolfcamp (Delaware) play). The area contains the nation's largest known concentration of potash reserves (Austin, 1980). It is expected that such an intensive development could have significant spillover effects onto the surrounding counties. To measure the spillover effects, the model includes *basin oil* and *basin oil*distance*^{2} to quantify the magnitude. The coefficient estimates should be interpreted in the following way: at a given distance from the center of the Basin, for every additional 1000 BBLs of oil equivalent production (at the center of the Basin) how much would employment and annual income change? In the employment model, for example, at the distance of 100 miles from the center of the Basin (note that the *distance* variable is measured in 1000 miles), the average impact of additional 1000 BBLs of oil equivalent production on employment is:

$$0.0335 + (-0.5291) * 0.1^2 = 0.0282$$

which suggests that for every additional 1000 BBLs of oil equivalent production (at the center of the Basin) the number of jobs will increase by 0.0282. In other words, 35,461 BBLs of oil

[7] 54 jobs represent 0.51% of the average county total employment between 1998 and 2016. Also, note that such an economic impact interpretation is only valid as a marginal effect which does not hold when the change in covariates (*oil* variable in this case) are considerably large.

equivalent production at the center of the Basin can generate one job at a county that is roughly 100 miles away through the spillover effects. The impact estimates in the income model can be computed and interpreted in the same way. Figure 5 depicts the spatial spillover effects through employment (left) and income (right) channels. Note that since the *distance* variable is computed as the geographic distance from the center of the Basin to the center of each surrounding counties, the minimum distance in this analysis is 28.25 miles instead of 0. In theory, the spillover effects for distances less than 28.25 miles can be computed. To put the analysis more into context, we compute the spillover effects for distances between 30 miles and 200 miles. All of the plotted spillover effects in Figure 5 are computed based on a one million BBLs increase in oil equivalent production.



Note: income is measured in 2015 dollar. All employment and income effects are computed based on a one million BBLs increase in oil equivalent production.

Figure 5: Spatial spillover effects from production near the center of the Basin

Given that the model discounts the spatial spillover effects with the square of *distance*, it is no surprise that the estimated spillover effects drop quickly as we move away from the center of the Basin. For example, the geographic distance from the center of the Basin to Midland, TX is about 110 miles. At this range, the spillover effects on employment and annual income are about 27 jobs and $150/job, respectively. These are the economic impacts that on average counties located at this range should expect, holding other factors constant. Within the last decade, the oil equivalent production near the center of the Basin has increased from around 100 million BBLs to around 200 million BBLs per year (Figure 3). The increase implies an employment effect of 2700 jobs and an income effect of $15,000/job on average for counties at this range, holding the region-wide macro trends in jobs and income as given (Figure 4). The estimates suggest that the economic impact from the oil and natural gas development in the Permian Basin is significant and large. Note that the economic impact estimates here have to be interpreted carefully. The total economic impacts on jobs and income (Figure 2, what we observe directly) reflect two types of changes on the top of county-specific fixed effects: (1)

the economic impact from the oil and natural gas development (direct and spillover effects); (2) the fluctuation of region-wide economic conditions.

4. Other Studies Concerning New Mexico

Most of the existing studies on the economic impact of conventional energy development do not include New Mexico as part of their study area. One possible reason is the availability of production data at a finer scale and the small number of observations. Almost all New Mexico oil production occurs in four southeast counties (Chaves, Eddy, Lea, and Roosevelt). Another more important reason is that New Mexico as a state has not been recognized widely as a major energy production state until the recent decades. Traditionally, New Mexico had more likely been considered as a mining state (e.g. uranium mining). Among a few studies that include New Mexico as part of the study area, Haggerty et al. (2014) show that there is no long-term economic gain from oil and natural gas specialization even with possible short-term positive income effects. A new national study by Allcott and Keniston (2018) that includes New Mexico as part of the study area finds that between 1964 and 2014 on average a county with one standard deviation additional oil and natural gas endowment had about 1% higher real wages. Based on the estimates from this analysis with a newer data sample from 1998 to 2016, comparably, one standard deviation additional oil equivalent production (18.9354 million BBLs) on average increases the real wages by 9.5% and the employment by 9.7%. The main reason for the much higher estimates in this analysis is that the data is collected for an oil/natural gas-rich region during a mostly energy boom period. For a study based on average across the country, the economic impact estimates are expected to be significantly smaller. Another difference between this analysis and Allcott and Keniston (2018) is that the latter focuses on the resources endowment while the current analysis focuses on the actual production output.

Most of the existing studies do not consider the potential spatial spillover effects from drilling and extraction activities. One exception is the national study by Feyrer et al. (2017) which focuses particularly on the spatial spillover effects. The study finds that one million dollars of new production on average generates $250,000 in wages and $286,000 in royalty and business income within 100 miles. Lee (2015) is another study that touches on the spatial aspect of the economic impacts, but more from a methodological perspective. The spatial effects in Lee (2015) are considered implicitly through a spatial autoregressive model. Spatial autoregressive models have at least two drawbacks in this particular application context: (1) the estimated spatial effect is difficult to interpret; (2) a spatial weights matrix based on spatial contiguity often suffers from misspecification (Wang, 2018). Lee (2015) finds that natural gas wells have a much larger job multiplier than oil wells. Weber (2014) uses a similar spatial econometrics model to examine the economic impact of natural gas development and finds evidence supporting the spatial spillover effects from mining jobs to non-mining jobs. The job multiplier found is larger than one.

There are several studies that carry a context and research questions similar to this analysis. Weber (2012) finds that every million dollars of natural gas production creates 2.35 jobs in the county of production. An API (American Petroleum Institute) report suggests that New Mexico oil and natural gas industry had a production value (value-added) of 11,273.6 million dollars in 2011[8]. In the same year, according to the New Mexico State Oil Conservation Division, New Mexico produced 71.515 million BBLs crude oil and 1,263.647 million MCFs natural gas. Converting oil to natural gas equivalent and a back-of-the-envelope calculation suggest that each MCF natural gas has a production value of $6.76. Then, the findings from Weber (2012) can be equivalently converted to: every one million BBLs of oil equivalent production generates 89.9 jobs. Though Weber (2012)'s estimate is larger than the estimate (54 jobs) from this analysis, two estimates are along the same magnitude. This is actually consistent with Lee (2015)'s findings that natural gas production has a much larger employment effect than oil production. Another possible reason for the difference is that Weber (2012)'s study was conducted when the oil and natural gas industry was at a different market condition. Also, the study area is different.

Overall, this analysis presents a set of economic impact estimates landing on the lower side of the entire spectrum of oil and natural gas economic impact estimates. This is in line with some of the comments made by the peer-review literature on several economic impact reports from other states. For instance, Kinnaman (2011) argues that a lot of economic impact estimates are very likely overstated due to questionable assumptions. It is worth pointing out that the estimates in this analysis are reported in the form of marginal effects (e.g. change in jobs or income for every additional one million BBLs of oil production). Given the large and increasing scale of oil and natural gas production in the Permian Basin, the aggregate economic impacts can be considerably large. For example, the oil equivalent production near the center of the Basin (Lea County and Eddy County) has increased from around 100 million BBLs to around 200 million BBLs per year within the last decade (Figure 3). Given the impact estimates (Table A1), a rough approximation suggests that the additional 100 million BBLs production has added 5400 new jobs and an extra annual income of $16,940 (2015 dollar) to each job in these two counties. In addition, we find significant spatial spillover effects on both employment and income from the intensive production around the center of the Basin. Nevertheless, the interpretation of the spillover effects to each particular county should take caution as discussed in the previous section.

---

[8] https://www.api.org/~/media/files/policy/jobs/economic_impacts_ong_2011.pdf, accessed Sep 22, 2018.

5. Concluding Remarks

In this analysis, we have found significant economic impacts of the Permian Basin oil and natural gas development on state revenue, local employment and income levels. The impacts are estimated based on extrapolating the historical trends in both the economic measures and oil & natural gas production. And the estimates are on the top of any county-level fixed effects as well as any macro-level or region-wide temporal effects. Note that this analysis does not report a projection of economic impacts based on future production scenarios. As Schneider (2018) reported, the New Mexico's Permian Basin has an estimated 50-year oil supply. How much of it has already been extracted, how the future pace of development will be, and how accurate is the estimate are all important technical questions to be answered before any reasonable projections for the near future can be conducted.

When the estimated economic impact coefficients are used for prediction purpose, the practitioners should be aware of the following:

1) Projections on both oil production and natural gas production are needed. Because of the strong linkage and interaction between oil and natural gas either at the production phase or on the commercial market, a model that integrates the production of both should be preferred assuming the data is available.
2) Two dimensions of benchmarks have to be properly chosen. The first is the temporal dimension – which year should be chosen as the benchmark year, for example, the most recent year or an average of the most recent five years? Prediction is all about using history as a reference to infer the future. A reasonable benchmark year is necessary for a meaningful prediction.
3) The other dimension is the spatial/locational dimension. Normally, the fixed effect estimated for the given county is chosen as the benchmark. The only thing to note is that the spatial benchmark is estimated with information from all historical years instead of just one year. Both benchmarks are necessary for the prediction and they are additive.
4) An implicit but essential assumption of the prediction is that the oil and natural gas industry will progress similarly as in the past. There will be no major structural change in the industry (e.g. evolutionary technology change in extraction).
5) As time goes, the model should be re-estimated whenever there is new data observed.

One crucial question about the economic impact that this analysis does not provide a sufficient answer is: is the oil and natural gas led economic development sustainable in the long term? There are studies attempting to answer the question. However, rarely do any of them succeed. In general, people tend to be less optimistic about the oil and natural gas led long-term economic development compared to on its short-term ‘boom’ effect. Haggerty et al. (2014) find that the positive economic impacts start declining as counties remain specialized in oil and natural gas for a longer time. The decline in oil and natural gas industries will happen naturally when the resources are getting exhausted. The question is if there are other industries established at the same time to fill in the holes left by the oil and natural gas industries. A good example is the City of Daqing in northeast China that has been evolving from an oil-rich city to an automobile manufacturing cluster[9]. A national study by Tsvetkova and Partridge (2016) shows that the employment spillover effect from the energy sector tends to be short-lived and fading over time. They also found that similar shocks in other sectors could produce even more jobs on average than oil and natural gas shocks. This suggests that a diversified industrial structure and development sets a more solid foundation for sustainable long-term economic development even with a rich resource endowment as part of the portfolio.

References

Agerton, M., Hartley, P. R., Medlock III, K. B., and Temzelides, T. (2017). Employment impacts of upstream oil and gas investment in the United States. *Energy Economics* 62, 171-180.

Allcott, H. and Keniston, D. (2018). Dutch disease or agglomeration? The local economic effects of natural resource booms in modern America. *The Review of Economic Studies* 85(2), 695-731.

Austin, G.S. (1980). Potash in New Mexico. *New Mexico Geology*, 1980 (February), 7-9.

Feyrer, J., Mansur, E. T., and Sacerdote, B. (2017). Geographic dispersion of economic shocks: Evidence from the fracking revolution. *American Economic Review* 107(4), 1313-1334.

Flynn, R. (2017). Oil, natural gas industries central to New Mexico economy. Available at: https://www.abqjournal.com/933091/oil-gas-industry-fuels-nm.html, accessed Sep 10, 2018.

Graeser, L. (2002). The Oil and Gas Industry in New Mexico - An Economic Perspective. Decision Makers Field Conference 2002: New Mexico’s Energy, Present and Future.

[9] http://www.chinadaily.com.cn/business/2017-04/18/content_28970422.htm, accessed Sep 23, 2018.

Socorro, NM: New Mexico Bureau of Geology and Mineral Resources.

Haggerty, J., Gude, P. H., Delorey, M., and Rasker, R. (2014). Long-term effects of income specialization in oil and gas extraction: The US West, 1980–2011. *Energy Economics* 45, 186-195.

Hedden, A.C. (2018). New Mexico doubles oil rig count as Permian Basin thrives. Available at: https://www.currentargus.com/story/news/local/2018/03/03/new-mexico-oil-rig-count-permian-basin-baker-hughes-general-electric/390646002/, accessed Sep 14, 2018.

Iglesias, D. (2018). New Mexico Cost Burden on the Oil and Gas Extraction Industry. New Mexico Legislative Finance Committee Hearing Brief, June 4, 2018. Available at: https://www.nmlegis.gov/handouts/ALFC%20060418%20Item%203%20LFC%20Hearing%20Brief_Effective%20Tax%20Rates%20on%20Oil%20and%20Gas%20Industry.pdf, accessed Sep 13, 2018.

Kinnaman, T. C. (2011). The economic impact of shale gas extraction: A review of existing studies. *Ecological Economics* 70(7), 1243-1249.

Lee, J. (2015). The regional economic impact of oil and gas extraction in Texas. *Energy Policy* 87, 60-71.

Merva, J. (2017). Oil Economics - How Much Does an Oil and Gas Well Cost? Available at: https://seekingalpha.com/article/4034075-oil-economics-much-oil-gas-well-cost, accessed Sep 12, 2018.

RegionTrack, Inc. (2018). Oklahoma Oil and Gas Industry Taxation: Comparative Effective Tax Rates in the Major Producing States. Available at: https://www.regiontrack.com/www/wp-content/uploads/RegionTrack-OK-Oil-Gas-Taxation-20180121.pdf, accessed Sep 12, 2018.

Robinson-Avila, K. (2018). BLM oil and gas lease sale busts records. Available at: https://www.abqjournal.com/1218213/latest-sale-of-nm-oil-leases-sets-national-record.html, accessed Sep 12, 2018.

Schneider, K. (2018). Here's why New Mexico's oil boom is raising a lot of questions about water. Available at: http://www.latimes.com/nation/la-na-new-mexico-permian-basin-20180325-story.html, accessed Sep 22, 2018.

Tsvetkova, A. and Partridge, M. D. (2016). Economics of modern energy boomtowns: Do oil and gas shocks differ from shocks in the rest of the economy? *Energy Economics* 59, 81-95.

US EIA (2016). Trends in U.S. Oil and Natural Gas Upstream Costs. *Independent Statistics & Analysis*, March 2016. Washington, DC: US Energy Information Administration.

Wang, H. (2018). The Spatial Structure of Farmland Values: A Semiparametric Approach. *Agricultural and Resource Economics Review*, 1-24. doi:10.1017/age.2017.35.

Weber, J. G. (2012). The effects of a natural gas boom on employment and income in Colorado, Texas, and Wyoming. *Energy Economics* 34(5), 1580-1588.

Weber, J. G. (2014). A decade of natural gas development: The makings of a resource curse? *Resource and Energy Economics* 37, 168-183.

Appendix

Table A1: Coefficient estimates for regressing employment and income on oil production

Variable	Model			
	Oil only		Oil equivalent (includes natural gas)	
	Employment	Income (2015 $)	Employment	Income (2015 $)
Oil	0.1085 (0.0187)***	0.2941 (0.0557)***	0.0540 (0.126)***	0.1694 (0.0375)***
Basin oil	0.0391 (0.0096)***	0.2182 (0.0287)***	0.0335 (0.0080)***	0.1758 (0.0238)***
*Basin oil * Distance*^{2}	-0.6997 (0.2980)**	-2.9872 (0.8887)***	-0.5291 (0.2558)**	-2.1025 (0.7611)***
Year = 1999	-53.3177	1789.1880	-78.7960	1678.0550
Year = 2000	75.0623	2805.1030*	-43.1164	2199.6280
Year = 2001	194.8823	4110.0260***	-87.3724	2585.6790*
Year = 2002	171.2293	3189.7770**	-57.8845	1969.0730
Year = 2003	284.4354	3590.5590**	112.6561	2707.5980*
Year = 2004	596.4568	3018.5490**	434.2178	2201.1400
Year = 2005	692.7446	6346.6850***	607.3828	5821.0360***
Year = 2006	1130.1570**	7724.4980***	1070.3920**	7336.8400***
Year = 2007	1472.6570***	6129.3070***	1481.5500***	6183.1670***
Year = 2008	1823.1790***	7701.3390***	1950.0760***	8430.7330***
Year = 2009	1538.2990***	8323.1950***	1831.5650***	10018.5000***
Year = 2010	1316.6030***	8638.2430***	1728.6190***	10992.8900***
Year = 2011	1421.5830***	10324.1600***	1947.5760***	13283.6700***
Year = 2012	1424.0020***	7675.1930***	1923.2030***	10479.3900***
Year = 2013	1204.9290***	5413.2970***	1647.7890***	7946.3260***
Year = 2014	880.0052**	4992.4070***	1238.6050***	7070.3590***
Year = 2015	438.0440	1844.0750	660.5636	3210.4230**
Number of obs	1175	1175	1175	1175
Adjusted R^2	0.9914	0.5636	0.9912	0.5558

Note: (1) In this regression analysis, a neighborhood size of 200 miles is chosen. *Distance* variable in the regression is measured in 1000 miles. (2) *Oil* and *Basin oil* variables in the regression are measured in 1000 BBLs. (3) The fixed effect for year 1998 is naturally omitted to avoid collinearity, which is also set as the benchmark year; (4) the fixed effect for year 2016 is omitted due to collinearity, which happens because the dataset here is an unbalanced panel data. (5) Standard errors for year effect estimates are omitted to simplify the table, available upon request. (6) Asterisks (*, **, ***) indicate estimate significance at 10 percent, 5 percent, and 1 percent confidence level, respectively.