The Impact of Local Labor Market Conditions on Migration: Evidence from the Bakken Oil Boom

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Abstract

A central question in labor economics has been the extent to which local economic conditions impact labor migration. This question is of particular importance given that migration is a fundamental outcome of local economic growth and decline, as well as a primary mechanism of regional labor market adjustment. Surprisingly, the existing literature provides relatively few causal estimates of this relationship. In this paper, I exploit exogenous variation in local labor market conditions to estimate the impact of economic growth on net migration. The boom in oil production in the Bakken formation covering parts of Montana, North Dakota, and South Dakota created an unexpected labor demand shock that increased earnings, particularly for oil counties. Using the value of county oil reserves as an instrument for earnings, I estimate a causal relationship between local economic conditions and migration. I find a semi-elasticity of net migration with respect to county earnings of 0.2. My estimates suggest that the oil boom led to a 2.6 percentage point increase in the net migration rate for oil counties in North Dakota, consistent with basic models of local labor markets and migration.

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I. Introduction

A central question in labor economics has been the extent to which local economic conditions impact labor migration. This question is of particular importance given that migration is a fundamental outcome of local economic growth and decline, as well as a primary mechanism of regional labor market adjustment (Blanchard and Katz, 1992; Saks and Wozniak, 2011). Somewhat surprisingly, the existing literature in this area provides relatively few causal estimates of the relationship between local labor market conditions and migration.

In this paper, I provide new estimates of the effect of local labor market conditions, as measured by earnings, on permanent migration. I exploit exogenous variation in earnings growth over time across counties in Montana, North Dakota, and South Dakota (henceforth known as "the three-state region") due to a boom in oil production in the Bakken formation of the Williston Basin. From 2000 through 2010, oil production in these states more than quintupled from nearly 50 to 250 million barrels of oil per year. This increase is part of a larger boom in oil and natural gas production in the United States that was made possible by a combination of rising oil prices and advancements in extraction technologies, including horizontal drilling and hydraulic fracturing, colloquially known as fracking. As extractive industries increasingly rely on technological advancements and boom and bust cycles become a common feature of the industry, it is important to understand the impacts of these cycles on local labor markets and labor migration.

As there are several potential sources of bias in estimating the relationship between local labor market conditions and migration using ordinary least squares (OLS), I develop an instrumental variable (IV) estimation strategy that isolates the shocks to labor demand from factors that also directly affect labor supply and migration. I implement this strategy using a county-level panel dataset of administrative earnings and migration data from the Internal Revenue Service (IRS) for 1993 through 2010. To estimate the causal relationship between earnings and net migration, I use the value of county oil reserves as an instrument for earnings. I construct the instrument using oil reserves data and West Texas Intermediate (WTI) crude oil prices from the United States Department of Energy's Energy Information Administration (EIA). This methodology allows me to exploit natural variation in oil reserves across counties and time series variation in oil prices. In particular, the oil-rich counties in the three-state region experienced an exogenous shock to labor demand and earnings. Much of the oil activity and, by extension, economic activity takes place around the Bakken formation, where there are large amounts of proven reserves.

My IV estimates suggest a substantial, statistically significant, positive relationship between county-level earnings growth and net migration. I estimate a semi-elasticity of net migration with respect to earnings for North Dakota, which accounted for nearly 70 percent of the oil production in the three-state region since 2000. I find a semi-elasticity of 0.2. This estimate implies that if earnings increase by 10 percent, the net migration rate increases by 2 percentage points. Expanding the analysis to the three-state region, I find a semi-elasticity of migration with respect to county earnings of 0.4. This estimate suggests that if earnings increase by 10 percent, the net migration rate increases by 4 percentage points. Compared to the mean net migration rate of -0.8 percent (i.e. net out-migration), these estimates suggest a large impact of earnings growth on net migration. Although somewhat speculative, the net migration semi-elasticities suggest that the premium to earnings to compensate for the costs of moving to North Dakota is 64 percent.

These relatively large elasticities of migration with respect to local earnings that I find are consistent with the Blanchard and Katz (1992) findings that migration is a primary mechanism for labor market adjustment. Beyond providing these new estimates, this paper contributes to a growing body of literature that explores the impact of natural resources on various labor market outcomes, such as employment, earnings, and federal disability insurance. This literature includes studies by Acemoglu et al. (2013), Aldy (2014), Allcott and Keniston (2014), Black et al. (2002), Black et al. (2005), and Vachon (2014), among others.

The paper is organized as follows. Section II reviews the literature. Section III outlines the basic theoretical framework. Section IV provides an overview of the recent oil boom. Section V describes the data and econometric specifications. Section VI illustrates the identification strategy. Section VII presents the estimation and results, and Section VIII describes the results of various robustness checks and extensions. Finally, Section IX summarizes the results, describes caveats, and offers areas of future research.

II. Previous Literature

The local labor markets literature has examined the extent to which local labor supply and demand shocks impact labor market outcomes, including earnings, employment, migration, and the spatial equilibrium of labor. Bartik (2014) and Moretti (2011) provide reviews of the literature. Bartik (1991) and Blanchard and Katz (1992), among others, examine the general features of regional economic cycles by looking at the response of employment, wages, and migration to economic conditions. Blanchard and Katz (1992) study supply and demand and then simulate the impact of shocks on employment and wages. They find that labor migration is an important mechanism for interregional adjustment to labor demand shocks. While Blanchard and

Katz (1992) find that a local labor market generally returns to equilibrium less than a decade after a shock, Bartik (1991) finds a slightly slower adjustment. Topel (1986) examines a spatial equilibrium model in a dynamic setting. He finds that positive shocks to local labor demand increase nominal wages in that market, consistent with Bartik (1991) and Blanchard and Katz (1992). Partridge and Rickman (2006) estimate models of employment, migration, and wages and find that positive labor demand shocks increase employment-to-population ratios in both the short- and long-run, with stronger effects in Rustbelt and Farmbelt states. Gallin (2004) and Saks and Wozniak (2011) build upon these structural models of local labor markets, examining the impact of aggregate national economic conditions and business cycle fluctuations on internal migration.

More recently, a growing empirical literature examines the impact of local demand and supply shocks on county-level economic conditions. Aldy (2014), Allcott and Keniston (2014), Black et al. (2002), Black et al. (2005), Carrington (1996) and Vachon (2014) examine the impact of natural resource-induced shocks on local economic conditions. Aldy (2014) studies the 2010 Deepwater Horizon oil spill, spill response, and drilling moratorium. Using a difference-in-differences strategy, he finds increases in employment in the oil-intensive parishes in Louisiana as well as coastal Alabama, but decreases in employment in certain Gulf Coast Florida counties. Allcott and Keniston (2014) use a national, county-level panel dataset to estimate how resource booms and busts impact the manufacturing sector, finding that total manufacturing employment increases during booms and decreases during busts in natural resource-rich counties. Black et al. (2002) and Vachon (2014) study the impact of natural resource shocks on Disability Insurance (DI) payments and participation in the Appalachian and Bakken regions, respectively. Both studies find a negative relationship between a natural resource price-induced change in earnings and DI payments and participation. Carrington (1996) studies the impact of construction of the Trans-Alaska Pipeline during the 1970s on wages and employment at the state level, finding employment spillovers to non-construction industries and a fairly elastic labor supply on both the intensive and extensive margins. In particular, he finds that a 10 percent increase in earnings increases labor supply by approximately 7 percent. Black et al. (2005) examine the local labor market impacts of the coal boom and bust in Appalachia in the 1970s and 1980s, primarily focusing on spillovers from coal to no coal counties. They also examine the impact of the boom and bust on cohort-level migration by gender, finding increases in the in-migration of working-age men during the coal boom, while other populations generally experienced increased out-migration.

III. Basic Theoretical Framework

The migration decision is commonly viewed as a utility maximization problem in which individuals choose the location that provides the highest utility, typically modeled as a function of local earnings, amenities, and the cost of moving.[1] Figure 1 illustrates the basic market-level predictions of a change in demand for labor in a model of two labor markets, Region A and Region B, for which other inputs to production, such as land and capital, are perfectly elastic in supply. In particular, in equilibrium, individuals should be indifferent between locating in Region A or Region B. This requires that earnings plus the money-metric value of amenities minus the cost of moving are equal in the two locations.

[1] This model of income maximization closely follows Roy's (1951) framework, which is the foundation for a large portion of the migration literature. The Roy Model generally posits that workers will migrate to the regions which offer the best relative return to their skill, taking into consideration the costs of migrating from the origin to destination. Borjas (1999) and Greenwood (1975) provide reviews of the literature; see also Blanchard and Katz (1992), Borjas (1987), Dahl (2002), Davies, Greenwood, and Li (2001), Gallin (2004), Grogger and Hanson (2011), Saks and Wozniak (2011), and Topel (1986).

At the initial labor market equilibrium (E_A) in Region A, earnings equal Y_A and the labor force participation is N_A. In Region B, at the initial labor market equilibrium (E_B), earnings equal Y_B, and labor force participation is N_B. For Region B, earnings Y_B are equal to Y_A minus the cost, C, of moving from Region B to Region A:

(1) $$Y_A - C = Y_B.$$

To simplify, I assume that moving costs, C, are net of the value of the amenity differential between the two regions. In this model, workers migrate from Region B to Region A when $Y_A > Y_B + C$. In equilibrium, labor supply equals labor demand in each region:

(2) $$D_A(Y_A) = S_A(Y_A)$$

and

(3) $$D_B(Y_B) = S_B(Y_B).$$

Now, assume Region A experiences an exogenous shock to labor demand. This shifts the labor demand curve outward from D_A to D_A'. The new Region A labor market equilibrium is at E_A', with increases in earnings and labor force participation to Y_A' and N_A', respectively. The increase in earnings from Y_A to Y_A' in Region A induces a migration response from workers in Region B, and the Region B labor supply curve shifts inward from S_B to S_B'. This shift, in turn, shifts the Region A labor supply curve outward to S_A', resulting in the new equilibrium level of earnings Y_A'' and labor force participation N_A''. The initial increase in labor force participation from N_A to N_A' (movement along the labor supply curve) in Region A is due an increase in participation of current residents. In contrast, the increase from N_A' to N_A'' (outward shift of the supply curve to S_A'') is the result of net migration from Region B.[2]

[2] From Figure 1, the reduction in Region B labor force participation, $N_B' - N_B$, is equal to the increase in Region A labor force participation due to in-migration, $N_A'' - N_A'$.

As illustrated, the labor market response in Region A depends on the labor supply and demand elasticities in both regions and the moving cost. The goal of this paper is to estimate the migration response in Region B (N_B to N_B') to an exogenous increase in earnings in Region A (Y_A to Y_A'). The migration response from Region B, dD_B/dY_A, is out-migration from Region B to A in response to the increase in Region A earnings. So, this migration response represents net in-migration to Region A, expressed as $-dD_B/dY_A$. From equations (1) through (3), it can be shown that this migration response can be written in terms of the elasticity and cost parameters as

(4) $$\beta = \frac{-dD_B}{S_A} \Big/ \frac{dY_A}{Y_A} = \eta_A^S - \eta_A^D - \eta_B^S \left(\frac{S_B}{S_A}\right)\left(1 + \frac{C}{Y_B}\right).$$

Here, I have expressed β as a semi-elasticity, where $-dD_B/S_A$ is the migration rate, m, and dY_A/Y_A is the percent change in earnings for Region A.

To understand what drives changes in β, I display the partial derivatives from (4) below. First, there is a negative relationship between β and the cost of migration:

(5) $$\frac{\partial \beta}{\partial C} = -\eta^S \left(\frac{S_B}{S_A}\right)\left(\frac{1}{Y_B}\right) < 0.$$

Second, the relationship between β and the elasticity of labor supply for Region A is positive. As η_A^S increases, a shock to demand will lead to larger increases in Y_A and thus increase the migration response from Region B:

(6) $$\frac{\partial \beta}{\partial \eta_A^S} = 1 > 0.$$

Third, the relationship between β and the elasticity of labor supply for Region B is negative. As η_B^S increases, there will be a smaller migration response from Region B to a given increase in Region A earnings:

(7) $$\frac{\partial \beta}{\partial \eta^S} = -\left(\frac{S_B}{S_A}\right)\left(1 + \frac{C}{Y_B}\right) < 0.$$

Finally, there is a negative relationship between β and the elasticity of labor demand. As η_A^D increases (becomes less negative), a shock to demand will lead to smaller increases in Y_A, reducing the migration response from Region B:

(8) $$\frac{\partial \beta}{\partial \eta_A^D} = -1 < 0.$$

The goal of the empirical analysis in Section VII is to estimate β.

IV. Oil Boom Background

The source of oil is organic matter that is preserved and buried in some sedimentary rocks. For an oil deposit to be considered for commercial production, three important geological criteria must be met (Hyne, 2012). First, there must be a subsurface source rock that generated the oil (see Figure 2). The most common source rock is black shale. Shale originated as organic matter-rich mud on ancient seafloors.[3] As it was covered with more and more sediments and buried further below the Earth's surface, the heat from geological pressure turned the organic matter into oil. Second, there must be a separate subsurface reservoir rock that holds the oil. Reservoir rocks are sedimentary rock layers that contain billions of tiny spaces, or pores. Sandstone (composed of compressed grains of sand) and limestone (composed of broken down seashells and corals) are common reservoir rocks. Oil is able to flow through sandstone, limestone, and other reservoir rocks through the pore spaces between the sediments. Third, there must be a geological trap and cap rock to concentrate the oil into commercially extractable quantities. The trap is a geological high point in the formation that prevents the oil from flowing

[3] The shale oil extracted from the Bakken was formed approximately 350 million years ago during the late Devonian and early Mississippian geologic periods (Hyne, 2012).

upward; the cap rock is a seal that prevents oil from flowing through it, concentrating the oil in the reservoir rock.

In “conventional” oil extraction, a well is drilled into the reservoir rock. Such methods characterized oil production in the United States, including North Dakota, for much of the previous century.[4] In contrast, the recent oil boom uses “unconventional” oil extraction because it involves drilling into and extracting resources from the shale source rock, which is less porous and permeable than typical reservoir rocks (i.e. sandstone and limestone, among others) (Maugeri, 2012). In particular, shale oil is extracted using the combined application of horizontal drilling and fracking techniques. Horizontal drilling is particularly effective in these formations because more well surface area is exposed to the oil-rich rock as compared to traditional vertical drilling. Hydraulic fracturing is the process of injecting large volumes of fluids into a well to fracture the rock. The fluid used is generally combined with sand before it is injected. The sand particles, known as propping agents, hold open the fractures, allowing oil to flow into the well (Hyne, 2012).

Figure 3 presents the time-series price and production data for North Dakota. Geologists and petroleum experts have been aware of North Dakota’s reserves since the middle of the previous century when Amerada Petroleum Corporation drilled the area’s first commercial oil well at the Clarence Iversen farm in Tioga, North Dakota in 1951. However, later that year Amerada made another important discovery at the Henry O. Bakken farm, also in Tioga. The Bakken well is important because it was the first in the area drilled into the older (deeper) geologic formation that became known as the Bakken formation. From 1951 through the 1970s,

[4] While the focus of this paper is on the Bakken formation, the explanations of the geology of fossil fuels and extraction technologies can generally be applied to other regions with shale oil and gas reserves and extraction (i.e. Marcellus and Utica in the Appalachian region, Eagle Ford and Barnett in Texas, and Woodford in Oklahoma, among others).

oil production averaged a modest 20 million to 25 million barrels per year. Beginning in 1973 with the OPEC embargo and continuing through the oil crisis of 1979, rising oil prices led to a boom in production in North Dakota in the 1980s. Even with record-high oil prices, annual production peaked at approximately 50 million barrels in 1984, compared to nearly 900 million barrels produced in Texas that year (U.S. Energy Information Administration, 2014).

While oil companies have had access to horizontal drilling and fracking technologies for some time, their combined application was not successful until 2000, when Mitchell Energy extracted natural gas from the Barnett shale in Texas (Maugeri, 2012). In North Dakota's Bakken, Continental Resources is credited with the first commercially successful combined horizontal drilling and fracking oil well in 2004 (Continental Resources, 2014). North Dakota oil production hit nearly 250 million barrels in 2012 and continues to increase. Production resulting from this most recent boom dwarfs that of the 1980s.

V. Econometric Specifications and Data

The basic prediction of the model in Section III is that a labor demand shock increases earnings in the destination region and, ultimately, induces an in-migration response, increasing the supply of labor in the destination (and reducing labor supply in the origination region). Following the literature and treating the county as the local labor market, I present the reduced-form relationship between net migration and local earnings below:

$$m_{ist} = \varphi + \beta ln(y_{ist}) + \varepsilon_{ist}, \tag{9}$$

where m_{ist} represents the net migration rate for county *i* in state *s* in year *t*, and ε_{ist} is the error term.[5] Specifically, a migrant is someone who moves to or from county *i* between year *t* and year

[5] Commuting zones (CZs) have also been used by researchers to define local labor markets (e.g. Cascio and Narayan, 2015). CZs are clusters of adjacent counties that are grouped based on commuting patterns. While this

$t+1$. The migration rate is defined as the number of in-migrants minus the number of out-migrants from a county divided by the beginning-of-period number of inhabitants of the county. The explanatory variable is $ln(y_{ist})$, the natural logarithm of real earnings per household. The focal parameter β represents the semi-elasticity of migration with respect to local earnings and is the reduced-form of the four parameters (η_A^S, η_A^D, η_B^S, and C) as shown in equation (4).

I model ε as

(10) $$\varepsilon_{ist} = \pi_i + \tau_t + \phi_{st} + \mu_{ist} \ ,$$

where π represents a county-specific fixed effect, and τ represents a linear time trend. To account for this fixed effect, I first-difference equation (9) to yield:

(11) $$\Delta m_{ist} = \delta + \beta \Delta ln(y_{ist}) + \omega_{ist}$$

where Δ indicates a first difference, and ω is the differenced error term from equation (10):

(12) $$\omega_{ist} = \gamma_{st} + u_{ist},$$

where $\gamma_{st} \equiv \Delta \phi_{st}$ is a state-by-year effect, and δ is the new intercept, where $\delta \equiv \Delta\tau_t$. As described below, consistent estimates of β from equation (11) are identified by within state, over time, across county differences in earnings.

The dataset used in this analysis is based on county-level administrative data from IRS Statistics of Income (SOI), based on federal income tax returns. Migration status is based on year-over-year address changes on federal individual income tax returns. I use the number of returns, rather than exemptions, as the primary measure of migration, as they approximate households; exemptions declared on those returns approximate the population and include children and other non-participants in the labor market. I calculate county-level net migration by subtracting total out-migration from total in-migration. Dividing net migration by the total

study treats the county as the local labor market area, the use of CZs does not change the interpretation of the results. Estimates using CZs are available upon request.

number of returns filed in the county gives the rate, m_{ist}. The net migration rate will be negative if outflows are greater than inflows in a given year. I measure real earnings in 2010 dollars as county mean wage and salary income reported on federal income tax returns, adjusted for inflation using the Consumer Price Index (CPI). Dividing real earnings by the number of returns filed in the county gives the earnings per household, y_{ist}.

Panel A of Table 1 presents summary statistics for the entire sample period. Column 1 of Panel A presents sample means. Montana, North Dakota, and South Dakota are small states; according to the 1990 Census, their respective populations were 799,000, 639,000, and 696,000. The average number of households per county is 5,500, and average household earnings are approximately $27,000. Average annual earnings growth is 0.9 percent. Throughout the period of interest, the three-state region experienced, on average, net migration rates of approximately -0.8 percent.

VI. Identification Strategy

Because earnings and migration are jointly determined, I estimate the parameters in equation (11) using an instrumental variables strategy following Black et al. (2002) and Vachon (2014). This strategy is based on natural variation in county-level oil reserves. The oil reserve data come from the 2004 EIA assessment of the Bakken formation of the Williston Basin and the 2001 assessments of Montana Thrust Belt and Powder River Basin.[6] I calculate oil reserves using EIA shape files and MapInfo software. I use midpoint estimates for each oil field, as the reserves are listed in ranges, then aggregate to the county level. Based on this method, there are

[6] I use a static measure of county-level reserves, from assessments prior to the boom, for the purposes of this analysis. This is important because reserves are a function of the quantity of the resource as well as the technology available to extract it. As such, a measure of reserves that varies with time would likely be correlated with local economic activity.

32 counties in the three-state region that have oil reserves, and 143 counties that have no reserves. From Column 2 of Table 1, the average oil county has nearly forty-four million barrels of oil reserves. I calculate the value of oil reserves by multiplying county-level reserves by the price of WTI crude oil. From Panels B and C of Table 1, the average price per barrel of West Texas Intermediate (WTI) crude oil increased from $31 to $76 between the early and later years of the oil boom. I use the value of oil reserves and that value interacted with a dummy variable for the presence of horizontal drilling and fracking extraction technologies as instruments for earnings to econometrically capture the impact of the oil price-generated increase in local labor market earnings on migration.

Figures 4 through 6b present a visual depiction of my identification strategy. Figure 4 shows the level of county oil reserves for the Bakken formation of the Williston Basin (eastern Montana, western North Dakota, and northwest South Dakota), Montana Thrust Belt (northwestern Montana), and Powder River Basin (southeast Montana and southwest South Dakota). The darkest shaded counties have the highest levels of oil reserves, and those areas shaded white have no oil reserves. The darkest shaded counties have between 50 and 217 million barrels of oil. The counties shaded in dark gray have between 5 and 50 million barrels of oil. The counties shaded in the lightest gray have less than less than 5 million barrels of oil (but more than zero). The most oil-rich part of the region is the Bakken formation of the Williston Basin.

Figures 5a and 5b present quartiles of average annual earnings growth rates for the pre-boom (1993-2004) and boom (2005-2010) periods, respectively. The areas with the darkest shading have the greatest increases in average annual earnings growth over the timeframe. During the pre-boom period in Figure 5a, the first through fourth quartiles represent earnings growth below 0.75 percent, between 0.75 percent and 1.6 percent, between 1.6 percent and 2.5

percent, and above 2.5 percent, respectively. During the early period, the lowest growth county experienced a 1.3 percent decrease in earnings; the highest growth county experienced an 8.2 percent increase in earnings.

For the boom period in Figure 5b, the first through fourth quartiles represent earnings growth below 1.51 percent, between 1.52 percent and 2.29 percent, between 2.3 percent and 3.3 percent, and above 3.4 percent, respectively. The lowest growth county experienced a 4.9 percent decrease in average annual earnings; the highest growth county experienced a 10.8 percent increase. The average annual earnings growth was 2.9 percent greater in oil counties than no oil counties during the boom.

Figures 6a and 6b present quartiles of average changes in net migration for the pre-boom and boom periods, respectively. The areas with the darkest shading have the greatest change in average net migration over the timeframe. During the pre-boom period in Figure 6a, the first through fourth quartiles represent changes in net migration below -0.12 percentage points, between -0.12 percentage points and -0.025 percentage points, between -0.025 percentage points and 0.09 percentage points, and above 0.09 percentage points, respectively. From Figure 6b, the first through fourth quartiles represent changes in net migration below -0.02 percentage points, between -0.02 percentage points and 0.132 percentage points, between 0.132 percentage points and 0.29 percentage points, and above 0.29 percentage points, respectively. During the oil boom, the lowest growth county experienced a 0.5 percentage point decrease in its net migration rate; the highest growth county experienced a 1.3 percentage point increase.

Figures 4, 5a, and 5b represent the first-stage relationship between oil reserves and earnings growth. Those counties with high earnings growth have the highest levels of oil reserves, as evidenced by the dark shading on both maps. The reverse is also true; areas with low earnings growth have little to no oil reserves. Figures 4, 6a, and 6b represent the reduced-form relationship between oil reserves and net migration. There is a positive relationship between oil reserves and changes in net migration. Those areas with high levels of oil reserves have high changes in net migration.

VII. Estimation and Results

The first-stage of the IV estimation is:

$$\Delta ln(y_{ist}) = \alpha_0 + \alpha_1 \Delta ln(v_{ist}) + \alpha_2 D^{Post\ 2004} * \Delta ln(v_{ist}) + \gamma_{st} + u_{ist}, \quad (13)$$

where the instruments are $\Delta ln(v_{ist})$ and $D^{Post\ 2004} * \Delta ln(v_{ist})$. The term $ln(v_{ist})$ represents the natural logarithm of the value of county oil reserves for each year in 2010 dollars; $D^{Post\ 2004}$ is a dummy variable with value 1 for years 2005 through 2010, when the combination of horizontal drilling and fracking was available in the three-state region, and 0 otherwise.

Table 2 presents estimates of α_1 and α_2 from equation (13). These estimates illustrate the relationship between growth in the value of oil reserves, the presence of new extraction technologies, and earnings growth. Column 1 presents the estimates for North Dakota. The estimate for α_1 implies that a doubling in the value of oil reserves leads to a 2.5 percent increase in earnings. The coefficient on the interaction term, α_2, suggests that if the value of oil reserves doubles during this period, earnings increases by an additional 4 percent. I find a strong positive relationship between earnings growth and value of oil reserves; the *F*-statistic from the test on excluded instruments is 12.6 for North Dakota, suggesting that these are strong instruments.

Column 2 presents the first-stage relationship for the three-state region. The estimate for α_1 implies that a doubling in the value of oil reserves leads to a 0.4 percent increase in earnings. The coefficient on the interaction term suggests that if the value of oil reserves doubles during this period, earnings increases by an additional 3.2 percent. For the three-state region, the *F*-statistic from the test on excluded instruments is 3.8, suggesting the instruments are relatively weak in this case.

Table 3 presents OLS and IV estimates of β, the impact of earnings growth on net migration for North Dakota as well as the three-state region. Column 1 presents OLS estimates for North Dakota. I find a semi-elasticity of net migration with respect to county earnings of 0.04. This estimate suggests that a 10 percent increase in earnings will increase the net migration rate 0.4 percentage points. Compared to the mean net migration rate of -0.8 percent for the three-state region, this is a large impact. However, OLS does not isolate shocks to labor demand from important factors that directly influence both labor supply and migration.

Column 2 of Table 3 presents IV estimates of β for North Dakota. I find a semi-elasticity of net migration with respect to earnings growth of 0.2; if earnings increase by 10 percent, the net migration rate will increase by 2 percentage points.[7] Column 3 of Table 3 presents estimates for the three-state region. I find a semi-elasticity of net migration with respect to earnings growth of 0.4. If earnings increase by 10 percent, the net migration rate will increase by 4 percentage points. In reality, during the oil boom, earnings for oil counties increased by approximately 13 percent in North Dakota and increased by approximately 8 percent in the three-state region. For North Dakota, these estimates suggest the increase in earnings during the oil boom led to a 2.6 percentage point increase in the net migration rate in oil counties; for the three-state region, these estimates suggest the increase in earnings led to a 3.2 percentage point increase in the net

[7] There are three potential sources of OLS bias. First, endogeneity suggests OLS estimates would be biased upward. Second, while classical measurement error may lead to downward biased estimates of β using OLS, it is unlikely the source of potential bias given that I use administrative migration and earnings data. The net impact of these first two sources of bias is unclear. Finally, mobility costs may represent an omitted variable that is negatively correlated with migration but positively correlated with wage growth. At the same time, migration is positively correlated with wages. Given that oil counties are generally less populous and more rural than counties without oil, it is plausible that high earnings growth counties also had higher mobility costs, so OLS estimates of β will be biased downward.

migration rate in oil counties. These estimates imply a large statistically significant, positive impact of earnings growth on net migration.

VIII. Robustness Checks and Extensions

During the sample period, parts of the United States, including the three-state region, experienced an agricultural boom in addition to the boom in oil production. Since agricultural production varies across counties, such additional sources of county-by-time variation could confound my results. To account for this, I control for the value of agricultural land using land price data from the United States Department of Agriculture (USDA), which are only available for North Dakota during the entire period of interest.[8]

Table 4 presents OLS and IV estimates of the relationship between earnings and net migration rates, controlling for land values. The OLS estimates in Column 1 suggest a positive relationship between earnings growth and net migration. I find a semi-elasticity of migration with respect to earnings of 0.04. The semi-elasticity of net migration with respect to cropland value is -0.005. These estimates suggest a positive, significant relationship between earnings growth and net migration and a negative, insignificant relationship between cropland value and net migration. Column 2 presents IV estimates of the relationship, suggesting a semi-elasticity of net migration with respect to earnings of 0.2. I find a semi-elasticity of net migration with respect to cropland value of -0.008. While the large earnings growth estimates are consistent with my previous results, the land value estimates are quite small, suggesting that land value growth has little impact on net migration.

In Column 3, I treat cropland value as an endogenous regressor, as in Rosen (1979) and Roback (1982). Because I have two instruments, this specification is just identified. From Table

[8] Data for Montana and South Dakota are only available sporadically for the period of interest.

2, the F-statistic from the test of excluded instruments from the first-stage regression of oil reserves on cropland values is 9.1. I find a semi-elasticity of net migration with respect to local earnings of 0.2; the semi-elasticity of net migration with respect to cropland value is 0.005.

As an additional robustness check, I use an estimator based on Cliff and Ord (1973, 1981) to provide IV estimates of the relationship between local economic conditions and net migration that account for spatial autocorrelation. I generate an inverse-distance spatial weighting matrix (spatial correlation decreases with the distance between two counties), where distance is measured between the geographic center of one county and another. Table 5 presents IV estimates from the spatial error model of the relationship between local labor market conditions and net migration rates for North Dakota.[9] Estimates from the spatial error model in column 1 suggest a semi-elasticity of 0.24, implying that a 10 percent increase in earnings will increase the net migration rate by between 2.4 percentage points. The estimate of the semi-elasticity of net migration with respect to earnings growth is quantitatively similar to my primary estimate from column 2 of Table 4.

The IRS data used in this paper measure those who filed federal income tax returns as residents of or migrants to the three-state region (i.e. permanent residents and permanent migrants). Permanent migrants should be less elastic in their response to changes in earnings than temporary migrants, as the fixed costs associated with a permanent move are relatively high. Anecdotal evidence from this boom suggests large temporary migration responses to earnings growth, especially in oil-rich counties. For example, large "man camps" provide housing for

[9] These specifications use only the first difference of the natural logarithm of oil reserves as an instrument for earnings. The spatial regression analysis used requires that panel data be strongly balanced. Observations prior to 1998 were dropped due to missing values. For the same reason, one county with missing data after 1998 was also dropped from the sample. Column 2 provides estimates from the specification in Table 4 that rely on the same sample as the spatial error model. The estimates in column 2 suggest that a 10 percent increase in earnings will increase the net migration rate by 2.8 percentage points.

workers who may spend. As a final robustness check, I use Friedman's (1957) permanent income hypothesis to provide suggestive evidence of a temporary migration response. The permanent income hypothesis states that consumption decisions are based on expectations about permanent income rather than transitory income shocks. Accordingly, measures of consumption may represent expectations of permanent income for permanent as well as temporary migrants. In contrast, the IRS earnings measures used in this paper are for permanent residents.

I modify (11) to present the following relationship between net migration rates and consumption for counties in North Dakota:

(14) $$\Delta m_{it} = \lambda + \psi \Delta ln(c_{it}) + \nu_{it},$$

where m_{it} is the net migration rate for county i in year t, c_{it} is consumption per capita, and ν_{it} is the error term. I use data from the North Dakota Office of the State Tax Commissioner (ND OSTC) that contain the value of county-level taxable sales, which measure consumption. The period of interest for these specifications is 1999, rather than 1993, through 2010 due to ND OSTC data availability. Any wedge between the estimates of β from (11) and ψ from (14) provides suggestive evidence of the presence of temporary migrants. Given the presence of temporary migrants, using consumption as the primary dependent variable should result in coefficient estimates of ψ that are lower than estimates of β.

Column 1 of Table 6 presents IV estimates of the relationship between consumption growth and net migration rates from (14). The coefficient estimate indicates a semi-elasticity of net migration with respect to consumption of 0.05, suggesting that a 10 percent increase in consumption will increase the net migration rate (of permanent migrants) for oil counties in North Dakota by 0.05 percentage points. In addition, the semi-elasticity of net-migration with respect to earnings in column 2 of Table 6 is 0.2. This estimate suggests that a 10 percent increase (of permanent residents) in earnings will increase (permanent) net migration rates by 2 percentage points. The estimates in columns 1 and 2 of Table 6 illustrate a wedge between estimates of β and ψ, providing evidence of the presence of temporary workers. In addition, these estimates show that shocks to the earnings of temporary workers in oil-rich counties have a smaller impact on permanent migration than do shocks to the earnings of permanent residents.

Finally, in columns 3 and 4 of Table 6, I extend the analysis to include various sources of income. In addition to the earnings measure from (11), wage and salary income, the IRS data include the Adjusted Gross Income (AGI) for permanent residents. AGI is the sum total of labor income (wage and salary earnings) and non-labor income, which includes business income as well as royalty payments to landowners from oil extraction. The estimates in columns 3 and 4 in Table 7 suggest semi-elasticities of 0.04 and 0.07 for non-labor income and AGI, respectively. The semi-elasticity of net-migration with respect to AGI growth represents a weighted average of the estimates in columns 2 and 3 that use its component parts as the primary independent variable. A 10 percent increase in wage and salary earnings (column 2) will increase net migration rates by 2 percentage points, whereas a 10 percent increase in non-labor income (column 3) will increase net migration rates by 0.4 percentage points. The estimates in columns 2 through 4 suggest that permanent migrants are much more responsive to changes earnings rather than changes in non-labor income.

IX. Summary, Implications, and Caveats

In this paper, I exploit exogenous variation in local labor market conditions to estimate the impact of economic growth on net migration. The boom in oil production in the Bakken formation covering parts of Montana, North Dakota, and South Dakota created an unexpected labor demand shock that increased earnings, particularly for oil counties. Overall, my estimates suggest a statistically significant, positive impact of earnings growth on net migration rates. I find semi-elasticities of net migration with respect to earnings of 0.2 and 0.4 for North Dakota and the three-state region, respectively. During the oil boom, earnings for oil counties increased by approximately 13 percent in North Dakota, and this earnings growth led to a 2.6 percentage point increase in the net migration rate. For the same period, earnings growth in the three-state region increased by approximately 8 percent, and this suggests the earnings growth led to a 3.2 percentage point increase in the net migration rate in oil counties in the three-state region.

More recently, however, between June 2014 and September 2015, oil prices fell by over 50 percent from \$106 to \$44 per barrel. This decrease in prices represents a negative shock to local economic conditions. The new estimates that I present in this paper can provide insight into how changes in the price of oil will impact net migration rates. Based on my first-stage estimates, this decrease in prices will reduce earnings by nearly 3.25 percent. From my IV estimates, a 50 percent decrease in prices will reduce net migration rates by 0.65 percentage points. These somewhat speculative estimates assume a symmetric response of economic conditions to increases and decreases in the price of oil.

In addition, I use the estimates of β to estimate migration costs. From (4), it follows that

(15) $$\theta = \frac{C}{Y_B} = \frac{-\beta - \eta_A^D + \eta_A^S}{\eta_B^S\left(\frac{S_B}{S_A}\right)} - 1,$$

where θ is the earnings premium paid to workers to compensate them for the cost of migrating from Region B to Region A. To calibrate this, I make reasonable assumptions about the elasticities of labor supply and demand as well as the population ratio between the two regions, $\frac{S_B}{S_A}$. Consistent with the literature, I assume the uncompensated elasticity of labor supply is 0.1. I calculate a weighted average of the elasticity of labor demand. This estimate is based on Slaughter's (2001) elasticities of -1.3 and -0.8 for production and nonproduction labor, respectively.[10] Production labor makes up approximately 24 percent of the total labor force in North Dakota's oil counties. From these estimates,

$$\eta_A^D = (-1.3)(0.24) + (-0.8)(0.76) = -0.92 \quad (16)$$

is the industry-weighted labor demand elasticity. Finally, in this calibration, I assume oil counties in North Dakota comprise Region A and Montana and South Dakota make up Region B, which implies $\frac{S_B}{S_A}$=5. With these assumptions, θ is equal to 0.64, or workers require a 64 percent increase in earnings if they are to migrate to North Dakota.

Overall, my research contributes to the literature in three ways. First, the use of a natural experiment is a novel approach that provides new causal evidence of the impact of economic booms on county-level internal migration within the United States. Despite an extensive body of research examining migration, we know little about the impact of natural resource booms on migration in impacted localities. Second, my large elasticity estimates are consistent the Blanchard and Katz (1992) finding that migration is an important mechanism of labor market adjustment in the presence of a shock to local economic conditions The local labor markets literature explains that a positive demand shock, such as an oil boom, should increase wages, employment, and in-migration. Finally, this paper contributes to the growing literature examining impact of natural resources on labor market outcomes (Acemoglu et al., 2013; Aldy, 2014; Allcott and Keniston, 2014; Black et al., 2002; Black et al., 2005; Carrington, 1996; Cascio and Narayan, 2015; Feyrer et al., 2014; Vachon, 2014).

[10] While largely based on Slaughter's (2001) estimates, these demand elasticities are consistent with those in the literature, including Hammermesh (1996).

While my findings suggest large impacts of earnings on net migration, there are three primary limitations to this study. First, this paper examines permanent rather than temporary migration. In addition, the focus of the current paper on permanent migration implies that these migrants viewed the shock as permanent rather than transitory. Finally, the three-state region I examine in this paper is less populous and more rural than the rest of the United States. As such, caution should be taken when attempting to generalize these estimates beyond the three-state region. These caveats provide natural avenues for future research. Estimating temporary migration into the region and expanding this analysis beyond the three-state region to other areas impacted by the national shale boom are important extensions, as they may shed new light on this relationship between earnings growth and migration.

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Figure 1 – Local Labor Markets and Migration

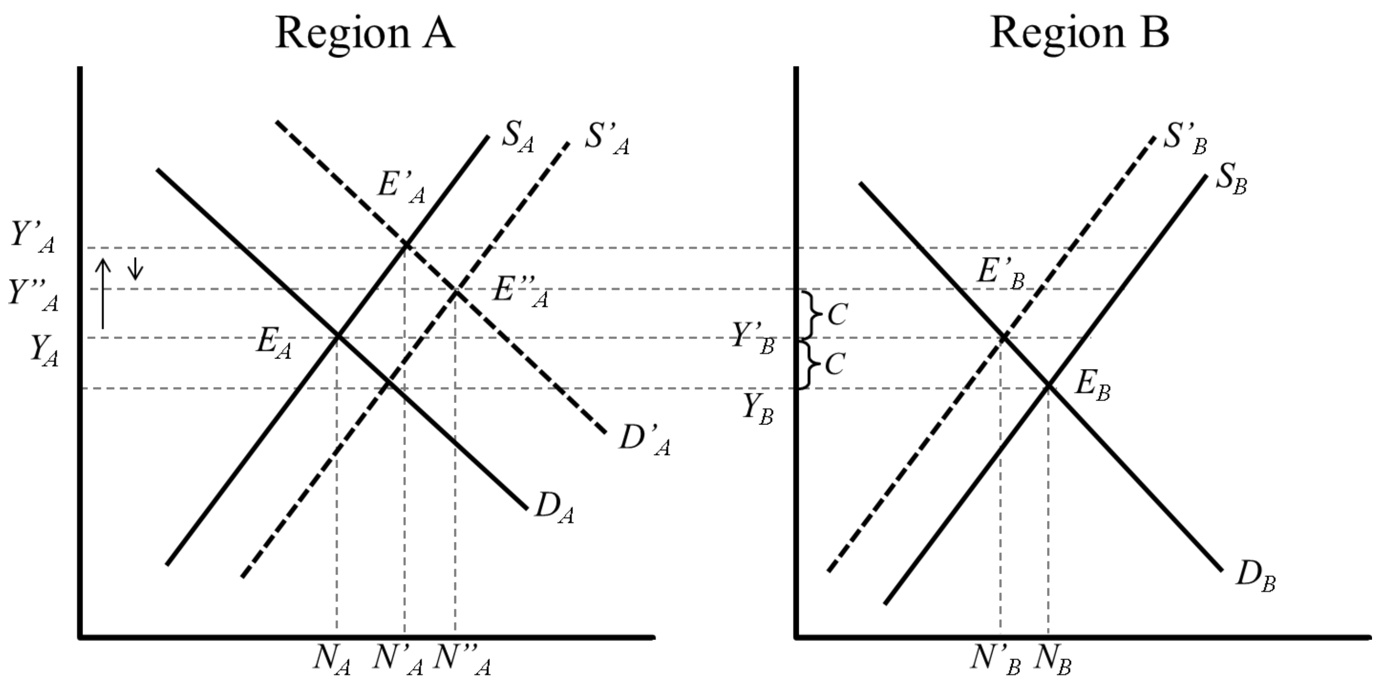

Figure 2 – Petroleum Geology and Extraction

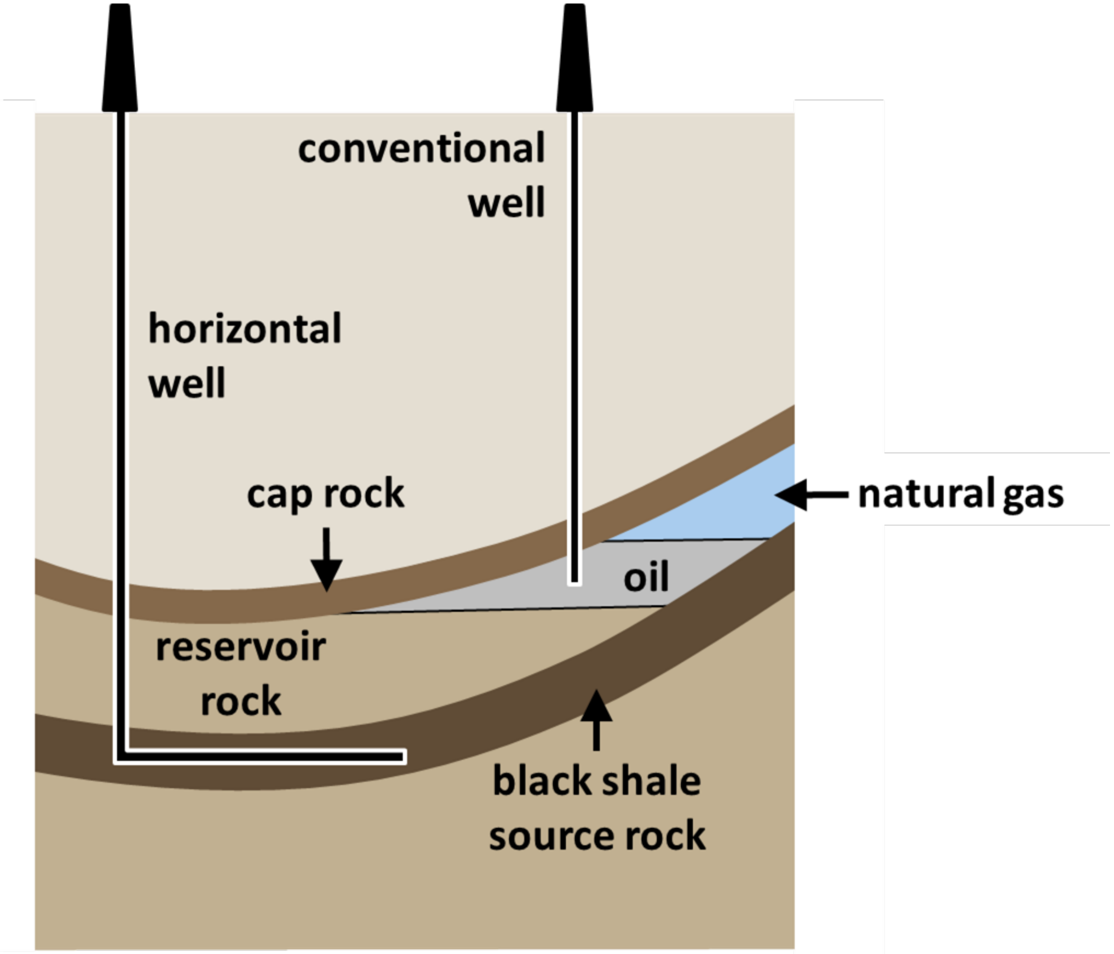

Figure 3 – Historical North Dakota Oil Production and Prices

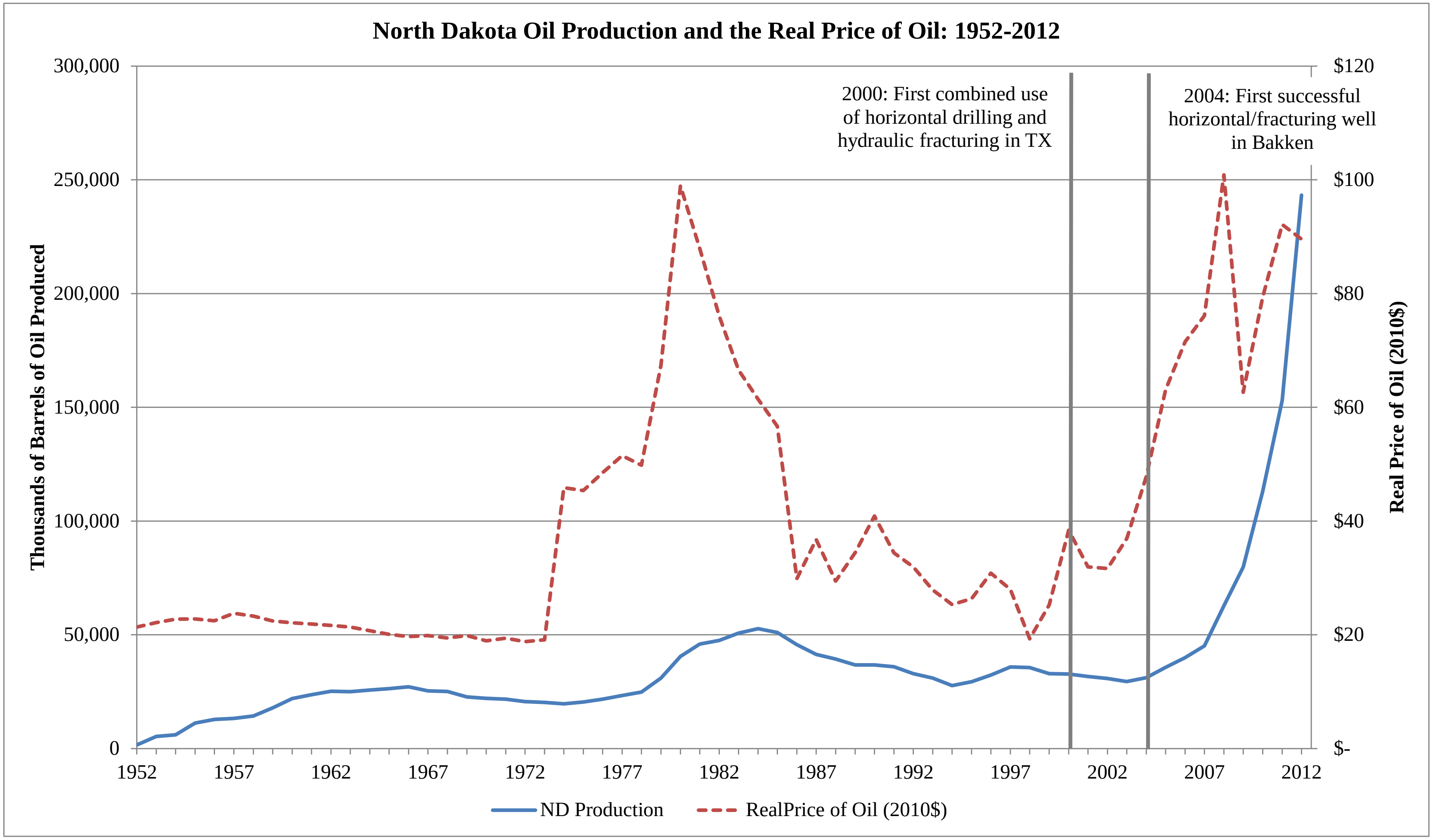

Figure 4 – Oil Reserves in Montana, North Dakota, and South Dakota

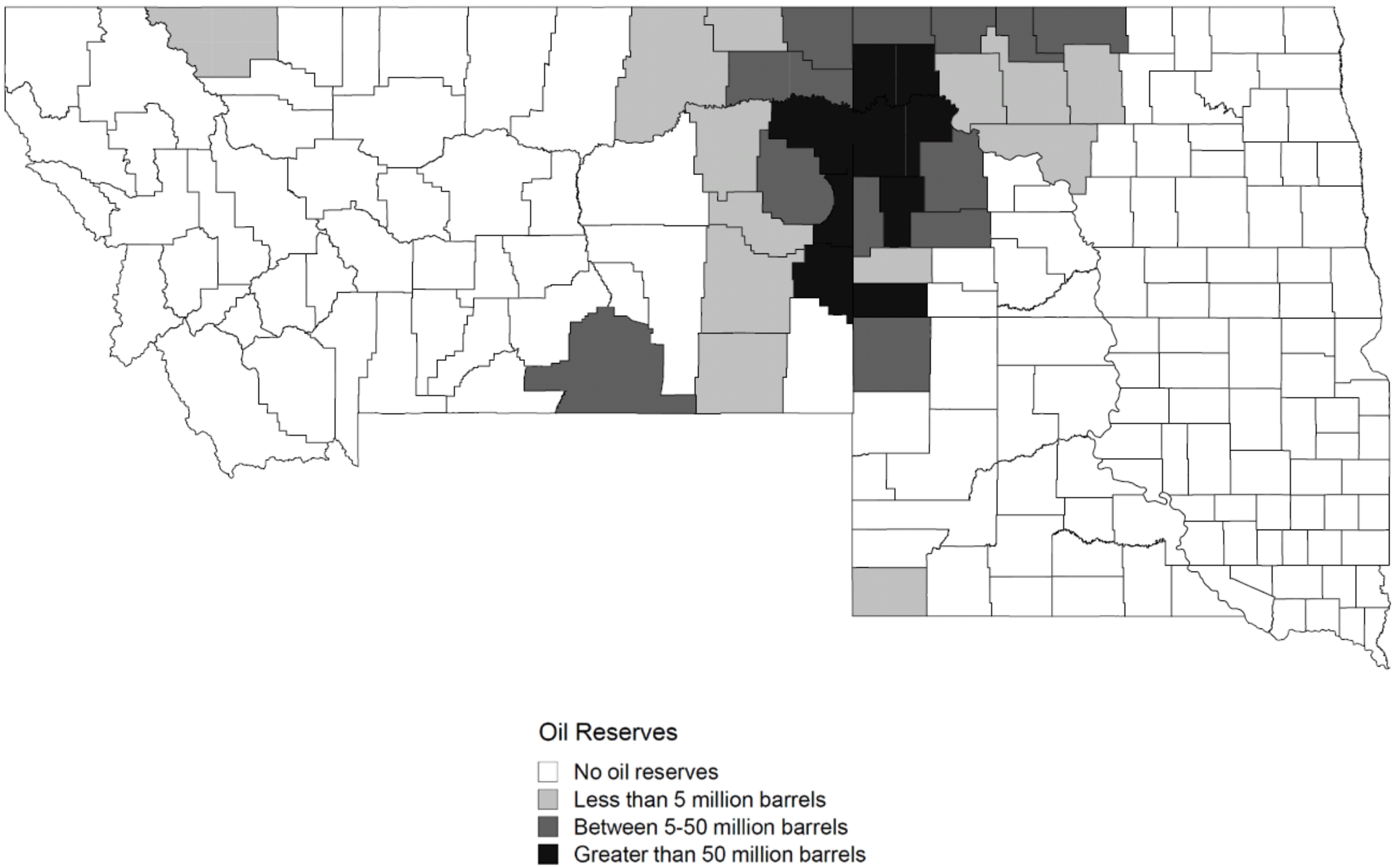

Figure 5a – Quartile of Average Annual Earnings Growth:
Montana, North Dakota, and South Dakota, 1993-2004

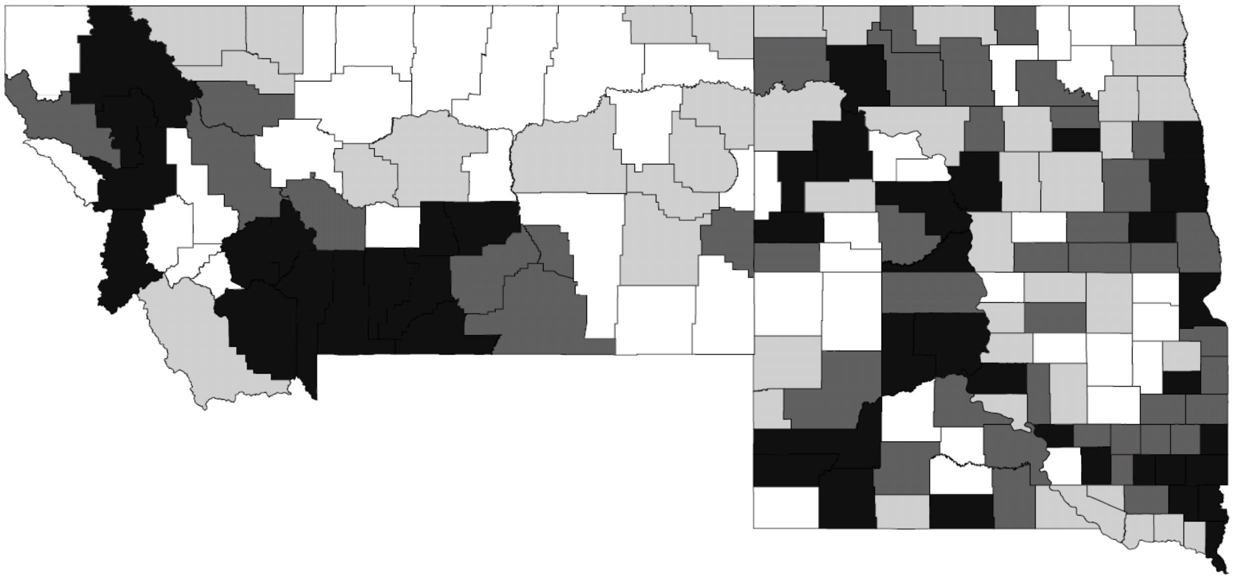

Figure 5b – Quartile of Average Annual Earnings Growth:
Montana, North Dakota, and South Dakota, 2005-2010

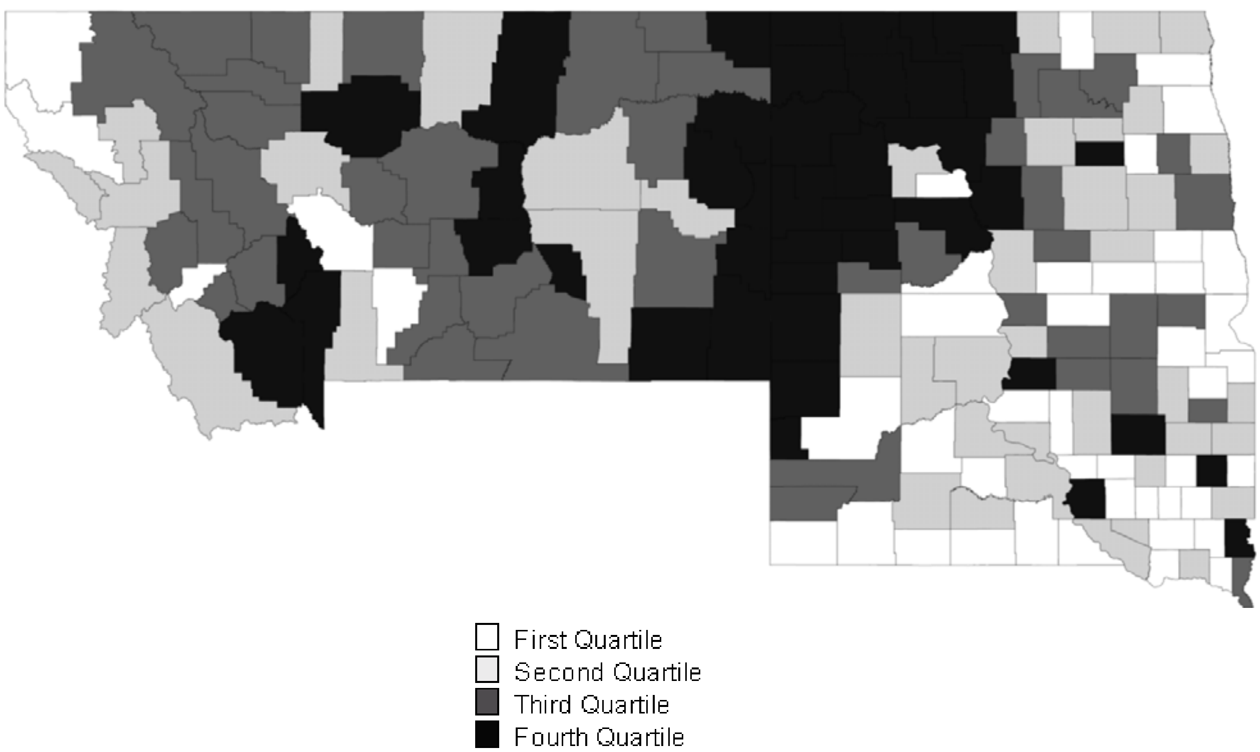

Figure 6a – Quartile of Average Change in Net Migration:
Montana, North Dakota, and South Dakota, 1993-2004

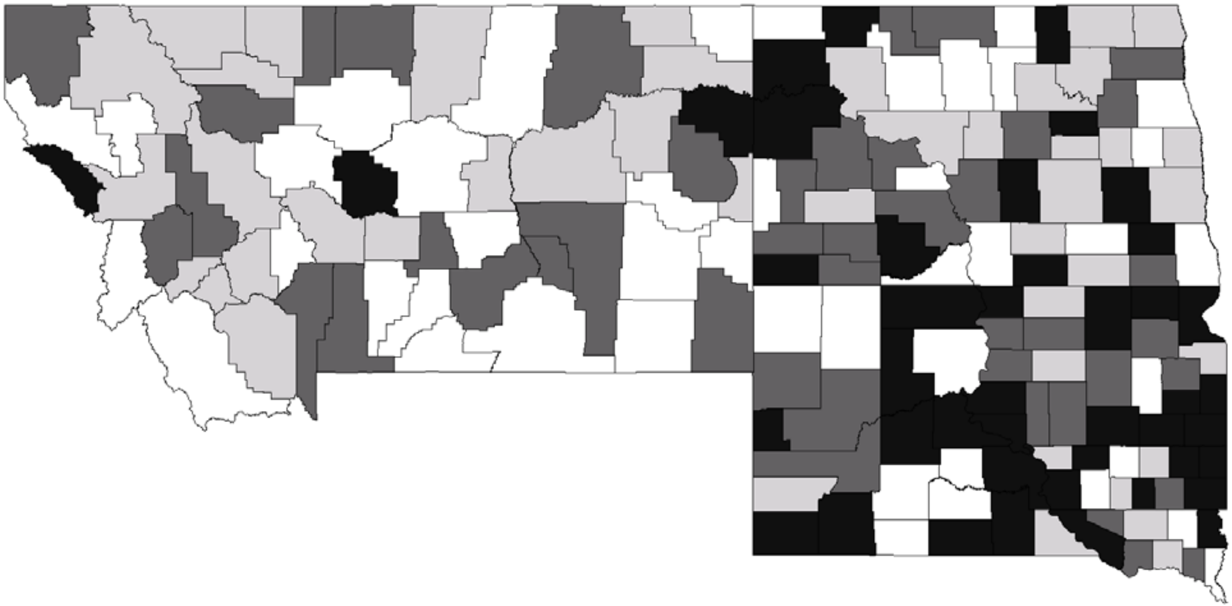

Figure 6b – Quartile of Average Change in Net Migration:
Montana, North Dakota, and South Dakota, 2005-2010

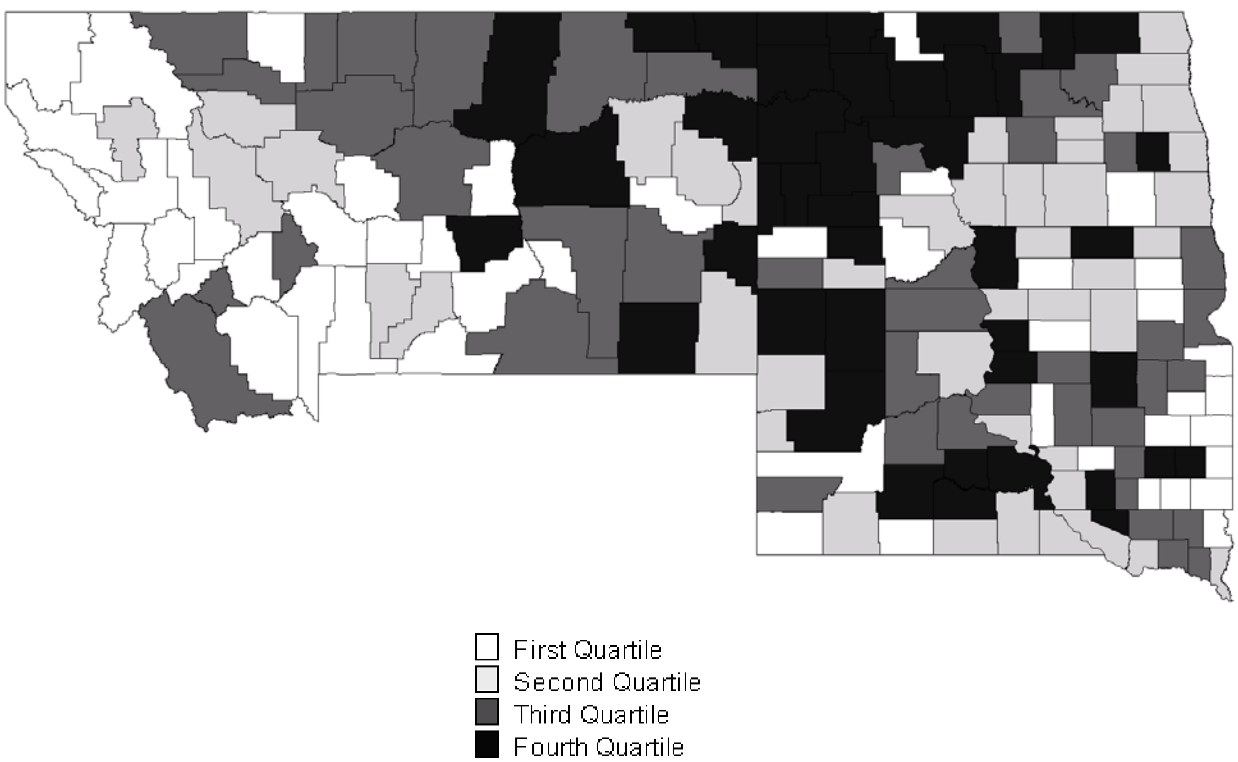

Table 1 - Sample Means by Period: Montana, North Dakota, and South Dakota, 1993-2004 and 2005-2010

	All Counties (1)	Oil Counties (2)	No Oil Counties (3)
Panel A: Sample Means (1993-2010)			
Returns In	385.3	196.0	427.7
Returns Out	388.3	215.8	426.9
Net Migration	-2.9	-19.8	0.8
Total Returns (Households)	5556.1	3206.1	6131.9
Net Migration Rate	-0.008	-0.010	-0.008
Total Exemptions (Population)	11798.9	7048.1	12963.0
County Earnings per Return (Thousands of 2010$)	27.03	26.1	27.3
Logarithmic Difference in Earnings	0.009	0.016	0.007
Oil Reserves (Thousands of Barrels)		43,993.7	
West Texas Intermediate Crude Oil Price per Barrel (2010$)	45.8		
Logarithmic Difference in the Value of Oil Reserves		0.06	
Panel B : Pre-Boom (1993-2004)			
Returns In	372.0596	182.9	414.3
Returns Out	382.9537	218.5	419.7
Net Migration	-10.9	-35.6	-5.4
Total Returns (Households)	5,282.8	3,109.2	5,842.6
Net Migration Rate	-0.01	-0.015	-0.009
Total Exemptions (Population)	11,551.2	7,065.9	12,706.4
County Earnings per Return (Thousands of 2010$)	26.2	24.5	26.7
Logarithmic Difference in Earnings	0.016	0.017	0.015
Oil Reserves (Thousands of Barrels)		43,993.7	
West Texas Intermediate Crude Oil Price per Barrel (2010$)	30.8		
Logarithmic Difference in the Value of Oil Reserves		0.049	
Panel C: Oil Boom (2005-2010)			
Returns In	411.8	222.0	454.6
Returns Out	399.0	210.4	441.5
Net Migration	12.9	11.6	13.2
Total Returns (Households)	6034.0	3395.9	6624.3
Net Migration Rate	-0.0045	-0.0013	-0.005
Total Exemptions (Population)	12,231.9	7,013.2	13,399.7
County Earnings per Return (Thousands of 2010$)	28.4	29.3	28.2
Logarithmic Difference in Earnings	-0.002	0.015	-0.005
Oil Reserves (Thousands of Barrels)		43,993.7	
West Texas Intermediate Crude Oil Price per Barrel (2010$)	75.7		
Logarithmic Difference in the Value of Oil Reserves		0.084	
Number of Counties	175	32	143

Table 2 - First-Stage Relationship between Oil Reserve Instruments and Earnings Growth and Land Value Growth: Montana, North Dakota, and South Dakota, 1993-2010

	Earnings		Cropland Value
	North Dakota	Three-State Region	North Dakota
	(1)	(2)	(3)
Change in the Value of Oil Reserves (α_1)	0.025	0.004	-0.087
	(0.011)	(0.007)	(0.024)
Dummy Variable for Post-2004 x Change in the Value of Oil Reserves (α_2)	0.041	0.032	0.140
	(0.025)	(0.013)	(0.043)
F-Statistic	12.6	3.8	9.1
Observations	884	2,669	884

Notes: Robust standard errors in parentheses are clustered at the county level. All models include state-by-year fixed effects.

Table 3 - Estimates of the Impact of Earnings Growth on Net Migration: Montana, North Dakota, and South Dakota, 1993-2010

	North Dakota		Three-State Region
	OLS	IV	IV
	(1)	(2)	(3)
Earnings Growth	0.043	0.214	0.429
	(0.025)	(0.115)	(0.222)
Observations	884	884	2,669

Notes: Robust standard errors in parentheses are clustered at the county level. All models include state-by-year fixed effects.

Table 4 - Estimates of the Impact of Earnings and Land Value Growth on Net Migration: North Dakota, 1993-2010

	OLS (1)	IV (2)	IV (3)
Earnings Growth	0.042	0.215	0.213
	(0.025)	(0.115)	(0.112)
Cropland Value Growth	-0.005	-0.008	0.005
	(0.007)	(0.007)	(0.059)
Cropland Value as Endogenous Regressor	No	No	Yes
Observations	899	884	884

Notes: Robust standard errors in parentheses are clustered at the county level. All models include state-by-year fixed effects.

Table 5 - Spatial IV Estimates of the Impact of Earnings Growth on Net Migration: North Dakota, 1998-2010

	(1)	(2)
Earnings Growth	0.237	0.281
	(0.134)	(0.115)
Spatial Error Model	Yes	No
Observations	673	673

Notes: Standard errors are in parentheses. All models include state-by-year fixed effects. The spatial regression analysis used requires that panel data be strongly balanced. Observations prior to 1998 were dropped due to missing values. For the same reason, one county with missing data after 1998 was also dropped from the sample.

Table 6 - IV Estimates of the Impact of Various Measures of Economic Activity on Net Migration: North Dakota, 1999-2010

	(1)	(2)	(3)	(4)
Consumption	0.053 (0.026)			
Earnings		0.218 (0.117)		
Non-Labor Income			0.042 (0.021)	
Adjusted Gross Income				0.066 (0.035)
Observations	628	681	681	681

Notes: Robust standard errors in parentheses are clustered at the county level.