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NATURAL RESOURCE, REGIONAL GROWTH, AND HUMAN CAPITAL ACCUMULATION

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Na Zuo, Student

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NATURAL RESOURCE, REGIONAL GROWTH, AND HUMAN CAPITAL ACCUMULATION

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Agriculture, Food and Environment at the University of Kentucky

By

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Lexington, Kentucky

2017

ABSTRACT OF DISSERTATION

NATURAL RESOURCE, REGIONAL GROWTH, AND HUMAN CAPITAL ACCUMULATION

The dissertation research will comprise three essays on the topic of the resource curse hypothesis and its mechanisms. The phenomenon of low economic growth in resource-rich regions is recognized as the “resource curse”. These essays will contribute to an understanding of the regional resource-growth relation within a nation.

Essay one tests the resource curse hypothesis at the U.S. state level. With a system of equations model, I decompose the overall resource effect to account for the two leading explanations — crowding-out and institution effects, thus investigate whether the institutions mediate the crowding-out effects. I did not find evidence of an overall negative effect on growth by resource wealth. Both the crowding-out and institution appear present, but they offset: the resource boom crowds out industrial investments, but good institutions mitigate the overall effect. Resources do reduce growth in states with low-quality institutions, including Louisiana, Oklahoma, and Texas.

Essay two compares the effects of resource revenues on the economic growth and growth-related factors across Chinese provinces and American states, using panel data from 1990 to 2015. With the Instrumental Variable (IV) strategy, I show that regions with higher resource revenues grow faster than other regions in both China and the U.S. The positive resource effect is larger and more statistically significant in the U.S. Further testing impacts of three resource-related policies in China, e.g. the market price reform, the fiscal reform, and the Western Development Strategy, I show that the market price reform together with the privatization process on coal resources contribute the positive resource effect in China. Though strong and positive resource – growth relations appear in both countries, evidence also suggests consistent negative resource effects on certain growth-related factors in both countries, such as educational attainments and R&D activities.

Essay three explores the schooling response to the oil and gas boom, taking advantage of timing and spatial variation in oil and gas well drilling activities. Development of cost-reducing technologies at the time of higher crude oil and natural gas prices in the early

2000s has accelerated shale oil and gas extraction in the United States. I show that intensive drilling activities have decreased grade 11 and 12 enrollment over the 14 year study window − approximately 36 *fewer* students per county on average and overall, 41,760 *fewer* students across the 15 states enrolled considered in the analysis. On average, with one additional oil or gas well drilled per thousand initial laborers, grade 11 and 12 enrollment would decrease 0.24 percent at the county level, all else equal. I investigate heterogeneous effects and show that the implied effect of the boom is larger in states with a younger compulsory schooling age requirement (16 years of age instead of 17 or 18), lower state-level effective tax rate on oil and gas productions, traditional mining, non-metro, and persistent poverty counties.

KEYWORDS: Resource Curse, Economic Growth, the United States, China, Energy Boom, High School Enrollment

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Student Signature

May 23rd,2017

Date

NATURAL RESOURCE, REGIONAL GROWTH, AND HUMAN CAPITAL ACCUMULATION

By

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Director of Graduate Studies

May 23rd, 2017

To my mother, father, and husband

For their love, support, and faith in me

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Chapter 1 Introduction

1.1. Motivation

Many economically important commodities could be described as natural resources – land, oil, coal, ores, fish populations, and so on. Economic growth depends on production factors, such as capital, labor, and natural resources. However, does resource wealth promote economic development? Counter-intuitively, some of the fastest growing economies over recent decades are regions with little natural wealth, whereas some countries with enormous resources suffer from poor economic performance, such as Angola, Nigeria and the Democratic Republic of Congo. The phenomenon that resource-rich regions develop less quickly, called the *resource curse*, was formally presented by Auty in 1993 and has become "*one of the most intriguing puzzles in economic development and a great example of how organized empirical observations can guide economic theory and inform policy*" (James and Aadland, 2011 pp440).

Empirical tests of the *resource curse* hypothesis started with cross-country studies and led to no consensus conclusions. Some economists observed the resource curse as a general phenomenon in a large sample of countries from the 1960s to 2000s (Sachs and Warner, 1995; Papyrakis and Gerlagh, 2004; et al.) while others have refuted the resource curse hypothesis (Brunnschweiler and Bulte, 2008; et al.). It is not surprising that effects of natural resources on the economy vary from country to country and across different episodes in history. However, the inconsistent empirical results could also reflect biases lying in cross-country analyses. Country-level observations offer significant variations in resource endowments, and economic growths, which facilitate the analysis. Yet many confounding features, such as geography, culture, and institution quality, also exist and could potentially bias the results, especially in cross-sectional analysis. The concern persists with panel-data given the time-varying hard-to-measure factors like macroeconomic policies. To address concerns in cross-country studies, this dissertation exploits variation within a country, where variables that might confound the relationship between resources and macroeconomic outcomes do not vary and the danger of spurious correlation is minimized.

Two main explanations for the *resource curse* have been proposed. The *crowding-out effect* suggests that resource wealth crowds out growth-inducing factors such as investment, human capital, innovation and so on. The *institution effect* argues that whether resource wealth is a curse or not depends on the governance quality in the resource-rich region. Good institutions mediate the potential curse. Both explanations have been supported by empirical work (Sachs and Warner, 1995, 1999 and 2001; Mehlum et al., 2006; Michaels, 2011; Boschini et al., 2013). In literature, the crowding-out effect and the institution effect have been tested separately or not at all. In Chapter two, this gap is addressed by decomposing the resource effect into direct effect, crowding-out effect, and institution effect in the U.S.

Regional level analyses reduce the danger of spurious correlations by analyzing subnational regions facing the same economic system, institution arrangement, macroeconomic policies, and less various cultures and institutional qualities. The tradeoff is to forgo opportunities of testing impacts from persistent features, such as the economic system and institution arrangement. Chapter three explores the role of economic systems in the resource – growth relation with a comparison analysis between China and the U.S.

Horizontal drilling and hydraulic fracturing technologies have induced an oil and gas drilling boom in the U.S. since the 2000s. Oil and gas extraction has rapidly increased from shale formations. Comparing to conventional gas deposits which are in permeable rocks typically located much closer to the surface, the shale deposits are trapped in fine-grained sedimentary rocks with very low permeability and located 1,000 to 13,500 feet below the surface (Joskow 2013). According to U.S. Energy Information Administration (EIA), hydraulic fracturing (commonly called "fracking" or "fracing") is a technique in which water, chemicals, and sand are pumped into the well to unlock the hydrocarbons trapped in shale formations by opening cracks (fractures) in the rock and allowing natural gas to flow from the shale into the well. When used in conjunction with horizontal drilling, hydraulic fracturing enables gas producers to extract shale gas economically. Simply, fracking is to produce natural gas from shale rock by bombarding it with water and chemicals.

The increase in oil and gas related employment is the other side of the shale gas boom. Many new jobs related to the energy boom are task-skill based – meaning that education and work experience requirements for entry are low – and have the potential to raise the opportunity cost of schooling significantly. During energy boom periods, increased demand for and earnings of task-skill labor with low education requirements could widen the wage differential and increase the opportunity cost of staying in school, thus drawing teenagers out of school (Black, McKinnish and Sanders 2005b; Emery, Ferrer and Green 2012). Chapter four exploits variation in timing and spatial patterns of oil and gas well drilling activities across 15 American states since the 2000s to investigate the schooling impact of the rent shale oil and gas boom.

1.2. Objectives and Structure

The objectives of this dissertation are four-fold. The first is to test the resource curse hypothesis within the U.S. and China. Second, investigate the mechanisms, e.g. the crowding-out effect and the institution effect, in the U.S. to shed light on the meditation strategies to the “cursed” regions. Then compare the U.S. and China case to draw insights on how the distinct economic systems could alter the resource – growth relation. Finally, take advantage of the shale oil and gas boom in the U.S. and investigate the impact of resource booms on schooling decisions.

Chapter two tests whether a resource curse exists in the U.S. and further decomposing the resource effect into direct effect, crowding-out effect, and institution effect. A panel data set of 50 states from 1997 to 2014 with a system of equations model. It contributes to the literature with the decomposition of the overall resource effect thus investigates the two mechanisms simultaneously.

Chapter three uses comparable measures to examine the effects of resource revenues on the economic growth and growth-related factors across Chinese provinces and American states from 1990 to 2015. For economies in transition, such as China, weak price signals and prevailing state ownership likely lead to inefficient resource allocation, leaving a weak or even negative resource-growth relation. The main goal of this chapter is to illustrate this argument using comparative regional-level analysis of the resource wealth impacts in China and the United States. It contributes to the literature with the first comparison piece between Chinese provinces and the U.S. states on testing the resource-growth relation. Several resource-related policies during the study period in China, such as the market price reform, the fiscal reform, and the Western Development Strategy, provide variations in China’s transition to a market economy. To the best of my knowledge, this is also the first study in the China literature to link and empirically test impacts of market price reforms and the fiscal reform in the resource-growth relation.

Chapter four exploits county and year variation in drilling activities across 1170 counties in 15 oil and gas production states in the U.S. between 2000 and 2013. The instrumental variable approach with various fixed effects provides estimates of how this recent oil and gas boom affected high school enrollment at the county level. It improves the literature by drawing on rich well drilling data at an annual frequency that both identifies the location, timing, and intensity of the oil and gas boom and allows me to explore heterogeneous effects. Chapter five closes the dissertation discussing conclusions and applications.

Chapter 2 Do Institutions Mediate the Crowding-out Effects? The Resource Curse Revisited at the U.S. State Level

2.1. Introduction

Economic growth depends on production factors, such as capital, labor, and natural resources. However, does resource wealth promote economic development? Counter-intuitively, some of the fastest growing economies over recent decades are regions with little natural wealth, whereas some countries with enormous resources suffer from poor economic performance, such as Angola, Nigeria and the Democratic Republic of Congo. The phenomenon that resource-rich regions develop less quickly, called the *resource curse*, was formally presented by Auty in 1993 and has become "*one of the most intriguing puzzles in economic development and a great example of how organized empirical observations can guide economic theory and inform policy*" (James and Aadland, 2011 pp440).

Two main explanations for the resource curse have been proposed. The *crowding-out effect* suggests that resource wealth crowds out growth-inducing factors such as investment, human capital, innovation and so on. The *institution effect* argues that whether resource wealth is a curse or not depends on the governance quality in the resource-rich region. Good institutions mediate the potential curse. Both explanations have been supported by empirical work (Sachs and Warner, 1995, 1999 and 2001; Mehlum et al., 2006; Michaels, 2011; Boschini et al., 2013).

While the resource curse literature began with cross-country analysis, within-country evidence has also emerged (Papyrakis and Gerlagh, 2007; Corey, 2009; Weber, 2013). However, the crowding-out effect and the institution effect have been tested separately or not at all. In this study, I address this gap in the literature by investigating whether a resource curse exists in the U.S. and further decomposing the resource effect into direct effect, crowding-out effect, and institution effect. I analyze a panel data set of 50 states from 1997 to 2014 with a system of equations model and find that both the crowding-out effect and the institution mediation contribute to the resource-growth relation, but that the net resource effect is positive or neutral. In other words, I did not find evidence of a general resource curse for U.S. states and good institutions do mediate the crowding-out effect. The results are robust to different institution measures, model specifications, and econometric approaches. To my best knowledge, this study is the first attempt to test both effects simultaneously. A system of equations model with both state and year fixed effects allows me to test various resource effects systematically, and further addresses the endogeneity due to time-invariant omitted variables and the simultaneous co-movements among macro-variables at the U.S. state level.

2.2. Literature Review

2.2.1. Resource Curse across countries

Are natural resources a curse or a blessing? The empirical evidence is diverse: some economists observed the resource curse as a general phenomenon in a large sample of countries from the 1960s to 2000s (Sachs and Warner, 1995; Papyrakis and Gerlagh, 2004; et al.). However, others have refuted the resource curse hypothesis (Brunnschweiler and Bulte, 2008; et al.). In fact, the same author could claim two opposing views in different studies: Bulte et al. (2005) used resource exports over total exports as a proxy for resource abundance and found that resource-intensive countries tend to suffer lower levels of human development. However, with a similar sample and time frame, Brunnschweiler and Bulte (2008) claimed that the resource curse might be a red herring because the commonly used measure of “resource abundance” is a proxy for “resource dependence,” which is endogenous to underlying structural factors. Using total natural capital and subsoil assets as measures, they found that resource abundance positively affects growth. As summarized in Van der Ploeg (2011), the effects of natural resources on the economy vary from country to country and across different episodes in history.

2.2.2. Are resources a curse? Crowding-out effect and institutions

Economists have developed two main mechanisms to explain the resource curse: the crowding-out effect and the institution explanation. (See Van der Ploeg, 2011)

Crowding-out can be summarized as resource abundance reducing activity *X*, where *X* drives growth. Different crowding-out stories focus on different *X* activities. Sachs and Warner (1995, 1999, and 2001) applied a Dutch Disease model, in which *X* is the manufacture of traded goods. The extra wealth generated by the sale of natural resources induces an appreciation of the real exchange rate so that natural resource windfalls cause deindustrialization (Corden and Neary, 1982; Corden, 1984). This model assumes that learning by doing in the manufacturing sector is the key driver of growth. Other growth-driving activities that may be crowded out by natural resource wealth include education (Gylfason, 2001; Stijns, 2006), knowledge creation (Papyrakis and Gerlagh, 2004), and investment (Beck, 2011).

No matter which *X* factors are examined, the crowding-out explanation suggests that the problem lies in resources themselves: the production function of the resource sector is inferior due to lack of knowledge accumulation (Sachs and Warner, 1995) or fewer backward or forward linkages (Hirschman, 1958). Though a resource boom brings out higher returns at first, it drags the economy into a lower growth path in the long run. This explanation, however, does not explain notable counter-examples, such as Norway and Botswana.

The institution explanation suggests that whether resources are blessed or cursed depends on the quality of institutions. Mehlum et al. (2006a, 2006b) modeled a resource-abundant economy with an allocation of entrepreneurial activity between production and grabbing (i.e., rent-seeking), affected by the quality of institutions. They used Sachs and Warner's dataset to test the institution explanation and concluded that institutions are decisive for the effect of resources. Boschini et al. (2007 and 2013) also concluded that mineral-rich countries are cursed only if they have low-quality institutions (e.g., dysfunctional legal system and low transparency).

Further, resource revenues may encourage bad institutional practices, such as imperfect markets, poorly functioning legal systems, buying off the opposition, or overspending on public service employment (Gelb, 1988; Auty, 2001a; Ross, 1999; Brunnschweiler and Bulte, 2008). In particular, point resources (e.g., minerals and fossil fuels) generate concentrated production and revenue patterns, which are more likely to be controlled by relatively small groups of society, exhibiting so-called "executive discretion in revenue allocation" (Jensen and Wantchekon, 2004). Murshed (2004) argued that point resources (e.g., agriculture, forestry) tend to breed rent-seeking behaviors and harm political institutions, while diffuse resources are better, and manufactured goods are the best for the development of good governance institutions. In contrast, Tompson (2005) studied the political implications of Russia's resource-based economy and concluded that attribution of Russia's politics to its resource-based economy was unconvincing.

The preceding argument lies in the crowding-out camp even though it also recognized institutions as the crucial link. With the crowding-out effect, institutional quality is another growth-driving factor *X* that is retarded by resource abundance, whereas the institution explanation focuses on *ex-ante* institutional quality. In this latter narrative, resource rents could either be captured by interest groups for personal enrichment or be allocated into a productive economy, and the choice depends on institutional qualities. Indeed, the source of the windfall (e.g., natural resources or foreign aid) is irrelevant—it is a *revenue curse* due to bad institutions rather than a resource curse (Morrison, 2010). Australia, Canada, New Zealand, Iceland, Norway, and Botswana are all examples of countries in which strong institutions have made resource abundance a blessing, rather than a curse (Acemoglu et al., 2003).

2.2.3. Within-country variation on resource curse

Subnational studies of the resource curse take advantage of less variation in factors that might confound the relationship between resources and macroeconomic outcomes, reducing the danger of spurious correlations. At the U.S. state level, both Papyrakis and Gerlagh (2007) and Corey (2009) confirmed the resource curse, but the former explained it with crowding-out effects and the latter supported the institution explanation. At the U.S. county level, Michaels (2011) showed evidence that oil abundance increased local employment in both the mining and manufacturing sectors and that the South's oil endowment helped to overcome its slow start, rather than impede its growth, compared to the North's. Weber (2013) reached a similar conclusion on natural gas development since

2000. However, James and Aadland (2011) investigated 3,092 U.S. counties and showed clear evidence of a resource curse.

Factor mobilities are higher within a country than across countries. The spatial equilibrium model suggests that people “vote with their feet” and that high income can be interpreted as compensation for negative site-specific attributes (Roback, 1982; Glaeser and Gottlieb, 2008). As a result, income may not be a good proxy for state or local wellbeing. Change in employment, population, and poverty rate are used as alternative measures (Weber 2012 and 2013; Partridge et al., 2013). Spatial modeling is further applied to consider other neighbor effects within a country (Weber 2013). In this study, I focus on the growth rate of state per capita income, to be consistent with the original resource curse hypothesis proposed by Auty and make results comparable to the literature. I further check the robustness with alternative dependent variables like state population growth and additional spatial analyses.

I contribute to the literature by using U.S. state-level panel data in a system of equations to test the resource curse hypothesis. I decompose the overall resource impact into the direct effect, the crowding-out effect, and the institution effect, thus investigating the two mechanisms simultaneously. At the county level, the lack of data on institution proxies prevents investigation of the institution explanation. At the state level, previous studies have independently tested the two mechanisms. Also, these studies rely on cross-sectional data, whereas my use of panel data models can control for state-specific effects, thus reducing omitted variable bias.

2.3. Empirical Model and Data

The empirical analyses aim to test the resource curse hypothesis at the U.S. state level and its two mechanisms, the crowding-out effect, and the institution effect.

2.3.1. Resource wealth and growth

A system of equations is proposed to identify and decompose the resource-growth relation:

$$G_{it} = \beta_0 + \beta_1 \ln(Inc)_{i,t-1} + \beta_2 R_{it} + \beta_3 (R_{it} * Institution_i) + \boldsymbol{\beta}'\mathbf{X}_{it} + S_i + T_t + \varepsilon_{it}, \quad (1)$$

$$\mathbf{X}_{it} = \boldsymbol{\alpha}_0 + \boldsymbol{\alpha}_1 \ln(Inc)_{i,t-1} + \boldsymbol{\alpha}_2 R_{i,t} + \mathbf{S}_i + \mathbf{T}_t + \boldsymbol{\mu}_{it}, \quad (2)$$

Subscripts *i* and *t* indicate state and time, respectively. Equation (1) implements the income convergence growth model in the growth and resource curse literature (e.g., Kormendi and Meguire, 1985; Barro and Sala-i-Martin, 1992; Sachs and Warner, 1995 and 1999a; Papyrakis and Gerlagh, 2004 and 2007; et al.). *G* is annual growth in real per capita income, and *Inc* is annual real per capita income. The natural log of per capita income with one period lag ($ln(Inc)_{i,t-1}$) controls for the initial income level and a negative β_1 would imply conditional income convergence in growth. *R* is resource wealth. The interaction term between resource wealth and institutional quality (*Institution*) identifies the institution effect (Mehlum et al., 2006a and 2006b; Boschini et al., 2013): the marginal effect of natural resources on growth is conditional on the level of institutional quality, given by ($\beta_2 + \beta_3 \times Institution$). A positive β_3 signals that a sufficiently high level of the institutional quality can offset the potentially negative β_2, thus break the curse. I call it the *institution effect*. **X** is a matrix of growth-related variables including investment, human capital, and R&D. $\boldsymbol{\beta}'$ is the vector of coefficients on different growth-related variables aforementioned. S_i is a state-specific fixed effect for each state i. T_t is the dummy variable for year, which allows for nationwide shocks and growth trends over time not otherwise accounted for by the explanatory variables.

The crowding-out effect was tested by regressing growth-friendly factors (X) on the resource variable as specified in equation (2) (Sachs and Warner, 1995; Papyrakis and Gerlagh, 2007; Shao and Qi, 2009). Since matrix **X** consists of three vectors: investment, human capital, and R&D intensity, (1) and (2) constitute a system of four equations. A negative α_2 implies that factor X decreases with the resource abundance level so that x is crowded-out by resources.

To test crowding-out and institution effects systematically and fully identify the resource-growth relation, I substitute equation (2) into equation (1) and obtain the reduced form equation (3):

$$G_{it} = \gamma_0 + \gamma_1 ln(Inc)_{i,t-1} + \gamma_2 R_{it} + \gamma_3 (R_{it} * Institution_i) + \boldsymbol{\gamma}' \boldsymbol{\mu}_{i,t} + S_i + T_t + \varepsilon_{it}, \quad (3)$$

Where $\gamma_0 = \beta_0 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_0$;

$\gamma_1 = \beta_1 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_1$;

$\gamma_2 = \beta_2 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_2$;

$\gamma_3 = \beta_3$;

$\boldsymbol{\gamma}' = \boldsymbol{\beta}'$

Both $\boldsymbol{\beta}'$ and $\boldsymbol{\alpha}$ are vectors of coefficients and $\boldsymbol{\mu}_{i,t}$ is a vector of residuals from equation (2). Finally, the overall marginal effect of natural resources on growth is given by equation (4):

$$\partial G / \partial R = \gamma_2 + \gamma_3 * Institution_i = \beta_2 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_2 + \beta_3 * Institution_i, \quad (4)$$

Four testable hypotheses are parameterized in equation (4). The general resource curse would be reflected by a negative coefficient for the overall impact of resource wealth on growth ($\frac{\partial G}{\partial R}$). This impact is decomposed into three effects: the direct effect (β_2), the crowding-out effects ($\boldsymbol{\beta}' * \boldsymbol{\alpha}_2$), and the institution effect ($\beta_3 * Institution_i$). While theory has not suggested a specific sign on the direct effect β_2, a negative $\boldsymbol{\alpha}_2$ multiplying a positive $\boldsymbol{\beta}'$ implies a crowding-out effect on growth-inducing factors, and a positive β_3 signals the institution effect that mediates any potential negative effect. The overall resource effect depends on the sign, magnitude, and significance of all three effects. The decomposition differentiates this study from other empirical specifications. The resource curse literature either estimated equation (1) only and tested the direct and the institution effect, or investigated the crowding-out mechanism without the interaction between resource wealth and institutional quality (e.g. Papyrakis and Gerlagh, 2004 and 2007). The system of equations model allows me to decompose the overall resource effects and test both effects simultaneously.

A system of equations with panel data can be estimated with single equation approach, such as applying panel estimators (e.g. Fixed Effect), equation-by-equation, or with system estimators such as three-stage least squares (3SLS). The single equation approach assumes that (i) all regressors are exogenous, and (ii) correlations among errors in the system are zero. When these assumptions are likely to be violated, 3SLS allows correlation among errors and endogenous regressors. I report the results of both approaches. State and year fixed effects are controlled in each equation. With the 3SLS estimator, the system is identified with both included and excluded instruments. The included instruments are natural log of real per capita personal income with a one-year lag, resource wealth with a one-year lag, ex-ante institutional quality measures, state and year dummies. Moreover, two-year lagged investment, human capital, and R&D density are employed as excluded instruments[1]. In addition to my main analysis, I report a number of diagnostic tests following the 3SLS regression, and I further check robustness by employing alternative econometric approaches incorporating dynamic and spatial dimensions. These results are discussed in Section 2.5.

2.3.2. Justification for the covariates and the measure

2.3.2.1. Measuring resource wealth

Table 1 lists variable definitions and descriptive statistics. In my baseline analysis, my measure of resource wealth is *Resource_point*, which is the share of gross state product (GSP) derived from the extraction of point resource (i.e., mining sector). According to the literature, point resources are more likely to contribute to the resource curse (Jensen and Wantchekon, 2004; Murshed, 2004). However, I also examine alternative measures: *Resource_diffuse* is the GSP share from the extraction of the diffuse resource (i.e., agriculture, fishing, and forestry), while *Resource_oil&gas*, *Resource_coal&metal,* and *Resource_supportactivities* are measures that further segment the GSP share from point resources. In the 2000s, the U.S. has experienced large increases in the extraction of oil and natural gas from shale, while coal extraction has declined. Analysis of the last two

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[1] Ideally, I would like one unique explanatory variable for each of the three equations in (2) to obtain sufficient exclusion restrictions. However, under the specification with both state and year fixed effects, explanatory power is already very high for the investment, human capital and R&D equations (R^2 are all above 90%). The panel setting (i.e., annual variation) makes it difficult to obtain such explanatory variables. Thus I apply two-year lagged investment, human capital, and R&D expenditure as excluded instruments, and they all pass various diagnostic tests as discussed in the text.

measures allows me to consider the effects of this trend and the differing technologies associated with these different resources.

These variables are flow measures equivalent to the share of natural resources in export or GDP in cross-countries studies (Sachs and Warner, 1995; Mehlum et al., 2006a and 2006b; Boschini et al., 2013). Other studies have employed stock measures such as the share of natural capital in total capital or the value of subsoil assets (Alexeev and Conrad, 2009, Brunnschweiler and Bulte, 2008, Gylfason, 2001; Hodler, 2006). I agree that it is important to distinguish between resource "endowments" (e.g., the stock measures) and resource "dependency" (e.g., the flow measures)[2]. I also agree that stock measures suffer fewer problems with endogeneity[3]. However, I believe that it is when resources come into the production process and the resource rents are realized that they are most likely to influence growth. Unexploited resources may connect with economic performance tenuously. As Boschini et al. (2013) pointed out, when politicians face some trade-off between grabbing the resources today or developing other sectors in expecting more future gains, or when an individual choose to work in the booming resource sector rather than investing in education, "*it is the share that resources makeup of the economy at the point of deciding that matters*" (page 21).

Regardless of these important aspects, flow measures may be viewed as conditionally exogenous. First, mining activity is highly related to resource availability, which is

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[2] The distinction was first made in Stijins (2005) and later developed by Brunnschweiler and Bulte (2008).
[3] As van der Ploeg and Poelhekke (2010) pointed out, resource reserve measures are not necessarily exogenous since countries that have long been industrialized or with better institutions are more likely to have explored and found more of their reserves. In the subnational case though, reserves across a country seem more exogenous due to homogeneous exploration technology across states.

geologically exogenous[4]. Second, the main criticism of flow measures in the literature is that economic policies and institutions may influence resource dependency. For example, Brunnschweiler and Bulte (2008) suggested that sectoral lobbying can alter policies. In some studies (e.g., Weber, 2013), this endogeneity is addressed by use of geological instruments, such as the percent of the region covering an oil or gas formation, but this approach is precluded by my use of state fixed effects. Instead, I check the sensitivity of my results to endogeneity with the *Added Controls Approach* (ACA) by including proxies for lobbying and rent-seeking behaviors. These results are discussed in Section 2.5.

2.3.2.2. Measuring institutional quality

Several aspects of institutions have been studied in the resource curse context. One division is between "rules" and "institutional outcomes" (Boschini et al., 2013)[5]. Rules refer to constraints on governance or the executive, such as constitutional arrangements, the degree of democracy, or trade restrictions. Institutional outcomes, in contrast, reflect government actions. In cross-country studies, scholars have employed several standard indices to indicate both sides of institutional quality[6]. In my study, measures of institutional "rules" are unlikely to show much variation across U.S. states. I, therefore,

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[4] In fact, many studies has employed exogenous geological factors to instrument resource dependence (Weber, 2012 and 2013; Borge et al., 2013), which suggests that most part of the resource production is exogenous and related to the exogenous resource availability rather than other factors.

[5] In the same line, Brunnschweiler and Bulte (2008) differentiate between institutions as "durable constraints" and "changeable policy outcomes". In the institution literature but not the resource curse context, Acemoglu and Johnson (2005) distinguish between economic and political institutions, capturing a similar point. Also see Glaeser et al. (2004) and Persson (2005)

[6] Indicators for "institution rules" include the degree of democracy from Polity IV data set (Murshed, 2004); for "institutional outcomes" include rule of law and government effectiveness measured by the World Bank (Bulte et al., 2005), various country risk indices from the International Country Risk Guide (Mehlum et al., 2004; Boschini et al., 2007; et al.) and transparency (Williams, 2011).

focus on the "institutional outcomes" dimension. Based on literature and available data, I use four indices of institutional quality: a constructed government efficiency index, public official corruption convictions, the score of state liability systems by the U.S. Chamber of Commerce, and the Economic Freedom of North America Index (EFNA) by the Fraser Institute. I use the first measure in my baseline analysis, and investigate the institution effect in detail with all four proxies.

For my first measure of institutional quality, I constructed an index of government efficiency following Borge et al. (2008), Borge et al. (2013) and Andrews and Brewer (2013). The output of each state government is measured by the z-scores for 15 indicators across five public service sectors: Education, Health, Highways, Public Safety, and Environment (accounting for 89% of direct general expenditures in 2010)[7]. These scores are weighted by the sector expenditure shares and summed. The index then divides this output measure by the real revenue per capita received by state and local governments, reflecting inputs to the public sector[8]. This index reflects, to some extent, government behavior to allocate rent, thus hinting whether the economy is a producer- or grabber-friendly.

The second measure, the number of state public official corruption convictions per 1,000 elected officials (data from the U.S. Department of Justice[9]), measures rent-seeking

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[7] Calculated from "State and Local Government Finances Summary: 2010", table A-1 "State and Local Government Finances by Level of Government: 2010", http://www.census.gov/prod/2012pubs/g10-alfin.pdf

[8] Details of the index construction and data are provided in Appendix A 1.2.

[9] The Public Integrity Section of U.S. Department of Justice surveys the U.S. Attorneys' Offices nationwide annually on public corruption, defined as crimes involving abuses of the public trust by government officials. The statistics are published in the annual *Report to Congress on the Activities and Operations of the Public Integrity Section*.

behavior directly. Third, the score of state liability systems comes from the 2002 State Liability System Ranking Study, a survey of 1,482 in-house general counsel, senior litigators or attorneys, and other senior executives. It explores how reasonable, fair, and balanced the state tort liability systems are perceived to be by U.S. business. Finally, the Economic Freedom of North America Index (EFNA) indicates the degree of government intervention in the economy beyond its protective function. The government collects resource rent and expand. Although some would argue that a larger public sector is a drag on economic growth, that threat is reduced when institutional quality is high, and government revenues are used for the economically efficient provision of public goods. The Government Efficiency Index captures these government behaviors on productivity, while the Economic Freedom Index considers government expansion only. Thus, the Government Efficiency Index is my preferred institutional quality measure.

With the institution effect, whether resource wealth is a blessing or a curse depends on institutional quality when the resource rent is realized. To address endogeneity concerns, I use a time-invariant measure for each of the four variables discussed above. Specifically, I use the average value of the variable over several years (based on data availability, see Table 1) *prior to* the start of my other data series. In my panel data setting, the state fixed effects preclude an estimation of the marginal effects of the institutional quality variables themselves. However, by including the interaction term $(R_{it} * Institution_i)$ in equation (1), I can still test for the institution effect as a moderator of the resource curse.

In addition to the pre-determined institutional quality measures, I further address the endogeneity issue in several ways. First, any time-invariant omitted variables, such as state geographical characteristics, are captured in the state fixed effect term, s_i, for which the fixed effect estimator correct. Then, I employ the statistics introduced by Altonji et al. (2005 and 2008)[10] to test for bias caused by unobserved time-varying factors. Since the test statistics can be conducted only in a single-equation setting, I report it in the sensitivity analysis with the fixed effect and first difference models.

2.3.2.3. Other covariates

The vectors in **X** (investment, human capital, and R&D) play two roles in the analysis. First, they are used as controls in the growth regression (equation 1). Second, in the resource curse context, each factor is a channel possibly linking resource wealth to growth. In other words, they are factors potentially crowded-out by resource wealth. Although the issue of resources affecting institutions is discussed at length in the literature, I omit institutional quality as a crowded-out factor in this analysis. First, the crowding-out of institutions may be most relevant in the long run, which annual variations in the data would hardly reflect. Second, I have chosen to mitigate endogeneity issues by using time-invariant measures of prior institutional quality, which is exogenous to contemporary resource production. Thus, I can address the importance of institutions in mitigating the resource curse but not the crowding-out of institutional quality.

The first potentially crowded-out factor is the investment. Anticipating a stream of returns from the natural resource, an agent has less desire to invest in man-made capital for future periods (Corden, 1984; Gylfason and Zoega, 2006). A wage premium in the

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[10] Please refer to Altonji, Elder, and Taber (2002, 2005 and 2008) for more details on the methodology. I sincerely appreciate Dr. Elder (Northwestern University) for generously discussing the Altonji-Elder-Taber statistics and sharing the STATA code.

resource sector, for example, can signify the reallocation of production factors from the manufacturing sector to the booming resource sector (Sachs and Warner 2001). While an expanding resource sector could crowd out the manufacturing sector, the investment on the margin is more likely to be reallocated into the resource sector. The manufacturing sector is often characterized by increasing returns to scale and positive externalities (forward and backward linkages). A decline in the scale of the manufacturing further decreases the productivity of investments, which accelerates the decrease in investments (Sachs and Warner, 1995 and 1999a; Gylfason and Zoega, 2006; Papyrakis and Gerlagh, 2007). Moreover, the volatility of the resource revenue creates uncertainty for investors in resource economies (Sachs and Warner, 1999b). At the U.S. state level, data on the gross investment (public and private) by the state is not available. I follow Papyrakis and Gerlagh (2007) and use the share of industrial machinery production in GSP as a measure of investment.

The second factor is human capital, long recognized as an important factor to economic growth (Lucas, 1988; Mankiw et al., 1992) and a channel causing the resource curse (Gylfason, 2001; Sachs and Warner, 2001; Papyrakis and Gerlagh, 2007; Shao and Qi, 2009). Resource abundance may discourage both private and public incentives to accumulate human capital due to short-sighted behaviors. With higher wage and non-wage incomes related to the resource abundance in the short term, individuals or public sectors of high discount rates become less motivated in investing in human capital (Gylfason and Zoega, 2006). At the same time, the typically low skill requirements and high pay for labor in the resource sector further reduce returns to education with a resource boom (Gylfason, 2001). These imply a crowding-out of human capital.

Different measures of human capital have been used in the literature. Some focus on education inputs, such as public expenditure on education (Gylfason, 2001), the share of educational services in gross state product (Papyrakis and Gerlagh, 2007), and gross secondary-school enrollment (Gylfason, 2001). Education input measures ignore the effect of labor mobility on the regional human capital stock, and thus on regional growth. While cross-country research is less concerned with labor movement, the effect could be significant within a country, especially the U.S. (Weber, 2013). Other indicators measure regional human capital endowment and use educational attainment in the population, such as the share of the population with at least a bachelor's degree (James and Aadland, 2011; Weber, 2013). I use the latter measurement to account for a more direct effect of the human capital stock on regional growth[11].

Third, research and development (R&D) activities promote economic growth with technology and productivity improvements. As with investment, a flow of wealth from natural resources may harm the incentive to innovate for long run benefit; i.e., natural resource abundance may crowd out innovation[12] (Sachs and Warner, 2001). I use each state's R&D intensity, which is the ratio of total R&D performed both from private and public sectors in a state to its GSP, to indicate the state innovation level. In the case when R&D occurs in one state but is applied in other states, this measure omits the

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[11] I also replaced the human capital stock measure with an education measure, state high school graduation rate, and re-estimated the model. The results are consistent and can be provided upon request.

[12] The resource sector directly contributes to R&D expenditures, e.g. the development of horizontal drilling technology in unconventional oil and gas extraction. However, R&D expenditures in oil and gas exploration and development counts only 0.0.54% to 1.49% of the overall R&D expenditures in the U.S. during my sample periods (authors calculated based on data from U.S. Energy Information Administration and National Science Foundation, National Center for Science and Engineering Statistics). This should mitigate any concern on the autocorrelation between R&D expenditures and oil and gas development.

growth effect of applying R&D outside own state thus fails to capture the complete growth effect. The degree of omitted variable bias will be tested with Altonji-Elder-Taber statistics aforementioned.

2.3.3. Data description

The panel dataset covers the 50 U.S. states from 1997 to 2014. Data for R&D activities come from National Patterns of R&D Resources, and other data are from the U.S. Census Bureau. The time range of this study starts from 1997 partly because the U.S. Census Bureau has replaced the Standard Industrial Classification (SIC) with the North American Industry Classification System (NAICS) since 1997. Most variables contain 900 observations (Table 1-1).

Across the sample, the average annual growth in real per capita personal income is 1.29%, while the average fraction of earnings from both diffuse and point resource sectors is 4.52%. The variation in point resource specialization is substantial. On the low end, Delaware has experienced approximately zero point resource extraction in 2011, 2012 and 2014, while Alaska derived 40.71% of earnings from point resource extraction in 1997. Average mining earnings exceed 10% of the GSP in five states: Wyoming (29.97%), Alaska (25.84%), West Virginia (12.53%), Louisiana (11.15%), and Oklahoma (10.00%), compared to the sample mean of 3.06%.

The Government Efficiency Index shows considerable variation. On average from 1990 to 1995, the most efficient state and local government is New Hampshire, with an index of 1.84, meaning the state and local governments there are 1.84 standard deviations higher than the mean. Other states with an index higher than 1 are Wisconsin (1.52), North Dakota (1.43), Vermont (1.42), Minnesota (1.22), Montana (1.16) and Iowa (1.15), and the states with an index lower than -1 are Mississippi (-2.25), Louisiana (-1.58), South Carolina (-1.39), Texas (-1.18) and Alabama (-1.12).

2.4. Discussion of the Econometric Results

I did not find evidence of an overall negative impact on growth by resource wealth across U.S. states. Decomposing the overall effect, both crowding-out and institution effects are present: the resource boom crowds out industrial investment, but good institutions mediate the potential curse. A significant positive direct effect leads the overall resource effect to be positive. However, the resource effects vary among states, and an overall negative impact appears in states with low-quality institutions. Moreover, different types of resources affect growth differently, and oil/gas extraction drives the main results in my analysis.

2.4.1. Baseline analysis

Table 1-2 reports estimates of the system of equations (1) and (2) with the point resource measure. In column I, the system is estimated by Fixed Effect (FE) estimator applied equation-by-equation, while columns II shows the results of the 3SLS estimator with state and year dummies. In the growth equation, the coefficient on the resource variable is insignificant for FE estimator and significantly positive for a 3SLS estimator, implying a positive direct resource effect on growth. Meanwhile, the coefficient on the interaction between resources and government efficiency is consistently positive and significant, suggesting an institution effect. In the equations for investment, human capital, and R&D, the resource coefficient is negative and significant in the investment equation and positive and significant in the human capital equation. The former supports the crowding-out effect about industrial investment, while the latter suggests an opposite pattern of human capital development. The results also suggest conditional income convergence, as the coefficient on the natural log of lagged per capita income ($\ln(\text{Inc})_{t-1}$) is consistently negative and significant in the growth equation.

The assumption that all regressors are exogenous is unlikely to hold in a system, leading to bias. Also, the insignificance of the investment, human capital and R&D coefficients in growth equation casts further doubt on the FE results. In the 3SLS estimation, investment, human capital, and R&D are endogenous in the system and instrumented by included exogenous variables (i.e., state and year dummies, prior income level, and institutional quality) and excluded instruments of their two-year lags. The diagnostics showed at the bottom of column II support the identification strategy. The Anderson LM statistics clearly indicates that the model is not underidentified, and the Angrist-Pischke F statistics are well above the rule-of-thumb critical value 10, which suggests that the instruments are not weak. With 3SLS, the coefficients on investment, human capital, and R&D show the expected sign and are significant at the 5% confidence level at least.

While endogeneity owing to simultaneous relations among variables can be addressed by a system of equations model, omitted variables present another possible source of bias. In my panel setting, dummy variables control for state and year fixed effects, such as geographical characteristics and time-specific macroeconomic shocks. Regarding time-variant unobserved variables, I apply the Altonji-Elder-Taber statistic to test for bias, as a robustness check (see section 2.5.2). The statistic is greater than one so that it is unlikely that unobservables will explain away the result of interest (Altonji et al., 2005; Fenske, 2014).

Table 1-3 further assesses the direct, crowding-out, and institution effects, and also shows the overall resource effect. According to equation (4), it illustrates the linear combination of coefficients estimated by 3SLS in Table 2. First, the direct resource effect is positive and significant. When the crowding out effects and the institution effects are isolated out, theories do not suggest specific direct resource effects (β_2). In a Solow growth model, the resources enter the production function as one of the production factors among physical capital, human capital and technology, implying a positive or neutral direct effect from resources on growth.

Second, evidence shows a crowding-out effect on investment but not on human capital or R&D. Measured as the earning share of industrial machinery productions, industrial investments are crowded out by the expanding resource sector in the 2000s. The effect of resources on human capital is mixed. A resource boom will draw new employment to the mining industry at first, which could lower the human capital stock since the mining sector attracts low- or semi-skilled labor more. However, as local demand increases with rising incomes rise, living expenses such as house prices or rent rise, as well. This could encourage lower income, less educated labor to move out of the resource-rich region, thereby increasing some measures of human capital. Also, resource rents could add to the state budget thus increasing education expenditure and educational attainment in a state. These offsetting forces might explain why the effect on human capital is neutral in a high labor mobility environment such as the U.S. Regarding R&D, the role of technological developments in extracting unconventional oil and gas may explain the insignificant crowding-out effect.

In addition to supporting crowding-out of investment, the evidence also suggests that institution effects can mitigate the resource curse. The Government Efficiency Index serves as a measure of ex-ante institutional quality. At the mean level of $Institution_i$, the coefficient estimate shows a positive effect, significant at the 1% confidence level. The evidence supports the institution explanation: the resource-growth relation is conditional on the institutional quality and resource wealth will not be harmful to growth when the institutional quality is strong. Finally, adding up all three effects, the overall resource effect is significant and positive. Sampling counties in the south-central U.S. during a similar time period, Weber (2013) also found little evidence of an emerging curse from greater natural gas production.

In summary, I did not find evidence of an overall negative effect on growth by resource wealth in my sample. Further decomposing the resource effect, both crowding-out and institution effects contribute: the resource boom could crowd out industrial investment, yet good institutions mediate that effect so that the overall impact of resources on growth is neutral. However, resource effects vary among states due to variation in the quality of institutions. Moreover, different types of resources can affect growth in different ways. I explore these issues at further length in the next section.

2.4.2. More on the Institution Effects

Table 1-4 shows the institution effects and overall resource effects in the six most resource-rich states. The point resource share is above 10% in all six states, as high as 29.97% in Wyoming. Five of these states show a negative Government Efficiency Index, indicating low government efficiency relative to the national mean. With “bad” *ex-ante* institutions, the institution effect worsens the negative impact of resources. Thus a resource curse emerges in these states. As shown in the last column of Table 1-4, the overall resource effect is negative and significant in Louisiana, Oklahoma, and Texas, whereas it is positive or neutral in Wyoming, Alaska, and West Virginia.

This further confirms the logic of the institution mediation mechanism: the resource curse is conditional on the institutional quality, and resource wealth becomes a curse in a grabber-friendly economy where rent distribution and management are inefficient and unproductive. In the literature, the United States is an example of resource-rich countries with strong institutions (Acemoglu et al., 2003). The results suggest that government actions function well enough on average to avoid a curse. However, government efficiency varies across states, and institutions in states at the low end may be bad enough that resource wealth in such states becomes harmful to growth.

I further examine the institution effects with different measures of institutional quality. Table 1-5 shows the coefficient estimates for the growth equation using 3SLS with each of the institutional quality measures. The coefficients on the resource-institution interaction term are consistently significant with the expected sign, except with the Economic Freedom Index, where the estimate is insignificant. These results lend support to the institution effect as a mechanism for mitigating the potentially negative impact of resource wealth on growth and are consistent with cross-countries evidence by Mehlum et al. (2006a, 2006b), Dietz et al. (2007) and Boschini et al. (2013).

2.4.3. Different Type of Resources

Table 1-6 shows the decomposition of the overall resource effect using different measures of resources in the 3SLS approach[13]. The second row, with point resources, is the same as the baseline results reported in Table 1-3. The diffuse resource shows no crowding-out effects on growth factors and a less significant institution effect, with an insignificant overall resource effect. This is consistent with the literature arguing that point resources are more likely to be a curse due to their concentrated production and revenue patterns.

The development of point resources has been heterogeneous in the recent decade. The U.S. has experienced the large-scale development of unconventional natural gas, which has been described as a bonanza (Burnett and Weber, 2014). On the other hand, coal production has contracted. Also, the recent oil and gas revolution is motivated by technology breakthroughs such as horizontal drilling and hydraulic fracturing. This deviates from the traditional characterization of the resource industry as low in innovation and relying intensively on low-skilled workers. These heterogeneities motivate me to analyze oil and gas versus other point resources separately[14].

Therefore, I further break down point resources into oil and gas, coal and metal, and support activities for mining. The last three rows in Table 6 show the comparison of results. The crowding-out effect on investment and institution effects are stronger with oil and gas extraction and supporting activities, implying that the oil and gas extraction drives the resource-growth relation in my sample. A positive resource effect is shown in

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[13] Full sets of results are provided upon request.

[14] I name extraction earning share other than oil and gas “coal and metal” to facilitate the interpretation.

human capital with oil and gas extraction. Compared with other forms of mining, oil and gas extraction, especially the unconventional one, requires a higher proportion of high-skilled workers (e.g. petroleum engineers). This may explain the different resource effects on human capital. No evidence of crowding-out effects is present with coal and metal. The institution effect turns negative and significant with coal and metal, which is inconsistent with the narrative of the institution effect. The overall resource effects are neutral across different types of resources.

2.5. Sensitivity Checks

I conduct three sensitivity checks, including the Added Controls Approach, dynamic and spatial models, and re-estimation with alternative dependent variables. The results are consistent with the baseline results reported above.

First, since time-varying unobserved variables are a common source of bias in a fixed effect setting, I employ the *Added Controls Approach (ACA)*, originally proposed by Altonji et al. (2005) and formally named by Lopez et al. (2011). This method enhances the controls by using a large set of additional time-varying control sets in sequence.

I am particularly concerned with the unobserved time-varying changes in institutional quality that may correlate with resource extraction. Studies have found that governance, demographic and social characteristics, and lobbying and other rent-seeking behaviors correlate with institutional changes. As I add the Governance, Demographics, and the Rent-Seeking Behavior sets of controls [15] in sequence into the fixed effect model on equation (3), the within R-square increases relative to the base model, suggesting a rise in

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[15] Detailed definition and data source on all the supplement variables are available in Appendix A 1.3.

the explanatory power. Moreover, the coefficients on the point resource and the interaction are consistent with my main results[16].

Second, to further check the sensitivity of results to dynamic and spatial effects, I estimate reduced form equation (3) using a static fixed effect estimator with Driscoll and Kraay's standard error (FE)[17], a first difference estimator (FD), a dynamic panel estimator (Sys-GMM), a spatial autocorrelation model (SAC), and a dynamic spatial panel estimator (Dynamic-SAC) . Again, the two coefficients of primary interest —on the point resource and the interaction— are consistent with the main results: the institution effect is significant and positive while the direct resource effect is neutral or positive[18]. I conclude that my baseline results are fairly robust to the dynamic and spatial effects of state growth.

Third, I replace the dependent variable, annual growth in per capita personal income, with growth in real Gross State Production (GSP) per capita, and growth rate in state population and re-estimate the system with 3SLS[19]. The main results are robust to using the population growth as the dependent variable, rather than personal income.

2.6. Conclusion

The resource curse hypothesis—resource rich economies underperform in economic growth— has been tested across countries, especially in developing countries. In this study, I tested that hypothesis within the highly developed the United States. A system of

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[16] Results are available in Appendix A 1.4.

[17] One approach to address spatial correlation is Driscoll and Kraay's (1998) nonparametric technique; another approach is to directly model the interdependence via spatial panel models. I apply both methods to check the sensitivity of the results.

[18] Results are available in Appendix A 1.5.

[19] Results are available in Appendix A 1.6.

equations model allows me to decompose the resource effect and account for the two mechanisms, crowding-out effects and institution effects, simultaneously in one setting. The results suggest that both effects contribute to the resource-growth relation, but also that the overall resource effect is positive or neutral. The results confirm that institutions mediate the crowding-out effect and reject the resource curse hypothesis within the U.S. in the past two decades.

This decomposition with the direct, crowding-out, and institution effects at a subnational level offers a better understanding of resource curse mechanisms. First, I found that the direct resource effect was positive or neutral once the crowding-out and institutional effects were isolated. Second, the evidence suggests that resource wealth crowds out industrial investment, thus hindering growth in the U.S. This result parallels the local Dutch Disease narrative that wealth generated by the sale of natural resources tends to crowd out the manufacturing sector. However, I did not find evidence supporting the crowding-out of other factors documented in the literature, such as human capital stock and R&D expenditure.

Third, the resource curse is conditional on institutional quality in the U.S., supporting the institution mediation effect. I focus on state and local government efficiency as a proxy for institutional outcomes and further employ ex-ante measures to minimize endogeneity concerns. In their careful cross-country study on the resource curse, Boschini et al. (2013) found that an outcome measure, “institutional quality” from the International Country Risk Guide, was the one exhibiting strong empirical regularity, comparing to other rule-oriented measures. Consistently in my study, the institution mediation effect shows explanatory power even within the U.S., where “rules” such as constitutional arrangements, the degree of democracy, or property rights are strong but state government efficiencies vary. The result suggests the importance of resource rent management in the short-run. A natural extension to this study would be to trace the analysis further back as "rules" varied along with time across the U.S., so that both aspects of institutions, as well as the long-run crowding-out effects, can be tested.

Finally, adding up all three effects, the overall effect of resource wealth on growth is positive or neutral as a general pattern in the U.S. However, the resource effects vary among states, and the resource "curse" seems to appear in states with low institutional qualities, including resource-rich Louisiana, Oklahoma, and Texas. Moreover, different types of resources affect growth differently, and oil and gas extraction drives the main results in my study. This should draw special policy attention in the context of the shale gas boom since the late 1990s.

In a recent overview of the resource curse literature, Frederick van der Ploeg (2011) stated that a key question remained "*why some resource-rich economies [.] are more successful while others perform badly despite their immense natural wealth*"(page 366). My study contributes another piece of evidence regarding the U.S.: even though relatively strong institutions work to avoid a widespread resource curse, some crowding out occurs and may be an issue in states with weaker institutions.

2.7. Tables in Chapter 2

Table 2-1 Variable Definition and Descriptive Statistics

Variable	**Definition**	**Mean**	**Std.Dev.**	**Min**	**Max**
Growth	Annual growth in real per capita personal income (%)	1.29	2.32	-11.50	13.38
Income	Annual real per capita personal income (chained 2009 $)	37464.22	5937.57	25022.48	58703.24
Resource_diffuse	Annual percent of earnings in agriculture, forestry, and fishing (%)	1.35	1.51	0.00	8.99
Resource_point	Annual percent of earnings in mining (%)	3.06	6.09	0.00	40.71
Resource_oil&gas[a]	Annual percent of earnings in oil and gas extraction (%)	1.47	3.92	0.00	38.05
Resource_coal&metal[a]	Annual percent of earnings in extractions other than oil and gas (%)	1.23	2.62	0.00	17.86
Resource_support[a]	Annual percent of earnings in support activities for mining (%)	0.44	0.95	0.00	6.98
Investment[a]	Annual ratio of industrial machinery production to its GSP (%)	0.97	0.85	0.01	5.55
Human Capital	Annual percentage of state population with a college degree (%)	26.45	4.95	14.60	41.20
R&D[1]	Annual ratio of total R&D performed in a state to its GSP (%)	2.12	1.52	0.10	8.76
Gov. Efficiency [b]	Average Z-score of government services per capita government revenue (state and local government only), 1990-1995	0.08	0.87	-2.25	1.84
Corruption	Average annual public official corruption convictions per 1,000 elected officials[3],1987-1997	2.49	3.83	0.09	24.34
Econ. Freedom Index	Average annual Economic Freedom of North America Index (scale from 0 to 10),1981-1995	6.73	0.72	5.06	8.02
Liability	Average annual score of state liability system (scale from 0 to 100), 2002[4]	57.16	8.72	28.40	78.60

Note: a. The five variables – resource_oil&gas, resource_coal&metal, resource_support, investment, and R&D – cover from 1997 to 2013, with 850 observations. b. Authors calculated. Please refer to Appendix 3.1 for details. c. The number of state public official corruption convictions is from the U.S. Department of Justice. The number of elected officials by the state is reported in 1987, 1992, and 1997 Census of Government. d. The earliest data available for *Liability* is 2002 from the U.S. Chamber of Commerce.

Table 2-2 Testing the Resource Curse in a System of Equations, Point Resources

		I. FE	II. 3SLS
Investment	Ln(Inc)$_{t-1}$	0.43	0.31
		(0.31)	(0.26)
	Resource_point	-0.03***	-0.03***
		(0.01)	(0.01)
	Constant	-3.66	-2.42
		(3.21)	(2.70)
	adj. R^2	0.92	0.92
Human Capital	Ln(Inc)$_{t-1}$	0.43	0.46
		(1.08)	(1.13)
	Resource_point	0.08**	0.10***
		(0.03)	(0.04)
	Constant	13.85	14.80
		(11.12)	(11.57)
	adj. R^2	0.95	0.96
R&D	Ln(Inc)$_{t-1}$	-0.79*	-1.06*
		(0.42)	(0.55)
	Resource_point	0.00	0.01
		(0.02)	(0.02)
	Constant	9.87**	12.58**
		(4.27)	(5.67)
	adj. R^2	0.88	0.89
Growth	Ln(Inc)$_{t-1}$	-8.61***	-10.78***
		(2.29)	(2.04)
	Resource_point	0.12	0.23***
		(0.14)	(0.08)
	Resource_point ×Gov. Efficiency	0.30**	0.41***
		(0.14)	(0.07)
	Investment	0.37	3.36***
		(0.28)	(0.75)
	Human Capital	0.06	0.26*
		(0.04)	(0.15)
	R&D	-0.08	1.52**
		(0.10)	(0.69)
	Constant	89.30***	102.7***
		(23.49)	(21.06)
	adj. R^2	0.57	0.61
No.Observations		847	747
State Fixed Effect		Yes	Yes
Year Fixed Effect		Yes	Yes
Anderson LM stat.			18.40***
Angrist-Pischke F-stat.		Investment	25.16***
		Human Capital	33.17***
		R&D	15.14***

Note: Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; in column (3) 3SLS estimation: instrumented: investment, human capital, R&D, included instruments: lagged per capita income level, lagged point resource, interaction of lagged point resource and pre-determined government efficient index, state fixed effect, and year fixed effect, excluded instruments: lagged investment, human capital, and R&D.

Table 2-3 Decomposition of the Marginal Resource Effect on Growth, Point Resources

Direct Effect	Crowding-out Effect			Institution Effect	Overall Resource Effect
	Investment	Human Capital	R&D		
0.23***	-0.11**	0.03	0.01	0.03***	0.19**
(0.08)	(0.04)	(0.02)	(0.03)	(0.01)	(0.07)

Note: according to Equation (4) $\frac{\partial G}{\partial R} = \beta_2 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_2 + \beta_3 * Institution_i$, calculated based on 3SLS estimation results of Equation (1) and (2) with point resources; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2-4 The Institution Effects and Overall Resource Effects in Six Resource-Rich States

Resource-rich states	Point Resource Share	Ex Ante Gov. Efficiency Index	Institution Effects	Overall Resource Effects
Wyoming	29.97%	0.24	0.10*** (0.02)	0.25*** (0.08)
Alaska	25.84%	-0.02	-0.01***(0.00)	0.15** (0.07)
West Virginia	12.53%	-0.47	-0.19***(0.03)	-0.03 (0.06)
Louisiana	11.15%	-1.58	-0.64***(0.11)	-0.48***(0.10)
Oklahoma	10.00%	-0.86	-0.35***(0.06)	-0.19***(0.07)
Texas	9.75%	-1.18	-0.48***(0.08)	-0.32***(0.08)

Note: "Institution Effects" are ($\beta_3 * Institution_i$) and "Overall resource effects" are calculated based on the equation (4) $\frac{\partial G}{\partial R} = \beta_2 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_2 + \beta_3 * Institution_i$, where the coefficient estimations are from 3SLS in column (3) table2 and the Government Efficiency Index values are listed in the third column.

Table 2-5 Institution Reversal Effects with Different Institutional Quality Proxies

Growth	I. Gov. Efficiency	II. Corruption	III. Econ. Freedom Index (EFI)	IV. Liability
$Ln(Inc)_{t-1}$	-10.78***	-8.60***	-8.85***	-8.91***
	(2.03)	(1.98)	(1.99)	(2.01)
Resource_point	0.23***	0.37***	4.60***	-1.81***
	(0.08)	(0.10)	(0.77)	(0.41)
Resource_point ×Gov.Efficiency	0.41***			
	(0.07)			
Resource_point ×Corruption		-0.13***		
		(0.03)		
Resource_point ×EFI			-0.64	
			(0.51)	
Resource_point ×Liability				0.04***
				(0.01)
Investment	3.36***	2.53***	2.83***	2.74***
	(0.75)	(0.71)	(0.71)	(0.73)
Human Capital	0.26*	0.27*	0.19	0.30*
	(0.15)	(0.15)	(0.15)	(0.16)
R&D	1.52**	1.60**	1.79***	1.58**
	(0.69)	(0.69)	(0.67)	(0.70)
Constant	102.7***	80.50***	84.39***	83.43***
	(21.06)	(20.76)	(21.05)	(20.95)
No.Observations	747	747	747	747
State Fixed Effect	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes

Note: the 3SLS estimation results of Equation (1) and results on equations (2) is omitted; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2-6 Decomposition of the Overall Resource Effect: Different Type of Resources

	Direct Effect	Crowding-out Effect			Institution Effects	Overall Resource Effect
		Investment	Human Capital	R&D		
Diffuse Resource	-0.46 (0.38)	0.20** (0.08)	0.00 (0.02)	0.05 (0.06)	0.033* (0.0195)	-0.18 (0.25)
Point Resource	0.23*** (0.08)	-0.11** (0.0395)	0.03 (0.02)	0.01 (0.03)	0.03*** (0.01)	0.19** (0.07)
Oil and Gas	0.13 (0.10)	-0.07** (0.03)	0.05* (0.03)	0.02 (0.03)	0.03*** (0.01)	0.15 (0.10)
Coal and Metal	0.13 (0.15)	0.01 (0.05)	- 0.01 (0.01)	- 0.02 (0.05)	-0.09** (0.02)	0.03 (0.15)
Support Activities for Mining	0.37** (0.16)	-0.19** (0.09)	-0.01 (0.02)	-0.05 (0.07)	0.06*** (0.01)	0.17 (0.16)

Note: according to Equation (4)) $\frac{\partial G}{\partial R} = \beta_2 + \boldsymbol{\beta}' * \boldsymbol{\alpha}_2 + \beta_3 * Institution_i$, calculated based on 3SLS estimation results of equations (1) and (2) with different resource types; Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Chapter 3 The Impacts of Resource Development in China and the United States: A Comparative Analysis

3.1. Introduction

The effect of resource wealth on economic growth has received considerable attention in the economics and political science literature over the last 20 years. Cross-country empirical studies tested the resource – growth relation, often referred as the resource curse hypothesis, with no consensus conclusions (Auty 1993; Sachs and Warner 1995; Papyrakis and Gerlagh 2004; Alexeev and Conrad 2009). Country-level observations offer significant variations in resource endowments, and economic growths, which facilitate the analysis. However, many confounding features, such as geography, culture, and institution quality, also exist and could potentially bias the results, especially in cross-sectional analysis. The concern persists with panel-data given the time-varying hard-to-measure factors like macroeconomic policies.

To alleviate these issues, within-country evidence have also emerged, sampling in China (Fan, Fang and Park, 2012; Ji, Magnus and Wang, 2014; Shao and Qi, 2009), the U.S. (Papyrakis and Gerlagh 2007; Weber 2013), Canada (Papyrakis and Raveh 2014), Russia (Alexeev and Chernyavskiy 2015) and Peru (Aragón, Rud and Arag, 2013) among other nations. Regional level analyses reduce the danger of spurious correlations by analyzing subnational regions facing the same economic system, institution arrangement, macroeconomic policies, and less various cultures and institutional qualities. The tradeoff is to forgo opportunities of testing impacts from persistent features, such as the economic system and institution arrangement. For economies in transition, weak price signal and prevailing state ownership likely lead to inefficient resource allocation, leaving a weak or even negative resource-growth relation. The main goal of this paper is to illustrate this argument using comparative regional-level analysis of the resource wealth impacts in China and the United States.

Among other nations, several unique characteristics endow China and the U.S. suitable for the resource-growth relation comparison. First, China and the U.S. were the top two countries in primary energy production in 2015. The resource endowment varies significantly across Chinese provinces and American states. Second, with similar size of gross economies, China and the U.S. contrast with each other in economic systems and institution arrangements. The comparison could shed light on impacts of market and fiscal reforms in China since the 1990s. Third, both countries have experienced booming in resource extractions in the 2000s yet with different resources. Being able to decompose resources into crude oil, natural gas, and coal helps to further identify the booming effect from the country effect.

In this study, I use comparable measures to examine the effects of resource revenues on the economic growth and growth-related factors across Chinese provinces and American states from 1990 to 2015. With the Instrumental Variable (IV) strategy implemented in the panel datasets, I show that regions with higher resource revenues grow faster than other regions in both China and the U.S. The positive resource effect is larger in the U.S. Further testing impacts of three resource-related policies in China, e.g. the market price reform, the fiscal reform, and the Western Development Strategy, I show that the market price reform together with the privatization process on coal resources contribute the positive resource effect in China. Though strong and positive resource – growth relations appear in both countries, evidence also suggests consistent negative resource effects on certain growth-related factors in both countries, such as educational attainments and R&D activities.

The resource – growth relation has been studied in both China and the U.S. at the regional level. A few empirical studies within China concluded mixed results. Using a panel dataset from 1985 to 2005 at the provincial level and pooled regression model, Zhang, Xing, Fan, and Luo (2008) associated a slower growth rate of per capita consumption with rich resources, especially in the rural region. Shao and Qi (2009) confirmed resource curse hypothesis in China, and the crowding-out effect is mainly towards human capital input. Moreover, Shao and Qi (2009) sampled ten provinces from western China, which may lead to selection bias because they are all from inland China with lower initial development comparing to the East. On the other hand, Fan, Fang and Park (2012b) found no supportive evidence to the “resource curse” phenomenon in city level of China over the period 1997-2005 for the 95 cities with a functional coefficient model. Ji, Magnus and Wang (2014) applied two different resource abundance measures- the resource reserve stock measure and the resource revenue flow measure – and found a positive resource effect on economic growth at the provincial level in China between 1990 and 2008. Overall, the mixed results can be attributed to different samples, measures and methods that have been applied, and also some drawbacks on measurements and models.

This study contributes to the literature with the first comparison piece between Chinese provinces and the U.S. states on testing the resource-growth relation. Closest to this study, Alexeev and Chernyavskiy (2014) examine the effect of oil on the growth of Russia’s regions and American states. I improve the analysis by employing an

Instrumental Variable (IV) strategy to address the omitted variable bias and potential reverse causality. To the best of my knowledge, this is also the first study in the China literature to link and empirically test impacts of market price reforms and the fiscal reform in the resource-growth relation.

3.2. Resource Development in China and the U.S.

3.2.1. Resource Production and Reserves

Both China and the U.S. have developed from rich land with large resource endowments. According to the Global Energy Statistical Yearbook (2016), China and the U.S. lead the world in primary energy productions[20] in 2015 at 2,640 and 2,012 million metric tons of oil equivalents (Mtoe) respectively, followed by Russian at 1,341 Mtoe. China surpassed the U.S. and became the world largest energy producer in 2005. Figure 2-1 and 2-2 compare the total primary energy production by resource types in China and the U.S. since 1990.

Despite large total energy productions, the two countries show different energy compositions[21]. Coal dominates the primary energy production in China. China has been the world's leading coal producer and consumer since the early 1980s. In 1990, 77.8 percent of the total primary energy production was from coal, while crude oil, natural gas, and other renewable energy made up 19.9, 2 and 0.3 percent respectively. Until 2014, coal remains the main energy source in China, accounting for 76.5 percent of the

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[20] Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process.

[21] To enable the comparison across resources, I convert different energy units for crude oil (barrels), natural gas (cubic feet) and coal (metric tons) into the heat unit – British thermal unit (Btu) based on heat content of fuels.

total primary energy production. Crude oil has dropped to 8.3 percent while natural gas and other energy have increased to 4.3% and 10.8% of total primary energy production. In the U.S., the energy composition has been balanced and stable. Natural gas has surpassed coal and taken the largest share of primary energy production at 33 percent since 2011. In 2014, natural gas, coal, crude oil, and other renewable energy was 33.5, 25.4, 22.6 and 18.4 percent of the total primary energy production respectively.

Energy productions have been increasing in both China and the U.S. during the study period, with distinct booming resources. In 2015, coal production more than quadrupled in China at 3.68 billion metric tons, comparing to the production in 2000 at 0.88 billion metric tons. The surge in coal production took place between 2000 and 2009 with more than 10 percent growth rate annually. 25 out of 31 provinces or province equivalent municipalities produced coal. The top three coal-producing provinces, Shanxi, Inner Mongolia, and Shaanxi, all located in northern and central China, supplied 64 percent of the total coal production. During the same period, coal production stagnated at around 0.8 to 1 billion metric tons in the U.S. (Figure 2-2 panel C). Wyoming alone accounted for 41.9 percent of total U.S. coal production in 2015. Four states in the Appalachian region, West Virginia, Kentucky, Illinois, and Pennsylvania, together produced another 20 percent. Owing to the shale oil and gas development, production of natural gas and crude oil has boomed in the U.S. after 2005. In 2013, the U.S. surpassed Russia and became the world largest gas producer. In 2015, the top five natural gas-producing states are Texas (27.4%), Pennsylvania (16.7%), Oklahoma (8.7%), Wyoming (6.2%), and Louisiana (6.2%), which accounted for approximately 65 percent of the total natural gas production in the U.S. Similarly, about 65 percent of U.S. crude oil production came from five states in 2015: Texas (37%), North Dakota (12%), California (6%), Alaska (5%), and Oklahoma (5%).

Different production pattern reveals different reserve mix in the two countries. Figure 2-3 compares proved reserves of the crude oil, natural gas, and coal in China and the U.S. in 1990. While both countries held similar crude oil, the U.S. was rich in natural gas and China was with much larger coal endowment. In China, coal fields concentrate in north central regions where the top three coal-producing provinces, Shanxi, Inner Mongolia, and Shaanxi, are adjacent. China's largest oil fields are located in the northeast region (Daqing field), the northwest's Xinjiang Uygur Autonomous Region (including the Junggar and Tarim basins), and north central region in Shaanxi, Inner Mongolia, and Gansu provinces (Ordos Basin) (Gordon, Sautin and Tao 2014[22]). The primary natural gas-producing regions in China are Sichuan province in the southwest (Sichuan Basin), the Xinjiang and Qinghai provinces in the northwest (Tarim, Junggar and Qaidam Basins), and Gansu province in the north center (Ordos Basin).

In summary, China and the U.S. are the top two energy producing countries in the world. Yet, the resource composition and extractions contrast between the two, where coal has been the dominant energy resource in China and natural gas has recently become the main energy in the U.S. In either China or the U.S., resource endowments tend to concentrate in certain regions but also show regional sparsity across oil, natural gas, and coal. These variations offer opportunities to identify resource type effects from the

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[22] Source: Carnegie Endowment for International Peace (Deborah Gordon, Yevgen Sautin, and Wang Tao), "China's Oil Future", May 6, 2014. http://carnegieendowment.org/2014/05/06/china-s-oil-future-pub-55437

country effect, which is driven by two distinct institution settings between China and the U.S.

3.2.2. Resource-related Policies in China

The distinctive economic systems in China and the U.S. could make a difference in resource-growth relations. As the world's largest national economy in nominal terms, the U.S. is a mixed economy and more towards a free market economy. Run by a single party, the Communist Party of China (CPC), China is an economy in transition from planning to market-orienting. Since the economic reform in December 1978, China has been the world's fastest-growing major developing economy. Given the strategic role in the economy and national security, resource sectors, especially energy sectors, fall behind in the market reform and are still heavily managed by state-owned enterprises (SOEs). I discuss three resource-related policy shifts in China since 1990 (Table 2-1).

3.2.2.1. Market Price Reforms

Before 1978, China adopted a state pricing system in which the state set prices of goods, including energy prices, regardless market forces. In 1984, a dual pricing system was implemented. State-owned enterprises (SOEs) could sell up to a predetermined quota of goods at state-set prices and then sell above the quota at higher prices. Facing energy shortages and weak incentive in energy conservation investment, China began to reform its energy prices in 1993 and pushed it forward with different paces and scales across energy types (Zhang 2014).

Coal was ahead of oil and natural gas in the price reform. In 1993, coal prices were formed in a two-track system: the price of non-utility-use coal was determined by the market, whereas the price of utility-use coal, the so-called power coal, was based on "guidance price" set by the National Development and Reform Commission (NDRC)[23]. NDRC abolished its guidance price for power coal in 2003 and set price bands for negotiations between coal producers and electricity generators, which was further abolished in December 2012. As shown in Figure 2-4 panel C, the state-set coal price was under market prices, e.g. the world coal price or the U.S. coal price before 1993. Since 1993, the average coal price in China has tracked the world coal price well with less fluctuation, due to the guidance price then later price bands for the power coal till 2012. Between 1994 and 1997, the crude oil price was set at irregular intervals by the State Planning Commission (SPC). Since 1998, domestic crude oil prices have tracked international prices but not the case for refined oil product price. Until May 2009, refined oil prices would be adjusted if the moving average of international crude oil prices changes more than 4 percent within 22 consecutive working days, which was shortened to 10 working days in March 2013. Comparing to the world and U.S. oil prices, the crude oil price in China moved from lower prices before 1993 to higher prices and had tracked the world price fluctuations closely since 1998 (Figure 2-4 panel A).

Natural gas prices are still set by the state throughout the supply chain today. Since 1978, the state has adjusted the wellhead price of natural gas five times in 1982, 1994, 2002, 2007, and 2010 (Shi et al. 2012). The most recent price adjustment in June 2010 has increased domestic producer price of natural gas by 25 percent (Figure 2-4 panel B).

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[23] In 2012, about half of the coal in China was used for power generation. The industrial sector, including steel, iron, cement, and coke, accounted for 41 percent usage, and the remaining share was consumed by the residential, service, and other sectors (National Bureau of Statistics, China, 2014).

With the shale development in the U.S., both world and U.S. natural gas prices have dropped since 2005.

Prices reveal values of natural resources and translate resource endowments into resource revenue or wealth in an economy. Market prices effectively signal the resource scarcity and market forces, thus lead to an efficient resource allocation. Therefore, I hypothesize that the market price reform on resource sectors in China will stimulate resource revenue to contribute the regional growth more or meditate a potential resource curse relation.

3.2.2.2. Resource Ownerships and the Fiscal Reform

That how the resource rent flow matters in the resource-growth relation. Point resources (e.g., minerals and fossil fuels) generate concentrated production and revenue patterns, which are more likely to be controlled by relatively small groups of society, exhibiting so-called "executive discretion in revenue allocation" (Jensen and Wantchekon 2004). In the U.S., both private and public sectors can capture the resource rent or wealth, depending on ownerships of land or resources (Weber, Burnett and Xiarchos, 2016; Weber, Wang and Chomas, 2016). Total resource rents are channeled to land owners, resource extraction companies, and governments through royalties, profit, and taxes respectively. Resource endowment could fuel regional economic growth if localities retain a certain share of resource rent and direct them to promote local development. For example, Weber, Burnett and Xiarchos (2016) show that the oil and gas tax base in Texas is capitalized into housing values and increases in school revenues through local property taxes on oil and gas wells.

The resource rent flow looks differently in China because the state owns all lands and natural resources. Three major national oil companies – China National Petroleum Corporation (CNPC), the China Petroleum and Chemical Corporation (Sinopec), and China National Offshore Oil Corporation (CNOOC) – dominate the oil and natural gas upstream and downstream sectors. CNPC is the upstream leader and accounts for an estimated 54 percent and 77 percent of China's crude oil and natural gas output, respectively, according to FACTS Global Energy (FGE)[24]. With relatively lower capital input, coal mining in China has traditionally been fragmented among large state-owned coal mines, local state-owned coal mines, and thousands of small-scale town and village coal mines. In turn, they account for about 50, 20, and 30 percent of the total coal output (Andrews-Speed et al. 2000). Nonetheless, the state would capture all the resource rent since it owns both natural resources and companies. Assume that revenues of provincial or local government influence regional economic growth more directly than central government revenues, the question becomes how central and provincial governments split resource revenues.

In the distribution of resource rents, the province and local governments have gained more rights from the state-owned enterprises (SOEs). In 1994, China adopted a tax-sharing system between central and provincial government: taxes that are broad and concentrated, such as the consumption tax and tariffs, are assigned to the central government; those are narrow and scatter are provincial and local taxes; and other taxes are split between the central and provincial governments. Onshore resource taxes are

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[24] FGE, China Oil & Gas Monthly: Data Tables, March 2015 (EIA estimates), pages 1 and 8.

assigned to provincial and local governments while the central government is collecting revenues from resource taxes offshore. In 2011, China installed an ad valorem resource tax of 5% on oil and natural gas, instead of taxes levied on extracted volume since 1985. Besides resource taxes, more than 30 taxes and fees are levied on the mining industry. Value-added tax, income tax, and resource tax account for about 80 percent of the tax revenue from mining industry (see Table 2-2). Overall, the central government captured 51.55 percent tax revenues from resources, leaving the rest with provincial governments and their localities. However, the tax-sharing system increased the share of the central government in the total government revenue to 55.7 percent in 1994 from 22 percent in the previous year (Zhang 2014). Nonetheless, under the new regulations since 1994, province governments were permitted to explore and develop mineral resources and allowed to auction the development rights of mineral resources to the private sector, including multinational companies, though SOEs still enjoyed preferential treatment in developing large mineral reserves. Province and local governments have a strong incentive to sell exploration and mining rights since it is a quick way to create revenues. As a result, many small-scale mines have been privatized since 1994.

In summary, I recognize the year 1994 and 2011 as key policy changing years with the fiscal reform and the adjustment of the resource tax rate in China. On the one hand, the tax-sharing system increased revenues for the central government and reduced provincial government tax revenues. It could weaken the link between resource endowments and the regional growth. On the other hand, the privatization process on small-scale mines since 1994 could help to retain the resource wealth at the local level. Therefore, the effect of the 1994 policy on the resource-growth relation leaves as an empirical question.

3.2.2.3. Regional Development Strategies

To narrow the development gap among regions, the Chinese government has implemented three large-scale development strategies since the 2000s (Figure 2-5). One of them, namely the Western Development Strategy, is energy focused. Moreover, the other two, the Revitalize Northeast China Strategy, and the Rise of Central China Strategy, show certain resource related elements.

The Western China Development Strategy was carried out in January 2000, covering six provinces, five autonomous regions, and one municipality. In 2000, this region produced 69.8 percent natural gas, 19.1 percent crude oil, and 27.19 percent coal of the national output respectively. Part of this significant policy package is to promote natural resource exploitation in this region with the help of infrastructure projects such as West-East Gas Pipeline, West-East Electric Transmission Line, and Qinghai-Tibet Railway. With most of the infrastructure projects completed by 2010, energy productions increased significantly comparing to those at the beginning of the Western China Development. In 2015, the western region contributed 80.1 percent natural gas, 32.4 percent crude oil, and 54.7 percent coal to the total primary energy output.

Northeast China consists of 3 provinces and the eastern part of the Inner Mongolia Autonomous Regions. The Daqing oil field, located in this region, is one of the oldest and most prolific fields in China, constituting 19 percent of the total crude oil production. Owing to the abundant resource endowment and geopolitical relations with the pre-Soviet Union, northeast China was built as the first and largest industrialized region in the 1950s to 1960s (Zhang 2008). It felt behind in development since 1978 when the reform and opening up policy focused on coastal areas and northeast region supplied raw and processed materials with low state-set prices to the southeast coastal area. The Revitalize Northeast China Strategy since 2004 targeted structure adjustment and transform the large and medium-sized State Owned Enterprises (SOEs) into the modern corporate system, including oil, chemical, and automobile industries. The three provinces closed 122 bankrupt SOEs in 2004 and 2005 (Zhang 2008). The share of primary energy production from this region has been declining – the region produced 52.69 percent crude oil, 28.66 percent natural gas, and 14.83 percent coal in 1990; however, in 2015, these shares dropped to 25.80 percent crude oil, 4.55 percent natural gas, and 3.69 percent coal.

The six provinces in the Rise of Central China strategy targeted agricultural industrialization except for Shanxi province. Due to the declining economic performance, Shanxi was nominated as the first national reform pilot area focusing on the resource sector transformation in 2010. In 2015, Shanxi is still the largest coal producing province, accounted for 25.6 percent of total coal output in China.

In central China, the traditional coal province, Shanxi, is under reform pilot to deal with the poor economic performance. In western China, the resource-rich region is encouraged to extract more to stimulate regional growth. Studies that investigated the role of the Western Development Strategy in the resource–growth relation have drawn various conclusions: Shao and Qi (2009) suggested the 2000 policy change induced a resource curse in the western region while Ji, Magnus and Wang (2014) found a positive correlation between economic growth and resource revenues after the 2000 policy shock, though the effect declines in the long run. I test policy impacts in China, aiming to explain differences or similarities of resource-growth relations between Chinese provinces and the U.S. states.

3.3. Empirical Analysis

Two main goals are in the empirical analysis: 1) to investigate and compare resource effects in China and the U.S. on regional economic growth and other growth-related factors, including investment, education attainment in the population, R&D activities, and corruptions; 2) to test policy interventions in altering the resource – growth relation in China.

3.3.1. Model Specification and Identification

A panel model is specified in equation (1) to test resource effects at province or state level in China and the U.S. respectively:

$$Y_{it} = \beta_0 + \beta_1 GDPpc_{i,t-1} + \beta_2 R_{it} + \boldsymbol{X}'_{it}\gamma + S_i + T_t + \varepsilon_{it} \tag{1}$$

Subscripts *i* and *t* index province (state) and time, respectively. *Y* represents outcome variables. In the resource – growth relation, *Y* is the growth in real per capita GDP. In testing resource effects on growth-related factors, *Y* is investment share, college population share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons respectively (Table 2-2). *GDPpc* is provincial or state GDP per capita with one period lag that controls for the initial GDP level. *R* is resource revenue per capita. I measure four resource revenues by resource types: crude oil, natural gas, and coal revenue per capita and total resource revenue per capita. The first three revenues are obtained by multiplying annual production with provincial or regional prices for each resource. Then sum all revenues from the three resources to obtain total resource revenue. All resource revenues are deflated into 2009 real currency and divided by the population to get the revenue per capita by province (or state) by year. Province or state level prices are used whenever possible to obtain province or state specific revenue on a certain resource. Regional prices are employed when the province or state-specific price data are not available. β_2 indicates the resource effect in testing. $\boldsymbol{X}$ is a matrix of growth-related variables including investment share, college population share, R&D expenditure share, patents per 1,000 persons, and duty crimes per million persons. They are omitted if the growth- related variable become the outcome variable to be tested. S_i is a province/state-specific fixed effect for each province/state i, which accounts for confounding factors that are common to the same province or state over time. T_t is the dummy variable for year, which allows for nationwide shocks and growth trends over time not otherwise accounted for by the explanatory variables. ε_{it} represents all remaining unobserved determinants of outcomes.

Two issues warrant discussion on the model specification: reverse causality and omitted variables. The regional economic growth or development level could alter resource production decisions thus draw concerns of reverse causality. In China, regional development strategies aim to promote economic development through favorable policy packages including industrial policies. In the case of the West Development Strategy, economic developments in the 12 western provinces or province equivalent regions were lagged behind, and energy sectors were picked to promote aiming to stimulate the regional growth, which could bias the result downward.

Omitted variable will bias coefficients if a third factor affects both resource revenues in the region and the outcome variable, e.g. regional growth or other regional growth-related factors. The province or state fixed effects sweep out time-invariant features of a province or state. The year dummies control for national shocks or other omitted factors that change over time across the country. Unobserved time-variant regional characteristics could bias the result. A province or state can influence whether or not extraction occurs in their area. With a fiscal decentralization process in the late 1980s and early 1990s in China, province and local governments have strong incentives to sell mining rights to generate revenues. In the U.S., the states of New York and Vermont have placed moratoria on unconventional energy extraction, due to the potential local externalities related to the practice, such as air, water, and noise pollution, amongst other things. Whether a regional economy is "producer friendly" or "grabber friendly" in allocating entrepreneurial activities is changing over time and a challenge to observe.

To address the potential reverse causality and omitted variable bias, I require an instrument for resource revenue measures, R, in equation (1). I rely on the geographic variations in resource reserves in the initial year 1990 and multiply them with the national primary resource prices. Oil, gas, coal and total resource revenue measures are instrumented with corresponding reserves and prices. The Two-Stage Least Square (2SLS) estimator is specified in equation (2) and (3).

$$Y_{it} = \beta_0 + \beta_1 GDPpc_{i,t-1} + \beta_2 \hat{R}_{it} + \boldsymbol{X}'_{it}\gamma + S_i + T_t + \varepsilon_{it} \qquad (2)$$

$$R_{it} = \alpha_0 + \alpha_1 GDPpc_{i,t-1} + \alpha_2 Reserve_{i,1990} * NationalPrice_t + \boldsymbol{X}'_{it}\delta + S_i + T_t + \mu_{it}$$

(3)

Two conditions are required for the instrumental variable strategy to be valid. First, resource reserves and national resource price must have a significant effect on regional resource revenues. This condition holds intuitively and can be tested statistically with the first-stage F test. Second, the instrument should be exogenous to the error term in equation (1). The spatial variation in initial resource reserves or endowments comes from the geological characteristic and the exploration technology at the time. The former is exogenous natural factors, and the latter might reflect general initial economic factors but exogenous to the provincial or state economic conditions. With state and year fixed effects control for the general shocks and trends, national resource prices are plausibly exogenous to regional time-variant unobservables. Similar strategies have been successfully implemented by Papyrakis and Raveh (2014), Allcott and Keniston (2014) and Cascio and Narayan (2015).

3.3.2. Data and Summary Statistics

I construct two panel datasets of Chinese provinces and U.S. states from 1990 to 2015. For consistent comparison, variables are defined as closely as possible given data availabilities (see Table 3). The China dataset covers 30 provincial level regions of mainland China. Mainland China consists of 22 provinces, five minority autonomous regions, four municipalities and two special autonomous regions. One minority autonomous region (Tibet) and two special autonomous regions (Hong Kong and Macao) were omitted due to the missing data issue. In 1996, Chongqing was separated from Sichuan Province as the fourth municipality after Beijing, Shanghai, and Tianjin. I combined Chongqing and Sichuan data after 1996 to keep consistency. The data were from China National Bureau of Statistics and China Economic Information Network. The U.S. dataset covers the 50 U.S. states. Resource related data are from the U.S. Energy Information Administration (EIA). Other data sources include the Bureau of Economic Analysis, National Science Foundations, the U.S. Patent and Trademark Office, the U.S. Department of Justice and Yamarik (2013). There are 750 observations in China dataset and 1,300 observations in the U.S. dataset.

Table 2-4 shows the summary statistics and comparison of Chinese provinces and U.S. states. Owing to a much larger population, the total resource revenue per capita in Chinese provinces is ¥1,417 (about $207.5), comparing to $1,630.5 in U.S. states on average. All three types of resource revenues per capita – crude oil, natural gas, and coal – are much lower in Chinese provinces than those in U.S. states. In Chinese provinces, revenues from crude oil and coal account for 95 percent of the total resource revenue, whereas in the U.S. states, crude oil and natural gas revenues take up 80 percent of their total resource revenue. In 1990, average oil and coal reserves in 1990 were larger in Chinese provinces, while the gas reserve is larger in the U.S. states. On average, the crude oil first purchase price is ¥465.74 per barrel (about $67.20) in China, which is 50 percent higher than $45.39 per barrel in the U.S. The natural gas wellhead price in China is 11 percent lower than the $4.04 per thousand cubic feet in the U.S. China average coal price is ¥383.60 per metric ton (about $56.16), comparing to $30.91 per metric ton in the U.S.

Turn to growth-related variables. Chinese provinces reached 9.64 percent annual growth rate of GDP per capita on average, with the average GDP per capita at ¥ 19,015 (about $ 2,784). The average GDP per capita among U.S. states is $ 42,545 with a 2.61 percent average annual growth rate. On average, Chinese provinces hold much lower statistics in investment share, college population share, R&D expenditure share and higher number in duty crimes per million persons. The patent numbers are comparable between two countries. In summary, Chinese provinces are developing economies in transition with lower resource revenue per capita and higher total resource reserves, comparing to the U.S. states.

3.4. Discussion on Comparison Result

Evidence suggests that resource revenues increase the regional growth in both China and the U.S. with a larger and more statistically significant effect shown across U.S. states. The booming resources, coal in China, oil and natural gas in the U.S., contribute to the positive resource – growth relation in the short term. Resource revenues show negative effects on education attainments and R&D activities while pushing up the investment in the region.

3.4.1. Resource Effects on Regional Growth

The results from testing the resource and regional growth relation across Chinese provinces and the U.S. states are summarized in Table 2-5. In turn, I regress four resource revenue measures – total resource revenue per capita, crude oil revenue per capita, natural gas revenue per capita, and coal revenue per capita – on the annual growth rate of GDP per capital. Results from both Fixed Effects (FE) and Instrumental Variable (IV) estimators are reported, where the IV estimator instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for resources respectively. All models in Table 5 include province/state and year fixed effects, and controls, such as investment share, college share, R&D expenditure share, patents per 1,000 persons, and duty crimes per million persons. The Kleibergen-Paap F-statistics for the first stage in IV models is well above a rule of thumb of 10 for one endogenous regressor and one instrument suggested by Staiger and Stock (1997), as well as the 16.38 level suggested by Stock and Yogo (2005).

Both countries show evidence that regional GDP per capita growth is increasing in the resource revenue but are driven by different resources. In China on average, an increase of ¥ 1,000 resource revenue per capita will lead to a 0.505 percent higher annual growth rate of provincial GDP per capita, all else equal (column (2) in panel A Table 2-5). Given the average resource revenue per capita at ¥ 1,417 and average growth rate of 9.64 percent, the estimated magnitude is small. Regarding elasticity, a one percent increase in the total resource revenue per capita will result in a 0.07 percent increase in the growth rate on average. In the U.S., the coefficient of the resource revenue suggests the elasticity at 0.0044: a one percent increase in the total resource revenue per capita leads to a 0.44 percent increase in state growth rate on average. Increasing resource revenues promote regional economic growth better in the U.S. than in China. Decompose the total resource revenue into oil, natural gas, and coal revenues per capita. Only coal revenue shows the positive and significant effect on growth in China. While in the U.S., the influence comes from oil and natural gas.

What could make the difference? With energy sectors in China experiencing the market reform since the 1990s, the less elastic resource effect on growth in China seems to suggest inefficient extractions of resources due to price control and the state ownership. Among the three resources, coal market was the first one to take on the market price reform. The pricing of coal has been liberalized to a great extent in the early 1990s, and "*by 1998 coal was, to all intents and purposes, traded on a free market*" (Andrews-Speed 2012, pp168). The privatized, then township and village mines contribute around 40 percent of total coal production in China. In the case of oil and natural gas, the crude oil price was linked to international prices through a formula set by the state in 1998, and natural gas prices continued to be set by the government throughout the supply chain (Andrews-Speed, 2004). It seems that the impact of a deeper market reform on coal has shown in the positive resource effect on regional growth in China. I will further investigate the policy impacts in section 3.5. Also, the coal production boomed during 2001 and 2009 with more than 10 percent annual growth (Figure 2-2 panel C). At the similar period, natural gas and oil had received growing higher revenues in the U.S. owing to the booming unconventional extraction and surging oil and gas prices in the 2000s. The booming resources seem to stimulate the regional growth.

The resource effect on annual growth rate and long-run growth could be different. The annual growth captures how the economy responds to fluctuations in resource sectors. Growth effects from the boom and bust cycle in resource revenues could be asymmetric and beyond annual impacts. Long-run cross-sectional specifications in literature bear concerns on omitted variable bias (Papyrakis and Gerlagh, 2007; James and Aadland, 2011). I reshape the datasets into 5-year panels to test the resource effect on growth in a longer term. Table 6 shows the results. The dependent variable is the average annual growth of every five years, constructed as $\frac{1}{T}\ln(\frac{GDPpc_{i,t+T}}{GDPpc_{i,t}})$. The independent variables are measures of initial years in each panel. The initial resource revenues show positive effects on 5-year regional growth in both countries, with an increased marginal effect in China comparing to the annual growth analysis. While coal still drives the result in China, oil and natural gas revenues lose their contribution to coal in the U.S. With price drops in natural gas, the natural gas revenue per capital kept declining since 2008 despite the increasing production. The insignificant result on natural gas in the U.S. could reflect that resource effects during boom and bust periods were canceled out, leaving no growth effect on average.

3.4.2. Resource Effects on Growth-related Factors

Resource revenues can affect regional growth through its influence on growth-related factors. On the one hand, resource development might push up the fixed assets investment in a region given that resource sectors are capital intensive. On the other hand, anticipating a stream of returns from the natural resource, an agent has less desire to invest in man-made capital for future periods (Gylfason and Zoega, 2006), such as human capital (Gylfason, 2001; Papyrakis and Gerlagh, 2007; Weber, 2013) and R&D activities (Sachs and Warner, 2001). Moreover, resource developments could erode the institution quality in resource-rich regions because the concentrated production and revenue pattern related to resource windfalls tend to breed rent-seeking behaviors and harm political institutions (Jensen and Wantchekon, 2004; Murshed, 2004).

I test and compare resource effects on regional investment, education attainment, R&D activities, and duty crimes among government officers[25]. Replaced the outcome variable in equation (2) with the investment share, college population share, R&D expenditure share, patents per thousand people and duty crimes per million people individually, both Fixed Effects (FE) and Instrumental Variable (IV) estimators are employed. Table 2-7 shows the results of the total resource revenue effect on the five growth-related factors. In China, an increase in total resource revenue per capita increases the share of total fixed asset investment over provincial GDP (the investment share), but decreases the percent of the total population with a college or higher degree (college share), public R&D

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[25] Duty crimes are crimes that committed by working personnel in government or state-owned companies, enterprises, institutions, and organizations, such as corruption, bribery, engaging in malpractices for personal gain, abuse their powers, and neglect their duties.

expenditure share, and the number of patents granted per thousand people. The results for the U.S. are consistent except no significant effect on college population share but evidence of corruptions per million people increasing in the resource revenue per capita.

Further decompose the resource revenue and the results show patterns as well as differences across resource types and countries (Table 2-8). With the resource ownership concentrated in the government (in the case of China) or large energy companies (in the case of the U.S.), one may speculate that resource rents were channeled away to either governments or corporation headquarters far from production sites. However, the results suggest otherwise. Revenues from all resources in both China and the U.S. increase the investment share in the region, with one exception oil revenue in China (column (1) in Table 2-8). It implies that resource-rich regions have attracted more investment on fixed assets in Chinese provinces and more gross private investment in U.S. states. Consistent negative effects are shown in R&D activities. Across resources and countries, resource revenues are crowding out R&D expenditure share as well as patents granted (column (3) and (4) in Table 2-8). Moreover, negative resource effects are larger in China.

Different resource effects are shown on college population share and duty crimes between two countries. In China, the coal revenue lowers percent of the total population with a college or higher degree across provinces while it is the natural gas revenue in the U.S. depresses the educational attainments in states. In a subnational context, two factors would result in a declining educated population in a region: low educational attainment of residents and skill-biased migration across regions. While literature shows evidence that the booming resource extraction reduces high school enrollment (Black et al. 2005; Cascio and Narayan, 2015), implying resource developments disrupt the formation of human capital. I focused on the education attainment measure – percent of the total population with a college or higher degree – to reveal the outcome of regional human capital stock considering the skill-biased migration within a nation. In other words, human capital formation might be crucial in long-run growth for a nation, but given the mobility across regions within a nation, it is the human capital stock contained in a region matters in regional growth at the time. Technically, resource extraction requires low-educated physical labor and coal production require more labor than oil or natural gas production. In the U.S., coal revenues did not show significant impact on college population share. The results suggest resources with booming production tend to decrease the education attainment in a region, such as surged production of coal in China and the shale gas boom in the U.S. Finally, only oil revenues seem to be related to rent seeking behaviors, such as duty crimes and corruptions, though the sign of the coefficient in China is not intuitive.

3.5. The China Case

I shift my focus on the China case in this section. I test impacts of three resource-related policies, the Market Price Reform, the Fiscal Reform, and the Western Development Strategy, on altering the resource – growth relation across regions.

3.5.1. Market Price Reforms

Market price reforms on coal, crude oil, and natural gas sectors have been rolled out one after another since 1993 (see Table 2-1 and detailed discussion in 2.2). I explore variations in policy timings across the three resources and identify the year 1993 and 2003 for coal, and year 1998 for crude oil as potential milestones in shifting the resource – growth relation. Interactions of resource revenue measures and corresponding policy years are then introduced into the instrumental variable (IV) specification shown in equation (2) and (3). The same specifications with interactions are also employed to natural gas, which serves as placebo tests.

Table 2-9 summarized the results on testing market price reform impacts. The market price reform in coal shows significant evidence in stimulating regional growth (column (1) and (2) in Table 2-9). With a state-set price before 1993, a negative resource effect shows on the regional growth: an increase of ¥1,000 coal revenue per capita decreases provincial growth by 0.01 percent. Once the two-track system freed the price of non-utility coals, the marginal effect of the coal revenue on growth becomes positive with much larger magnitude. As the price reform moved forward and the price of power coals linked to the market since 2003, the positive effect of the coal revenue on provincial growth became even larger. Evidence implies the market price reform in coal has significantly helped to promote a positive resource – growth relation.

On the other hand, the impact of the market price reform on crude oil has not been significant (column (3) and (4) in Table 2-9). Though the crude oil price has linked to the international price since 1998, it is still adjusted by the state periodically lagging the international price. More importantly, the international price reveals market forces in a world market but omits or underrepresents the demand and supply signal in the domestic Chinese market. Without market prices negotiated domestically but simply adopting the international price, resource allocations across regions would be still inferior to the efficient level. As for the natural gas price, where the state continued to set throughout the supply chain, no effects are shown with any price policy milestones as expected. Overall, market price reforms in energy sectors have been shown to be successful for coal, need to be deepened in crude oil sectors, and call for actions in the natural gas sector.

3.5.2. The Fiscal Reform

China adopted a tax-sharing system in 1994, under which the central government collected a larger share of the major taxes and provincial governments and their localities split remainders. Meanwhile, with the fiscal decentralization process, the province and local governments have gained more rights from the state-owned enterprises (SOEs) since 1994. Small-scale mines have been privatized. In 2011, a 5 percent resource tax rate was levied on crude oil and natural gas revenues, while other natural resources, including coal and other minerals, are still taxed on extracted volumes with the unchanged tax rate since 1984. For example, resource tax on raw coal is ¥ 2 to 5 per metric ton and ¥ 8 per metric ton for coking coal (Zhang, 2014). I identify the year 1994 and 2011 to indicate fiscal reforms and apply similar interaction approach in the IV specification.

Table 2-10 shows the results on testing impacts of the fiscal reform in resource- growth relations. Evidence suggest that the 1994 fiscal reform did not shift the insignificant relation between oil, natural gas revenues, and regional growth. Nor did the 2011 resource tax rate change for oil and natural gas. On the other hand, the significant effect of the year 1994 and 2011 on the coal revenue might be either driven by the privatization process of small-scale mines since 1994, or the overlap with the market price reform on coal since 1993. In summary, no convincing evidence is shown to indicate any impact of the fiscal reform on altering the resource-growth relations across Chinese provinces.

3.5.3. The Western Development Strategy

I adopt a difference-in-difference specification to test the impact of the Western Development Strategy in the resource-growth relation. Ten provinces or province equivalent regions[26] in the Western Development Strategy are identified with the dummy variable *WestPolicy*. The period is then divided into before 2000 and since 2000 with the dummy variable *Since2000*. I then add three variables into the basic IV specification in equation (2): two dummy variables *WestPolicy*, *Since2000*, and the interaction term of the resource revenue measure, *WestPolicy*, and *Since2000*. Table 11 shows the results. Coefficients of interaction terms show the average treatment effect of the Western Development Strategy.

Evidence shows a significant and positive average treatment effect of the Western Development Strategy is (column (2) in Table 2-11). The total resource revenue increases provincial growth more in the ten western provinces after the Western Development Strategy in 2000. A stronger resource – growth relation in western regions after 2000 is not surprising since the Western Development Strategy focuses on exploiting the resources in the western provinces more intensively and efficiently. The results are consistent with Ji, Magnus, and Wang (2014) using a kernel estimator that the Western Development Strategy has promoted the regional growth through natural gas and coal.

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[26] It was not 12 because Tibet is not in my sample, and Chongqing municipality is combined into Sichuan province to be consistent throughout the time period.

3.6. Conclusions

Using panel data from 1990 to 2015, I compared the effects of resource revenues on the economic growth and growth-related factors across Chinese provinces and American states. To address the endogeneity issue of resource revenues with regional economic conditions, I employ the Instrumental Variable (IV) strategy and instrument the resource revenue with a product of the resource reserves in 1990 and the national primary energy prices. The comparison between the two largest energy-producing nations in the world shed light on the resource – growth relation in distinct economic systems and institution arrangements.

Evidence suggests that resource revenues increase the regional growth in both China and the U.S. with a larger and more statistically significant effect shown across U.S. states. The booming resources, coal in China, oil and natural gas in the U.S., contribute to the positive resource – growth relation in the short term. However, resource revenues show negative effects on growth-related factors, such as education attainments and R&D activities while pushing up the investment across regions. This cast concerns on the long-term economic growth in resource-rich regions.

Further testing impacts of three resource-related policies in China, e.g. the market price reform, the fiscal reform, and the Western Development Strategy, I show that the market price reform together with the privatization process on coal resources contribute the positive resource effect in China. The Western Development Strategy also show a positive effect on strength the resource – growth relation in western provinces. On the other hand, with all natural resources owned by the state and majority managed by the state-owned enterprises, the fiscal reform does not seem to matter in the resource –

growth relation in the China case with my results. In summary, evidence point to the direction that building a market system that relies on efficient price signals for resource allocation thus promote economic growth.

This study can be extended in several directions. A long panel specification would hint persistent factors that alter the resource –growth relation, as well as the dynamic between natural resources and regional institutions in different institution arrangements across nations. The negative resource effects on educational attainments and R&D activities in the results suggests a potential reverse of the resource – growth relation in the long-run.

3.7. Tables in Chapter 3

Table 3-1 Key Resource-related Policy Summary, China

Time	Market Price Reform	Fiscal Reform	Regional Policy
1993	Coal price: two-track system for non-utility coal and power coal		
1994		Adopted a tax-sharing system between central and provincial government; onshore resource taxes are assigned to provincial government	
1998	Crude oil price linked to the international price		
2000			Large-Scale Development Strategy for the Western Region (12 provinces or equivalent) - infrastructure to transfer electricity, water, and gas from western to east - railroad construction
2003	Coal price: abolished its guidance price for power coal and set price bands for negotiations between coal producers and electricity generators.		
2010	Increase natural gas wellhead price by 230 $m/¥^3$, making it as 1,150 $m/¥^3$ (about 4.68 $\$/ft^3$)		
2011		Installed an ad valorem resource tax of 5% on oil and natural gas, instead of taxes levied on extracted volume since 1985	

Note: Author summarized.

Table 3-2 1994 Fiscal Reform in China

	Central - Province split ration (n% : n%)	Share over the total tax revenue from mining industry in 2015 (%)
Value-Added Tax	75 : 25	49.27
Income Tax	60 : 40	24.33
Resource Tax	Onshore resources 0 : 100 Offshore resources 100 : 0	15.88
Resource Compensation Fee	50 : 50	----

Source: Author summarized based on Hou (2016) and Lin (2016).

Table 3-3 Variable Descriptions

Variable	**Definition (China and the U.S.) and Units**	
Resource variables		
Resource Revenue per capita	Sum of all per capita revenues from crude oil, natural gas and coal production, 1,000 real currency[1] per person	
Oil Revenue per capita	Product of field crude oil production and provincial or state crude oil first purchase price, 1,000 real currency per person	
Gas Revenue per capita	Product of natural gas marketed production and provincial or state natural gas wellhead price, 1,000 real currency per person	
Coal Revenue per capita	Product of coal production and regional average coal price, 1,000 real currency per person	
Oil Reserve in 1990 [2]	Crude oil proved reserves by provinces/states in 1990, million barrels	
Gas Reserve in 1990 [2]	Natural Gas, Wet After Lease Separation Proved Reserves by provinces/states in 1990, billion cubic feet	
Coal Reserve in 1990 [2]	Recoverable coal reserves by provinces/states in 1990, million metric tons	
Oil Price	National crude oil first purchase price in China and the U.S., real currency per barrel	
Gas Price	National natural gas wellhead price in China and the U.S.[3], real currency per 1,000 cubic feet	
Coal Price	National average coal price in China and the U.S., real currency per metric ton	
Growth-related variables	**China**	**U.S.**
GDP per capita Growth	The annual growth rate of GDP per capita in 2009 RMB (Chinese provinces) or in 2009 $ (U.S. states), %	
GDP per capita	GDP per capita in 2009 RMB or in 2009 $	
Investment Share	Percent of gross increase in fixed assets over GDP, %	Percent of gross private investment over GDP [4], %
College Population Share	Percent of total population with a college or higher degree	
R&D Expenditure Share	Percent of government R&D expenditure over government total expenditure, %	Percent of total R&D expenditure over GDP, %
Patent per 1,000 persons	The number of patents granted per 1,000 persons	The number of utility patent[5] granted per 1,000 persons
Duty Crimes per million persons	The number of duty crimes[6] convicted per million persons	The number of public official corruption convictions per million persons

Sources: The China annual provincial data are from the China Statistical Yearbook and the China Economic Information Network (CEINET). The resource data of the U.S. states are from the U.S. Energy Information Administration (EIA). The U.S. state GDP data are from the Reginal Economic Accounts, the U.S. Department of Commerce, Bureau of Economic Analysis. The U.S. state level gross private investment. R&D, patent, and corruption data are taken from Yamarik (2013), National Science Foundations, the U.S. Patent and Trademark Office, and the U.S. Department of Justice.
Note: [1] – all monetary values, e.g. revenues and prices, are in real 2009 currency value.

[2] – The reserve data for China are only available since 2003. The reserve values are constructed using an estimate of the reserves in 1990, obtained by adding extraction flows from 1990 to 2003 to 2003 reserves.

[3] – The data on the wellhead price in the U.S. are only available till 2012. Data for the year 2013 to 2015 are replaced with Henry Hub Natural Gas Spot Price.

[4] – Yamarik (2013) provided the state gross private investment estimation from 1990 to 2007 in the U.S. State investment share data of 2008 to 2015 are constructed based on real investment in fixed assets nationwide and the share of the state investment over the U.S. total investment in 2007.

[5] – Utility patent is a type of patent on inventions. Based on the U.S. Patent and Trademark Office (USPTO), more than 90 percent of all patents are utility patents in 2015.

[6] – Duty crimes are crimes that committed by working personnel in government or state-owned companies, enterprises, institutions, and organizations, such as corruption, bribery, engaging in malpractices for personal gain, abuse their powers, and neglect their duties.

Table 3-4 Summary Statistics and Comparison, 1990-2015

	Unit	China		U.S.		Mean Ratio (China/U.S.)
		Mean	Std. Dev.	Mean	Std. Dev.	
Resource Variables						
Resource Revenue per capita	1,000 ¥ or $ per person	1.42	2.69	1.63	4.87	0.13
Oil Revenue per capita	1,000 ¥ or $ per person	0.68	1.83	0.80	3.30	0.12
Gas Revenue per capita	1,000 ¥ or $ per person	0.06	0.20	0.52	1.88	0.02
Coal Revenue per capita	1,000 ¥ or $ per person	0.67	1.65	0.31	1.12	0.32
Oil Reserve in 1990	Million barrels	997.70	1,890.88	468.12	1,459.49	2.13
Gas Reserve in 1990	Billion cubic feet	2,764.27	5,464.07	2,913.10	6,987.95	0.95
Coal Reserve in 1990	Million metric tons	12,047.17	23,022.02	468.52	1,035.06	25.71
Oil Price	¥ or $ per barrel	465.74	282.42	45.39	26.33	1.50
Gas Price	¥ or $ per 1,000 cubic feet	24.44	5.92	4.04	1.74	0.89
Coal Price	¥ or $ per metric ton	383.60	132.84	30.91	6.06	1.80
Growth-related variables						
GDP per capita Growth	%	9.64	5.43	1.44	2.61	6.70
GDP per capita	¥ or $, real 2009	19,015	17,718	42,545	9,435	0.07
Investment Share	%	0.47	0.22	8.51	4.02	0.06
College Population Share	%	6.43	5.75	25.25	5.44	0.25
R&D Expenditure Share	%	1.27	1.02	2.06	1.52	0.62
Patent per 1,000 persons	#	0.25	0.55	0.25	0.19	1.01
Duty Crimes per Million persons	#	43.41	32.96	3.17	2.90	13.67

Note: data cover annual measurement from 1990 to 2015; there are 750 observations in China and 1300 observations in the U.S.; all monetary values, e.g. revenues and prices, are in real 2009 currency value; the mean ratio of monetary value variables are calculated using the World Bank annual average nominal exchange rate in 2009, that is 1 U.S. dollar = 6.83 Chinese yuan.

Table 3-5 Resource Effects on Growth of GDP per capita, Annual Panel, 1990-2015

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
Resource Revenue	0.153	0.505^{**}						
[1.42]	(0.108)	(0.200)						
Oil Revenue			0.145	-0.093				
[0.68]			(0.164)	(0.186)				
Gas Revenue					0.282	0.628		
[0.06]					(1.174)	(0.994)		
Coal Revenue							0.154	0.529^{**}
[0.67]							(0.147)	(0.208)
Observations	725	725	725	725	725	725	725	725
adj. R^2	0.539	0.509	0.538	0.997	0.538	0.517	0.539	0.512
Kleibergen-Paap F-stat (1st Stage)		89.053		208.808		414.396		103.729

Panel B – U.S.

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
Resource Revenue	0.259^{***}	0.392^{***}						
[1.63]	(0.052)	(0.147)						
Oil Revenue			0.319^{***}	0.426^{**}				
[0.80]			(0.043)	(0.187)				
Gas Revenue					0.200^{***}	0.308^{***}		
[0.52]					(0.060)	(0.119)		
Coal Revenue							0.110	-0.204
[0.31]							(0.236)	(0.597)
N	1250	1250	1250	1250	1250	1250	1250	1250
adj. R^2	0.434	0.401	0.433	0.969	0.405	0.378	0.400	0.370
Kleibergen-Paap F-stat (1st Stage)		27.274		28.098		77.085		93.943

Note: the mean GDP per capita annual growth is 9.64 % in China and 1.44 % in the U.S.; variable means are listed in [ ] with 1,000 currency per capita unit; point estimates of resource revenues are summarized; IV columns instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for all resources, and crude oil, natural gas and coal respectively. Province/state and year fixed effects, and controls, including investment share, college share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-6 Resource Effects on Regional Growth, Five-year Panels, 1990-2015

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
Resource Revenue	0.216	0.668***						
[1.34]	(0.135)	(0.203)						
Oil Revenue			-0.005	-0.332				
[0.64]			(0.167)	(0.243)				
Gas Revenue					0.772	0.647		
[0.06]					(1.510)	(1.153)		
Coal Revenue							0.458***	0.698***
[0.63]							(0.110)	(0.213)
Observations	145	145	145	145	145	145	145	145
R^2	0.712	0.575	0.701	0.605	0.703	0.621	0.723	0.639
Kleibergen-Paap F-stat (1st Stage)		14.183		17.668		98.844		22.322

Panel B – U.S.

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
Resource Revenue	0.173***	0.231***						
[1.61]	(0.062)	(0.081)						
Oil Revenue			0.260***	0.394*				
[0.79]			(0.093)	(0.217)				
Gas Revenue					0.109**	0.025		
[0.51]					(0.052)	(0.083)		
Coal Revenue							0.557***	0.866***
[0.30]							(0.104)	(0.256)
Observations	250	250	250	250	250	250	250	250
R^2	0.653	0.554	0.659	0.551	0.610	0.503	0.613	0.507
Kleibergen-Paap F-stat (1st Stage)		17.962		8.989		25.740		153.187

Note: the mean GDP per capita annual growth is 9.08 % in China and 1.39 % in the U.S.; variable means are listed in [] with 1,000 currency per capita unit; point estimates of resource revenues are summarized; IV columns instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for all resources, and crude oil, natural gas and coal respectively. Province/state and year fixed effects, and controls, including investment share, college share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-7 Resource Effects on Growth Factors, All resources

Panel A – China	Investment Share		College Share		R&D Share		Patent		Duty Crime	
	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV	(9) FE	(10) IV
Resource Revenue	0.012^{*}	0.014^{***}	-0.083	-0.141^{***}	-0.109^{***}	-0.135^{***}	-0.065^{***}	-0.065^{***}	-0.494	0.115
[1.42]	(0.007)	(0.003)	(0.101)	(0.042)	(0.036)	(0.014)	(0.022)	(0.008)	(1.108)	(0.723)
Dependent Variable Mean		0.47		6.43		1.27		0.25		43.41
Observations	725	725	725	725	725	725	725	725	725	725
R^2	0.834	0.826	0.898	0.893	0.589	0.568	0.710	0.698	0.552	0.531
Kleibergen-Paap F-stat (1st Stage)		96.333		96.333		96.333		96.333		96.333

Panel B – U.S.	Investment Share		College Share		R&D Share		Patent		Corruptions	
	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV	(9) FE	(10) IV
Resource Revenue	0.134	0.383^{***}	-0.069^{**}	-0.055	-0.023^{**}	-0.025^{**}	-0.007^{***}	-0.009^{***}	-0.071	0.320^{*}
[1.63]	(0.119)	(0.126)	(0.032)	(0.163)	(0.012)	(0.010)	(0.002)	(0.003)	(0.102)	(0.171)
Dependent Variable Mean		8.51		25.25		2.06		0.25		3.17
Observations	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250
R^2	0.637	0.603	0.663	0.649	0.144	0.108	0.302	0.269	0.024	0.115
Kleibergen-Paap F-stat (1st Stage)		33.319		33.319		33.319		33.319		33.319

Note: variable means are listed in [ ] with 1,000 currency per capita unit; point estimates of resource revenues are summarized; IV columns instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for all resources, and crude oil, natural gas and coal respectively. Province/state and year fixed effects, and controls are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-8 Resource Effects on Growth Factors, Oil vs. Natural Gas vs. Coal, IV specifications

		(1) Investment Share	(2) College Share	(3) R&D Share	(4) Patent	(5) Duty Crime
China	Oil Revenue	0.0001	0.048	-0.119***	-0.037***	-5.497***
	[0.68]	(0.003)	(0.053)	(0.019)	(0.008)	(1.205)
	Gas Revenue	0.075**	0.046	-1.019***	-0.540***	1.955
	[0.06]	(0.033)	(0.482)	(0.166)	(0.099)	(3.572)
	Coal Revenue	0.015***	-0.160***	-0.133***	-0.067***	0.913
	[0.67]	(0.003)	(0.044)	(0.016)	(0.008)	(0.744)
U.S.	Oil Revenue	0.563***	-0.076	-0.047***	-0.014***	0.380*
	[0.80]	(0.171)	(0.206)	(0.014)	(0.005)	(0.220)
	Gas Revenue	0.448***	-0.214***	0.036	-0.005***	0.163
	[0.52]	(0.125)	(0.072)	(0.026)	(0.002)	(0.194)
	Coal Revenue	3.175***	0.096	-0.211***	-0.037***	0.523
	[0.31]	(0.564)	(0.273)	(0.044)	(0.008)	(0.518)

Note: variable means are listed in [ ] with 1,000 currency per capita unit; point estimates of specific resource revenues with Instrumental Variable models are summarized, which instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for crude oil, natural gas, and coal respectively. Province/state and year fixed effects, and controls, including investment share, college share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons, are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-9 The China Case – Market Price Reform Impacts

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
CoalRevenue	-0.009**	-0.010**						
	(0.004)	(0.005)						
CoalRevenue*Year1993-2002	8.650**	7.807**						
	(3.793)	(3.876)						
CoalRevenue*Since2003	9.013**	10.451**						
	(4.280)	(4.841)						
OilRevenue			0.002*	0.001				
			(0.001)	(0.002)				
OilRevenue*Since1998			-1.853	-0.706				
			(1.095)	(1.384)				
GasRevenue					-0.078*	-0.137	-0.026	-0.088
					(0.041)	(0.166)	(0.022)	(0.057)
GasRevenue*Year1993-2002					87.688**	90.492		
					(41.655)	(159.273)		
GasRevenue*Since2003					78.310*	136.177		
					(41.118)	(165.228)		
GasRevenue*Since1998							26.066	88.295
							(22.196)	(56.543)
Observations	725	725	725	725	725	725	725	725
R^2	0.546	0.523	0.540	0.517	0.550	0.506	0.540	0.503
Kleibergen-Paap F-stat (1st Stage)		11.487		53.478		17.344		26.761

Note: the mean GDP per capita annual growth is 9.64 % in China; Year1993-2002 = 1 if year is between 1993 and 2002; Since2003 = 1 if year is 2003 or later; Since1998 = 1 if year is 1998 or later; point estimates of resource revenues are summarized; IV columns instrument resource specific revenue measures with the product of resource reserves in 1990 and the national resource prices for coal and crude oil respectively; province/state and year fixed effects, and controls, including investment share, college share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-10 The China Case – the Fiscal Reform Impacts

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV
OilRevenue	0.365	0.304				
	(2.399)	(3.530)				
OilRevenue*Year1994-2010	-0.193	-0.306				
	(2.409)	(3.426)				
OilRevenue*Since2011	-0.230	-0.452				
	(2.400)	(3.448)				
GasRevenue			-51.400	-18.067		
			(35.131)	(99.510)		
GasRevenue*Year1994-2010			52.200	19.978		
			(35.371)	(99.074)		
GasRevenue*Since2011			51.409	18.132		
			(35.099)	(99.366)		
CoalRevenue					-5.562**	-5.057**
					(2.433)	(2.446)
CoalRevenue*Year1994-2010					5.950**	5.972**
					(2.435)	(2.320)
CoalRevenue*Since2011					5.554**	5.033**
					(2.442)	(2.394)
Observations	725	725	725	725	725	725
R^2	0.537	0.514	0.544	0.520	0.547	0.521
Kleibergen-Paap F-stat (1st Stage)		42.623		16.832		26.464

Note: the mean GDP per capita annual growth is 9.64 % in China; Year1994-2010 = 1 if year is between 1994 and 2010; Since2011 = 1 if year is 2011 or later; IV columns instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for all resources; Province/state and year fixed effects, and controls, including investment share, college share, R&D expenditure share, patent per 1,000 persons, and duty crimes per million persons are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

Table 3-11 The China Case – West Development Policy Impacts

	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
ResourceRevenue	0.003	-0.404						
	(0.121)	(0.358)						
ResourceRevenue*WestPolicy*Since2000	0.313**	1.280***						
	(0.145)	(0.334)						
OilRevenue			0.093	-0.272				
			(0.118)	(0.167)				
OilRevenue*WestPolicy*Since2000			-0.063	0.265				
			(0.200)	(0.237)				
GasRevenue					-16.322*	-31.426		
					(9.872)	(19.441)		
GasRevenue*WestPolicy*Since2000					17.294*	32.618*		
					(9.828)	(19.106)		
CoalRevenue							-0.499*	-0.534
							(0.278)	(0.393)
CoalRevenue*WestPolicy*Since2000							1.120***	1.692***
							(0.301)	(0.450)
WestPolicy	-1.862***	-3.215***	-1.226**	-1.277***	-1.367***	-1.403***	-2.181***	-2.868***
	(0.482)	(0.594)	(0.476)	(0.482)	(0.474)	(0.481)	(0.472)	(0.517)
Since2000	5.148***	5.151***	5.168***	5.235***	5.113***	5.037***	5.209***	5.219***
	(0.553)	(0.559)	(0.552)	(0.548)	(0.541)	(0.554)	(0.551)	(0.560)
Observations	725	725	725	725	725	725	725	725
R^2	0.218	0.155	0.206	0.198	0.212	0.208	0.235	0.218
Kleibergen-Paap F-stat (1st Stage)		77.772		230.668		38.831		55.102

Note: the mean GDP per capita annual growth is 9.64 % in China; WestPolicy = 1 if provinces are in the West Development Policy; Since2000 = 1 if year is 2000 or later; point estimates of resource revenues are summarized; IV columns instrument resource revenue measures with the product of resource reserves in 1990 and the national resource prices for resources respectively; province/state and year fixed effects, and controls are included. Robust standard errors are in parentheses. Significances: * at 10 percent level, **at 5 percent level, *** at 1 percent level.

3.8. Figures in Chapter 3

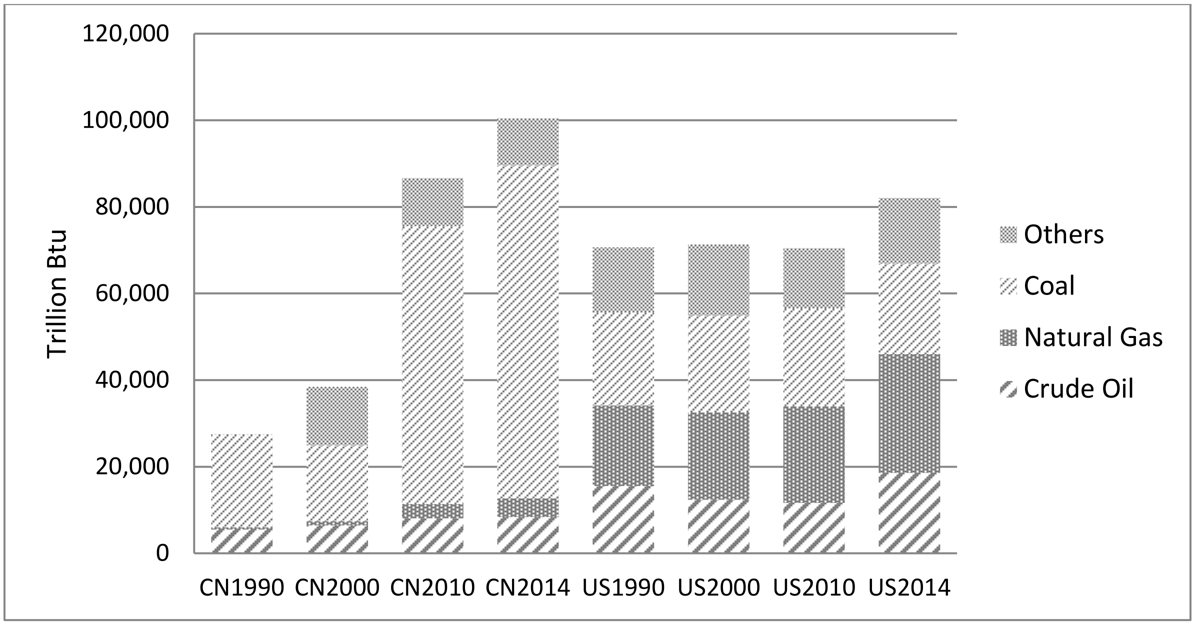
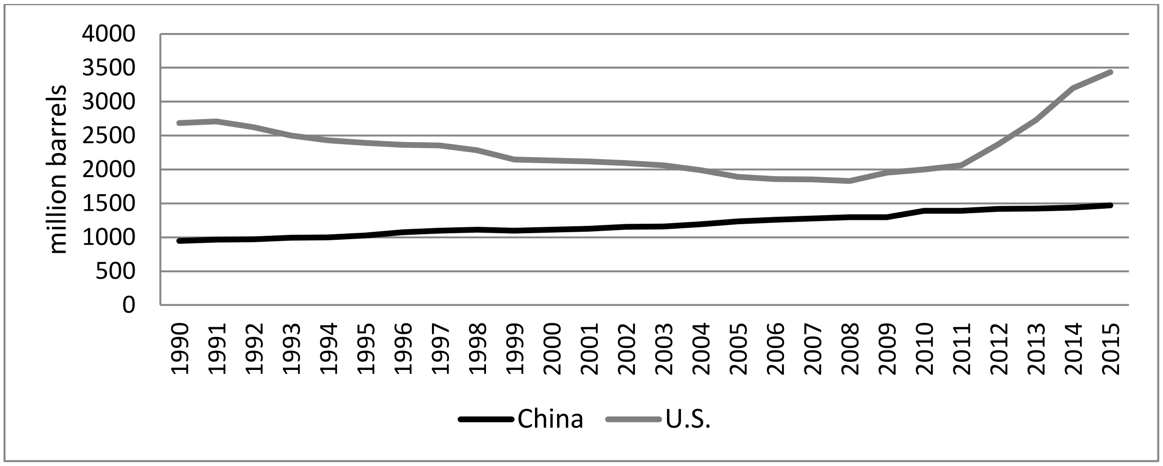


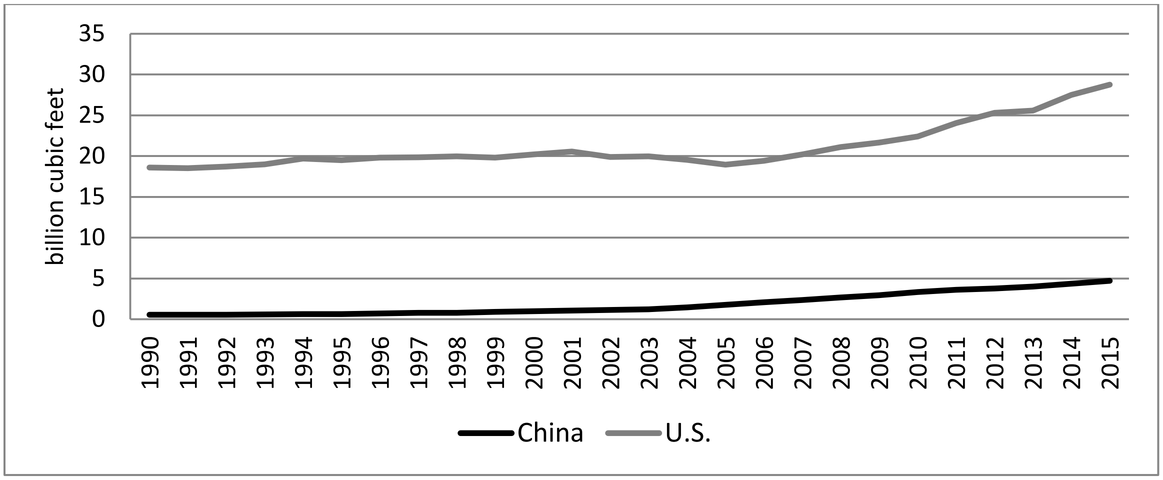
Figure 3-1 Total Primary Energy Production by Resource Types, China vs. the U.S.

Note: Author conducted based on data from China Statistic Year Book and the U.S. Energy Information Administration (EIA).

Panel A Crude Oil Production



Panel B Natural Gas Production



Panel C Coal Production

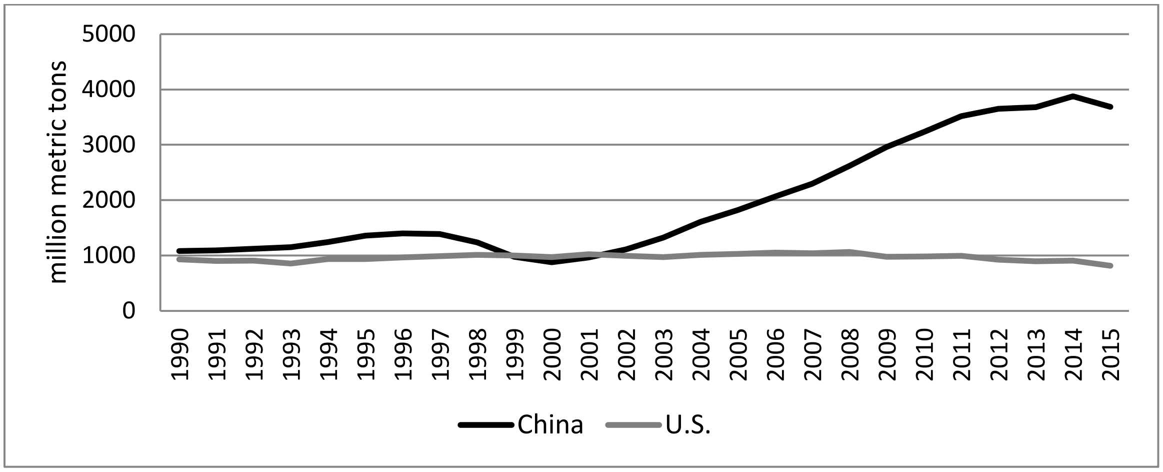


Figure 3-2 Three Main Resource Production Comparisons: China vs. the U.S.

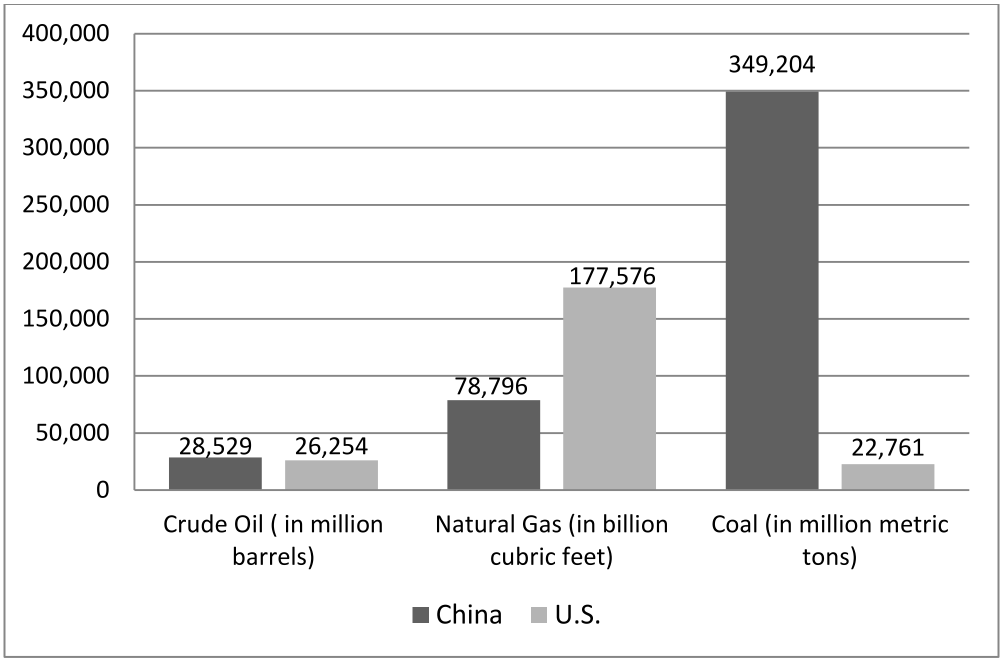
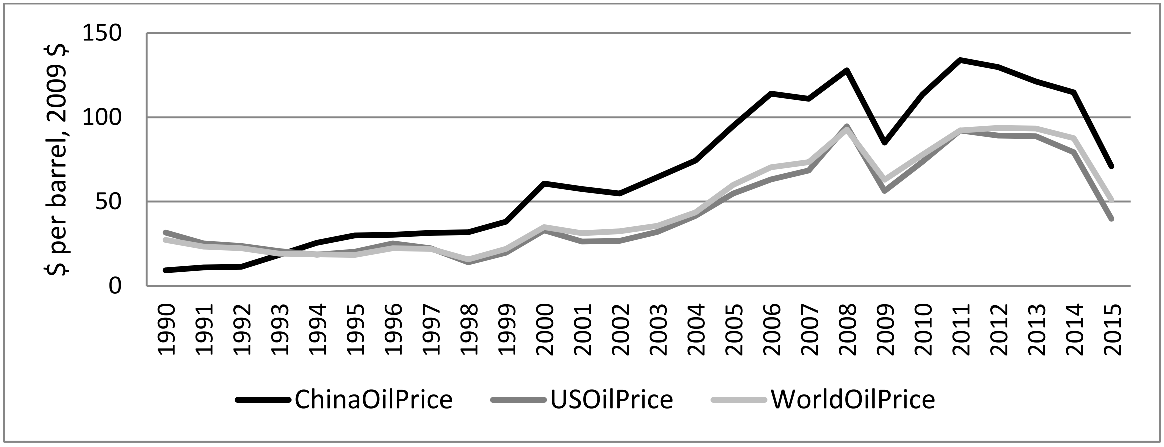


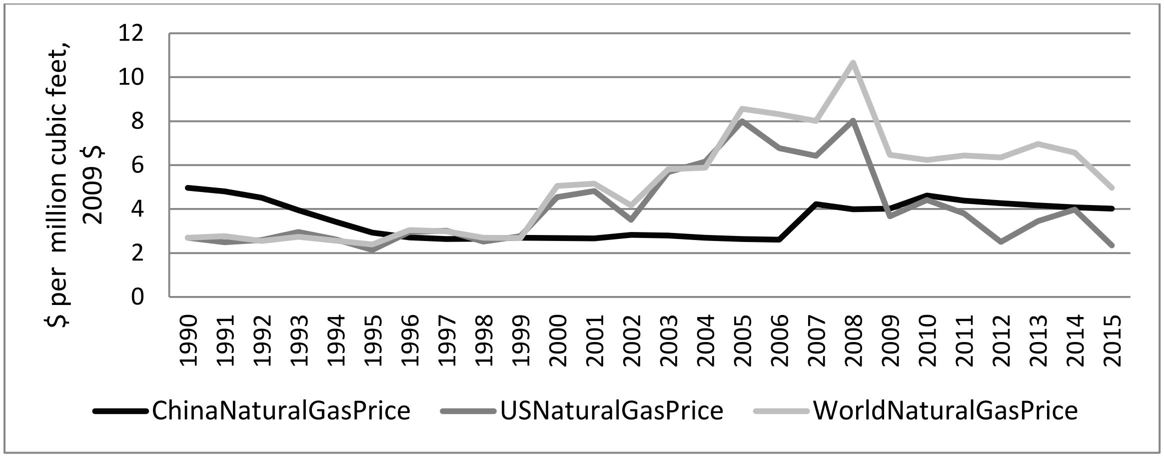
Figure 3-3 Resource Reserves in 1990 Comparison: China vs. the U.S.

Note: Author conducted based on data from China Statistic Year Book and the U.S. Energy Information Administration (EIA).

Panel A Crude Oil Price (2009 real $ per barrel)



Panel B Natural Gas Price (2009 real $ per million cubic feet)



Panel C Coal Price (2009 $ per metric ton)

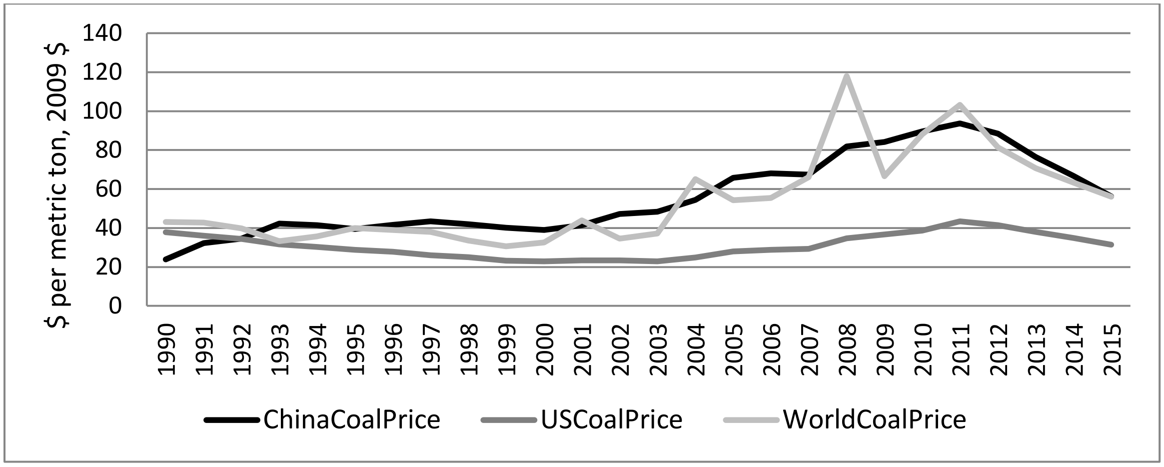


Figure 3-4 Three Main Resource Price Comparisons: China vs. the U.S. vs. the World

Sources: China Statistic Year Book, the U.S. Energy Information Administration (EIA), and the World Bank Commodity Price Data ("the pink sheet").

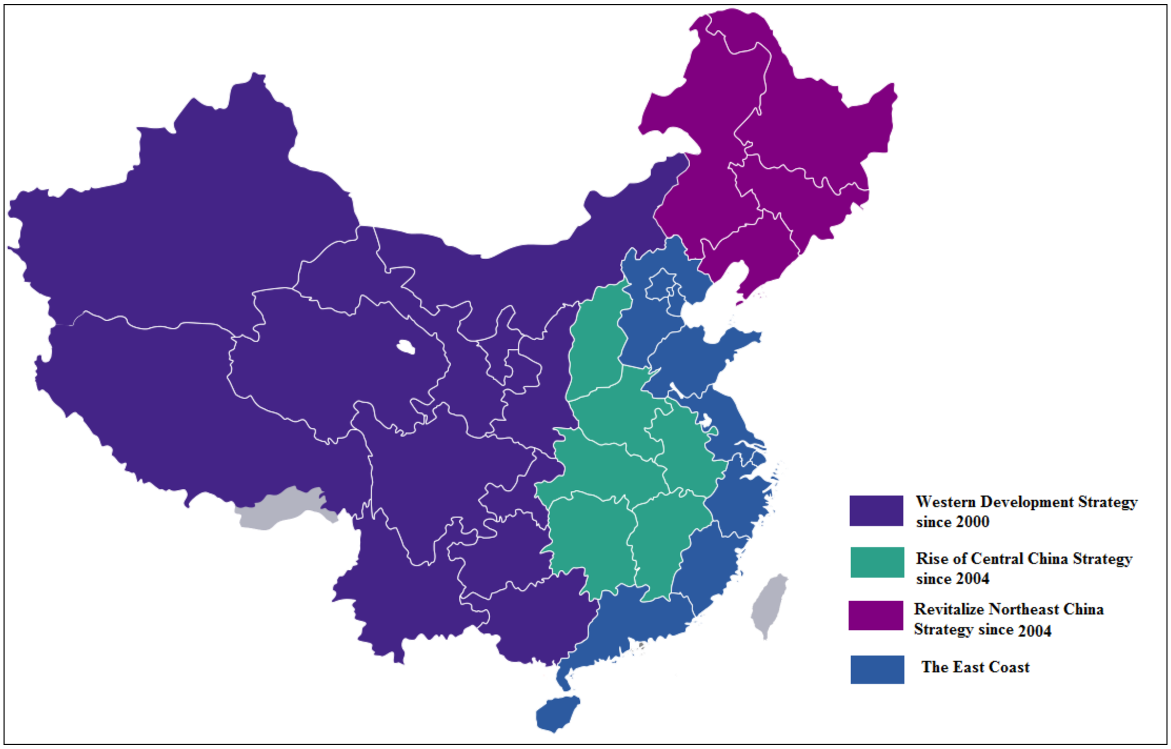


Figure 3-5 Regional Development Strategies in China

Source: Map of Chinese economic regions, based on File:China_provinces_blank.svg.

Chapter 4 The Effects of the Recent Oil and Gas Boom on Schooling Decisions in the U.S.

4.1. Introduction

Horizontal drilling and hydraulic fracturing technologies have induced an oil and gas drilling boom in the U.S. since the 2000s, which has had demonstrated impacts on local income, employment and wage increases (Weber 2012 and 2013; Weinstein 2014; Allcott and Keniston 2014; Fetzer 2014). Combined with the vast literature showing technology breakthroughs are often associated with rises in the returns to skilled labor (Goldin and Katz 1996; Galor and Tsiddon 1997; Acemoglu 1998; Acemoglu 2002), makes it tempting to conclude that schooling will rise with the arrival of an energy boom. However, such an inference ignores the fact that many new jobs related to the energy boom are task-skill based – meaning that education and work experience requirements for entry are low – and have the potential to raise the opportunity cost of schooling significantly. During energy boom periods, increased demand for and earnings of task-skill labor with low education requirements could widen the wage differential and increase the opportunity cost of staying in school, thus drawing teenagers out of school (Black, McKinnish and Sanders 2005b; Emery, Ferrer and Green 2012). This paper exploits variation in timing and spatial patterns of oil and gas well drilling activities to confirm the negative boom-schooling relation across 15 U.S. states between 2000 and 2013.

The schooling impacts of the recent shale oil and gas boom are of interest for several reasons. First, conventional thought among policy-makers is that the boom benefits the economy with jobs and enhances U.S. efforts to achieve energy independence. The major concerns so far lie in potential environmental degradation through water pollution, air pollution, congestion, and ecosystem changes (Kargbo, Wilhelm and Campbell 2010; Roy, Adams and Robinson 2014; Rozell and Reaven 2011; Parker et al. 2014). Second, human capital has long been recognized as an important factor to economic growth (Lucas 1988; Mankiw, Romer and Weil 1992) and a main channel causing the resource curse (Gylfason 1999; Stijns 2006; Papyrakis and Gerlagh 2004), which observes low economic growth in resource-rich regions. Therefore, understanding the particular schooling impacts of the energy boom is important for designing development policies that can increase short-run growth rates without trading off long-run education levels.

New job opportunities driven by the energy boom may have two offsetting effects. On the one hand, when the energy boom brings skill-biased jobs and increases the earnings of task-skill labor, it increases the opportunity costs of staying in school – the local labor market channel. On the other hand, the energy boom may increase school resources through increasing the local tax base, thus increasing student retention – the school resource channel. Which effect dominates during periods of energy boom is an empirical question.

This study exploits county and year variation in drilling activities across 1170 counties in 15 oil/gas production states between 2000 and 2013. The instrumental variable approach with various fixed effects provides estimates of how this recent oil and gas boom affected high school enrollment at the county level. The evidence shows that grade 9 to 12 enrollment decreases in counties and years with intensive drilling activities. The magnitudes I find suggest that for every *four* oil or gas wells drilled per initial 1,000 laborers, *one* student out of a hundred that could have enrolled would not enroll in grade

11 and 12 on average. In other words, given that the drilling density is 7.58 and that total count of grade 11 and 12 enrolled students is 1,962 in an average county during a year, about 36 *fewer* students per county and overall 41,760 *fewer* students across the 15 states enrolled in grade 11 and 12 with the energy boom.

The results are consistent with the findings in the literature exploring the 1970s energy boom (Black, McKinnish and Sanders 2005b). Closest to this paper, Cascio and Narayan (2015) find fracking has increased high school dropout rates of male teens across the U.S. at the commute zone level since 2005. This paper improves on these studies by drawing on rich well drilling data at an annual frequency that both identifies the location, timing, and intensity of the oil and gas boom and allows me to explore heterogeneous effects.

4.2. Background and Related Literature

4.2.1. The Energy Boom, Drilling Activities, and Local Impact Literature

Since the 2000s, oil and gas extraction has rapidly increased from shale formations. Compared to conventional gas deposits, which are in permeable rocks typically located much closer to the surface, shale deposits are trapped in fine-grained sedimentary rocks with very low permeability and located 1,000 to 13,500 feet below the surface (Joskow 2013). When used in conjunction with horizontal drilling, hydraulic fracturing[27] enables gas producers to extract shale gas economically. The Barnett shale play in the middle north of Texas became the first production shale gas play when Mitchell Energy made it

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[27] Hydraulic fracturing (commonly called "fracking") is a technique in which water, chemicals, and sand are pumped into the well to unlock the hydrocarbons trapped in shale formations by opening cracks (fractures) in the rock and allowing natural gas to flow from the shale into the well. Simply, fracking is the production of natural gas from shale rock by bombarding it with water and chemicals.

commercially viable by getting costs down to $4 per million British Thermal Units in 1998.

When cost-reducing technologies, horizontal drilling and hydraulic fracturing techniques in this case, met the higher prices of crude oil in the early 2000s, the shale gas industry surged. U.S. shale gas production increased by 14-fold from 2000 to 2010, and the production mostly lies in Texas, Louisiana, Oklahoma, Arkansas, and a major field that covers much of the Northeast (centered on Pennsylvania) called the Marcellus shale. Based on the well record data collected from various state agencies, figure 1 shows the time trend of the oil/gas well drilling activities in 15 oil and gas production states in the U.S. since 1900. In general, the 2000s energy boom is significant from a historical perspective yet not as intense as the 1970s-1980s boom. Traditional oil and gas states such as Texas and Oklahoma still dominate drilling activities. In Texas, oil/gas well drilling peaked at 30,670 wells drilled in 1985 and the recent boom featured a high of 23,200 oil/gas wells drilled in 2012. However, in some states, the recent energy boom is more sizable in comparison to the 1970s-1980s boom, such as Pennsylvania, North Dakota, Wyoming, Colorado, and Utah. In Pennsylvania, 2,276 oil/gas wells were drilled when the last energy boom was at its highest in 1984, whereas more than 4,000 oil/gas wells were drilled annually from 2006 to 2008.

Local impact studies have documented the recent energy boom as a local economic shock with employment and wage increases. Based on input-output models in earlier economic analyses, development of Marcellus shale was found to create more than 44,000 jobs in 2009 and more than 139,000 in 2010 (Considine, Watson and Blumsack 2009 and 2010). In the Barnett Shale near Fort Worth, Texas, the shale development was estimated to account for almost 89,000 jobs (Perryman Group 2007, 2008, 2011). Later studies have questioned these results as overestimating the employment effect, with concern for the potential violation of critical assumptions and the industry funding source. Kelsey et al. (2011) used survey and GIS data to refine an input-output analysis and showed that Marcellus shale development in Pennsylvania created or supported about 23,884 total jobs in 2009, which was half of what Considine et al.(2009) estimated. Utilizing the moratorium and later ban on fracking in New York as a natural experiment in the Marcellus region, Komarek (2016) found total employment and wages per job increased by 7% and 11% respectively above pre-boom levels in the three years after the boom. The results also show significant positive spillovers to related sectors, such as construction, transportation, retail trade, and accommodations. Employment increases associated with drilling are also found in Ohio (Weinstein and Partridge 2011), Colorado, Wyoming, and Texas (Weber 2012), the southwest four-state region of Texas, Louisiana, Arkansas, and Oklahoma (Weber 2013), nine states in the central U.S. (Brown 2014), and in the lower 48 states altogether (Weinstein 2014). In the synthesis of the literature on local labor markets and natural resources, Marchand and Weber (2017) concluded that the growth in resource extraction clearly increases employment. Created jobs spill over to other sectors of the local economy, which were estimated as the job multiplier, varying from 0.3 to 3.37 in literature (Marchand and Weber 2017).

The workforce relevant to recent oil and natural gas development can be distinguished from that of most other sectors. First, the drilling and production processes are much more labor intensive and industrial in nature than conventional shallow gas development. The deeper formation requires directional drilling, production stimulation, and other methods to produce commercial quantities of natural gas (Brundage, Kelsey and Lobdell 2011). Between 320 and 1365 heavy equipment truck trips are required to build out and bring a single well into operation (Moss 2008), implying that significant labor demand spills over in transportation and construction. A U.S. Bureau of Labor Statistics report in 2013 documented that employment grew by 27,954 jobs from 2007 to 2011 in the counties with wells in the Bakken Formation (North Dakota and Montana), of which 38.1% were in mining, quarrying, and oil and gas extraction, 17.5 % were in transportation and warehousing, and 12.9% were in construction (Ferree and Smith 2013).

Second, the drilling stage is the most labor demanding phase and is associated with the most inducement of local economic activities. Once a well is put into production, the workforce used in the process of drilling and the affiliated infrastructure construction will no longer be needed. A workforce needs assessment conducted in Pennsylvania (Brundage, Kelsey and Lobdell 2011) indicated that 80% of the total industry workforce would be required during the well drilling phase, with 18% for the pre-drilling phase and only 2% for the production phase after wells are drilled. Comparing the oil and gas production trend with related employment trends in 20 states, Weinstein (2014) also showed the employment growth that had accompanied the boom during the construction and drilling period immediately preceded the boom in production. Thus, the drilling phase period is often referred to as “the boom” in the oil and natural gas industries due to the high and sudden labor demand to perform tasks associated with natural gas development (Brundage, Kelsey and Lobdell 2011).

Third, when drilling activities were steady, the drill-related workforces were often transient workers who maintained temporary residency in the drilling area. With the large reserve and technology breakthrough of shale oil and gas, the development intensity kept increasing over the course of years. As a result, the industry is moving towards a workforce that contains fewer transient workers and more permanent local residents. For example, national and international drilling companies, as well as gas field service and construction firms, have opened regional offices in the southwest and northeast Pennsylvania due to the development of the Marcellus play (Brundage, Kelsey and Lobdell 2011). In addition, drill-related workforces spill over into boom-related labor demand in local services such as retail trade and accommodations, reinforcing the local impacts of the energy boom.

Finally, the local labor demand related to the energy boom is task-skill biased with low education and work experience needed for entry. Among the ten largest occupations in the mining sector, most occupations require less than high school or high school diploma or equivalent degree, and none require working experience, except petroleum engineers and general and operations managers (Appendix A 3.1, panel A). Looking at the education attainment for workers 25 years and older in these occupations, such as roustabouts, service unit operators, heavy and tractor-trailer truck drivers, rotary drill operators, 18% to 26% of the workers have less than a high school diploma, which is twice to three times the average rate for all occupations at 9.6% (Appendix A 3.1, panel B). In spill-over sectors such as retail and accommodations, the requirements are low as well. It is fair to conclude that this energy boom increases the demand for low-skilled labor.

In summary, driven by the technology change, an energy boom has intensively spread across the U.S. along shale formations. This energy boom stimulates local economic activities, especially employment. The labor demand triggered by the energy boom is largest during the drilling phase and favors task-skilled labors with lower education requirements.

4.2.2. Energy Shocks and Schooling

Human capital has long been recognized as an important factor for economic growth, and crowding out human capital development (e.g., education) may be a major cause of the resource curse, the phenomenon of low economic growth in resource-rich regions (Gylfason 2001; Stijns 2006; Papyrakis and Gerlagh 2004). Due to the low demand for a high-skilled labor force in resource sectors, the return to education declines with a resource boom (Gylfason 2001), which further decreases the incentive for educational investment. Gylfason (2001) showed evidence that public expenditure on education relative to national income, expected years of schooling for girls, and gross secondary-school enrollment is all inversely related to the share of natural capital in national wealth across countries.

In a subnational context, labor mobility among regions suggests analyzing this effect in two aspects: the high demand for task-skilled labor force can be filled either with immigrants to the boom region or with local laborers, including teens of high school age. Since the labor demand during the energy boom is biased towards low-skilled laborers, the former will reduce the average education attainment level in the region while the latter could block human capital accumulation by inducing more dropouts. In this study, I focus on the latter schooling effects.

Evidence shows that energy shocks influence schooling decisions. Black, McKinnish, and Sanders (2005b) utilized the substantial variation in wages available to teenagers in the Appalachian coal boom and bust and found that high school enrollment rates in Kentucky and Pennsylvania declined considerably in the 1970s during the coal boom and increased in the 1980s during the bust in coal-producing counties relative to counties without coal. The estimates indicated that a long-term 10 percent increase in the earnings of low-skilled workers could decrease high school enrollment rates by 5 to 7 percent. Focusing on the oil boom between 1970 and 1980 and college education, Kumar (2014) showed that the cohort reaching high school age during the oil boom was about 2 percentage points less likely to have a college degree by the time they turned 34 to 37 years of age in 2000. In the context of Canada, Emery, Ferrer and Green (2012) analyzed the effect of the OPEC oil shocks during 1973 to 1981 on the long-term human capital investments for Alberta birth cohorts and found that resource booms may delay education but do not reduce the total accumulation of human capital.

Most recent studies have explored the boom-schooling relation in the context of the energy boom since the 2000s. Morissette, Chan and Lu (2015) exploited variation in wage growth in Canada induced by increases in world oil prices from 2001 to 2008 and found that the aggregate increased wages tend to reduce young men’s full-time university enrollment rates but showed little evidence of an effect on high school dropouts. Cascio and Narayan (2015) showed that fracking had increased high school dropout rates of male teens across the U.S. at the commute zone level. Observing all primary and secondary school students and teacher quality in Texas school districts, Marchand and

Weber (2015) found that the shale boom slightly decreased student achievement with teacher turnover and inexperience increased.

4.3. Economics of the Schooling Decision

In the classical theory by Mincer (1958) and Becker (1964), schooling decisions are modeled as an investment decision. As summarized in Black, McKinnish and Sanders (2005b): If person *j* does not enroll in high school, the discounted value of the flow of earnings is $E_{jd} = \sum_{t=0}^{T} \frac{w_{dt}}{(1+\rho_j)^t}$, where w_{dt} is the earnings of a high school dropout at time *t* and ρ_j is person *j*'s discount rate. If instead person *j* enrolls in school *k* more years to complete high school, the present value of the flow of earnings of person *j* is $E_{jg} = \sum_{t=k}^{T} \frac{w_{gt}}{(1+\rho_j)^t}$. Assuming that secondary public education is free, the student will complete school if $E_{jg} > E_{jd}$. That is

$$\sum_{t=k}^{T} \frac{(w_{gt} - w_{dt})}{(1+\rho_j)^t} - \sum_{t=0}^{k-1} \frac{w_{dt}}{\left(1+\rho_j\right)^t} > 0$$

Under this model, the schooling decision is mainly determined by three factors: the wage differential between high school graduates and high school dropouts $(w_{gt} - w_{dt})$, the opportunity cost of a high school education (w_{dt}), and the individual discount rate ρ_j. Two channels – the local labor market and school resources – further link the schooling decision with the energy boom in the rational investment decision framework. The local impacts of energy booms on employment and earnings can be large and can spill over into other local sectors (Black, McKinnish and Sanders 2005a; Marchand 2012). In studies of the expansion of oil and gas drilling into shale formations in the 2000s, the estimates of new local jobs attributable to the energy boom range from 220,000 to

618,000 nationwide (Maniloff and Mastromonaco 2015; Cascio and Narayan 2015). Spillover effects have also been documented, finding that each oil and gas sector job creates around one to three jobs in other local sectors, especially in construction and transportation (Brown 2014; Fetzer 2014; Weber 2013; Marchand and Weber 2017). As discussed, the labor demand related to the energy boom is low-skill or task-skill biased. When demand for and the earnings of low-skilled labor increase with the energy boom, the opportunity cost of staying in school increases and the wage differential between a dropout and graduate of high school shrinks. Because the wage differential is positively related to the enrollment decision and opposite for the opportunity cost, the resource boom is predicted to affect school enrollment negatively.

School resources, such as school revenues, are another channel linking the energy boom with schooling (Marchand and Weber 2015). The energy development could expand the local tax base, such as the property tax base, and directly generate revenue for schools (Weber, Burnett, and Xiarchos 2016), or it may increase revenue to the state government, which is then redistributed to schools (Raimi and Newell 2014). On the contrary, disamenities from energy extraction might have reduced property values (Gopalakrishnan and Klaiber 2013) and possibly shrink the local tax base. Nonetheless, school resources may affect student achievements, and thus schooling decisions (Gibbons and Mcnally 2013; Papke 2005; Unnever, Kerckhoff and Robinson 2000).

Therefore, depending on the relative forces through two channels, the impact of the energy boom on the schooling decision leaves as an empirical question.

4.3.1. Data

I construct a panel dataset of 1170 counties in 15 oil and gas production states, covering the period between 2000 and 2013. The 15 states are those that overlay the shale plays based on the most recent digital map by the Energy Information Administration and the U.S. Geological Survey in 2011 (see Figure 3-2). More specifically, the sampled states are New York, Pennsylvania, Ohio, West Virginia, Kentucky on Marcellus shale play, Michigan on Antrim shale play, Arkansas on Fayetteville play, Oklahoma on Woodford and other plays, Louisiana on Haynesville shale play, Texas on Barnett, Eagle Ford, and part of Haynesville play, North Dakota and Montana on Bakken play, and Wyoming, Utah, and Colorado on other scattered plays. According to the U.S. Energy Information Administration (EIA), the Marcellus play (PA, WV, OH and NY) on average produced 9.9 billion cubic feet per day in 2013, making it the most productive shale play in the U.S. The Haynesville play (LA & TX) and the Barnett play (TX) produced 5.02 and 4.64 billion cubic feet per day each, coming as second and third in shale gas production. The oil and gas production in these 15 states constitutes 82.70% of the overall production in the U.S. in 2010, increasing from 67.25% in 2000.

4.3.2. Identify the Energy Boom

Four types of indicators have been applied in the literature to identify the energy boom: energy reserves, energy production, employment in the energy industry, and drilling activities measured by the number of wells drilled. If local labor demand shocks are indeed the mechanism linking the energy boom to teenage schooling decisions, it is ideal to have an employment measure that counts both the direct employment effects in the energy industry and the spillover employment effects from the energy development, such as in construction, transportation, services, and the retail sector. However, the overall employment effects related to energy boom are difficult to measure. Without an accurate direct employment measure, the timing of a boom is better identified when the measure identifies the phase of energy development with the largest local employment effects.

The initial drilling phase shows the highest labor requirements, compared to the mature production phase (Weinstein 2014; Kelsey, Partridge and White 2016). Brundage, Kelsey and Lobdell (2011) assessed that each wet gas well in southwest Pennsylvania requires the equivalent of 13.1 full-time jobs, spread across almost 150 occupations and 420 individuals, during the year when drilling and well completion occur on the well site, but only 0.18 full-time job equivalents during each of that well's subsequent producing years. Kelsey et al. (2011) further concluded that labor requirements and therefore most of the employment-based effects are highest during the active drilling years and largely are driven by the number of wells drilled per year. Therefore, a production measure will more likely lag the boom in employment requirements. While the energy reserve is arguably the most exogenous measure among the four, the lack of time variation makes it difficult to identify the timing of a boom. With drilling activities highly related to exogenous factors such as energy deposits distribution across the country, the measure of newly drilled well counts identifies the location, timing, duration and, finally, the intensity of the oil and gas development.

Comprehensive well records, including the timing and location of drilling for each oil and gas well, are requested from various state agencies[28]. Based on the spud date – the

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[28] State agencies such as Dept. of Natural Resource, Dept. of Environment Protect/Commission, Industrial Commission (ND, OK), and Geological Survey (AR, KY).

day that the drilling starts for a well – in well records, I then constructed the number of oil and gas wells drilled, the well spud, by year by county. Since a newly drilled well will have much more muted effects on local labor market conditions in a large county than in a small rural county, I further divide the well spud by the number of the labor force. As labor force counts may be endogenous to drilling activities, I use the labor force of the initial sample period in 2000. Equation (1) shows the main identification variable: the drilling density, which is the number of oil and gas wells drilled per initial 1,000 laborers by county (*c*) by year (*t*).

$$\text{(1)} \qquad DrillingDensity_{ct} = \frac{the\ number\ of\ oil\ and\ gas\ wells\ drilled\ _{ct}}{the\ number\ of\ 1{,}000\ labor\ force_{c,2000}}$$

This unique drilling measure displays significant temporal and spatial variation within the energy boom. Figure 3 shows the time trends of average drilling density across the sample. In general, drilling activities took off after 2002 until the Great Recession in 2008 and surged again after 2009. Beyond averages, there are significant differences in the timing of drilling in booming counties. The fast growing activity since 2010 is mostly driven by top drilling counties in Texas and North Dakota. While in Pennsylvania, the drilling activities began in earnest around 2006 and 2007. Some counties saw a peak of the boom around 2005, e.g. Johnson County in Wyoming or Yuma County in Colorado, while a few counties boomed around 2000, e.g. Campbell County in Wyoming or Terrell County in Texas [29].

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[29] Since the drill density measure counts both conventional and unconventional oil and gas well, it is not surprising to see the early 2000s boom. Conventional and unconventional drillings are correlated and both could trigger demand shock in local labor markets. I argue that there is no reason to distinguish them in this study.

Figure 3-4 further compares the spatial variation of the drilling density across all sample counties in the year 2000 and 2013. In 2000, 555 counties, about 47% of the sample, did *not* experience any oil/gas well drilling. The number of zero drilling counties increases to 687 in 2013. Meanwhile, the oil and gas drillings became enormously intense and highly concentrated in a few areas. In both 2000 and 2013, drilling densities at the 90th percentile are around 7 to 8 wells per initial 1,000 labors. Then they surged to about 86 wells in 2000 and 197 wells at the 99th percentile. In the densest drilling county, Love county in Texas, the drilling density increased from 265 well drilled per 1,000 labors in 2000 to 3,857 well drilled per 1,000 labors in 2013, indicating almost 15 times increase. The top 1% counties – 117 counties – were drilling hundreds of more times than the other counties. These top drilling counties in 2013 were concentrated in south and southwest of Texas, the border corner among Wyoming, Utah, and Colorado, and west of North Dakota.

4.3.3. Schooling Decisions in High School and Controls

I focus on grade 11 to 12 high school enrollment to measure aggregated schooling decisions of high schoolers by county by year. Age 16 to 18 is the exposure age period to low-skill job opportunities. In the U.S., the Fair Labor Standards Act allows teenagers aged 14 to 15 to work outside school hours and teenagers aged 16 to 17 to work unlimited hours[30]. The compulsory school attendance law varies by state and ends from

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[30] Fair Labor Standards Act listed Mining as hazardous job that teenage age 14 to 17 should not work in. However, I argue that with a local labor demand shock triggered by drilling, low-skill job opportunities are not only in mining but also in non-tradable sectors like service and retails.

age 16 to 18 (Table 2-5). Thus, grade 11 to 12 high schoolers provides a feasible age group to investigate the boom-schooling relation.

I obtain the main outcome variable, the enrollment count of grade 11 and 12, from the Common Core of Data (CCD) by the National Center for Education Statistics (NCES). I prefer the Common Core of Data (CCD) to household survey data because the sample size of either the American Community Survey (ACS) or the Current Population Survey (CPS) prevents accurate estimates in rural areas, such as locals where the population is under 65,000. This is important because most of the natural gas production takes place in nonmetro-noncore counties where the population is less than 20,000 (Brown, Weber, and Wojan 2013). Given that it is a universe data collection from administrative records in state education agencies, the data is relatively accurate and reliable without sampling errors. However, the limitations are the omission of data on private schools, and the data can be sensitive to student mobility patterns. The student mobility issue needs special attention in this study because when a resource boom draws immigrants from outside the region, the local high school enrollment could increase. Thus, the schooling measures based on CCD could be overestimated due to the migrant effect[31].

Drawing on the review of Rumberger and Lim (2008), I further identify three sets of control variables that may affect schooling at the high school level in the U.S.: schooling conditions, e.g. pupil-teacher ratio, total revenue per student, total expenditure per student, percentage school revenue from local funding sources; economic conditions, e.g.

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[31] There are observations with the calculated enrollment rate and/or the AFGR greater than 100%. It could be due to migrant effect or other measurement error. In the proceeding empirical analysis, I imputed those greater-than-100% observations with 100%.

median household income, income per capita, poverty rate, job numbers, unemployment rate, earnings per job; and demographic measures, e.g. population density, population share of black, Hispanic, senior, and crime rate. All schooling condition data are from National Center for Education Statistics (NCES). I gather other county-level control data from the Census Bureau's U.S. Counties database. The U.S. Counties database pulls together various databases from the federal government and summarizes key information at the county level[32]. Table 1 reports the summary statistics of the data.

4.4. Empirical Model

4.4.1. Empirical Specification

In order to determine the impact of drilling activities on the schooling of grade 11 and 12, I regress high school enrollment on oil and gas related well-drilling density:

$$Y_{cst} = \beta_0 + \beta_1 DrillingDensity_{cst} + \boldsymbol{\gamma}'\boldsymbol{X}_{cst} + r_c + \lambda_{st} + \varepsilon_{cst} \qquad (2)$$

Y_{cst} is the natural logarithm of the grade 11 and 12 enrollment count in county *c* state *s* in year *t*. An alternative measure, grade 9 to 12 enrollment rate, is also used to check robustness. $DrillingDensity_{cst}$ is the number of oil and gas wells drilled per initial 1,000 laborers in county *c* state *s* in year *t*. I then include county fixed effects, r_c, and state-by-year fixed effect, λ_{st}, where *s* indexes the state. Observed time-variant variables are controlled in vector X_{cst}, as listed in detail in the end of session 4.3.3. ε_{cst} represents all remaining unobserved determinants of outcomes. The county fixed effects account for unobserved determinants of schooling that are common to the same county over time.

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[32] Unfortunately, the U.S. Counties database terminated in 2009. I traced to the original data sources to update the data through 2013.

State-by-year fixed effects control for the general schooling trend and shocks to all counties, as well as the state-level shocks, such as changes in state education policy or other aggregate economic development.

The empirical strategy compares the average high school enrollment during time periods when oil and gas wells are drilled intensively to time periods in the same county when it did not receive such a shock. I flexibly control for time trend using schooling in counties where no drilling activities are observed during others' booming periods. I now turn to discussing the potential threats to the identification and present an instrumentation strategy.

4.4.2. Threats to Identification and Instrumentation Strategy

I discuss three econometric concerns: omitted variables, reverse causality, and measurement error. Omitted variables will bias coefficients if a third factor affects both a county's schooling level and its attractiveness as a location for oil and gas wells. County fixed effects sweep out time-invariant features of the county. State-by-year fixed effects control for omitted variables that change over time within a state and across the U.S. Three omitted variables may affect schooling and correlate with de-trended local drilling activities. First, there may be local demand shocks that both affect schooling decisions and alter the demand for drilling outputs - oil and gas. My focus on oil and gas industries mitigates this concern as most demand for energy comes from national or foreign rather than local consumers. Second, states or counties can influence whether or not large scale extraction occurs in their area. Due to the potential local externalities related to unconventional energy extraction, such as air, water, and noise pollution, amongst other things, the states of New York and Vermont have placed moratoria on the practice. In the

November 2014 elections, there were eight ballot measures banning the practice in Ohio, Texas, and California [33] (Kraus, 2014). Unobserved time-variant county characteristics, such as social attitudes, could potentially affect local teenagers' schooling decisions. Third and similarly, oil and gas companies may target oil and gas formations in counties based on characteristics not observed by researchers and that affect the outcome of interest.

One observed characteristic, the schooling level, draws concerns of reverse causality. The local education distribution determines the relative wages of different skill groups, and relative wages may affect drilling location decisions. An oil or gas company may wish to drill in a low-skill location or in a location where skills are declining over time. If well drilling lowers education, and low schooling levels also attract drilling, the point estimation $\widehat{\beta_1}$ will be biased in an ambiguous direction. In my panel setting, bias occurs if deviations in de-trended high school enrollment or graduation affect (i.e. after accounting for county and year fixed effects, and state-specific time trends) affect past, present or future drilling location decisions.

To deal with omitted variable bias and reverse causality, I require an instrument for $DrillingDensity_{cst}$ in equation (2). I rely on the geographic variation of shale formations and calculate the percentage of area of a county that is over a shale formation. I further multiply it with the world energy price index to obtain the instrument in my panel. Two conditions are required for the instrumental variable strategy to be valid. First, shale play beneath counties and world energy price must have a significant effect

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[33] Four of these eight were passed, including in Denton, Texas; San Benito County, California; Mendocino County, California; and Athens, Ohio.

on drilling activities. Second, the instrument should be exogenous to the error term in equation (2). That is, the instrument variable can only affect deviations in schooling – those not accounted for by the county fixed effects, year fixed effects, state-specific time trends and additional controls – through oil and gas drilling.

The first condition holds both intuitively and statistically. The recent energy boom is driven by shale gas extraction. The shale formation, combined with world energy price index, correlates strongly with $DrillingDensity_{cst}$. The Kleibergen-Paap F-statistics for the first stage in the IV modeling is well above a rule of thumb of 10 for one endogenous regressor and one instrument suggested by Staiger and Stock (1997), as well as the 16.38 level suggested by Stock and Yogo (2005). I further argue the second exclusion restriction is plausibly satisfied. First, the shale formation as an initial geological endowment is outside of human control. Further, since shale formations are subsurface geologic formations, it is unlikely to have an impact on local economic conditions, let alone teenagers' schooling decisions, except through oil and gas extraction. Second, the world energy price index, the other component of my instrument, is typically driven by external demand or supply shocks, instead of changes in local labor or schooling distributions. With state-by-year fixed effects control for the general shocks and trends, the world energy price index is plausibly exogenous to local time-varying unobservables. Similar strategies have been successfully implemented by Weber (2012), Papyrakis and Raveh (2014) and Maniloff and Mastromonaco (2015) in the energy resource development context.

The third econometric concern is measurement error in the schooling measures Y_{cst}. The CCD enrollment data does not distinguish migrant students. In areas with a tight local labor market, the energy boom is more likely to attract immigrants filling in the labor demand. Households might move into a booming area with teenage children who transfer into local schools. In this case, the enrollment or diploma counts would over-measure the local schooling in booming areas. In addition, marginal teenagers in other areas could drop out and migrate into a booming area for work. Consequently, the point estimation on the drilling-schooling relation could be biased upwards and the results underestimate the true schooling decline. Thus, if a bias related to measurement error existed, it would strengthen the results rather than weaken them.

Finally, I cluster all standard errors at the county level to prevent misleading inference due to serial correlation in the error term across years within a county (Bertrand, Duflo, and Mullainathan 2004). A large number of groups (1170 counties) mitigates concerns regarding spurious correlation.

4.5. Basic Results and Discussion

4.5.1. Does the Energy Boom Affect the Local Labor Market or School Resources?

First, I investigate the effects of drilling activities on the local labor market and school with the instrumental variable strategy. While my data set does not allow me to identify the skill-specific labor demand, analysis using a total number of jobs and average earnings per job by the county as outcome variables shows significant positive effects from drilling density (column (1) and (2) in Table 3-2). This suggests the labor market channel is important in the energy boom and schooling relation.

I regress drilling activities on various school resources measures at the county level in my sample. Results show that a higher drilling density is related to the higher share of school revenue from local, but shows no significant effects on per student total school revenue from all local, state and federal sources, as well as per student expenditure (column (3) to (5) in Table 3-2). On average, no increase in school resources is found in my sample. Thus, the school resource is less likely to be the mechanism to explain the energy boom and schooling relation. In summary, I hypothesize that schooling persistence decreases during energy boom in booming regions.

4.5.2. The Effect of the Energy Boom on Schooling

Table 3-3 presents the results from running the regression specification in equation (2). The outcome variable is the natural logarithm of grade 11 and 12 enrollment count. Column 1 compares drilling counties to zero-drilling counties in a given year with the ordinary least squares (OLS) estimator. In column 2, I replace the categorical measure of drilling activities with the *Drilling Density* measurement with the OLS estimator. Column 3 contains the panel fixed effect (FE) results, which include county and state-by-year fixed effects. Column 4 contains the instrumental variable (IV) results, in which I instrument the *Drilling Density* measure with the product of the proportion of county covering a shale play and the world energy price index. Finally, observed control variables are added onto the IV specification, and the results are shown in column 5. In both IV results, the first stage Kleibergen-Paap F statistics are well above the threshold value at 10, rejecting the weak instrument null hypothesis.

Various estimators consistently show evidence of a negative energy boom and schooling relation. Both pooled OLS and FE estimates will be biased if drilling density is correlated with unobserved determinants of high school enrollment. General economic shocks, such as the 2008 great recession, could depress both high school enrollment and drilling activities at the same time. Fixed county characteristics related to geography, such as hilly areas, might also affect schooling and drilling activities in the same direction. Omitting these year and county fixed effects will bias the estimates upwards, leading to overestimation in pooled OLS results. Once the county, year fixed effects, and state-specific linear time trend are included in FE specifications, the coefficients of drilling density become much smaller and not statistically different from zero. Time-varying unobservables could bias FE estimates. As discussed in detail in section 4.5.2, I apply an instrumental variable strategy to address the omitted variable bias and potential reverse causality concern.

The IV estimations show evidence that drilling density decreases grade 11 and 12 enrollment. The magnitude of the coefficient implies substantial educational impacts. On average, with one additional oil/gas well drilled per initial 1,000 laborers, grade 11 and 12 enrollment would decrease 0.24% at the county level, all else equal. As a concrete example, the 90th percentile of the distribution of annual drilling densities corresponds to 10.43 oil/gas wells drilled per 1,000 initial laborers. Based on the IV point estimations in column 5 table 3, such a shock results in a 2.5% decrease in grade 11 and 12 enrollment on average. Alternatively, for every *four* oil/gas wells drilled per initial 1,000 laborers, *one* student out of a hundred that could have enrolled would not enroll in high school on average.

4.5.3. A Placebo Test and Robustness

Evidence has shown the negative effect of a local energy boom on grade 11 and 12 enrollment on average. In the United States, the ending age of compulsory school attendance law varies from 16 to 18 across states. Given that the compulsory school regulation is implemented strictly, I should *not* expect that the energy boom has a significant effect on younger teens in any grade lower than grade 11. I take advantage of the compulsory school regulation and conduct a placebo test of the boom-schooling relation on grade 8 to 10 enrollments.

Table 3-4 shows results of the placebo test among different grades. The energy boom, indicated with the drilling density measure, shows no significant effect on grade 8 to 10 enrollments (column (1) to (3) in Table 3-4). The main response groups are grades 11 and 12, when the youths are mostly between 16 and 18 years old and could legally leave school in certain states. The placebo test further validates the identification strategy.

In addition, alternative schooling and drilling measures are employed to check the robustness of the main finding. The grade 9 to 12 enrollment rate, calculated by dividing the grade 9 to 12 enrollment counts with the county population of age 15 to 19, is employed as an alternative schooling measure. An alternative drilling density measure observes the number of new oil/gas well drilled per square mile. To address concerns with some extreme outliers in the drilling data, I further follow Maniloff and Mastromonaco (2014) and Cascio and Narayan (2015) in also taking the inverse hyperbolic sine (IHS) of the drilling density measures. The IHS effectively allows me to take the natural logarithm of the drilling measures but retain observations with zero wells drilled in the estimation sample[34]. In summary, there is a negative impact of drilling activities on the grade 9 to 12 enrollment rate (Appendix Table A 3-2).

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[34] The inverse hyperbolic sine of x is $\sinh^{-1} x = \ln(x + \sqrt{x^2 + 1})$. It is a convenient choice for a nonlinear specification because it is defined at zero and for a large portion of the real line, its derivative is equivalent to the derivative of the natural logarithm. Accordingly, I can interpret coefficient estimates as elasticities when the dependent variable is the natural logarithm of an outcome variable. (Maniloff and Mastromonaco 2015)

Further, studies have adopted the Difference-in-Difference (DID) model to investigate local impacts of the recent energy boom (Weber 2012 and 2013, Manifloff and Mastromonaco 2014, Cascio and Narayan 2015). However, given the panel nature of my enrollment and drilling density data, a clear experimental design can rarely be constructed without *ad hoc* cut-offs on treatments. For example, one could use a specific year to indicate the start of the boom despite the considerable variation in the timing of the boom across areas. Therefore, I employed the panel model in the basic analysis. Nonetheless, I further check the robustness of the results with a boom spell analysis. The results confirm the negative boom-schooling relation (Appendix A 3.3).

4.6. Heterogeneous Effects

In the previous sections, I argued that a local energy boom could alter the opportunity cost of schooling; and that I identified the effect on schooling by comparing grade 11 and 12 enrollments within and across counties experiencing diverse drilling densities. In this section, I further explore the heterogeneous effects with respect to the compulsory school regulations, taxation, county types and intensities of the energy boom.

4.6.1. Heterogeneous Effects by Compulsory Schooling Regulations

Across states in the U.S., the ending age of compulsory school attendance law varies from 16 to 18. Table 5 summaries age ranges for compulsory schooling in 15 sample states in the year 2000 and 2010. In 2000, 7 out of 15 sample states set the ending age at 16. By 2010, 4 states have lifted the ending age of compulsory schooling to 17 or 18 years old. If compulsory schooling laws constrained schooling choices, I would expect the negative effect of drilling activities on schooling to be larger in states with lower age requirements, e.g. the ending age at 16 years old.

Utilizing variations in compulsory schooling regulations in my sample, I interact the drilling density measure with compulsory schooling age dummies in the IV specification to investigate heterogeneous effects. The result is shown in column (1) Table 3-6. In states where a 16-years-old compulsory schooling age is enforced, one more oil/gas well drilled per initial 1,000 labors decreases grade 11 and 12 enrollment by 0.60%. That is, for every *two* oil/gas wells drilled per initial 1,000 laborers, *one* student out of a hundred that could have enrolled would not enroll in high school on average. While in states with a 17- or 18-years-old age regulation, the negative effect significantly drops to 0.19%, which is less than one-third of 0.60%. In other words, when experiencing the same level of drilling activities locally, 16 to 18 years old teenagers facing a 16-years-old compulsory schooling law are three times *more* likely to *not* enroll in school, than those constrained by a 17- or 18-years-old age regulation. Literature has well documented that longer years of schooling increase individual's lifetime earnings (e.g. Angrist and Krueger 1991, Acemoglu and Angrist 2001), as well as promote economic development (e.g. Lucas 1988, Mankiw, Romer and Weil 1992). The findings call for a rise in ending ages of the compulsory schooling law to mediate the negative schooling effect in energy booming areas.

4.6.2. Heterogeneous Effects by Taxations on Oil and Gas Production

The basic results discussed in section 4.5 suggest the local labor market channel dominates the negative energy boom and schooling relation. In this subsection, I ask whether state and local taxation on oil and gas productions could meditate the negative effect. The school resource channel supports a yes answer. A favorable school financial status allows schools to purchase better equipment and pay higher salaries, which promote student retention. According to the U.S. Department of Education, federal, state, and local sources of public school revenue account for 8%, 46%, and 46% of total revenues respectively in 2012-2013 school year, and 81% of local revenues for public and elementary secondary school districts were derived from local property taxes (Digest of Education Statistics 2016).

Revenue windfalls from an energy boom could channel into school revenues through state taxation on oil and gas production and local sources, e.g. property taxes on oil and gas wells. Names of the resource taxes and the workings vary considerably across states in the U.S. Utilizing the state average effective tax rates on oil and gas production estimated by Weber, Wang and Chomas (2016), I am able to investigate the heterogeneous effect driven by state tax variations. The effective tax rate estimations exclude property taxes since they are set and collected by local governments rather than state government. I further identify states that allow local government to levy property taxes on oil and gas wells in my sample. Table 3-7 summarizes this information. Sorted by the average effective tax rates from lowest to highest in 15 sample states, the comparison suggests the substitution between the tax rates and local property tax policy – for states tax oil and gas production less at the state level, property taxes are usually levied on oil and gas wells from local governments.

I hypothesize that state or local taxation on oil and gas productions could mediate the negative boom and schooling effect. I test them by interacting the drilling density with the state average effective tax rates on oil and gas production from Weber, Wang and Chomas (2016), and local property tax dummies respectively. Column (2) and (3) in Table 3-6 show the results. The positive and significant coefficient on the interaction term suggests that higher state taxes on oil and gas production mediates the negative boom and schooling relation (column (2) Table 3-6). No evidence suggests the local property tax policy makes the difference (column (3) Table 3-6).

4.6.3. Heterogeneous Effects by County Type

The similar density of drilling activities could be perceived differently across counties. The boom-schooling relation can vary with county characteristics. I explore the heterogeneous effects of county types in three aspects: mining counties, metro-nonmetro-rural distinction, and persistent poverty counties.

The significance of the mining industry in a local economy could alter youth's perception about the energy boom. In a mining town, the earnings and employment related to the energy sector are sizable and stable. Local residents are generally familiar with the industry and likely to hold a general acceptance towards it. When an energy boom takes place with increasing labor demand and wages, teenagers are more likely to see the boom as an opportunity for a long-term job option, thus are more likely to choose to work. Therefore, I would expect a larger negative effect on schooling in traditional mining towns. I test this hypothesis by introducing an interaction term, *DrillingDensity*× *MineCounty*, into the basic model in equation (2). *MineCounty* is a dummy variable and identifies a mining county if the mining industry accounts for an annual average of 15 percent or more of total county earnings during 1998-2000, according to the USDA ERS County Typology 2004 edition. 92 counties are identified as mining counties in my sample. The results are shown in columns (4) in Table 3-6. As expected, on average, one additional oil or gas well drilling per initial 1,000 laborers is associated with a significant 0.48% decline in grade 11 and 12 enrollment in mining counties, compared to a significant 0.20% decline in all other counties. The negative boom-schooling relation is doubled in mining counties.

The metro-nonmetro-rural distinction could alter the boom-schooling relation in two ways. On the one hand, a sparsely populated non-metro area implies a tight local labor market. Compared with the sufficient labor supply in the metro area, wages are more likely to be forced up in less populated non-metro areas with an energy boom. Therefore, the opportunity cost of staying in school could be higher for teens in non-metro or rural areas. On the other hand, along with the mining county argument earlier, with a generally more diverse industry mix in a metro area, a similar size energy boom will be more visible in non-metro and rural areas and thus more likely to be perceived by local teens. As a result, teenagers are more likely to response to an energy boom by working and not enrolling in school.

To test this hypothesis, I employ the USDA Rural-Urban Continuum Codes in 1993 and divide my sample counties into 3 exclusive groups: metro counties where a county is in or adjacent to a metro area with more than 250,000 population; nonmetro counties where counties have more than 2,500 urban population and are not metro counties; and completely rural counties with less than 2,500 urban population. In my sample counties, there are 298 metro counties, 578 non-metro counties, and 293 completely rural counties. Leaving out metro counties as the comparison group, *NonmetroCounty* and *RuralCounty* dummies are introduced as interactions with *DrillingDensity* respectively. The results are shown in columns (5) in table 6. The significant and negative estimates on two interactions confirm the hypothesis that grade 11 and 12 enrollment are more likely to be negatively affected by the drilling activities in non-metro and rural areas. Evidence suggests that the largest effect takes place in non-metro counties: with one additional oil or gas well drilling per initial 1,000 laborers, on average the grade 11 and 12 enrollment significantly declines 1.38% in non-metro counties and decreases 0.98% in completely rural counties.

Finally, the energy boom may hit persistent poverty counties differently. The boom boosts income, which could loosen the budget constraint for households in poverty and therefore encourage education investment. However, the emerging job opportunities and raised wages could be more attractive in persistent poverty counties. The overall effect is thus ambiguous. With similar methodology, I introduce an interaction term, *Drilling Density*×*PovertyCounty*, into the basic model. *PovertyCounty* is a dummy variable to identify 172 persistent poverty counties in the sample, where 20 percent or more of county residents were poor, measured by the 1970, 1980, 1990 and 2000 censuses. Shown in column (6) in Table 3-6, the results suggest a significant 0.32% larger negative effect on grade 11 and 12 enrollment in persistent poverty counties than others counties.

4.6.4. The Heterogeneous Effect of Drilling Density

The panel model in the basic analysis yields the average marginal effects of drilling density on high school enrollment across the sample. Given the considerable variation in drilling across sample counties, the effects on high school enrollment could vary depending on how intense the drilling is in a county. This implies a nonlinear boom-schooling relation and a threshold effect: no effect may take place until drilling intensity reaches a certain level. For example, when investigating the employment effect of shale gas development in extraction counties in Pennsylvania, Wrenn, Kelsey and Jaenicke (2015) found that only high well activity (90 or more wells) impact employment significantly. Given a threshold of drilling activities to boost local employment, I would expect even higher drilling activities to alter teenager's behavior.

To explore this effect, I follow Wrenn, Kelsey and Jaenicke (2015) and group annual drilling density in various ways. Then I replace the continuous drilling density measure with different group dummies to detect the threshold effect. The results are shown in Table 3-8. In column (1), I specify a binary variable that is 1 for counties have any drilling activity in a given year and zero otherwise. In column (2), I assign levels of drilling activities to three discrete bins: drilling density is between 1 to 10 oil or gas wells drilled per initial 1,000 laborers in a given year (Drill 1-10), then between 10 to 100 oil or gas wells drilled per initial 1,000 laborers in a given year (Drill 10 -100), and more than 100 oil or gas wells drilled per initial 1,000 laborers in a given year (Drill 100 +). In column (3), I further divide the Drill 100 + group into Drill 100 -200 ($100 \leq$ drill density < 200) and Drill 200 + (drill density ≥ 200). The coefficients represent percent changes for the effects relative to the baseline enrollment trend in counties when no drilling activity took place. When the drilling density is less than 100 wells per initial 1,000 laborers, the impact of drilling activities on grade 11 and 12 enrollment is not significant. Evidence show significant negative relations when the drilling density is more than 100, implying a threshold effect. The threshold effects or the nonlinear relation can be explored further with nonparametric models in further research.

4.7. Conclusions

Energy booms can discourage investments in education by increasing the opportunity cost for students to stay in school, especially for students who highly discount the future. This paper finds that for the 15 oil and gas production states in the U.S. during the period

2000 to 2013, the intensive drilling activities altered enrollment decisions of teenagers. The magnitudes I find suggest that for every *four* oil or gas wells drilled per initial 1,000 laborers, *one* student out of a hundred that could have enrolled would not enroll in grade 11 and 12 on average. More specifically, given that the drilling density is 7.58, and that total count of grade 11 and 12 enrolled students is 1,962 in an average county during a year, about 36 *fewer* students per county (0.24% × 7.58 × 1,962) and overall 41,760 *fewer* students across the 15 states enrolled in grade 11 and 12 with the energy boom.

While recent oil and gas development across the U.S. benefits the economy with jobs and may set the U.S. on a path toward energy independence, this study points to another potential negative side effect on schooling besides environmental concerns. The decision of not enrolling in school but rather working could well be a rational one in the face of relatively high wages. Those students who drop out may re-enroll later in their lives (Emery, Ferrer and Green 2012) thus mediating the overall effect on human capital accumulation. Nonetheless, teenagers who overweight the present could give up education earlier than they should have.

Given the trade-off in recent oil and gas development, it is beneficial to recognize and identify the heterogeneous effects of the benefits and costs related to the energy boom. This study shows that the negative boom-schooling relation is larger in states with a 16-years-old compulsory schooling age regulation, lower state effective tax rate on oil and gas productions, traditional mining, non-metro, and persistent poverty counties. Also, drilling activities may not significantly impact local schooling until they reach a certain intensity. Future research can focus on the heterogeneity across regions to better facilitate local policy making.

Along the lines of Atkin (2016), some policy remedies can mitigate the negative schooling impact of the energy boom by lowering the opportunity cost of schooling while welcoming the local economic boom at the same time. For example, an increase in the ending age of compulsory attendance in some states, payments to households conditioned on children’s school attendance, and finally, opportunities and reduced costs of returning to school or other further education that allows dropouts to obtain the foregone education in times of energy bust.

4.8. Tables in Chapter 4

Table 4-1 Summary Statistics

	Obs.	Mean	Std. Dev.	Min	Max
Outcome Variables					
Grade 11 and 12 Enrollment Counts	16,179	1,962.08	5,201.08	3	101,966
Grade 8 Enrollment Counts	16,256	1,109.31	3,123.08	1	71,481
Grade 9 Enrollment Counts	16,190	1,241.33	3,708.60	1	101,687
Grade 10 Enrollment Counts	16,185	1,119.16	3,172.83	1	85,923
Grade 11 Enrollment Counts	16,183	1,010.95	2,708.02	1	53,115
Grade 12 Enrollment Counts	16,181	951.53	2,496.53	1	48,851
Key Explanatory Variable					
Newly Drilled Oil and Gas Well Counts (#)	16,380	30.55	96.41	0	2708
Well Spud per 1,000 labors in 2000	16,380	7.58	63.58	0	3857.14
Well Spud per Square Mile	16,380	0.03	0.08	0	1.21
Share of County Area Covered by a Shale Play [0,1]	1,170	0.34	0.43	0	1.00
Controls – Schooling Conditions					
Pupil-Teacher Ratio	16,167	0.14	0.03	0.01	2.03
Total School Revenue per Students ($1,000/student)	15,108	11.78	6.70	0.56	172.92
Total School Expenditure per Students ($1,000/student)	15,108	11.71	6.70	0.28	148.50
Share of School Revenue from Local [0,1]	15,129	0.39	0.17	0.07	1.00
Controls – Economic Conditions					
Median Household Income ($10,000)	16,380	3.93	1.03	0	10.52
Income per Capita ($10,000)	16,378	2.99	0.97	1.02	18.96
Poverty Rate [0,1]	16,380	0.16	0.06	0	0.53
Youth Poverty Rate [0,1]	16,380	0.23	0.09	0	0.70
Total Count Number of Jobs (#)	16,378	504.19	1,651.68	0.60	29,612.08
Unemployment rate [0,1]	16,380	0.06	0.03	0	0.24
Earn per Job ($10,000)	16,378	3.42	0.99	0.70	11.94
Controls – Demographics					
Population per Square Mile (1,000 persons /sq. mi.)	16,380	0.18	1.28	0	71.49
Population between Age 15 and 19 (#)	16,377	6,332.76	17,099.04	1	301,079
Share of African American [0,1]	16,377	0.06	0.10	0	0.69
Share of Hispanic [0,1]	16,377	0.10	0.16	0	0.98
Share of population above age 65 [0,1]	16,377	0.15	0.04	0.03	0.37

Table 4-2 (continued)

The number of Violent Crimes per Person	15,454	0.002	0.002	0	0.031
The number of Property Crimes per Person	15,464	0.016	0.014	0	0.241

Notes: units are in ( ) and ranges are in [ ]; outcome variable and schooling condition control variable data are obtained from the National Center for Education Statistics (NCES); oil and gas well records are requested from state agencies such as Department of Natural Resource, Department of Environment Protect/Commission, Industrial Commission, and Geological Survey. Other data of control variables are from the Census Bureau’s U.S. Counties database.

Table 4-3 The Effects of Drilling Activities on Local Labor Market and School Resources

	Total Number of Jobs (log) (1)	Earn per Job (log) (2)	Share of School Revenue from Local (3)	Total School Revenue per Student (log) (4)	Total School Expenditure per Student (log) (5)
Drilling Density	0.0011^{***} (0.0004)	0.0016^{***} (0.0005)	0.0006^{*} (0.0003)	-0.0001 (0.0007)	-0.0013 (0.0009)
Dependent Variable Means (in levels)	504	34,200	0.39	11,780	11,710
Observations	14193	14193	14393	14372	14372
R^2	0.418	0.766	0.127	0.661	0.550
Kleibergen-Paap F-stat (1st Stage)	31.591	31.591	36.811	37.221	37.221
County FE	Yes	Yes	Yes	Yes	Yes
State-by-year FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: the point estimates of coefficients on *Drilling Density* - the number of new oil and gas well drilled per initial 1,000 labors in 2000 – are summarized. All models instrument Drilling Density measures with the product of the proportion of county covering a shale play and the world energy price index. Controls in column (1) and (2) include three sets of control variables: schooling conditions (e.g. pupil-teacher ratio, log of total revenue per student, log of total expenditure per student, percentage school revenue from local), economic conditions (e.g. log of median household income, log of income per capita, poverty rate), and demographic (e.g. population density, African-American population share, Hispanic population share, senior population share, and crime rate). Controls in column (3) to (6) include two sets of control variables: economic conditions and demographics. County clustered standard errors in parentheses. − * significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

Table 4-4 The Effect of Drilling Activities on High School Grade 11 and 12 Enrollment, 2000-2013

	Grade 11 to 12 Enrollment Count (log)				
	(1) OLS	(2) OLS	(3) FE	(4) IV	(5) IV
AnyDrill	-0.1507*** (0.0225)				
DrillingDensity		-0.0079*** (0.0015)	-0.0001 (0.0001)	-0.0026*** (0.0007)	-0.0024*** (0.0009)
Observations	16179	16179	16179	16179	14103
R^2	0.003	0.036	0.164	0.102	0.127
Kleibergen-Paap F-stat (1st Stage)				43.692	34.628
County FE	No	No	Yes	Yes	Yes
State-by-year FE	No	No	Yes	Yes	Yes
Controls	No	No	No	No	Yes

Notes: The mean enrollment of grade 11 to 12 in level is 1,962 students per county; *AnyDrill* =1 if counties have any oil or gas well drilled in a given year; *Drilling Density* is the number of new oil and gas well drilled per initial 1,000 labors in 2000. The IV columns instrument *Drilling Density* measures with the product of the proportion of county covering a shale play and the world energy price index. Controls includes three sets of control variables: school conditions (e.g. pupil-teacher ratio, log of total revenue per student, log of total expenditure per student, percentage school revenue from local), economic conditions (e.g. log of median household income, log of income per capita, poverty rate, log of job numbers, unemployment rate, log of earn per job), and demographic (e.g. population density, black population share, Hispanic population share, senior population share, and crime rate). County clustered standard errors in parentheses. −* significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

Table 4-5 The Placebo Test among Grade 8 to 12

Dependent Variables: Enrollment Counts (log)	Grade 8 (1)	Grade 9 (2)	Grade 10 (3)	Grade 11 (4)	Grade 12 (5)
Drilling Density	0.0013	0.0002	-0.0005	-0.0025***	-0.0023**
	(0.0008)	(0.0008)	(0.0008)	(0.0009)	(0.0010)
Dependent Variable Means (in level)	1,109	1,241	1,119	1,011	952
Observations	14,140	14,105	14,106	14,105	14,103
R^2	0.154	0.195	0.166	0.089	0.084
Kleibergen-Paap F-stat (1st Stage)	35.665	34.472	34.611	34.629	34.630
County FE	Yes	Yes	Yes	Yes	Yes
State-by-year FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: the point estimates of coefficients on *Drilling Density* - the number of new oil and gas well drilled per initial 1,000 labors in 2000 – are summarized in two panels. All models instrument Drilling Density measures by the product of the proportion of county covering a shale play and the world energy price index. County fixed effects, state-by-year fixed effects, and controls are included in all models. County clustered standard errors in parentheses.–*significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

Table 4-6 Age Ranges for Compulsory School in 15 Sample States, 2000 and 2010

	2000	2010	Policy Changing Year
Arkansas [1]	5 to 17	5 to 17	---
Colorado	---	6 to 17	2007
Kentucky	6 to 16	6 to 16	---
Louisiana [1]	7 to 17	7 to 18	2006
Michigan	6 to 16	6 to 18	2010
Montana [1]	7 to 16	7 to 16	---
New York [1,2]	6 to 16	6 to 16	---
North Dakota	7 to 16	7 to 16	---
Ohio	6 to 18	6 to 18	---
Oklahoma	5 to 18	5 to 18	---
Pennsylvania [1]	8 to 17	8 to 17	---
Texas	6 to 18	6 to 18	---
Utah	6 to 18	6 to 18	---
West Virginia	6 to 16	6 to 17	2010
Wyoming [1]	6 to 16	7 to 16	---

Notes: [1]- Child may be exempted from compulsory attendance if he/she meets state requirements for early withdrawal with or without meeting conditions for a diploma or equivalency.

[2]-New York City and Buffalo require school attendance until age 17 unless employed.

Source: Council of Chief State School Officers, *Key State Education Policies on PK–12 Education*, 2000; Education Commission of the States (ECS), ECS StateNotes, *Compulsory School Age Requirements*, retrieved August 9, 2010, from http://www.ecs.org/clearinghouse/86/62/8662.pdf.

Table 4-7 Heterogeneous Effects among Counties

	Grade 11 – 12 Enrollment Count (log)					
	(1)	(2)	(3)	(4)	(5)	(6)
DrillingDensity	-0.0019**	-0.0121***	-0.0031	-0.0020**	0.0091	-0.0019**
	(0.0010)	(0.0026)	(0.0019)	(0.0009)	(0.0056)	(0.0008)
DrillingDensity × CompulsoryAge16	-0.0041*					
	(0.0024)					
DrillingDensity × CompulsoryAge17	0.0028					
	(0.0038)					
DrillingDensity × AveEffectiveTaxRates		0.0023*** (0.0005)				
DrillingDensity × LocalPropertyTax			0.0008 (0.0020)			
DrillingDensity × MineCounty				-0.0028*** (0.0010)		
DrillingDensity × NonMetroCounty					-0.0138*** (0.0052)	
DrillingDensity × RuralCounty					-0.0098* (0.0054)	
DrillingDensity × PovertyCounty						-0.0032** (0.0015)
Observations	13853	13426	14103	14103	14103	14103
R^2	0.122	0.035	0.145	0.106	0.087	0.163
Kleibergen-Paap F-stat (1st Stage)	12.814	15.512	10.483	16.356	14.309	14.620

Notes: Drilling Density is the number of new oil and gas well drilled per initial 1,000 labors in 2000. Interactions of *Drilling Density* and different state/county typologies are introduced into the basic model. Data of average effective tax rates by state are from Weber et al. (2016) Table A4. CompulsoryAge16=1 if the ending compulsory school age is 16 in a given year; similarly applies to CompulsoryAge17. LocalPropertyTax=1 if states allow local government to levy ad-valorem property taxes on oil and gas property. Based on USDA ERS County Typology 2004 edition, MiningCounty=1 if the mining industry is accounting for an annual average of 15 percent or more of total county earnings during 1998-2000. PovertyCounty=1 for persistent poverty counties, where 20 percent or more of county residents were poor, measured by the 1970, 1980, 1990 and 2000 censuses. Based on USDA Rural-Urban Continuum Codes in 2003, NonmetroCounty=1 if counties with more than 2,500 urban population and not in or adjacent to metro areas; RuralCounty=1 if counties with less than 2,500 urban population. All models instrument Drilling Density measures with the product of the proportion of county covering a shale play and the world energy price index. County and state by year fixed effects are included. County clustered standard errors in parentheses. −* significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

Table 4-8 Taxation on Energy Windfalls

State	Average Effective Tax Rates on Oil and Gas Production (%, state tax only, 2004-2013)[1]	Whether Levy Local Property Taxes on Wells[2]	Share of School Revenue from Local (%, average across counties, 2000-2013)[3]
Ohio	0.3	Yes	42.8
Arkansas	0.9	Yes	29.1
Pennsylvania	1.2	No	52.0
Colorado	1.7	Yes	50.5
Utah	2.0	Yes	33.4
Texas	4.1	Yes	48.1
West Virginia	4.2	Yes	27.2
Wyoming	4.4	Yes	43.4
Kentucky	4.7	Yes	22.9
Michigan	4.8	No	36.3
Louisiana	5.3	No	34.1
Oklahoma	6.2	No	31.2
North Dakota	8.1	No	48.9
Montana	8.6	No	39.8
New York	----	No	41.0

Note: [1]-Data cited from Weber, Wang, and Chomas (2016) table A4.

[2]- Information from Independent Fiscal Office (IFO) of Pennsylvania (2014) and Newell and Raimi (2015)

[3]- Data downloaded from the National Center for Education Statistics (NCES)

Table 4-9 Threshold Effects of Drilling Density

	Grade 11 – 12 Enrollment Count (log)		
Drilling Density Dummies	(1)	(2)	(3)
AnyDrill	-0.0023		
	(0.0054)		
Drill 1-10		-0.0021	-0.0021
		(0.0054)	(0.0054)
Drill 10-100		-0.0074	-0.0073
		(0.0095)	(0.0095)
Drill 100+		-0.0925**	
		(0.0433)	
Drill 100-200			-0.0981*
			(0.0511)
Drill 200+			-0.0765*
			(0.0448)
Observation	6680	6680	6680
R^2	0.356	0.359	0.359
County FE	Yes	Yes	Yes
State-by-year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Note: *Drilling Density* is replaced with group dummies in the basic model. *AnyDrill* =1 if counties have any oil or gas well drilled in a given year; *Drill 1-10* =1 if counties have more than zero but less than 10 oil or gas wells drilled per initial 1,000 labor in a given year; *Drill 10 -100* =1 if counties have more than 10 but less than 100 oil or gas wells drilled per initial 1,000 labor in a given year; *Drill 100 +* =1 if counties have more than 100 oil or gas wells drilled per initial 1,000 labor in a given year; *Drill 100 -200* =1 if counties have more than 100 but less than 200 oil or gas wells drilled per initial 1,000 labor in a given year; *Drill 200 +* =1 if counties have more than 200 oil or gas wells drilled per initial 1,000 labor in a given year. Fixed effect estimators are applied. County clustered standard errors in parentheses. –* significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

4.9. Figures in Chapter 4

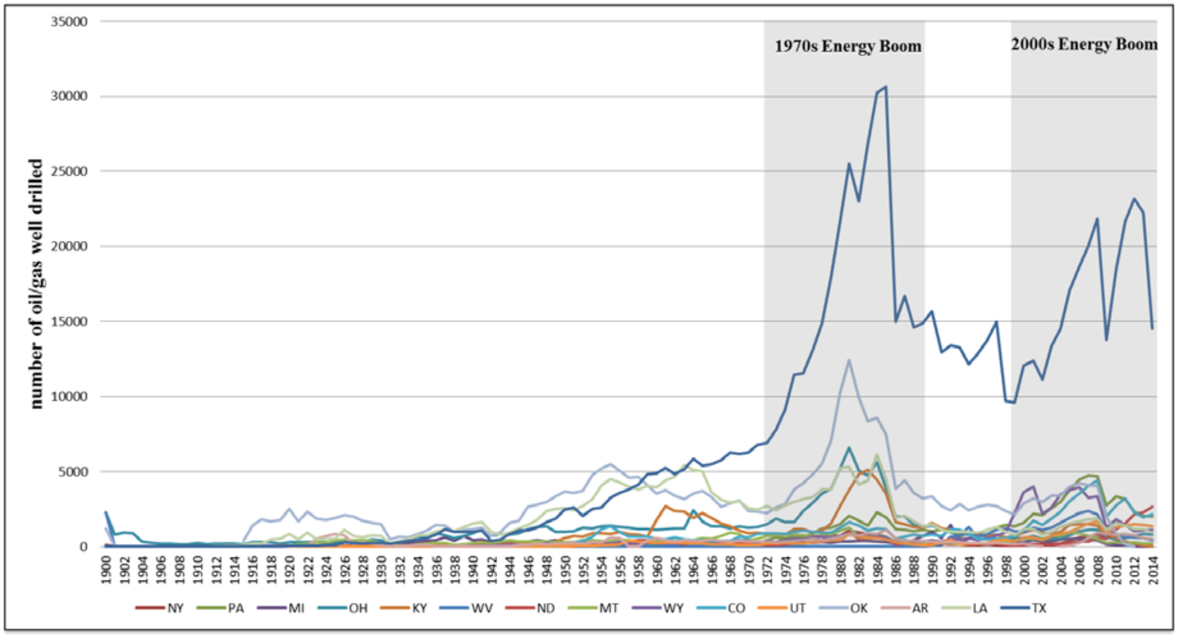

Figure 4-1 Time Trend of the Oil/Gas Well Drilling in 15 States in the U.S., 1900-2014

Note: Author's calculations based on well records data from various state agencies

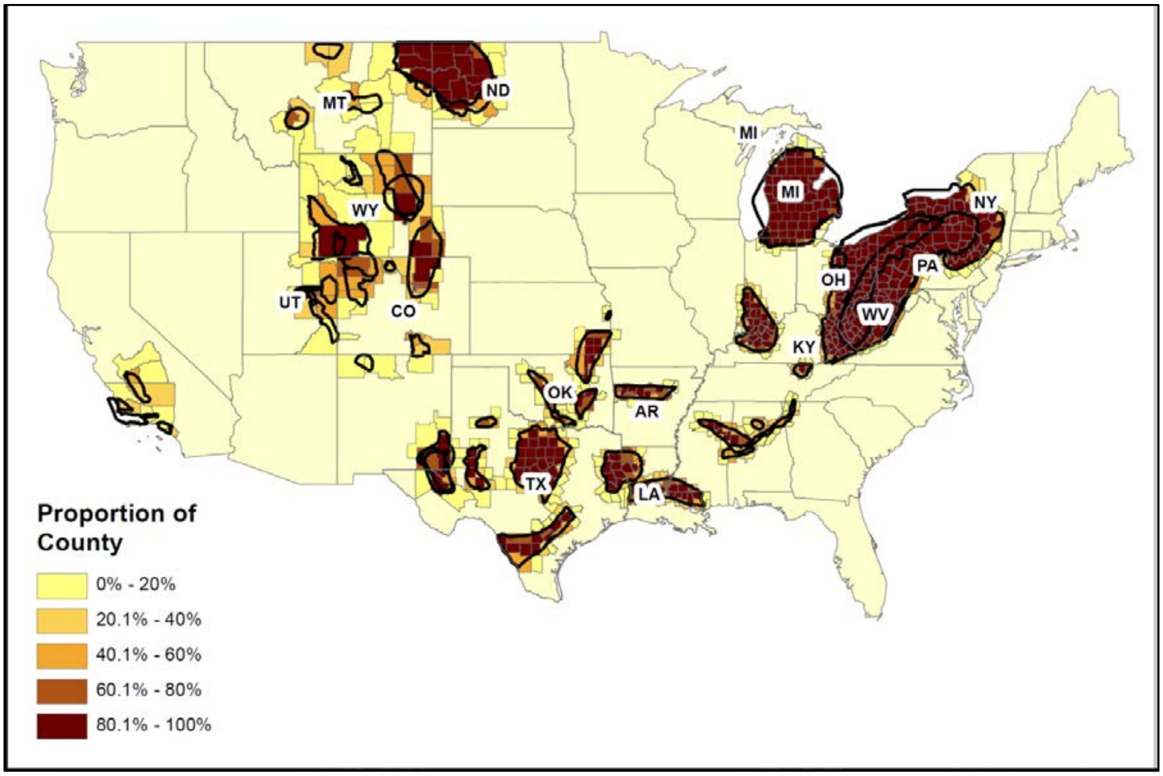

Figure 4-2 Fifteen States in the Sample and Proportion of Each County Contained above a Shale Play

Note: Author's calculations based on the U.S. shale play shapefile from EIA.

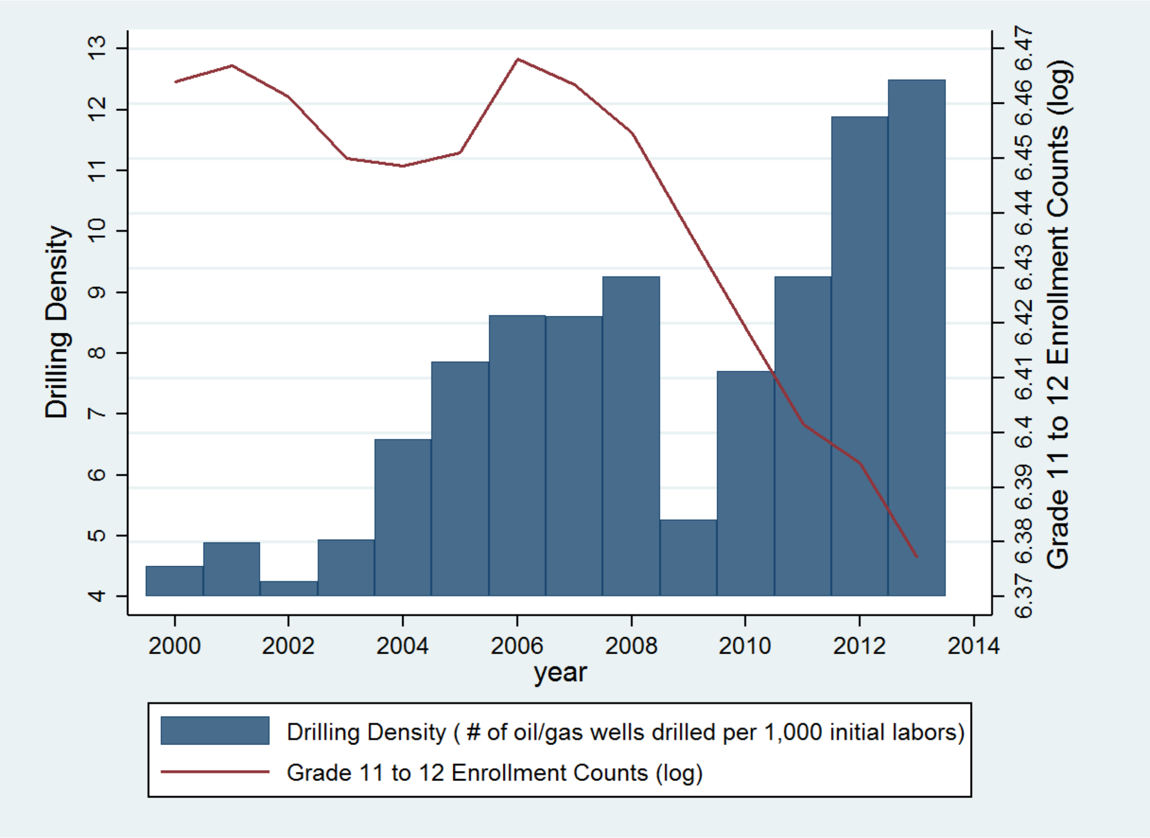

Figure 4-3 Average County Drilling Activities and Grade 11 to 12 Enrollment, 2000-2013

Note: Author's calculations based on well records data from various state agencies and schooling data from National Center for Education Statistics (NCES).

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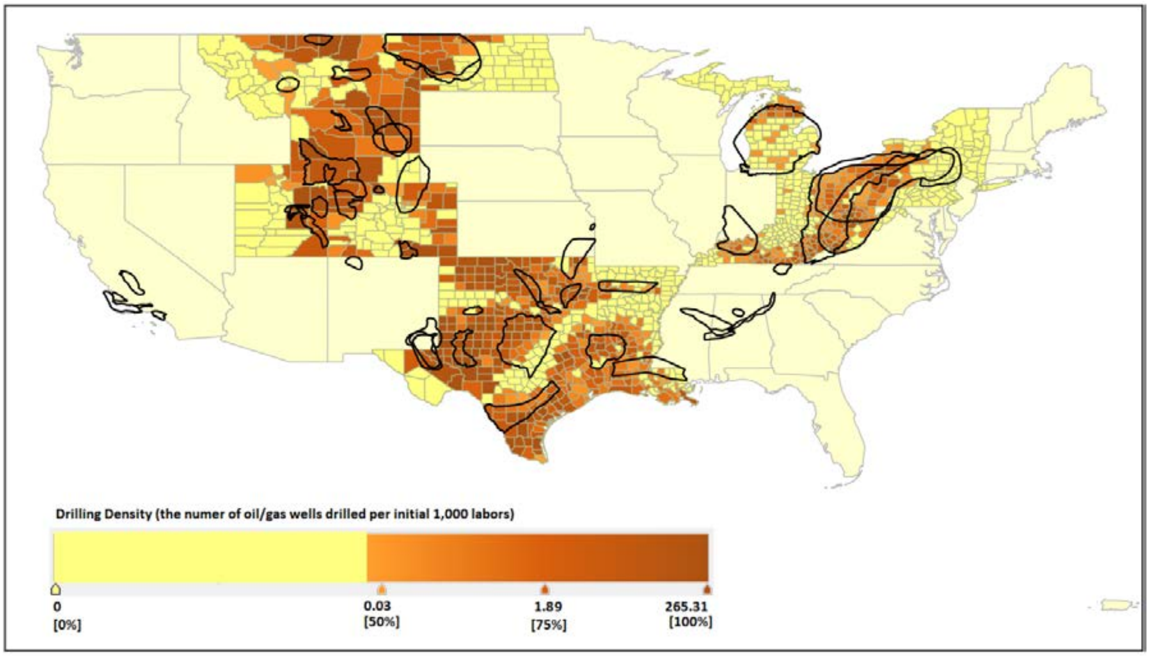
Panel A: 2000



Panel B: 2013

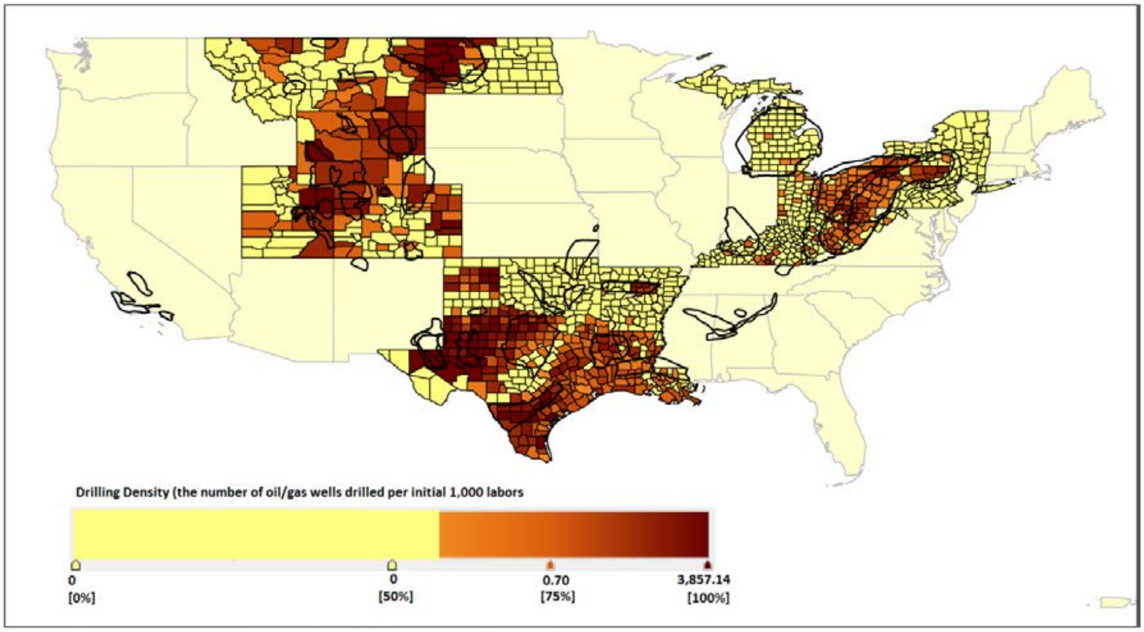


Figure 4-4 Drilling Densities across Sample Counties, 2000 vs. 2013

Note: Author's calculations based on well records data from various state agencies.

Chapter 5 Conclusion

The dissertation research comprises three essays on the topic of the resource curse hypothesis and its mechanisms. The phenomenon of low economic growth in resource-rich regions is recognized as the “resource curse”. These essays will contribute to an understanding of the regional resource-growth relation within a nation.

The resource curse hypothesis was tested within the highly developed United States. A system of equations model allows me to decompose the resource effect and account for the two mechanisms, crowding-out effects and institution effects, simultaneously in one setting. The results suggest that both effects contribute to the resource-growth relation, but also that the overall resource effect is positive or neutral. The decomposition with the direct, crowding-out, and institution effects at a subnational level offers a better understanding of resource curse mechanisms. First, I found that the direct resource effect was positive or neutral once the crowding-out and institutional effects were isolated. Then, the evidence suggests that resource wealth crowds out industrial investment, thus hindering growth in the U.S. This result parallels the local Dutch Disease narrative that wealth generated by the sale of natural resources tends to crowd out the manufacturing sector. Finally, I focus on state and local government efficiency as a proxy for institutional outcomes and further employ ex-ante measures to minimize endogeneity concerns. The results confirm that institutions mediate the crowding-out effect and reject the resource curse hypothesis within the U.S. in the past two decades.

The comparison between the two largest energy-producing nations in the world shed light on the resource – growth relation in distinct economic systems and institution arrangements. Using panel data from 1990 to 2015, I compared the effects of resource revenues on the economic growth and growth-related factors across Chinese provinces and American states. To address the endogeneity issue of resource revenues with regional economic conditions, I employ the Instrumental Variable (IV) strategy and instrument the resource revenue with a product of the resource reserves in 1990 and the national primary energy prices. Evidence suggests that resource revenues increase the regional growth in both China and the U.S. with a larger and more statistically significant effect shown across U.S. states. The booming resources, coal in China, oil and natural gas in the U.S., contribute to the positive resource – growth relation in the short term. However, resource revenues show negative effects on growth-related factors, such as education attainments and R&D activities while pushing up the investment across regions. This cast concerns on the long-term economic growth in resource-rich regions.

Further testing impacts of three resource-related policies in China, e.g. the market price reform, the fiscal reform, and the Western Development Strategy, I show that the market price reform together with the privatization process on coal resources contribute the positive resource effect in China. The Western Development Strategy also show a positive effect on strength the resource – growth relation in western provinces. On the other hand, with all natural resources owned by the state and majority managed by the state-owned enterprises, the fiscal reform does not seem to matter in the resource – growth relation in the China case with the results.

Investigating the human resource channel in particular, evidence suggests that the intensive drilling activities altered enrollment decisions of teenagers for the 15 oil and gas production states in the U.S. during the period 2000 to 2013. The magnitudes I find suggest that for every four oil or gas wells drilled per initial 1,000 laborers, one student out of a hundred that could have enrolled would not enroll in grade 11 and 12 on average. More specifically, given that the drilling density is 7.58, and that total count of grade 11 and 12 enrolled students is 1,962 in an average county during a year, about 36 fewer students per county and overall 41,760 fewer students across the 15 states enrolled in grade 11 and 12 with the energy boom. that the negative boom-schooling relation is larger in states with a 16-years-old compulsory schooling age regulation, lower state effective tax rate on oil and gas productions, traditional mining, non-metro, and persistent poverty counties. Policies remedies can mitigate the negative schooling impact of the energy boom by lowering the opportunity cost of schooling while welcoming the local economic boom at the same time. For example, an increase in the ending age of compulsory attendance in some states.

In an overview of the resource curse literature, Frederick van der Ploeg (2011) stated that a key question remained "*why some resource-rich economies [.] are more successful while others perform badly despite their immense natural wealth*"(page 366). This dissertation contributes pieces of evidence that resource promotes regional economy better with more effective local governments (e.g. across the U.S. states) and more efficient market system (e.g. the China case). Furthermore, resource developments tend to mediate human capital accumulation, thus cast concern on the economic growth in the long run.

Appendices

A 1.1 the Government Efficiency Index Measure

Following Borge, Falch, and Tovmo (2008), Borge, Parmer, and Torvik (2013) and Andrews and Brewer (2013), the efficiency is measured as the ratio between total output and available resource. The output is a weighted Z-scores summation of five main public service sectors (s): Education, Health, Highways, Public Safety, and Environment, which account for about 89% of the state and local government direct general expenditures in 2010. All sectors are weighted by their expenditure share (p_s). The measure relies on a total 15 indicators (x_{sjt}^{i}) of production from the different service sectors (see table A1). Indicators are equally weighted within each sector (q_{sj}). The calculation of the aggregate output measure is as follows:

(1) $Output_{it} = \sum_{s=1}^{5}[p_s(\sum_{j=1}^{J_s} q_{sj} Z_{sjt}^{i})\ ],$

where $Z_{sjt}^{i} = \frac{(x_{sjt}^{i} - \overline{x_{st}^{i}})}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_{sjt}^{i} - \overline{x_{st}^{i}}\right)^2}}$; $\sum_{s=1}^{S} p_s = 1$; $\sum_{j=1}^{Js} q_{sj} = 1$;

Here, x_{sjt}^{i} is indicator *j* in sector *s* of state and local governments at state *i* at time *t*, $\overline{x_{st}^{i}}$ is the sample mean for each indicator *j* across 50 states. *p* and *q* are, respectively, sector and indicator weights. *N* is the sample size of 50 states.

To obtain the efficiency measure, I divide the output by real per capita revenue of state and local governments ($Total\ Revenue_{it}$) for each state *i* at time *t* (equation 6). State and local government revenue data are collected from the Census of Government Finances and Annual Survey of Local Government Finances, which sums intergovernmental revenue, total taxes, charges and miscellaneous general revenue, utility revenue, liquor store revenue and insurance trust revenue. The revenues are deflated by annual Consumer Price Index (CPI).

$$Efficiency_{it} = \frac{Output_{it}}{Total\ Revenue_{it}}$$

A 1.2 Indicators, weights and sources in the aggregated output measure

Sectors	Sector weights (p_s)	Indicators (x_{sjt}^{i})[1]	Source
Education	0.40	Test score on K12 (Ratio at or above basic): NAEP 4th reading; NAEP 4th math; NAEP 8th reading; NAEP 8th math	National Center for Education Statistics
		Test score on college entrance: SAT mean score; ACT mean score	Annual SAT Report on College & Career Readiness, The College Board; ACT website
		Teens ages 16 to 19, not in school and not high school graduates	the KIDS COUNT Data Center, the Annie E. Casey Foundation
		High School Graduation	
Health	0.29	Infant deaths per 1,000 births	National Vital Statistics System, U.S. Department of Health and Human Services
		Limited activity days per 30 days: poor physical health days; poor mental health days	America's Health Rankings[2] Publications, United Health Foundation
		Immunization coverage-children	
		Infectious disease per 100,000 population: Chlamydia, Pertussis, and Salmonella	
Highways	0.10	Percentage of highway bridges that are structurally sound	Federal Highway Administration, U.S. Department of Transportation
Public Safety	0.10	Violent crime rate per 100,000 population	Bureau of Justice Statistics
		Property crimes rate per 100,000 population	
		Parole violators among prison admissions	
		Fire death rate per million (1,000,000) population	U.S. Fire Administration
Environment	0.10	Air Pollution: Average exposure of the general public to particulate matter of 2.5 microns or less in size (PM2.5)	EPA
		Count number of sites of brownfield grant	EPA Brownfields Grant Fact Sheet

Note: a. Some of the indicators were inverted to ensure that a higher score would reflect better performance (e.g. Teens ages 16 to 19 not in school and not high school graduates, most of the health indicators except Immunization coverage, and all public safety and environment indicators). b. America's Health Rankings is the longest running annual assessment of the U.S. health on a state-by-state basis. For detailed measures and sources, please refer to http://www.americashealthrankings.org/about/annual.

A 1.3 Description of variables used in the robustness checks

Variable	Definition	Year available	Source
Governance			
Economic Freedom Index	Annual Economic Freedom of North America Index, state and local government	1981-2013	Fraser Institute
Government size	EFNA score of area 1: size of government (state and local)[3]	1981-2013	Fraser Institute
Government employment	State and local government employment as a percentage of total state employment	1995-2014	Regional Economic Accounts, Bureau of Economic Analysis, U.S. Department of Commerce
Demographical and Social Characteristics			
Ethnic diversity Index	$=[1-\sum(\text{Race})^2]*100$, where Race denotes the share of population self-identified as race (White, Black or African-American, American Indian or Alaska Native, Asian or Pacific Islander, Some Other Race and Two or More races)[4]	1995-2014	U.S. Census, Current Population Survey
Population density	People per square mile	1990-2014	U.S. Census, Current Population Survey
Rent-seeking behavior			
Rent Seeking Density	The density per 10,000 persons for following establishment: legal services(5411), Management, Scientific and Technical Consulting Services (5416), Advertising, Public Relations, and Related Services (5418); Social Advocacy Organizations (8133), and Business, Professional, Labor, Political, and Similar Organizations (8139)[1]	1997-2013	County Business Pattern

A 1.3 (continued)

Campaign Contribution share from Energy sector	The share of the contributions from energy and natural resource sector to selected offices candidates, such as gubernatorial, state house/assembly, state supreme court, state senate and other state-wide candidates.	1994-2014 Biennale	National Institute on Money in State Politics[2]
Variable	Definition	Year available	Source
Lobby Groups	The data represent the totals of interest groups registered to lobby or that were represented by a registered lobbyist in the state for that year or legislative session per 10,000 persons.	2006-2013	National Institute on Money in State Politics[2]
Lobbyists		2006-2013	
Alternative dependent variable			
Growth of GSP per capita	Per capita real GDP by state, percent change from preceding period	1997-2014	Regional Economic Accounts, Bureau of Economic Analysis, U.S. Department of Commerce
Population Growth	Population percent change from preceding period by state	1997-2014	Population Estimates Program, Population Division, U.S. Census Bureau

Note: a. The sector selected are based on Sobel and Garrett (2002) and the updated work by Hall and Ross (2010) table 2 “Traditional, In-Kind, and Indirect Rent Seeking industries”(page 12).

b. http://beta.followthemoney.org

c. Part 1 of EFNA index is Size of Government, which includes 1A. General Consumption Expenditures by Government as a Percentage of GDP; 1B. Transfers and Subsidies as a Percentage of GDP; 1C: Social Security Payments as a Percentage of GDP.

d. Calculated by authors following Alesina et al. (1999) and Rupasingha et al. (2002).

A 1.4 Added Control Approach Robustness Checks

		I.	II.	III.	IV.	VI.
Specification		Base	+GOV	+DEM	+RS1	+RS2
Base	Ln(Inc) $_{t-1}$	-10.70***	-8.25*	-9.18*	-5.64***	-34.59***
		(3.91)	(4.73)	(4.66)	(1.83)	(3.10)
	Resource_point	**0.06**	**0.30****	**0.29****	**0.60*****	**0.28***
		(0.10)	(0.14)	(0.14)	(0.11)	(0.15)
	Resource_point× Gov. Efficiency	**0.25****	**0.53*****	**0.50*****	**0.60*****	**0.58*****
		(0.09)	(0.13)	(0.14)	(0.15)	(0.11)
	Investment (u)	0.48	0.41	0.34	0.95*	-1.88***
		(0.31)	(0.34)	(0.34)	(0.52)	(0.31)
	Human Capital(u)	0.03	0.02	0.03	0.09	-0.083
		(0.06)	(0.06)	(0.06)	(0.08)	(0.20)
	R&D(u)	-0.02	-0.02	0.02	-0.05	-0.24
		(0.07)	(0.10)	(0.09)	(0.21)	(0.16)
Governance (GOV)	Corruption		-0.00	0.00	-0.00	0.02
			(0.00)	(0.00)	(0.01)	(0.03)
	Eco. Freedom Index		0.516	0.01	0.86	-0.16
			(0.81)	(0.77)	(0.96)	(0.51)
	Gov. Efficiency		0.18	0.33**	0.06	0.11
			(0.13)	(0.14)	(0.15)	(0.20)
	Gov. Size		-0.01	0.15	-0.54	0.11
			(0.26)	(0.26)	(0.35)	(0.44)
	Gov. Emp. Share		0.79***	0.69**	0.61*	0.56
			(0.29)	(0.30)	(0.31)	(0.75)
Demographics (DEM)	Ethnic Diversity Index			0.01	-0.05	-0.20***
				(0.02)	(0.03)	(0.05)
	Population Density			-0.04***	-0.02**	-0.04***
				(0.01)	(0.01)	(0.01)
Rent Seeking Behavior (RS)	Rent Seeking Density				-0.241	-0.81***
					(0.19)	(0.26)
	Campaign Contribution from Energy Sector				0.05	-0.16***
					(0.06)	(0.06)
	Lobby Groups					-0.03
						(0.34)
	Lobbyists					-0.07
						(0.30)
	Constant	112.1***			58.78***	0
		(41.39)			(20.30)	(0)
	No. Observations	798	699	699	362[1]	174[1]
	Within R^2	0.56	0.55	0.56	0.55	0.74

Note: Fixed Effect models with Driscoll and Kraay standard errors (in parentheses) are used to estimate; u indicates the residuals from equation (2); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; The sample size drops dramatically due to missing values: The variable “Campaign Contribution from Energy Sector” covers the statewide general elections, which take places biannually depending on the states, so data on almost half of the years are missing. The National Institute on Money in State Politics started to report the data on lobby groups and lobbyists since 2006.

A 1.5 Robustness Check with the Reduced Form Eq. (3)

Growth	I. FE	II. FD	III. Sys-GMM	IV. SAC	VI. Dynamic SAC
L1.Growth			-0.00		-0.03
			(0.03)		(0.03)
W.Growth				0.65***	0.91***
				(0.10)	(0.05)
Ln(Inc)_{t-1}	-10.70***	-85.72***	-24.27***	-9.40***	-7.02***
	(3.91)	(4.99)	(3.42)	(2.23)	(1.44)
Resource_point	**0.06**	**0.20**	**0.07****	**0.11****	**0.08****
	(0.10)	(0.13)	(0.03)	(0.05)	(0.04)
Resource_point× Gov. Efficiency	**0.25****	**0.29***	**0.42*****	**0.23*****	**0.19*****
	(0.09)	(0.17)	(0.08)	(0.04)	(0.05)
Investment (u)	0.48	-0.29	-0.53	0.38	0.37
	(0.31)	(0.30)	(0.56)	(0.33)	(0.62)
Human Capital(u)	0.03	0.06	0.03	0.04	0.08
	(0.06)	(0.05)	(0.03)	(0.05)	(0.07)
R&D(u)	-0.02	-0.08	-0.22***	-0.04	-0.10
	(0.07)	(0.09)	(0.05)	(0.10)	(0.15)
Constant	112.1***	2.03***	256.9***	98.54***	74.01***
	(41.39)	(0.16)	(35.88)	(23.28)	(15.12)
No. Observations	798	746	798	768	720
No. of states	50	50	50	48	48
adj. R^2	0.54	0.72		0.68	0.69
State Fixed Effect	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes
Altonji-Elder-Taber Statistics	1.50***	1.94***			
	(0.34)	(0.26)			
System GMM post-estimation tests					
AR(1) test			[0.00]		
AR(2) test			[0.30]		
Sargan over-identification test			[1.00]		
Spatial panel autocorrelation tests					
LM SAC (LMErr+LMLag)				[0.00]	[0.00]

Note:” L1.Growth” is dependent variable with one period lag; “W.Growth” is spatial lagged dependent variable W is the row-standardized N×N rook contiguity-based binary matrix in which each element is set to one if two states share a common border, and zero otherwise; u indicates the residuals from equation (2); Standard errors are in parentheses, Driscoll and Kraay standard errors are used in FE model; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$;p values are reported in square brackets; only 48 continental states are included in spatial analyses; the number of observations varies because of lagged variables.

A 1.6 Robustness Check with Different Dependent Variables

		I.	II.	III.
		Growth_Income	Growth- GSPpc	Growth_Pop.
Investment	Ln(Inc)$_{t-1}$	0.31(0.26)		
	Ln(GSPpc)$_{t-1}$		0.36*(0.22)	
	Ln(Pop)$_{t-1}$			-0.17(0.32)
	Resource_point	-0.03***(0.01)	-0.04***(0.01)	-0.03***(0.01)
	Constant	-2.42(2.70)	-2.98(2.25)	3.35(4.80)
Human Capital	Ln(Inc)$_{t-1}$	0.46(1.13)		
	Ln(GSPpc)$_{t-1}$		2.27**(0.93)	
	Ln(Pop)$_{t-1}$			-3.48***(1.34)
	Resource_point	0.10***(0.04)	0.07*(0.04)	0.12***(0.04)
	Constant	14.80(11.57)	-3.95(9.65)	72.62***(20.51)
R&D	Ln(Inc)$_{t-1}$	-1.06*(0.55)		
	Ln(GSPpc)$_{t-1}$		-0.54(0.46)	
	Ln(Pop)$_{t-1}$			0.84(0.66)
	Resource_point	0.01(0.02)	0.01(0.02)	-0.00 (0.02)
	Constant	12.58**(5.67)	7.24(4.75)	-11.24(10.10)
Growth	Ln(Inc)$_{t-1}$	-10.78***(2.04)		
	Ln(GSPpc)$_{t-1}$		-10.34***(2.19)	
	Ln(Pop)$_{t-1}$			-5.40***(0.66)
	Resource_point	0.23***(0.08)	0.12(0.11)	0.18***(0.02)
	Resource_point× Gov. Efficiency	0.41***(0.07)	0.38***(0.09)	0.09***(0.02)
	Investment	3.36***(0.75)	2.55***(0.96)	1.54***(0.21)
	Human Capital	0.26*(0.15)	0.51**(0.20)	0.03(0.05)
	R&D	1.52**(0.67)	2.45***(0.88)	0.27 (0.20)
	Constant	102.7***(21.06)	95.06***(21.67)	81.05***(10.28)
	No.Observations	747	747	747
	State Fixed Effects	Yes	Yes	Yes
	Year Fixed Effects	Yes	Yes	Yes

Note: Growth-income refers to annual growth rate in real per capita personal income, Growth-GSPpc is the annual growth rate in real Gross State Production per capita, Growth-Pop is the annual growth rate in state population; 3SLS are applied to estimate; standard errors are in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A 3.1 Occupations and Educational Attainment in Mining Sector

Panel A Largest Occupations in Sector 21 Mining and Requirements for Entry

Occupation	Employ-ment	Share of total employment in mining sector	Typical education needed for entry	Work experience in a related occupation
Roustabouts, Oil, and Gas	60,830	7.88%	Less than high school	None
Service Unit Operators, Oil, Gas, and Mining	55,850	7.24%	Less than high school	None
Heavy and Tractor-Trailer Truck Drivers	41,720	5.41%	Postsecondary non-degree award	None
First-Line Supervisors of Construction Trades and Extraction Workers	34,190	4.43%	High school diploma or equivalent	5 years or more
Operating Engineers and Other Construction Equipment Operators	30,070	3.90%	High school diploma or equivalent	None
Rotary Drill Operators, Oil, and Gas	23,590	3.06%	Less than high school	None
Derrick Operators, Oil, and Gas	18,840	2.44%	Less than high school	None
Helpers--Extraction Workers	18,600	2.41%	High school diploma or equivalent	None

Panel B Educational attainment for workers 25 years and older by Largest Occupations in Sector 21 Mining

Occupation	Less than high school diploma (%)	High school diploma or equivalent (%)	More than High School (%)
Roustabouts, Oil, and Gas	26.4	45.8	27.8
Service Unit Operators, Oil, Gas, and Mining	26.4	45.8	27.8
Heavy and Tractor-Trailer Truck Drivers	18.8	48.9	32.4
First-Line Supervisors of Construction Trades and Extraction Workers	13.6	42.6	43.9
Operating Engineers and Other Construction Equipment Operators	21.2	53.4	25.5
Rotary Drill Operators, Oil, and Gas	26.4	45.8	27.8
Derrick Operators, Oil, and Gas	26.4	45.8	27.8
Helpers--Extraction Workers	22.4	50.9	26.6

Sources: Occupational Employment Statistics and Employment Projections program, U.S. Bureau of Labor Statistic

A3.2 the Robustness Check with Alternative Measures

	Grade 9 to 12 Enrollment Rate							
	(1) FE	(2) IV	(3) FE	(4) IV	(5) FE	(6) IV	(7) FE	(8) IV
DrillingDensity1	-0.0004 (0.0035)	-0.0614* (0.0359)						
IHS (DrillingDensity1)			-0.1199 (0.1609)	-1.4139* (0.7980)				
DrillingDensity2					-0.6145 (1.3105)	-13.2738* (7.5428)		
IHS (DrillingDensity2)							-0.6514 (1.4347)	-13.9803* (7.9353)
Observations	14100	14100	14100	14100	14100	14100	14100	14100
R^2	0.121	0.005	0.121	0.030	0.121	0.031	0.121	0.031
Kleibergen-Paap F-stat (1st Stage)		33.992		144.379		104.960		113.914
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Drilling Density 1 is the number of new oil and gas well drilled per 1,000 labors in 2000. *Drilling Density* 2 is the number of new oil and gas well drilled per square mile. IHS(Drilling Density) is the inverse hyperbolic sine of drilling density measures respectively. More specifically, the inverse hyperbolic sine of x is $\sinh^{-1} x = \ln(x + \sqrt{x^2 + 1})$ .The IV columns instrument Drilling Density measures by the product of the proportion of county covering a shale play and the world energy price index. County clustered standard errors in parentheses. −* significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

A 3.3 Heterogeneous Effects with Drilling Boom and Decline Spells

	Grade 11-12 Enrollment Count (log)		
	(1)	(2)	(3)
$\mathrm{BoomSpell}_{\mathrm{cit}}$	-0.0738**	-0.1180*	
	(0.0295)	(0.0605)	
$\mathrm{DeclineSpell}_{\mathrm{cit}}$	-0.0104	0.0484	
	(0.0258)	(0.0775)	
$\mathrm{BoomSpell}_{\mathrm{cit}}$ * $\mathrm{BoomDuration}_{\mathrm{i}}$		0.0094	
		(0.0075)	
$\mathrm{DeclineSpell}_{\mathrm{cit}}$ *$\mathrm{DeclineDuration}_{\mathrm{i}}$		-0.0135	
		(0.0160)	
Duration Dummies			
$\mathrm{BoomDuration}\ 3-4\ \mathrm{yrs}_{\mathrm{i}}$			-0.0766*
			(0.0409)
$\mathrm{BoomDuration}\ 5-6\ \mathrm{yrs}_{\mathrm{i}}$			-0.0752*
			(0.0444)
$\mathrm{BoomDuration}\ 7-8\ \mathrm{yrs}_{\mathrm{i}}$			-0.0388*
			(0.0208)
$\mathrm{BoomDuration}\ 10\ \mathrm{more\ yrs}_{\mathrm{i}}$			0.0100
			(0.0347)
$\mathrm{DeclineDuration}\ 3-4\ \mathrm{yrs}_{\mathrm{i}}$			0.0118
			(0.0338)
$\mathrm{DeclineDuration}\ 5-7\ \mathrm{yrs}_{\mathrm{i}}$			0.0022
			(0.0353)
Observations	9,452	9,452	10,294
R^2	0.319	0.319	0.320
County FE	Yes	Yes	Yes
State-by-year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Notes: Point estimates of coefficients δ_1 and δ_2 are summarized in column (1) for model $y_{cit} = \delta_0 + \delta_1 BoomSpell_{cit} + \delta_2 DeclineSpell_{cit} + \boldsymbol{\gamma}'\boldsymbol{X}_{cst} + r_c + \lambda_t + \alpha_s t + \varepsilon_{cit}$. $BoomSpell_{cit} = 1$ if at least three consecutive years are boom years in a spell *i* within a county. $DeclineSpell_{cit} = 1$ if at least three consecutive years are bust years in a spell *i* within a county. Define a year as a boom (decline) year if the annual change of drilling density is more (less) than 10 oil/gas wells per initial 1,000 labors. $BoomDuration_i$ ($DeclineDuration_i$) is the number of years that a boom (decline) spell *i* lasts. $BoomDuration\ 3-4\ yrs_i$ = 1 if a spell *i* lasts for 3 or 4 years. Additional Controls includes three sets of control variables the same as in the basic results. County clustered standard errors in parentheses. –* significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level.

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Vita

Na Zuo

Education

M.S., Economics, University of Kentucky	May 2013
M.S., Economics, School of Public Economics & Administration, Shanghai University of Finance and Economics (SUFE) *Thesis*: Industrial Structure Evolution under Energy Constraints: An analysis with Chinese Provincial Panel Data Major Advisor: Keqiang Wang	June 2011
B.S., Finance, Department of Finance, Shandong University	June 2009

Professional Experience

Research Assistant, University of Kentucky	2015 - 2017
Visiting Student Researcher, University of California, Berkeley	May-July 2016
Visiting Assistant Professor, Department of Agriculture, Eastern Kentucky University	Aug. 2015 – May. 2016
Instructor, University of Kentucky	Spring 2015
Instructor, University of Kentucky	Spring 2014
Graduate Teaching Assistant, University of Kentucky	Fall 2013
Research Assistant, University of Kentucky	Summer 2012
Research Assistant, Institute of Resources & Environment Policy, Shanghai University of Finance and Economics.	2009 - 2011

Publications

Book Chapters

Na Zuo and Keqiang Wang, 2012, "On the Mineral Security Market in China" & "On the Mineral Futures Market in China", in Keqiang Wang et al. *Study on Mineral Resource Markets in China*, Beijing, China: China Petrochemical Press. (in Chinese)

Peer-Reviewed Journals

Keqiang Wang, **Na Zuo**, and Hongmei Liu, 2011, "Study on Problems and Countermeasures of Futures Market for Mineral Resources in China", *Journal of Shanghai University of Finance and Economics*, 13 (2): pp63-59. (in Chinese)

Keqiang Wang, **Na Zuo**, and Hongmei Liu, 2009, "A Study on the Trend of International Energy Development", *Journal of Shanghai University of Finance and Economics*, 11 (6): pp57-64. (in Chinese)

Research Grant

Na Zuo and Jack Schieffer, $1,948, "The Effect of the Energy Boom on Schooling Decisions in the U.S.", Student Sustainability Council, University of Kentucky

Conference Presentations

2017: North American Colleges and Teachers of Agriculture (NACTA) Annual Meeting, West Lafayette, Indiana

2017: American Environmental and Resource Economists (AERE) Summer Meeting, Pittsburg, Pennsylvania

2016: American Agricultural Economics Association (AAEA) Annual Meeting, Boston, Massachusetts

2015: American Agricultural Economics Association (AAEA) & Western Agricultural Economics Association (WAEA) Joint Annual Meeting, San Francisco, California

2014: The 8th Biennial Conference of Hong Kong Economic Association (HKEA), Shandong University, Jinan, China

2014: Southern Agricultural Economics Association (SAEA) Annual Meeting, Dallas, Texas

2013: Southern Economics Association (SEA) Annual Meeting, Tampa, Florida

2013: Southern Agricultural Economics Association (SAEA) Annual Meeting, Orlando, Florida

Awards, Scholarships, and Fellowships

Graduate Student Teaching Award, Teaching Learning & Community (TLC), AAEA	Aug. 2017
Sponsored Paper Travel Funding, American Environmental and Resource Economists (AERE), $1,000	May 2017
Graduate Student Travel Funding (Domestic), Graduate School, UKY, $400 *4	2017, 2016, 2013, 2012
Student Travel Award, Graduate Student Congress of UKY, $200	May 2015
Graduate Student Travel Funding (International), Graduate School, UKY, $800	Nov.2014
Tuition Scholarship, Graduate School, UKY, $20,035	2011- 2014
National Scholarship Fund, the China Scholarship Council, $76,800	2011- 2014
Outstanding Master Thesis Award, SUFE, ￥1,500 RMB,	May 2012
Ye Wan'an Fellowship, SUFE,￥1,000 RMB	Oct. 2010
The National Scholarship, Shandong University, ￥8,000 RMB	Nov.2007