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Richard Jaimes, Reyer Gerlagh

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Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
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Resource-Richness and Economic Growth in Contemporary U.S.

Abstract

Between 1997 and 2014, US corn, soybean and cotton production almost fully converted to genetically modified crops. Starting around 2007, improved tight oil and shale gas technologies turned the declining US fossil fuel production into a booming industry. We study the effects of these two resource technology revolutions on US state income. We find that the shale revolution increased income in states abundant in oil and gas resources. States dependent on agricultural production also saw an increase in income, which we, however, attribute not to the GM innovation, but to a demand increase brought by the Energy Policy Act of 2005. We also document the resource boom indirect effects on other growth-enhancing activities, particularly, on private and public education expenditures, and distortionary taxation.

JEL-Codes: C210, C230, I250, H720, O130, Q330.

Keywords: natural resources, economic growth, resource curse, resource blessing.

Richard Jaimes
Department of Economics & CentER
Tilburg University
Tilburg / The Netherlands
R.V.JaimesBonilla@uvt.nl

Reyer Gerlagh
Department of Economics & CentER
Tilburg University
Tilburg / The Netherlands
R.Gerlagh@uvt.nl

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1 Introduction

During the late 1990s and mid 2000s, two resource technology revolutions, the large-scale introduction of genetically modified crops and the development of tight oil and shale gas, substantially increased production in the respective resource sectors. Moreover, the 2005 federal Energy Policy Act boosted demand for energy crops, pushing up agricultural prices. The technology revolutions and the federal demand policies provide a natural experiment to test ideas about the relationship between natural resource endowments, economic growth rates, and transmission variables in US states.[1]

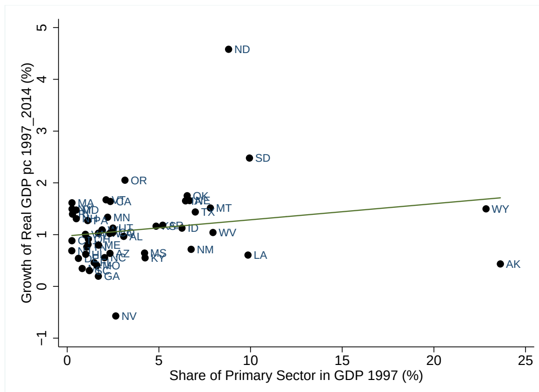


Figure 1: Resource Abundance and Economic Growth

Notes: The underlying data come from the Bureau of Economic Analysis. Real GDP per capita in 2009 chained dollars.

Our first finding is that, over the period 1997-2014, resource abundant US states reported higher economic growth rates in comparison with US states that have a smaller primary sector. Figure 1 shows the positive correlation between the share of the primary sector in GDP at 1997 and the average annual growth of real GDP per capita over the period 1997-2014 for the 50 US states. Table 1 shows the statistical analysis: natural resource endowments were correlated with increased economic growth at 1% significance levels, controlling for initial income differences, investments in R&D and industrial machinery, openness, private and public schooling, distortionary taxation, budget surplus and corruption levels. Our findings contrast with the reported negative effect of resource abundance on growth for the previous decades (Papyrakis and Gerlagh,

[1] A large number of studies supports a negative relationship between natural resource dependence and economic growth, the so-called "resource curse", e.g. Auty (1993, 2001), Rodriguez and Sachs (1999), Sachs and Warner (1995, 1999, 2001), Papyrakis and Gerlagh (2004), among others. Different explanations have been provided, e.g. Dutch disease mechanisms, volatility in commodity prices, institutional aspects, corruption, rent-seeking, conflict. Badeeb et al. (2017), Papyrakis (2017), Cust and Poelhekke (2015), van der Ploeg (2011) and Frankel (2010) provide excellent surveys of this literature.

2007); while it corroborates the positive effect of fossil fuel reserves documented in Allcott and Keniston (2017). The main aim of this paper is thus to document and discuss the fortunes of resource-rich states over the last decades, and to separate supply-side from demand-side causes (technological change vs. policies).

Table 1: Effect of Resource Abundance on Economic Growth, 1997-2014

Dep. var.: av. ann. gr. of pc real GDP 1997-2014	(1)	(2)	(3)	(4)
Constant	14.4**	22.1***	20.7***	19.8***
	(6.68)	(7.13)	(6.77)	(7.14)
Initial GDP per capita (ln), 1997	-1.27*	-2.18***	-2.11***	-2.00***
	(0.63)	(0.72)	(0.69)	(0.71)
Natural Resources, 1997	0.03	0.09***	0.09***	0.12***
	(0.02)	(0.03)	(0.03)	(0.03)
Investment, 1997		0.35**	0.38**	0.38**
		(0.16)	(0.18)	(0.17)
Private Schooling, 1997		0.55***	0.57***	0.71***
		(0.13)	(0.14)	(0.14)
Public Schooling, 1997			0.24	0.54**
			(0.20)	(0.25)
Distortionary Taxation, 1997				-0.17***
				(0.06)
Budget Surplus, 1997				0.12
				(0.09)
Openness, 2000-2009		0.17*	0.22*	0.22**
		(0.09)	(0.11)	(0.11)
R&D, 1998		0.12*	0.13*	0.16**
		(0.07)	(0.07)	(0.07)
Corruption, 2001-2010		0.10	0.10	0.11
		(0.09)	(0.08)	(0.08)
Observations	50	50	50	50
Adjusted R^2	0.10	0.32	0.33	0.38

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. The dependent variable is the average annual growth in real GDP per capita from 1997 to 2014. *Natural resources* denote the share of the primary sector's production (agriculture, forestry, fishing and mining) in GDP (%). All the variables are defined as GDP shares, except initial GDP pc, Openness and Corruption. The additional control variables are defined in Section 2.

Notice that table 1 reports the results for different empirical model specifications. For instance, Column 2 uses the same set of control variables as in Papyrakis and Gerlagh (2007) to check that the highly significant and positive effect of natural resource abundance on economic growth rates over the last two decades is not driven by a distinct specification. In addition, Column 3 includes public schooling as an independent variable since James (2017) points to a differential effect of resource revenues on public and private education expenditures in US states, and we extend his analysis to the impacts on growth. However, previous literature has suggested that the effect of higher public education spending on economic growth can only be assessed when controlling for fiscal policies (Kneller et al., 1999; Blankenau et al., 2007). In line with this literature, while we do not find a significant effect of public schooling when we do not include fiscal policy variables (see Column 3), once we control for variables such as distortionary taxation and budget surplus, public schooling becomes a statistically significant and positive determinant of economic growth in the US states.[2]

We use all 50 US states for our basic empirical analysis; we have a balanced panel data over the period 1997-2014. Previous studies on the natural resource curse in US states sometimes used smaller samples because of limited data availability. For example, while Papyrakis and Gerlagh (2007), James and James (2011) and Rode (2013) use data for 49 US states, excluding Delaware due to missing data points; Boyce and Emery (2011) and James (2015b) employ a data set that covers the 50 US states, and James (2017) and Alexeev and Chih (2017) use a panel data set of 48 US states. In the robustness section, we discuss sensitivity to sample selection, based on Acemoglu et al. (2017)'s procedure for weighing or dropping outlier observations.

We proceed in three steps. First, we look into more specific resource sectors; particularly, we separate oil and gas extraction, from agricultural production, and mining excluding oil and gas. Our data show that each of these resource industries were significant contributors to growth over the period 1997-2014. Second, we split the period in pre- and post-2007. Oil and gas contributed to growth mainly in the second period 2007-2014. We find that the agricultural sector contributed positively in both periods. The mining sector's contribution materialized mostly in the first period 1994-2007. Third, we exploit the panel data structure to separate supply from demand factors explaining the resource-growth correlations. For oil and gas,we identify post-2007 tight oil and shale gas innovations (e.g. new horizontal drilling and hydraulic fracturing techniques) leading to a rapid oil and gas production increase after a long period of gradual decline, as main cause for the sector's contribution to growth. For the first period, we identify the adoption of genetically engineered seeds (commercially released in 1996), while for the second period we identify energy policies as cause for the agri-

[2] This result is consistent with Hanushek et al. (2017a), whom document a positive relationship between educational achievement and economic growth across US states. See also Hanushek et al. (2017b) for a discussion of human capital accumulation effects in explaining income differences in US states.

cultural sector's contribution to growth. For mining, we identify pre-2007 high international commodity prices as explaining factor.

Our contribution to the literature is threefold. Firstly, we provide new evidence suggesting a positive relationship between natural resource abundance and economic growth in US states, over a specific period, controlling for industry-specific characteristics within the primary sector. Secondly, we consider innovations and commodity price booms as distinct mechanisms that change the fortune of resource-abundant states. We exploit cross-sectional state differences in resource abundance and time series variation in real value-added and commodity price indexes at the industry level, following a method laid out in Allcott and Keniston (2017). Thirdly, we report effects of resources on growth-enhancing variables; the contemporary positive relationship between resources and growth may conceal a negative impact of natural resources on private education spending, though we find some positive impacts on public spending.

Our analysis builds on a recently developed empirical literature that studies the within-country correlation between resource abundance and economic growth. Papyrakis and Gerlagh (2007) show that, for US states over the period 1986-2000, natural resource abundance is negatively correlated to growth enhancing activites such as investment and private schooling, and positively correlated to corruption. James and James (2011) and James and Aadland (2011) report empirical evidence of a natural resource curse in United States at the state and county level, respectively.[3] The latter study uses personal income data at the county level over the period 1980-2005, and confirms that mineral resource abundance decreases growth, even after controlling for education levels, poverty rates, population density, and age distribution. They point to commodity price movements leading to low growth rates in the mining sector as one of the causes for the local resource curse.[4] Jacobsen and Parker (2016) analyze the impacts of resource booms on employment, wages and personal income in US counties, using variation in oil prices and location of oil and gas reserves to establish causality. They find a negative long-run relationship between personal income and oil endowments which suggests a resource curse at the county level. Other studies report positive ef-

[3]Similar results for the US states can be found in Boyce and Emery (2011) and Guilló and Perez-Sebastian (2015), from a theoretical and empirical point of view.

[4]James (2015a) also provides evidence of this fact using cross-country data during certain periods which are selected in order to follow oil price booms and busts. In contrast, for a set of countries, Alexeev and Conrad (2009) show that mineral resources in general have a positive impact on per capita income levels. See also Alexeev and Chih (2017) for a detailed analysis of the impact of oil price shocks on economic growth in US states over the period 1987-2014.

fects of resource abundance, specifically for fossil fuels. Using county data for Kentucky, Ohio, Pennsylvania and West Virgina, Black et al. (2005) report a positive effect of the coal boom in the 1970s on employment and income levels. Michaels (2010) finds a positive oil-abundance effect in Southern US. Exploiting geographic and temporal variation in the fracking revolution, Feyrer et al. (2017) also identity positive effects of fossil fuel resources on income and employment in US counties. Using county data from 1960 to 2014, Allcott and Keniston (2017) find positive effects on local real wages during oil and gas booms. James (2017) considers the effects of real oil price booms on education spending over the period 1970-2008, and he finds a significant positive impact on the provision of public education and no effect on private education spending.[5] We contribute to this literature as we consider both supply and demand shocks, and consider three resource sectors separately: oil&gas, agriculture, other mining. We use cross-section techniques as in Papyrakis and Gerlagh (2007), but also interact spatial variation for abundance with temporal variation for technology and demand for a panel data analysis (Allcott and Keniston, 2017).

Our findings also relate to the literature on technological innovation and commodity prices.[6] Kilian (2016) provides an overview of the impacts of improved tight oil technologies on oil production and gasoline, in a historical perspective. He points to infrastructure constraints, uncertainty, international trade, and quality differences between tight oil and standard oil, as reasons why oil and gasoline prices have not dropped after the increase in supply. Arezki et al. (2017) documents the gas price-gap between the US and Europe, opening after 2007, resulting from the US shale gas revolution. Both Michielsen (2013) and Arezki et al. (2017) present evidence of positive effects on US manufacturing production and trade, specifically, for energy-intensive industries.

The third strand of literature relevant to our study considers agricultural commodity price developments.[7] Avalos (2014) considers the 2005 renewable fuels standard and its effect on agricultural prices. He shows that the policy generated a strong relationship between corn and oil prices.[8] Indirectly, the price correlation even spills over to

[5] We extend this analysis by studying the specific effects of both private and public education spending on economic growth. To identify the latter channel, we also document the impact of fiscal policy, particularly of distortionary taxes, in the spirit of Kneller et al. (1999) and Blankenau et al. (2007).

[6] Ferraro and Peretto (2017) develop an endogenous growth model and show that whereas commodity prices are correlated with short-run economic growth, this effect vanishes in the long run due to market adjustments on innovation incentives.

[7] In a recent work, using a cross-country database over the period 1970-2007, Cavalcanti et al. (2015) study commodity price volatility as a mechanism and find that it explains most of the negative correlation between resource abundance and economic growth.

[8] In a theoretical study, Hassler and Sinn (2016) provide a framework to assess how technical innovations

substitute crops such as soybeans. Using a counterfactual analysis, Carter et al. (2017) find that, particularly from 2007 to 2014, biofuel policies raised corn prices by 30% in comparison with a scenario without intervention.[9]

The remainder of the paper is organized as follows. In section 2, we describe the data used in the empirical exercises. In section 3, we present the technology and commodity prices stylized facts. In Section 4, the empirical strategy is laid out, it also presents the main results and performs robustness checks. Conclusions are offered in section 5.

2 The Data

We use data from different sources over the period 1997-2014. Table 2 and 3 report summary statistics. Data on commodity prices (coal, oil, gas, corn, soybeans, cotton, and minerals) come from the International Monetary Fund, available at a monthly frequency. We use annual average real price indexes to construct unweigthed commodity price indexes for three industries within the primary sector: Agriculture (corn, cotton and soybeans), Oil and Gas (oil and gas prices) and Mining (Coal and other minerals).

Table 2: Descriptive Statistics for Real Commodity Prices, 1997-2014

Variable	**Units**	**Mean**	**Std. dev**	**Min**	**Max**
Oil	(WTI, barrel)	58.3	25.9	18.9	98.9
Gas	(MmBtu)	5.06	2.08	2.55	9.73
Corn	(metric ton)	163	54.4	108	276
Soybeans	(metric ton)	333	95.3	204	498
Cotton	(hundred pounds)	77.8	21.4	55.1	146
Coal	(metric ton)	66.1	31.1	32.3	135

Notes: Prices are in real 2009 dollars. Annual averages. The underlying data are obtained from the International Monetary Fund.

We have GDP by industry in current values, real state GDP in 2009 chained dollars, and population at the state-year level, from the Bureau of Economic Analysis (BEA). Data on value-added by industry come from the same source. R&D investments, our measures of openness and corruption at the state level come from the Industrial Research and Development System (IRIS), the US Census Bureau and the US Department of Justice, respectively. State government fiscal data, such as public education expen-

in fossil fuel extraction and biofuel policies could affect food prices, exploiting the fact that corn production is a good substitute for oil in energy production.

[9] Serra and Zilberman (2013) and Zilberman et al. (2013) provide a review of the growing literature about the link between biofuel policies and commodity food prices.

ditures, taxes and budget surplus are from the U.S. Census Bureau. Oil and gas annual production data come from the U.S. Energy Information Administration (EIA). To measure GM technology adoption, we use the estimations prepared by the United States Department of Agriculture (USDA).

Table 3: Summary Statistics

Variable	Mean	Std. dev	Min	Max
Growth in Real GDP per capita 1997-2014	1.10	0.73	-0.57	4.58
Natural Resources, 1997	3.96	4.78	0.25	23.6
Oil&Gas, 1997	0.97	2.94	0	18.2
Agriculture, 1997	1.63	1.86	0.10	8.84
Other Mining, 1997	0.78	1.65	0.01	9.55
Investment, 1997	1.16	0.93	0.01	4.43
Private Schooling, 1997	0.77	0.49	0.15	2.35
Public Schooling, 1997	1.65	0.59	0.79	4.11
Distortionary Taxation, 1997	7.88	2.80	4.76	24.8
Budget Surplus, 1997	1.94	1.96	0.19	14.4
Openness, 2000-2009	2.31	1.44	0.31	5.48
R&D, 1998	1.49	1.39	0.01	6.89
Corruption, 2001-2010	3.32	1.90	0.96	8.45

Notes: All variables defined as shares are in percentages. Data for 50 US States.

Natural resources is the share of the primary sector's production (Agriculture, forestry, fishing and mining) in GDP; *Oil&Gas* is the initial share of oil and gas production in GDP; *agriculture* is the initial share of farms' production in GDP; *Other Mining* is the initial share of mining production, except oil and gas, in GDP; *Investment* is measured by the share of initial industrial machinery production in GDP; *Private Schooling* is defined as the initial contribution of private educational services in GDP; *Public Schooling* denotes state spending on education services; *Distortionary Taxation* is the share of general revenue from own sources (e.g., property, sales, individual and corporate income taxes) in GDP; *Budget Surplus* corresponds to the share of budget surplus, defined as the difference between total state income and total state spending where duplicative intergovernmental transactions are excluded, in GDP; *Openness* which denotes the ratio of net international migration to total population by state; *R&D* is measured by the share of total (company, federal, and other) funds for industrial R&D performance in GDP by state; and *Corruption* is defined as the number of prosecuted corrupted public officials per 100,000 citizens by state.

3 Stylized Facts

There are some outstanding empirical patterns during the period 1997-2014. We begin with the adoption of genetically engineered seeds, after their commercial release in 1996, by farmers in the United States. Figure 2 displays the share of planted acres using herbicide-tolerant (Ht) and insect-resistant (Bt)[10] seeds in soybeans, cotton and corn. While the Ht seeds allow the farmers an effective weed control, through specific herbicides, without crop damages, the Bt seeds reduce the chemical pesticide use. It is worth noting that although this technological innovation reduces input costs and increases yields, at the same time, it raises the market power of the biotech industry as it forces the famer to buy new seeds for each harvest, since these are under patent protection (Carlson, 2016).[11]

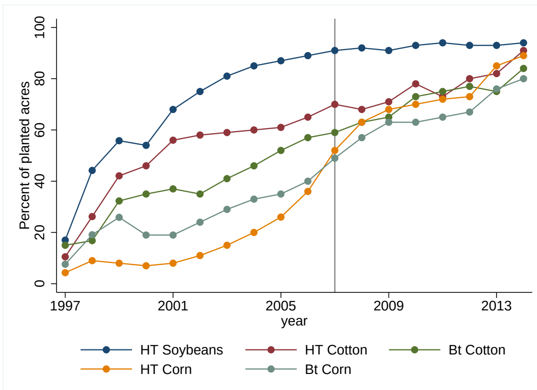


Figure 2: Adoption of GM technology, 1997-2014

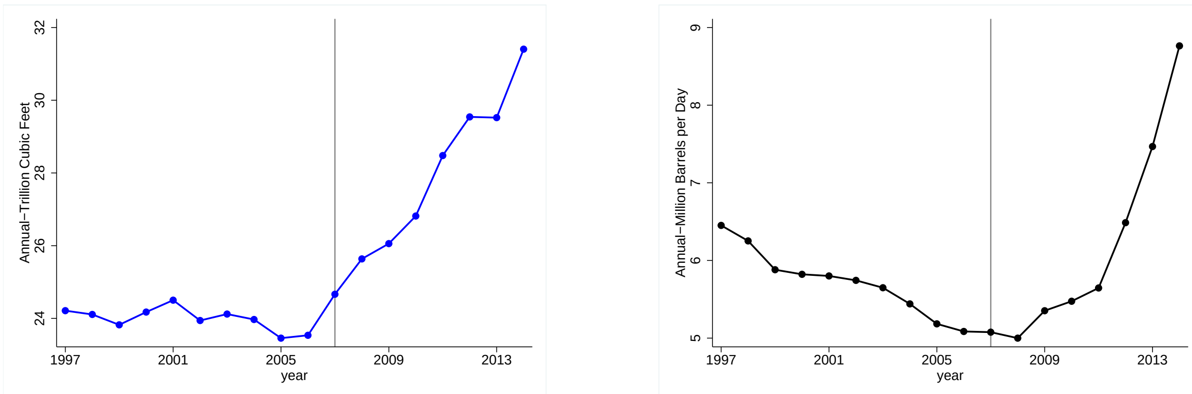
Notes: The vertical line denotes 2007. Average of the share of GM crops in total planted land for all corn, cotton and soybean varieties. HT refers to herbicide tolerant crops and Bt Crops are named for Bacillus thuringiensis (Bt), a bacteria that naturally produces a crystal protein that is toxic to many pest insects. Sources: USDA, Economic Research Service using data from Fernandez-Cornejo and McBride, Adoption of Bioengineered Crops, Agricultural Economic Report No. 810 (2002), for the years 1997-99 and USDA, National Agricultural Statistics Service, June Agricultural Survey for the years 2000-14.

Figure 3a shows the natural gas production in the United States over the period 1997-2014. Until 2006, natural gas production was stable at around 24 annual-trillion cubic feet, with a weak downwards trend. The shale gas revolution is clearly visible, as from 2007 onwards production increased dramatically. In 2014, over 44% of total natural gas US production came from shale wells. Figure 3b plots the comparable figure for annual

[10]Named after Bacillus thuringiensis, a soil bacterium producing a protein toxic to herbivorous insects. Genes of this bacterium are introduced in plants.

[11]For an extensive overview of the adoption of GM crops, its economic impacts, risks and advantages, see Qaim (2015).

production of crude oil, in million barrels per day, from 1997 to 2014. It shows how improved tight oil technologies turned the declining US production into a booming industry. According to EIA estimations in selected plays, in 2014 the United States produced about 48% of crude oil (or 4.5 million barrels/day) using new drilling and hydraulic fracturing techniques.



(a) Gas

(b) Oil

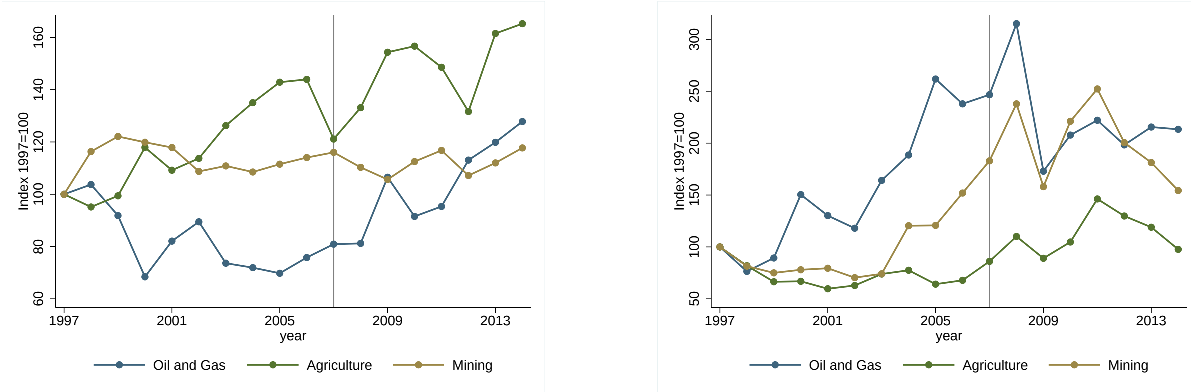
Figure 3: Oil and Gas production in the United States, 1997-2014

Notes: The vertical line denotes 2007. Oil and gas production data are from the U.S Energy Information Administration.

We do not have evidence on large innovations in the other mininig industry. We construct real value-added indexes for each resource sector as a proxy for aggregate productivity levels. Figure 4a displays these indexes over the period 1997-2014. We see the decline of oil and gas up to 2005, followed by the tight oil and shale gas revolutions afterwards. Agriculture shows a robust growth although it also presents some drops in 2007 and 2012. Finally, value-added in the mining sector, is stable without remarkable movements.

In addition to VA as a measure of supply side changes, we consider prices revealing some of the demand side shocks. Agricultural prices were moderately stable, slightly decreasing until 2005, after which they began to increase rapidly. The Energy Policy Act of 2005 increased demand and prices for corn (Tyner, 2008); Figure 5a shows the steep rise in corn prices beginning in 2006. Soybeans prices also increased vigorously due to competition for land with corn producers, with a one year delay (Avalos, 2014).[12] At a later stage, cotton prices also joined the rise, through the same mechanism (Mutuc et al., 2011).

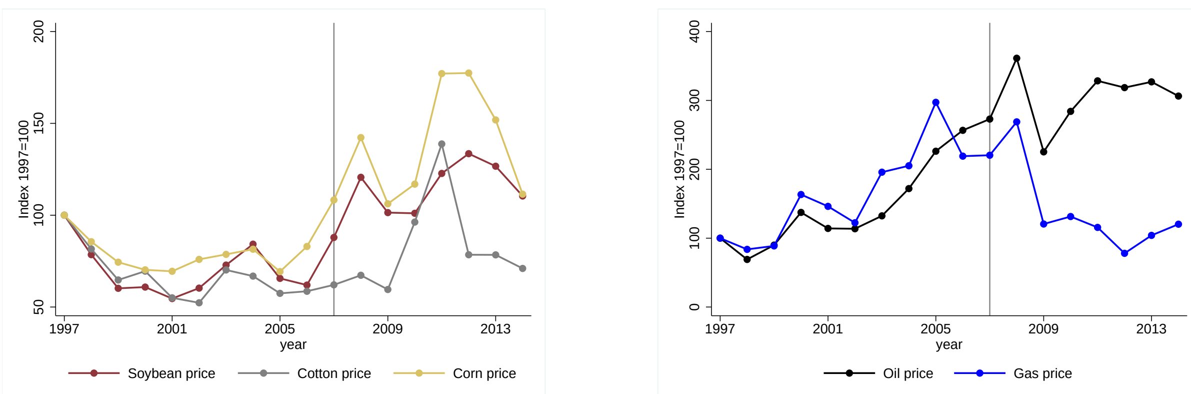
[12] Hassler and Sinn (2016) and Avalos (2014) suggest that energy policies generated after 2006 a link



(a) Real Value Added (b) Real Prices

Figure 4: Sectoral Real Value-Added and Price Indexes, 1997-2014

Notes: Agricultural real value-added index refers to real farms' production; oil and gas indicates real oil and gas production, and mining alludes to real mining production except oil and gas. Annual Average Prices. Agricultural price index only includes Corn, Cotton and Soybeans prices. Mining price index includes coal and mineral (Copper, Aluminum, Iron Ore, Tin, Nickel, Zinc, Lead, and Uranium) prices. Oil and Gas price index refers to oil and gas prices. Prices are real 2009 dollars. The underlying data are from the Bureau of Economic Analysis and the International Monetary Fund.



(a) Cotton, Soybean and Corn (b) Oil and Gas

Figure 5: Real price indexes for different commodities, 1997-2014

Notes: The vertical line denotes 2007. Commodity price data are from the International Monetary Fund.

Prices for oil and gas report a sustained increase over the period 1997-2007, but show a remarkable different pattern after 2007. Figure 5b displays the price indexes. Oil prices maintained a high level after 2007 despite the tight oil revolution, but gas prices began falling when supplies sharply increased with the shale gas development. The characteristics of these fuels are different. Arezki et al. (2017) argue that oil is integrated

between oil and corn prices and put presssure in some substitute goods e.g., soybeans.

in international markets, while natural gas uses different facilities for national transport and trade versus international transport and international trade.

For the statistical analysis, we aggregate real price developments into commodity price indexes for the three resource sectors, as shown in Figure 4b. It plots unweighted sector-specfic price indexes from 1997 to 2014. The oil and gas price increase between 1997 and 2008 is clearly visible, as well as the crops price increase after 2005.

4 Empirical Analysis and Main Results

4.1 Cross-Section Analysis

We first consider the main patterns over the period 1997-2014, through cross-state growth regressions as in Papyrakis and Gerlagh (2007). We estimate:

$$G_i = \alpha + \beta Y_{i,0} + \gamma R_{i,0} + \varphi Z_i + \epsilon_i \tag{1}$$

where i denotes US states, G_i represents the average annual per capita growth in real state GDP, $Y_{i,0}$ is (log of) initial per capita GDP, R_i is a vector that measures natural resource abundance, e.g. the initial share of a resource industry in GDP, and Z_i is a set of control variables such as investment; private schooling; public schooling; openness; R&D; corruption, among others.[13]

Table 1 (in the introduction), column 4, reports results for the aggregate primary sector. The results show a positive and highly statistically significant effect of the primary sector's share in the economy on overall economic growth, ($\widehat{\gamma} > 0$), and support conditional convergence, ($\widehat{\beta} < 0$). A one-percentage point increase in the natural resource share raises economic growth by 0.12% per year. This effect contrasts with the negative impact reported by Papyrakis and Gerlagh (2007) for the period 1986-2000, and suggests that the effect of natural resource abundance on growth varies over time. The coefficients for the control variables are also substantial and highly significant. A one percentage point increase of the share of industrial machinery, R&D, private and public educational services, raises growth by 0.38%, 0.16%, 0.71% and 0.54% per year, respectively. As expected, distortionary taxation reduces growth by 0.17%. Openness also has a positive and significant correlation to economic growth. The coefficients for budget surplus and corruption are not statistically significant.

[13]See Papyrakis and Gerlagh (2007) for theoretical justifications of our control variable set selection.

Table 4: Effects of resource-specific abundance on Economic Growth

Dependent variable: Average annual growth of real GDP per capita												
	1997-2014				1997-2007				2007-2014			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	2.92	11.3*	9.92	13.6**	-3.59	10.4	10.4	12.2	5.97	19.8	9.26	7.15
	(5.52)	(5.92)	(6.10)	(6.57)	(6.31)	(7.00)	(6.87)	(8.11)	(8.55)	(14.8)	(14.1)	(15.0)
GDP per capita (ln)	-0.21	-1.15*	-1.08*	-1.42**	0.48	-1.00	-1.00	-1.15	-0.60	-2.07	-1.15	-0.98
	(0.52)	(0.58)	(0.58)	(0.64)	(0.59)	(0.67)	(0.67)	(0.78)	(0.79)	(1.41)	(1.31)	(1.38)
Oil&Gas	0.01	0.05*	0.05	0.04	-0.04	0.04	0.04	0.06	0.04	0.08**	0.07**	0.05
	(0.03)	(0.03)	(0.03)	(0.0471)	(0.03)	(0.03)	(0.03)	(0.06)	(0.03)	(0.03)	(0.03)	(0.05)
Agriculture	0.22***	0.24***	0.24***	0.25***	0.19***	0.27***	0.27***	0.28***	0.43**	0.43**	0.41**	0.39**
	(0.08)	(0.06)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.20)	(0.19)	(0.17)	(0.18)
Other Mining	-0.01	0.09**	0.10**	0.13**	0.07	0.16*	0.16*	0.18**	-0.08	0.06	0.04	0.03
	(0.04)	(0.04)	(0.05)	(0.05)	(0.09)	(0.09)	(0.09)	(0.08)	(0.12)	(0.12)	(0.11)	(0.10)
Investment		0.22	0.26	0.27*		0.05	0.05	0.05		0.50	0.52*	0.55
		(0.14)	(0.16)	(0.16)		(0.09)	(0.10)	(0.10)		(0.30)	(0.30)	(0.33)
Private Schooling		0.59***	0.61***	0.76***		0.67***	0.67***	0.76***		0.59***	0.60***	0.59***
		(0.12)	(0.12)	(0.14)		(0.13)	(0.13)	(0.14)		(0.16)	(0.18)	(0.19)
Public Schooling			0.23	0.44*			0.01	0.17			0.37	0.35
			(0.20)	(0.23)			(0.12)	(0.18)			(0.23)	(0.30)
Distortionary Taxation				-0.14**				-0.10				0.02
				(0.06)				(0.08)				(0.11)
Budget Surplus				0.20*				0.10				0.08
				(0.10)				(0.11)				(0.12)
Openness		0.14	0.18*	0.20*		0.26***	0.26***	0.27***		0.36	0.26	0.25
		(0.08)	(0.10)	(0.10)		(0.06)	(0.07)	(0.08)		(0.40)	(0.35)	(0.37)
R&D		0.10*	0.11*	0.13*		0.08	0.08	0.10		0.19	0.19	0.18
		(0.06)	(0.06)	(0.07)		(0.06)	(0.06)	(0.07)		(0.12)	(0.13)	(0.14)
Corruption		0.10	0.10	0.11		0.02	0.02	0.03		0.06	0.07	0.0689
		(0.08)	(0.08)	(0.07)		(0.05)	(0.05)	(0.05)		(0.07)	(0.07)	(0.07)
Observations	50	50	50	50	50	50	50	50	50	50	50	50
Adjusted R^2	0.28	0.43	0.45	0.47	0.20	0.44	0.42	0.42	0.34	0.44	0.47	0.45

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. All the variables denote initial values except for openness (columns 1-8 use data from 2001-2010, columns 9-12 from 2010 to 2014), R&D (columns 1-8 refer to observations at 1998, columns 9-12 to data at 2007) and corruption (columns 1-8 represent data from 2001 to 2010, and columns 9-12 from 2005 to 2014).

Next, we separate natural resources into oil&gas, other mining, and agriculture, and include resource-specific features. These help to get more grip on the mechanisms through which resources impact economic growth. *Oil&gas* and *Other mining* measure the initial share in GDP of oil and gas production and other mining, respectively; *agriculture* measures the initial share of farms' production in GDP.

Considering the stylized facts described above, we split the 1997-2014 in a pre- and a post-2007 period. Most of the GM crop transition took place before 2007, while most of the effects of the Energy Policy Act materialized after 2006. Also, most of the tight oil and shale gas revolution occurred after 2006. The OLS estimation results are presented in Table 4. Columns 1-4 show that the impact of resource abundance is strong and positive over the whole period for all three resource types, though the agriculture sector stands out and it is difficult to establish significance for oil&gas. A state with a 10 percent share of agriculture would see approximately a 2.5 percent higher growth rate each year, all else equal. The other explanatory variables remain positive and significant with the exception of distortionary taxes which is negative and corruption which is not significant.

Columns 5-8 and 9-12 display the point estimates for the periods 1997-2007 and 2007-2014, respectively. The coefficient for oil&gas is insignificant in the first period, and highly significant and positive for the second period in two specifications. It losses explanatory power when we include fiscal policy variables (Columns 4 and 12), this is consistent with the strong correlation between oil&gas revenues, public education expenditures and other US state fiscal policies described in James (2015b) and James (2017). It also suggests that the tight-oil and shale-gas revolution was instrumental in the income increase observed in the oil and gas-rich states, more than the oil and gas price increase during the first period. The coefficient for the agricultural sector increases from .25 to .39 between the two periods. This finding suggests that for agriculture, the price increase following the biofuel policies outweigh the introduction of GM crops in importance. The mining coefficient is significant for the first period, but not for the second period, suggesting that for this sector also the price increase plays an important role. Private schooling is highly signficant and positive in the different specifications, in contrast with public schooling which is only weakly significant over the whole period 1997-2014 (Column 4).

4.2 Panel Data Analysis

The OLS regressions, in combination with the stylized facts, are suggestive that for oil and gas innovation played a major role in the positive correlation with growth, whereas for agriculture, the demand policies were more important. To further test these hypothesis, we now turn to panel data analysis, exploiting the annual variation in commodity prices and country-wide real value added indexes by industry, interacting these time variations with the spatial variation of the resource abundance measures (Allcott and Keniston, 2017). We estimate the fixed-effects panel model:

$$G_{i,t} = \alpha + \gamma_1 R_i \cdot \mathit{\Delta} P_t + \gamma_2 R_i \cdot \mathit{\Delta} VA_t + \delta_i + \eta_t + \varepsilon_{i,t} \tag{2}$$

where $G_{i,t}$ denotes the annual growth in real GDP per capita, $\Delta P_{j,t}$ corresponds to the annual growth in sectoral price indexes, $\Delta VA_{j,t}$ is the annual growth in real value-added indexes at the industry level in constant prices so that it measures productivity improvements, δ_i identifies the time-invariant state-specific fixed-effects, which absorbs the initial resource shares and the (constant) control variables, and η_t is the time fixed-effects without prior distribution, which absorbs the time-dependent linear terms of the interaction. Notice that i identifies the US states, and t the year. The use of annual data helps to control for unobserved variables varying between states and years, while also potentially providing more precise estimators.

For each resource sector we add the interaction between the initial size of the industry and price changes, $R_i \times \mathit{\Delta} P_t$, and the interaction between the size of the sector and real value added changes, $R_i \times \mathit{\Delta} VA_t$, as in Perez-Sebastian and Raveh (2016) and Allcott and Keniston (2017). This procedure allows us to exploit cross-sectional variation in initial conditions at 1997 and time-series variation in both international commodity prices and technological levels over the period 1997-2014.[14] A positive coefficient for the first interaction, $\widehat{\gamma}_1 > 0$, suggests that the sector benefits from price increases, for instance, due to national demand policies pushing up prices. A positive coefficient for the second interaction, $\widehat{\gamma}_2 > 0$, points to aggregate income benefits connected to productivity innovations within the resource industry. As the stylized facts suggest that the market for oil is more international, while gas is a national market, and the

[14]Using cross-country data, Perez-Sebastian and Raveh (2016) interact initial mineral production (as share in GDP) with an international mineral price index. For the US, Allcott and Keniston (2017) interact initial endowments of oil and gas at the county level with national employment in the oil and gas industry.

prices show different trends, we separate the two price index interactions.

Table 5: Effects of resource-specific abundance on economic growth rates, 1997-2014

Dependent variable: Δ ln(Real GDP per capita)			
	(1)	(2)	(3)
Constant	2.52***	2.52***	2.52***
	(0.27)	(0.28)	(0.25)
Oil&Gas, 1997 $\times$ Δ_t Real Gas Price Index	-0.57***		-0.26
	(0.16)		(0.18)
Oil&Gas, 1997 $\times$ Δ_t Real Oil Price Index	0.22		0.54***
	(0.16)		(0.13)
Oil&Gas, 1997 $\times$ Δ_t Real Value-Added Index		1.15***	1.38***
		(0.16)	(0.23)
Agriculture, 1997 $\times$ Δ_t Real Sectoral Price Index	0.84***		0.86***
	(0.16)		(0.13)
Agriculture, 1997 $\times$ Δ_t Real Value-Added Index		-0.11	0.13
		(0.56)	(0.54)
Other Mining, 1997 $\times$ Δ_t Real Sectoral Price Index	0.55**		0.52**
	(0.22)		(0.20)
Other Mining, 1997 $\times$ Δ_t Real Value-Added Index		0.06	0.49
		(0.50)	(0.51)
State fixed-effects	YES	YES	YES
Time fixed-effects	YES	YES	YES
Number of US States	50	50	50
Number of periods	17	17	17
Observations	850	850	850
Adjusted R^2	0.41	0.40	0.43

Notes: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. Δ_t *Real Value Added* denotes annual growth in the real value added index for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector.

The results are detailed in Table 5. Column 1 introduces the interactions between the initial resource sector size and commodity price changes. We find a strong and positive effect in both agricultural and mining; increasing commodity prices support aggregate economic growth in states abundant in the relevant resources. Surprinsingly, we find a negative impact of gas prices, and no significant effect for oil, for states abundant in oil and gas. The outcome possibly presents an omitted variable bias, as gas prices are negatively correlated to the shale-gas innovation. Indeed, in Column 2 we find a strongly significant positive coefficient for the interaction between oil and gas abundance with the resource sector's real value added. These results confirm the suggestion from the OLS estimations that the adoption of new drilling and hydraulic fracturing techniques pushed up growth rates vigorously in resource-abundant states from 2007 onwards. In Column 3, when we introduce both interactions, we observe that the price interaction coefficient has become insignficant for gas, while it becomes positive and significant for oil. The findings confirm the different mechanisms at play for oil and gas (Kilian, 2016; Arezki et al., 2017).

At the same time, Columns 2 and 3 suggest that for agriculture and other mining, there is no significant technology effect, while the price effects remain positive and significant in both Columns 1 and 3. Specifically, the panel data estimations support the interpretation that agricultural regions did not experience benefits from the adoption of GM technology.

4.3 Indirect resource effects

In addition to the direct effects of resource abundance on growth, we investigate the indirect effects through intermediate variables. We examine the correlation between resource-specific abundance on the vector of control variables described above and calculate the potential full effects. We follow the procedure proposed by Papyrakis and Gerlagh (2007) and consider the next specification:

$$Z_i = \sigma + \Theta R_i + M_i \tag{3}$$

where Z_i and R_i represent the set of control variables and resource abundance meausures, respectively, and Θ is a matrix that maps resource sectors to control variables, while M_i (capital μ_i) are the residuals. Then, instead of using the original variables, we substitute the right-hand side for the control variables in equation 1, in order to calculate the overall impact of natural resources on economic growth. After substitution, we get an equation that depends on residuals M_i, which contain the variation in those variables that cannot be explained by resource-specific abundance:

$$G_i = (\alpha + \sigma\varphi) + \beta Y_{i,0} + [\gamma + \varphi\Theta]\, R_i + \varphi M_i + \epsilon_i \tag{4}$$

Table 6: Indirect transmission channels

	(1) Investment	(2) Pri. Schooling	(3) Pub. Schooling	(4) Openness	(5) R&D	(6) Corruption	(7) Dist. tax	(8) B. Surplus
Constant	1.05***	0.98***	1.49***	2.99***	2.09***	2.81***	7.06***	1.58***
	(0.17)	(0.11)	(0.13)	(0.27)	(0.29)	(0.34)	(0.35)	(0.20)
Oil&Gas, 1997	-0.04**	-0.03***	0.02	-0.06	-0.07**	0.22***	0.73***	0.58***
	(0.02)	(0.01)	(0.02)	(0.05)	(0.03)	(0.07)	(0.22)	(0.13)
Agriculture, 1997	0.16	-0.08**	0.07	-0.30***	-0.25***	0.20	0.08	-0.05
	(0.10)	(0.03)	(0.05)	(0.07)	(0.07)	(0.20)	(0.11)	(0.06)
Other Mining, 1997	-0.15***	-0.07**	0.04	-0.18	-0.17**	-0.03	-0.03	-0.16
	(0.04)	(0.03)	(0.06)	(0.11)	(0.07)	(0.17)	(0.34)	(0.11)
Observations	50	50	50	50	50	50	50	50
Adjusted R^2	0.15	0.15	0.01	0.17	0.13	0.08	0.55	0.68

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. Columns 1, 2, 3, 7 and 8 use GDP shares at 1997. Column 4 describes openness from 2000 to 2009. Column 5 reports the results for R&D at 1998. Column 6 uses data for corruption from 2001 to 2010.

As can be seen in Table 6 from the estimation of equation 3, oil&gas abundance is negative and significantly correlated to investment, private schooling and R&D and positively correlated with corruption, budget surplus and distortionary taxes. The latter positive correlation points to the observation that US states with the highest tax rates in 1997, such as Alaska, Wyoming, North Dakota and New Mexico, are also abundant in oil&gas. However, as shown below, fossil fuel-rich US state governments tend to make fiscal adjustments in their budgets in response to resource booms, as documented in James (2015b), reducing distortionary taxes and increasing public savings and education expenditures. With respect to openness, only the agricultural industry seems to have a strong and negative impact. Higher levels of corruption are associated positively with oil and gas production, but not with agriculture and other mining. Notice that private schooling is negatively correlated with resource-specific abundance. Though public schooling is positively correlated with resource abundance, these are not significant.

Based on the previous estimation, Table 7 reports the results derived from equation 4, which presents direct plus indirect effects of natural resource abundance. Interestingly, oil, gas, and other mining have lost their positive contribution to growth. That is, though there is a strong and significant positive direct effect of oil, gas and mining on GDP growth, these are canceled by the indirect negative effects. For agriculture, though, the positive effect is reduced, but it remains significant after controlling for the indirect effects through transmission channels.

In order to assess the relative contribution for the intermediate variables, Table 8 shows the relative importance of transmission channels for each resource sector by presenting the direct effects (γ) and the indirect effects through the control variables ($\varphi\Theta$).[15] We see that all negative indirect effects lead to a negligible overall impact of the mining sector, and the oil and gas production, on economic growth. The results suggest that, although high energy prices and innovation in oil and gas extraction pushed up economic growth in mineral-rich states, these states did not benefit so much overall, because of negative impacts on other important economic variables such as, for instance, private schooling.

Table 8 points to education as the most important transmission channel, with taxes and budget surplus also playing an important role in the indirect transmission channels for oil&gas abundance. We thus zoom in on the effects of resource abundance

[15] See the specification given by equation 4.

Table 7: Growth regressions controlling by indirect effects, 1997-2014

Dep. var.: av. ann. gr. of pc real GDP 1997-2014			
Constant	13.0**	12.2*	15.8**
	(6.17)	(6.18)	(6.79)
Initial GDP pc (Ln), 1997	-1.15*	-1.01*	-1.42**
	(0.58)	(0.58)	(0.64)
Oil&Gas, 1997	0.03	0.02	0.03
	(0.02)	(0.03)	(0.02)
Agriculture, 1997	0.18***	0.18***	0.17***
	(0.07)	(0.06)	(0.06)
Other Mining, 1997	-0.02	-0.02	-0.03
	(0.03)	(0.04)	(0.04)
Investment (r), 1997	0.22	0.26	0.27*
	(0.14)	(0.16)	(0.16)
Private Schooling (r), 1997	0.59***	0.61***	0.76***
	(0.12)	(0.12)	(0.14)
Public Schooling (r), 1997		0.23	0.44*
		(0.20)	(0.23)
Distortionary Taxation (r), 1997			-0.14**
			(0.06)
Budget Surplus (r), 1997			0.20*
			(0.10)
Openness (r), 2000-2009	0.14	0.18*	0.20*
	(0.08)	(0.10)	(0.10)
R&D (r), 1998	0.10*	0.11*	0.13*
	(0.06)	(0.06)	(0.07)
Corruption (r), 2001-2010	0.10	0.10	0.11
	(0.08)	(0.08)	(0.07)
Observations	50	50	50
Adjusted R^2	0.43	0.45	0.47

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The dependent variable is the average annual growth in real GDP per capita from 1997 to 2014. (r): residuals. Columns 1-3 use the residuals, $\mu_{i,k}$, from the equation (3) for each control variable, k.

Table 8: Relative importance of transmission channels

Transmission channels	φ	Θ	Contribution to $\gamma + \varphi\Theta$	Ratio to DE (%)
Oil and Gas Extraction				
Direct effect (DE)			**0.04**	**100**
Indirect effect (IE)			**-0.01**	**-21**
Investment	0.27	-0.04	-0.01	-27
Priv. Schooling	0.76	-0.03	-0.02	-57
Pub. Schooling	0.44	0.02	0.01	22
Dist. Taxation	-0.14	0.73	-0.10	-256
Budget Surplus	0.20	0.58	0.12	290
Openness	0.20	-0.06	-0.01	-31
R&D	0.13	-0.07	-0.01	-23
Corruption	0.11	0.22	0.02	61
Total effect (DE+IE)			**0.03**	**79**
Agriculture				
Direct effect (DE)			**0.25**	**100**
Indirect effect (IE)			**-0.08**	**-32**
Investment	0.27	0.16	0.04	17
Priv. Schooling	0.76	-0.08	-0.06	-24
Pub. Schooling	0.44	0.07	0.03	12
Dist. Taxation	-0.14	0.08	-0.01	-4
Budget Surplus	0.20	-0.05	-0.01	-4
Openness	0.20	-0.30	-0.06	-24
R&D	0.13	-0.25	-0.03	-13
Corruption	0.11	0.20	0.02	9
Total effect (DE+IE)			**0.17**	**68**
Mining, except oil and gas				
Direct effect (DE)			**0.13**	**100**
Indirect effect (IE)			**-0.16**	**-128**
Investment	0.27	-0.15	-0.04	-32
Priv. Schooling	0.76	-0.07	-0.05	-41
Pub. Schooling	0.44	0.04	0.02	14
Dist. Taxation	-0.14	-0.03	-0.00	-3
Budget Surplus	0.20	-0.16	-0.03	-25
Openness	0.20	-0.18	-0.04	-28
R&D	0.13	-0.17	-0.02	-17
Corruption	0.11	-0.03	0.00	-3
Total effect (DE+IE)			**-0.03**	**-28**

Notes: Coefficients: γ (Table 4, column 4); Θ (Table 6) ; and φ (Table 7).

on private and public schooling, and distortionary taxation. While Table 6 correlates initial resource abundance with initial values for those variables, we now estimate the effect of resource-specific abundance on growth of per capita real private and public spending on education, and state tax rates over the period 1997-2014. We estimate:

$$G_i^S = \alpha + \beta S_{0,i} + \gamma R_i + \varphi Z_i + \varepsilon_i \tag{5}$$

where G_i^S denotes the average annual growth in per capita educational spending, $S_{0,i}$ denotes the (log of) initial per capita educational spending, R_i are the resource sectors, and the vector of control variables Z^i is given by the average annual growth in real GDP per capita. A similar empirical model specification is estimated for distortionary taxation as share of GDP.

Table 9: Effects of Resource Abundance on Educational Spending and distortionary taxation, 1997-2014

	(1) Priv. Edu.	(2) Pub. Edu.	(3) Dist. Tax.
Constant	7.20***	6.83***	1.088
	(1.66)	(1.72)	(0.97)
Private Edu. Spending pc (Ln), 1997	-0.76***		
	(0.27)		
Public Edu. Spending pc (Ln), 1997		-0.76***	
		(0.26)	
Distortionary taxation (Ln), 1997			-0.44
			(0.49)
Oil&Gas, 1997	-0.12**	0.05**	-0.17***
	(0.05)	(0.02)	(0.04)
Agriculture, 1997	-0.21***	-0.13*	-0.05
	(0.07)	(0.07)	(0.06)
Other Mining, 1997	-0.07	-0.00	0.07
	(0.18)	(0.07)	(0.05)
Annual avg. economic growth, 1997-2014	0.08	0.37**	
	(0.18)	(0.14)	
Observations	50	50	50
Adjusted R^2	0.17	0.11	0.40

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The dependent variables are the average annual growth in private and public education spending per capita; and in the share of distortionary taxation in GDP at the state level during 1997-2014.

Table 9 shows the results. There is clear evidence for conditional convergence in private and public education expenditures, but not for tax rates in US states. Column 1 is in line with the findings of Papyrakis and Gerlagh (2007), where resource-rich US states tend to invest less on (private) education. Column 2, in contrast, reports a positive and significant impact of oil&gas on public spending on education as suggested in James (2017). The intution for this result is straightforward: during a resource boom, state governments receive a higher amount of resource revenues which allows them to increase general spending, particularly on education (James, 2017, 2015b). Column 3 shows the impact of initial resouce abundance on distortionary taxation; we find a negative and highly significant relationship with oil&gas abundance, which is also consistent with the findings of James (2015b).

To check that there are indeed differential effects on public and private education expenditures and connect to previous literature suggesting that oil is good for education, rejecting the idea of a "long-run resource curse mechanism" (James, 2017), we estimate the following panel data model:

$$S_{i,t} = \alpha + \gamma_1 R_i \cdot P_t + \gamma_2 R_i \cdot VA_t + \delta_i + \eta_t + \varepsilon_{i,t} \quad (6)$$

where $S_{i,t}$ denotes the (log of) real public and private education expenditures per capita. We control for annual sectoral price, P_t, and real value indexes, VA_t, and state-specific fixed-effects and time fixed-effects. Table 10 reports the point estimates. Columns 1 and 5 are geared to match the findings of James (2017) using a different approach. We find a highly significant and negative relationship between real oil prices and private educational spending, and a weakly significant and positive relationship with public spending in education. These results contrast with James (2017), who finds no effects on private spending, but a positive and significant effect on public education expenditures. Differences between the samples may cause the divergent results (Badeeb et al., 2017). While James (2017) uses a sample of 48 U.S. states over 1970-2008, a period which covers a continuous decrease in US oil production and two positive oil price shocks (the 1970s and early 2000s); we exploit data for 50 U.S states over the period 1997-2014, which contains one demand shock (a rise in the oil price in the early 2000s) and one supply shock (adoption of the new technology in the late 2000s). An in-depth exploration requires further study.

Table 10: Resource abundance effects on educational expenditures, 1997-2014

	Pri. Edu. Spending pc (Ln)				Pub. Edu. Spending pc (Ln)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	5.545***	5.545***	5.545***	5.545***	6.417***	6.420***	6.417***	6.417***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.011)	(0.011)	(0.011)	(0.011)
Oil&Gas, 1997 × Real Gas Price Index$_t$	0.003*	0.004**		0.001	-0.002***	-0.002***		-0.001
	(0.002)	(0.002)		(0.002)	(0.001)	(0.001)		(0.002)
Oil&Gas, 1997 × Real Oil Price Index$_t$	-0.006**	-0.007***		-0.007**	0.003*	0.002		0.001
	(0.003)	(0.003)		(0.003)	(0.002)	(0.002)		(0.002)
Oil&Gas, 1997 × Real Value-Added Index$_t$			-0.022**	-0.010***			0.010***	0.005
			(0.008)	(0.003)			(0.003)	(0.006)
Agriculture, 1997 × Real Sectoral Price Index$_t$		-0.023**		-0.017***		-0.001		0.003
		(0.009)		(0.006)		(0.011)		(0.007)
Agriculture, 1997 × Real Value-Added Index$_t$			-0.021	-0.015			-0.010	-0.011
			(0.014)	(0.012)			(0.015)	(0.012)
Mining, 1997 × Real Sectoral Price Index$_t$		0.008		0.008		0.010*		0.011**
		(0.013)		(0.013)		(0.005)		(0.005)
Mining, 1997 × Real Value-Added Index$_t$			-0.031	-0.024			-0.017*	-0.010
			(0.035)	(0.023)			(0.010)	(0.012)
State fixed-effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES	YES	YES	YES
Number of US States	50	50	50	50	50	50	50	50
Number of periods	18	18	18	18	16	16	16	16
Observations	900	900	900	900	800	800	800	800
Adjusted R^2	0.838	0.843	0.834	0.844	0.817	0.821	0.816	0.821

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. The dependent variable is the annual private (Columns 1 to 4) and public (Columns 5 to 8) education spending per capita from 1997 to 2014. There are no US state statistics available for public spending at 2001 and 2003.

The other columns (2-4,6-8) include all resources, and differentiate between supply and demand effects. We find a highly significant and positive effect on public spending, but negative and higher in magnitude for private education expenditures. An increase in oil and gas production leads to higher revenues for resource-rich states, which in turn, can expand public spending (James, 2015b). At the same time, increases in resource income tend to reduce private investment in human capital accumulation, since a booming oil&gas industry does not require the creation of additional high-skilled workers (Papyrakis and Gerlagh, 2007).

4.4 Robustness checks

In this section, we discuss a number of robustness checks to evaluate alternative model specifications. First, we use a different proxy for productivity growth and define a distinct separation year. Second, using a instrumental variable approach, we control for concerns about endogeneity of our natural resource measures. Third, we run a series of specifications to evaluate the sensitivity of our main conclusions to the presence of outliers.[16]

4.4.1 A different proxy for productivity growth and distinct sub-periods

We begin by using integrated multifactor productivity indexes, a measure of total factor productivity, at the industry level which account for intermediate input intensity; instead of using sectoral real value-added indexes. The data come from the Bureau of Economic Analysis and the Bureau of Labor Statistics. The results for our panel data estimations are detailed in Table 11. We confirm that there are no significant technology effects in the agriculture and mining sectors. Unsurprisingly, the impact of the technical change, increases in total factor productivity, in the oil and gas industry on economic growth in resource-rich states is now higher and remains statistically significant. By controlling for annual productivity growth rates, the main results for commodity price effects in each industry continue to hold.

We also evaluate whether the findings are robust to a different separation year. Table 12 presents the results for our preferred specification over the periods 1997-2006 and 2006-2014, respectively. As suggested above, while the oil and gas industry did not have a significant impact on economic growth rates over the first years, oil and gas-rich states

[16] In some estimations, we exclude public schooling and fiscal policy variables given the high correlation with oil&gas abundance detailed above. The additional results are available upon request.

Table 11: Effects of resource-specific abundance on economic growth rates, 1997-2014

Dependent variable: Δ ln(Real GDP per capita)		
	(1)	(2)
Constant	3.02***	3.02***
	(0.26)	(0.25)
Oil&Gas, 1997 $\times$ Δ_t Real Gas Price Index		-0.18
		(0.20)
Oil&Gas, 1997 $\times$ Δ_t Real Oil Price Index		0.38**
		(0.15)
Oil and Gas, 1997 $\times$ Δ_t Sectoral Productivity	2.07***	2.47***
	(0.35)	(0.86)
Agriculture, 1997 $\times$ Δ_t Real Sectoral Price Index		0.89***
		(0.16)
Agriculture, 1997 $\times$ Δ_t Sectoral Productivity	0.07	0.88
	(1.14)	(1.10)
Other Mining, 1997 $\times$ Δ_t Real Sectoral Price Index		0.66**
		(0.29)
Other Mining, 1997 $\times$ Δ_t Sectoral Productivity	-0.13	0.54
	(0.59)	(0.99)
State fixed-effects	YES	YES
Time fixed-effects	YES	YES
Number of US States	50	50
Number of periods	16	16
Observations	800	800
Adjusted R^2	0.40	0.43

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. Δ_t *Sectoral Productivity* denotes annual growth in total factor productivity for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector.

saw an increase in income during the second period due to the production innovations documented in the stylized facts section. The agriculture coefficient is statistically significant in both periods but higher from 2006 onwards, which confirms that the price increase due to the introduction of biofuel policies pushed up economic growth after 2006. The mining coefficient is no longer significant.

Table 12: Effects of Resource-Specific Abundance on Economic Growth

Dependent variable: Average Annual Growth Real GDPpc		
	(1)	(2)
	1997-2006	2006-2014
Constant	9.52*	19.1
	(5.13)	(12.7)
Initial GDP per capita (Ln)	-1.11*	-2.03
	(0.58)	(1.21)
Oil&Gas	0.01	0.09***
	(0.04)	(0.03)
Agriculture	0.22***	0.52**
	(0.04)	(0.20)
Other Mining	0.14	0.07
	(0.09)	(0.12)
Investment	0.02	0.56*
	(0.08)	(0.31)
Private Schooling	0.60***	0.56***
	(0.13)	(0.17)
Openness	0.23***	0.46
	(0.06)	(0.36)
R&D	0.08	0.21*
	(0.06)	(0.12)
Corruption	0.04	0.06
	(0.05)	(0.06)
Observations	50	50
Adjusted R^2	0.40	0.495

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. All the variables denote initial values except for openness (column 1 uses data from 2001-2010, column 2 from 2010 to 2014), R&D (column 1 refers to observations at 1998, column 2 to data at 2007) and corruption (columns 1 represent data from 2001 to 2010, and column 2 from 2005 to 2014).

4.4.2 IV estimations

One issue with our estimations is the endogeneity of our resource-specific abundance indicators given their possible correlation with the error term. We implement an in-

Table 13: 2SLS Estimation: First-stage results

Dependent variable:	Oil and Gas, 1997	Agriculture, 1997	Mining, 1997
	(1)	(2)	(3)
Panel A:			
Oil and Gas, 1996	0.57***	0.02	0.02
	(0.07)	(0.01)	(0.01)
Agriculture, 1996	-0.01	0.70***	-0.01
	(0.04)	(0.06)	(0.01)
Mining, 1996	-0.15	0.03	0.84***
	(0.13)	(0.05)	(0.03)
Observations	50	50	50
Adjusted R^2	0.91	0.94	0.99
F-statistic on excluded instruments	37.4	45.0	1225
Panel B:			
Value of stocks of oil and gas, 1990	5.07***	-1.29	1.24
	(1.07)	(1.07)	(1.02)
Land area per capita (Ln), 1990	0.19	1.11***	0.32*
	(0.18)	(0.28)	(0.19)
Value of estimated coal reserves, 2002	0.01	-0.07**	0.19***
	(0.03)	(0.03)	(0.07)
Observations	48	48	48
Adjusted R^2	0.57	0.41	0.48
F-statistic on excluded instruments	9.01	7.11	3.21

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. The value of stocks of oil and gas and the value of coal reserves are scaled by state land area. Panels A and B include all additional exogenous variables.

strumental variable approach to address this concern. We construct two set of instruments.[17] Our identification strategy relies on the assumption that the instruments do not have a direct impact on economic growth rates, that is, the exclusion restriction is satisfied, $\text{Cov}(R_{i,0}, \epsilon_i) = 0$ (see eq. 1); but solely through the resource abundance measures, the relevance condition holds, $\text{Cov}(R_{i,0}, R_{i,-1}) \neq 0$.

Firstly, we instrument our natural resource abundance measures with sectoral GDP shares at 1996, as in Perez-Sebastian and Raveh (2016). The correlations between sectoral shares in GDP at 1997 and 1996 are 0.95, 0.99 and 0.99 in the oil&gas, agriculture, and mining sectors, respectively. Secondly, we use the value of undiscovered, technically recoverable stocks of oil and natural gas at 1990 (Alaska and Hawaii are excluded because of missing data points), the value of estimated recoverable coal reserves at 2002,[18] and land area per capita at 1990, as instruments for oil and gas extraction, mining, and agriculture, respectively. The correlation between the share of oil and gas extraction in GDP at 1997 and the value of stocks of oil and gas per square mile at 1990 is 0.73, between the share of farms' production in GDP at 1997 and the logarithm of the land area per capita at 2000 is 0.61, and between the share of mining production in GDP at 1997 and the value of the estimated recoverable coal reserves per square mile at 2002 is 0.64. In the first case, we argue that resource production at 1996 is less correlated with economic growth rates over the period of analysis than the shares at 1997. In the second, to certain extent, we can claim that resource reserve stocks are more exogenous than actual resource exploitation.

Table 13 reports the first-stage estimations using the two sets of instruments. We find that lagged sectoral shares in GDP have higher predictive power and higher F-statistics than the other instruments. Table 14 displays the results for our 2SLS estimations under the two specifications. We find that our main results remain the same, particularly, for the instrumented variables with sectoral shares. It is worth noting that, using value of stocks and land area, the oil and gas, and agriculture coefficients are still positive and statistically significant. The point estimate for mining share, however, is no longer significant due to the possible weakness of the instruments.

Furthermore, to test the robustness of our main findings which indicate that productivity and commodity prices have different effects on economic growth through

[17] Data for the instruments come from the United States Census Bureau and the Bureau of Economic Analysis. We use the value of stocks of oil and gas at the state level calculated in James (2015b).

[18] Both instruments are divided by state area to control for its geographical size following the procedure of Allcott and Keniston (2017).

Table 14: 2SLS Estimation: Effects of Resource-Specific Abundance on Economic Growth, 1997-2014

Dependent variable: Average Annual Growth Real GDPpc		
	(1)	(2)
Constant	10.1*	12.3**
	(5.50)	(5.81)
Initial GDP per capita (Ln), 1997	-1.05**	-1.29**
	(0.53)	(0.57)
Oil&Gas, 1997	0.05*	0.14**
	(0.03)	(0.06)
Agriculture, 1997	0.29***	0.29***
	(0.08)	(0.11)
Other Mining, 1997	0.09**	0.10
	(0.04)	(0.06)
Investment, 1997	0.20	0.24*
	(0.12)	(0.14)
Private Schooling, 1997	0.63***	0.69***
	(0.11)	(0.12)
Openness, 2000-2009	0.15*	0.18**
	(0.08)	(0.08)
R&D, 1998	0.11**	0.14**
	(0.05)	(0.07)
Corruption, 2001-2010	0.09	0.09
	(0.07)	(0.07)
Observations	50	48
Adjusted R^2	0.42	0.39

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. Column 1 instruments our natural resource abundance measures using sectoral shares at 1996. Column 2 uses as instruments the value of undiscovered, technically recoverable stocks of oil and natural gas in 1990; land area per capita at 1990; and estimated recoverable coal reserves in 2002.

Table 15: 2SLS Estimations using GDP shares at 1996 as instruments, 1997-2014

Dependent variable: Δ ln(Real GDP per capita)			
	(1)	(2)	(3)
Constant	2.52***	2.52***	2.516***
	(0.28)	(0.28)	(0.26)
(Oil&Gas, 1997) $\times$ Δ_t Real Gas Price Index	-0.53**		-0.23
	(0.23)		(0.22)
(Oil&Gas, 1997) $\times$ Δ_t Real Oil Price Index	0.18		0.49**
	(0.21)		(0.225)
(Oil&Gas, 1997) $\times$ Δ_t Real Value Added Index		1.11***	1.35***
		(0.28)	(0.32)
(Agriculture, 1997) $\times$ Δ_t Real Sectoral Price Index	0.88***		0.88***
	(0.15)		(0.12)
(Agriculture, 1997) $\times$ Δ_t Real Value Added Index		-0.31	-0.06
		(0.70)	(0.69)
(Other Mining, 1997) $\times$ Δ_t Real Sectoral Price Index	0.56**		0.54**
	(0.23)		(0.22)
(Other Mining, 1997) $\times$ Δ_t Real Value Added Index		0.14	0.51
		(0.44)	(0.55)
State fixed-effects	YES	YES	YES
Time fixed-effects	YES	YES	YES
Number of US States	50	50	50
Number of periods	17	17	17
Observations	850	850	850
Adjusted R^2	0.41	0.39	0.42

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. To construct the interactions, we use the (fitted values) of our natural resource measures from the first stage estimations. Δ_t *Real Value Added* denotes annual growth in the real value added index for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector.

resource-specific abundance characteristics, Table 15 and 16 report the results when we use the instrumented variables (predicted in the first stage) and interact them with commodity price and real value-added growth rates, as in Perez-Sebastian and Raveh (2016) and Alexeev and Conrad (2009). All our previous conclusions hold.

Table 16: 2SLS Estimations using stock values and land area as instruments, 1997-2014

Dependent variable: Δ ln(Real GDP per capita)			
	(1)	(2)	(3)
Constant	2.80***	2.80***	2.80***
	(0.22)	(0.22)	(0.21)
(Oil&Gas, 1997) $\times$ Δ_t Real Gas Price Index	-0.28		0.23
	(0.22)		(0.27)
(Oil&Gas, 1997) $\times$ Δ_t Real Oil Price Index	-0.36*		0.26
	(0.19)		(0.27)
(Oil&Gas, 1997) $\times$ Δ_t Real Value Added Index		1.35**	2.43***
		(0.50)	(0.60)
(Agriculture, 1997) $\times$ Δ_t Real Sectoral Price Index	1.15***		1.12***
	(0.21)		(0.18)
(Agriculture, 1997) $\times$ Δ_t Real Value Added Index		-0.75	-0.41
		(0.74)	(0.73)
(Other Mining, 1997) $\times$ Δ_t Real Sectoral Price Index	0.64**		0.59**
	(0.31)		(0.29)
(Other Mining, 1997) $\times$ Δ_t Real Value Added Index		0.66	0.96
		(0.62)	(0.66)
State fixed-effects	YES	YES	YES
Time fixed-effects	YES	YES	YES
Number of US States	48	48	48
Number of periods	17	17	17
Observations	816	816	816
Adjusted R^2	0.43	0.41	0.44

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. To construct the interactions, we use the (fitted values) of our natural resource measures from the first stage estimations. Δ_t *Real Value Added* denotes annual growth in the real value added index for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector.

4.4.3 Outliers

To check the robustness of our main results to the presence of outliers, we follow the procedure of Acemoglu et al. (2017). First, we drop out observations with standardized residuals higher than 1.96 in absolute value. Second, we proceed to eliminate observations with a Cook's distance greater than $4/TN$, where T is the number of periods and

N the number observations. Third, based on the methodology proposed by Li (1985) and Huber (1973), we calculate two distinct robust estimators which weigh observations differentially according to their characteristics, that is, outliers in general either receive a lower weight or are dropped out.

Table 17: Effect of Resource Abundance on Economic Growth controlling for outliers, 1997-2014

Dep. var.: av. ann. gr. of pc real GDP 1997-2014	(1)	(2)	(3)	(4)	(5)
Constant	19.8***	13.0***	13.4*	13.0**	16.3***
	(7.14)	(4.70)	(7.71)	(6.03)	(5.10)
Initial GDP per capita (ln), 1997	-2.00***	-1.26**	-1.31*	-1.26**	-1.59***
	(0.71)	(0.47)	(0.72)	(0.58)	(0.52)
Natural Resources, 1997	0.12***	0.10***	0.10***	0.10***	0.11***
	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)
Investment, 1997	0.38**	0.20***	0.18*	0.18**	0.27**
	(0.17)	(0.06)	(0.10)	(0.09)	(0.11)
Private Schooling, 1997	0.71***	0.69***	0.71***	0.65***	0.69***
	(0.14)	(0.13)	(0.14)	(0.17)	(0.13)
Public Schooling, 1997	0.54**	0.29***	0.20	0.197	0.38**
	(0.25)	(0.10)	(0.22)	(0.19)	(0.17)
Distortionary Taxation, 1997	-0.17***	-0.13***	-0.09	-0.09	-0.15***
	(0.06)	(0.04)	(0.06)	(0.08)	(0.04)
Budget Surplus, 1997	0.12	0.06	0.12	0.12	0.09
	(0.09)	(0.05)	(0.10)	(0.10)	(0.06)
Openness, 2000-2009	0.22**	0.11*	0.11	0.11	0.15**
	(0.11)	(0.06)	(0.07)	(0.07)	(0.07)
R&D, 1998	0.16**	0.11**	0.09	0.09	0.13**
	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)
Corruption, 2001-2010	0.11	0.04	0.05	0.02	0.06
	(0.08)	(0.05)	(0.05)	(0.04)	(0.06)
Observations	50	48	45	49	50
Adjusted R^2	0.38	0.39	0.32	0.26	0.38

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. The dependent variable is the average annual growth in real GDP per capita from 1997 to 2014. Column 1 reproduces our main results. Column 2 drops out observations with standardized residuals higher than 1.96 in absolute value. Column 3 eliminates observations with a Cook's distance greater than $4/TN$. Column 4 compute the Li (1985) estimators. Column 5 reports the Huber (1973) estimation.

Table 17 reports the results for our estimations using the share of the primary sector in the GDP as independent variable. The point estimates indicate a positive and highly significant relationship with the average annual economic growth rates in the US states over the period 1997-2014, as reproduced before.

Likewise, Table 18 displays the results when we use resource-specific abundance

Table 18: Effect of Resource-Specific Abundance on Economic Growth controlling for outliers, 1997-2014

Dep. var.: av. ann. gr. of pc real GDP 1997-2014	(1)	(2)	(3)	(4)	(5)
Constant	13.6**	9.19*	4.99	7.36	10.7**
	(6.57)	(4.64)	(6.01)	(5.80)	(4.56)
Initial GDP per capita (ln), 1997	-1.42**	-0.90*	-0.52	-0.72	-1.07**
	(0.64)	(0.46)	(0.56)	(0.56)	(0.45)
Oil&Gas, 1997	0.04	0.07	0.06	0.06	0.05
	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)
Agriculture, 1997	0.25***	0.20***	0.16***	0.20***	0.22***
	(0.06)	(0.02)	(0.05)	(0.04)	(0.03)
Other Mining, 1997	0.13**	0.09***	0.06	0.08	0.11***
	(0.05)	(0.03)	(0.04)	(0.05)	(0.04)
Investment, 1997	0.27*	0.13*	0.06	0.09	0.17*
	(0.16)	(0.07)	(0.10)	(0.09)	(0.10)
Private Schooling, 1997	0.76***	0.72***	0.62***	0.67***	0.72***
	(0.14)	(0.11)	(0.11)	(0.16)	(0.10)
Public Schooling, 1997	0.44*	0.25**	0.22	0.15	0.30**
	(0.23)	(0.11)	(0.23)	(0.17)	(0.15)
Distortionary Taxation, 1997	-0.14**	-0.12***	-0.03	-0.08	-0.13***
	(0.06)	(0.04)	(0.06)	(0.08)	(0.04)
Budget Surplus, 1997	0.20*	0.10	0.17**	0.16*	0.15**
	(0.10)	(0.06)	(0.08)	(0.09)	(0.06)
Openness, 2000-2009	0.20*	0.10	0.14*	0.10	0.14**
	(0.10)	(0.06)	(0.07)	(0.07)	(0.07)
R&D, 1998	0.13*	0.10*	0.01	0.06	0.10*
	(0.07)	(0.05)	(0.06)	(0.06)	(0.05)
Corruption, 2001-2010	0.11	0.04	-0.01	0.02	0.06
	(0.07)	(0.03)	(0.05)	(0.04)	(0.05)
Observations	50	48	44	49	50
Adjusted R^2	0.47	0.50	0.26	0.37	0.47

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors in parentheses. The dependent variable is the average annual growth in real GDP per capita from 1997 to 2014. Column 1 reproduces our main results. Column 2 drops out observations with standardized residuals higher than 1.96 in absolute value. Column 3 eliminates observations with a Cook's distance greater than $4/TN$. Column 4 compute the Li (1985) estimators. Column 5 reports the Huber (1973) estimation.

across the different model specifications. As shown above, the coeffiicient for agriculture is highly significant and positive, though the oil&gas coefficient remains insignificant due mainly to the inclusion of fiscal policy variables such as public schooling, taxes and budget surplus, which are highly correlated with oil&gas abundance. For other mining, we find positive and significant effects in three estimations. Overall, we can conclude that over the period 1997-2014, resource-specific abundance was good for resource-rich states.

Table 19: Effects of resource-specific abundance on economic growth rates controlling for outliers, 1997-2014

Dependent variable: Δ ln(Real GDP per capita)	(1)	(2)	(3)	(4)	(5)
Constant	2.30***	2.17***	-4.09***	2.06***	-2.48**
	(0.25)	(0.28)	(0.33)	(0.45)	(1.18)
Oil&Gas, 1997 $\times$ Δ_t Real Gas Price Index	-0.26	0.02	-0.14*	0.13	-0.10
	(0.19)	(0.10)	(0.08)	(0.102)	(0.24)
Oil&Gas, 1997 $\times$ Δ_t Real Oil Price Index	0.54***	0.54***	0.68***	0.67***	0.60
	(0.13)	(0.12)	(0.13)	(0.14)	(0.58)
Oil&Gas, 1997 $\times$ Δ_t Real Value Added Index	1.38***	1.81***	1.89***	1.98***	1.61*
	(0.24)	(0.23)	(0.30)	(0.26)	(0.85)
Agriculture, 1997 $\times$ Δ_t Real Sectoral Price Index	0.86***	0.80***	0.93***	0.89***	0.95***
	(0.14)	(0.11)	(0.11)	(0.17)	(0.21)
Agriculture, 1997 $\times$ Δ_t Real Value Added Index	0.13	0.46**	0.27	0.43	0.44
	(0.56)	(0.22)	(0.30)	(0.31)	(0.41)
Other Mining, 1997 $\times$ Δ_t Real Sectoral Price Index	0.52**	0.44***	0.40**	0.15	0.40
	(0.21)	(0.08)	(0.17)	(0.16)	(0.40)
Other Mining, 1997 $\times$ Δ_t Real Value Added Index	0.49	0.75**	1.02***	0.19	0.54
	(0.53)	(0.33)	(0.31)	(0.60)	(0.83)
State fixed-effects	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES
Observations	850	797	786	850	850
Adjusted R^2	0.44	0.58	0.59	0.51	0.41

Notes: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. Δ_t *Real Value Added* denotes annual growth in the real value added index for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector. Column 1 reproduces our main results. Column 2 drops out observations with standardized residuals higher than 1.96 in absolute value. Column 3 eliminates observations with a Cook's distance greater than $4/TN$. Column 4 compute the Li (1985) estimators. Column 5 reports the Huber (1973) estimation.

In the same line, Table 19 shows the results for our panel data estimations. As before, we find that the interaction between oil&gas abundance with the resource sector's real value-added remains positive and significant, and no significant technology effects in the agriculture sector. As discussed before, sectoral prices also played a role in the economic growth experienced by the US states over the last two decades.

Finally, Table 20 displays the results for our estimations on the relationship between resource prices and education expenditures in the US states. All our previous conclusions hold, though in three specifications the positive impact of the real oil price on public educational spending is now highly significant as in James (2017).

Table 20: Effects of resource prices on educational spending controlling for outliers, 1997-2014

	(1)	(2)	(3)	(4)	(5)
Dependent variable: Public Education Spending pc (Ln)					
Constant	7.439***	7.085***	6.533***	7.431***	6.518***
	(0.0670)	(0.0562)	(0.0110)	(0.0436)	(0.0388)
Oil&Gas, 1997 × Real Gas Price Index$_t$	-0.002***	-0.002***	-0.002***	-0.002*	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Oil&Gas, 1997 × Real Oil Price Index$_t$	0.003*	0.003*	0.004**	0.003***	0.003***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
State fixed-effects	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES
Observations	800	755	752	800	800
Adjusted R^2	0.962	0.974	0.974	0.963	0.897
Dependent variable: Private Education Spending pc (Ln)					
Constant	7.191***	5.183***	5.195***	7.190***	5.177***
	(0.010)	(0.029)	(0.015)	(0.012)	(0.118)
Oil&Gas, 1997 × Real Gas Price Index$_t$	0.003*	0.003	0.002	0.003***	0.003***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Oil&Gas, 1997 × Real Oil Price Index$_t$	-0.006**	-0.007***	-0.007***	-0.007***	-0.007***
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)
State fixed-effects	YES	YES	YES	YES	YES
Time fixed-effects	YES	YES	YES	YES	YES
Observations	900	853	853	900	900
Adjusted R^2	0.987	0.994	0.994	0.995	0.947

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors clustered at the state level in parentheses. Prices are real 2009 dollars. Δ_t *Real Value Added* denotes annual growth in the real value added index for each resource industry. Δ_t *Sectoral Price Index* corresponds to annual growth in price indexes for each sector. There are no US state statistics available for public spending at 2001 and 2003. Column 1 reproduces our main results. Column 2 drops out observations with standardized residuals higher than 1.96 in absolute value. Column 3 eliminates observations with a Cook's distance greater than $4/TN$. Column 4 compute the Li (1985) estimators. Column 5 reports the Huber (1973) estimation.

5 Concluding remarks

In this paper we revisited the relationship between resource abundance and economic growth in the United States at the state level. We document that over the last twenty years resource abundant US states reported higher growth rates in comparison with the resource-scarce states that have a smaller primary sector. Our study contributes to a literature that shows mixed and inconclusive answers on the question whether natural resource abundance impedes or enhances economic growth. We add to the literature providing a more detailed look into commodity price movements and technological changes, exploiting the GM crop development and tight-oil and shale-gas revolution as a natural experiment.

Between 1997 and 2014, genetically modified crops began to dominate the agricultural landscape. States with a large agricultural sector saw an increase in income, but there is not much evidence for the contribution of the GM revolution to the income rise. Rents from GM seeds mainly accrued to the biotech industry. Land owners benefited from rising commodity market prices, induced by biofuel promotion policies that are part of the Energy Policy Act of 2005, and we find clear evidence for the contribution thereof to states' GDP growth.

Between 1997 and 2007, oil and gas prices rose sharply, increasing GDP in oil and gas producing states. From 2007 onwards, improved tight oil and shale gas technologies turned the declining US production into a booming industry. The shale revolution increased income in states abundant in tight-oil resources, but the shale gas developments also decreased gas prices, by so much that this effect offset the benefits for gas-rich states.

We also considered the indirect effects of natural resources on economic growth through inducing or crowding out growth-enhancing activities. After controlling for this indirect effects on investment, private and public schooling, distortionary taxation, budget surplus, R&D, openness and corruption, the positive impact of oil, gas, and other minerals on economic growth vanished, but the positive effect of the agricultural sector remained significant. Furthermore, we documented a negative impact of agriculture, oil and gas extraction, and mining on private educational spending, suggesting a negative long-term effect of resource abundance on overall economic growth, as pointed out in Papyrakis and Gerlagh (2007). However, we also find positive effects of oil&gas abundance on public education expenditures as described in James (2017).

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